An Assessment Of The Microbial Content Of Water Used For Irrigation And Their Effects On The Postharvest Quality Of Cabbage (*Brassica Oleracea Var. Capitata*) In The Tamale Metropolis

BY

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AN ASSESSMENT OF THE MICROBIAL CONTENT OF WATER USED FOR IRRIGATION AND THEIR EFFECTS ON THE POSTHARVEST QUALITY OF CABBAGE (*Brassica oleracea var. capitata*) IN THE TAMALE METROPOLIS

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of

MASTER OF SCIENCE (POSTHARVEST TECHNOLOGY)

BY

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DECLARATION

I hereby declare that this submission is my own work towards the Master of Science degree and that, to the best of my knowledge, it contains no material previously published by another person nor materials which have been accepted for the award of any other degree of the University, except where due acknowledgements have been made in the text

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DEDICATION

This research is dedicated to God Almighty for giving me life and seeing me through all my education, to my lovely wife, Modesta Akanlu and son, Bright A. Apaliya.

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ABSTRACT

An assessment of the microbial content of water used for irrigation and their effects on the postharvest quality of cabbage (*Brassica oleracea var. capitata*) was carried out in the Tamale Metropolis from January to May, 2011. Fifty percent each of the total producers and consumers of cabbage in the metropolis were randomly selected and interviewed. The equipment used for irrigation were buckets, watering cans and rubber hose and the main source of water for irrigation in the metropolis was pipe water. Water samples were taken from all the five sites (Nobisco, Lamashegu, Gumani, Waterworks and Choggu) on a monthly basis for quality analysis. The Most Probable Number (MPN) method was used to estimate faecal and total coliforms present in the samples at the Ghana Water Company Limited Laboratory, Tamale. It was found that water used for irrigation in the area was heavily polluted with both total and faecal coliforms. The findings also revealed that both producers and consumers were aware of the effects of irrigation water on postharvest quality of cabbage. Therefore cabbage produced in the area should be thoroughly washed with brine and vinegar before use.

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LIST OF ABBREVIATIONS

ACC -Aerobic Colony Count

EPA- Environmental Protection Agency

FDA -Food and Drugs Administration

MPF_s - Minimal Process Foods

MPN -Most Probable Number

SSA- Sub Saharan Africa

UPA- Urban and Peri-Urban Agriculture

WHO-World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

Urban and peri-urban agriculture is a dynamic sector that is characterized by the proximity of production to consumption sites. Its performance, however, is limited by unavailability of water. One of the strategies adopted to offset the water deficit is irrigation. The use of potable water for urban/peri-urban crop production in Ghana is constrained by high tariffs, making it uneconomical and nonviable (Sonou, 2001). There is also lack of accessibility of potable water typically in the peri-urban communities.

The benefits of application of wastewater are constrained by the presence of pathogens, heavy metals and other pollutants that can be a health hazard to the consumers of agricultural produce. A build up of heavy metals in soils results from the application of soil fertility improving sources like inorganic phosphorus fertilizers, sewage and sludge, wastewater, etc. (Smith *et al.*, 1996).

Therefore, the hygienic safety of cabbage is threatened by various factors including poor quality irrigation water, as such water could result in internal and external contaminations of vegetables. Pipe water, groundwater, surface water and human wastewater a re commonly used for irrigation. Pipe and ground waters are generally of good microbial quality, unless ground water is contaminated with surface runoff; human wastewater is usually of very poor microbial quality and requires extensive treatment before it can be used safely to irrigate crops; surface water is of variable microbial quality (Steele and Odumeru, 2004)

Large parts of Northern Ghana receive a moderate amount of rainfall with an annual average of 1100mm. It is therefore a region that relies heavily on irrigation systems to supplement rainfall in order to provide sufficient water to agricultural crops (Rahman *et al.,* 2002). Unfortunately there are no large and reliable rivers with tributaries passing through Tamale Metropolis alongside which many farms are situated. As a result of the inaccessibility to the rivers as well as the unavailability of treated water, cabbage farmers rely heavily on other sources of water.

Over the last decade, studies on the quality of many Ghanaian waters revealed an increase in pollution levels (EPA, 2001; Obuobie *et al*., 2006). The use of polluted irrigation water threatens public health. Market surveys in Kumasi, Accra and Tamale showed that it is very difficult to find any irrigated vegetable (e.g. lettuce, spring onions, cabbage) that is not contaminated with faecal coliforms. The microbiological pollution levels have, in more recent years, reached unacceptable and dangerous levels (Barnes and Taylor, 2004). There have also been widespread public discussions over the last years with media headlines such as: “Beware of badly polluted water"; and "Groundwater badly polluted with faecal matter*”*, occurring nearly every week.

Consumption of fresh fruits and vegetables is integral to a healthy diet supplying 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 (Matthews, 2006). The health aspects of fresh produce are now widely acknowledged by consumers and it is thus essential to ensure the availability of a safe product for the consumer. Consumers are also becoming more aware that produce consumed raw can be sources of disease-causing microbes.

Changes in consumer trends, consumer health awareness, population movements, increases in distances that food is transported and increased microbial resistance to anti-microbial compounds are impacting the incidence of foodborne diseases. The occurrence of food-related illness outbreaks have increased globally (Matthews, 2006) and this has stimulated research into food-related outbreaks and resulted in food safety becoming the fast growing and ground-breaking field of study that it is today. There has also been an increased awareness of the illnesses associated with foodborne pathogens as well as the carriers of these pathogens and the environmental conditions that lead to their survival and proliferation. The increase in both pollution levels and the frequency of food-related illnesses has led researchers to re-examine the link between polluted irrigation water and food safety (Johnston *et al*., 2006).

It has often been shown that poor quality water used for irrigation can serve as a source of foodborne pathogens on fruits and vegetables that are consumed fresh or even after undergoing a minimal processing step (Francis *et al*., 1999). Since this type of produce is consumed raw and no intervention practices are employed that will effectively control or eliminate potential pathogens prior to consumption it is a potential source of foodborne illness.

This places the responsibility of washing and disinfecting the produce on the retailers and consumers (Bruhn, 2006). Thus, negligence of food safety, particularly in more rural areas, can result in unsafe produce being sold to consumers. In other cases, even though retailers do have safety systems in place, the microbial loads on products may be too high, resulting in insufficient removal during the cleaning processes. Moreover, not all consumers are equally aware of a potential health risk associated with fresh produce, nor are many of them in a position to be educated. The ability to educate consumers depends on their level of formal education, the available resources for spreading this knowledge, the geographical location of the consumers and the availability of funds for this purpose (Bruhn, 2006).

It must also be kept in mind that not all consumers are in a position, financially or geographically to choose where they purchase their produce from and simply obtain produce from the local supplier. These suppliers may have different safety/hygiene requirements and therefore the safety of the consumer is left in the hands of the respective supplier. One way to increase the assurance of food safety is to improve the quality of the raw materials used in agriculture, including irrigation water (Johnston *et al*., 2006).

The microbial quality of fresh fruits and vegetables is essential to ensure a safe product for the consumer but preventing contact with microorganisms is nearly impossible as produce grown in a natural environment are exposed to a wide range of microbes. The carry-over of potential pathogens from irrigation water is also influenced by many environmental factors including the microbial load present in the water, survival and attachment characteristics of specific species, type of produce, water retainment on produce, and a host of other single or interacting factors. While much research has been done on pathogenic survival on produce during post-harvest conditions, pre-harvest microbial carry-over and survival is often overlooked. It was with this in mind that academic bodies and research institutions began to realize the importance of the quality of urban water to the entire agricultural sector, but especially to the producers of produce that is going to be consumed raw.

The state of many Ghanaian urban water currently poses a health risk to all who come into contact with the water (Barnes and Taylor, 2004). The pollution situation therefore requires immediate attention and actions need to be taken if further deterioration of the rivers is to be prevented.

1.1 Problem Statement

Cabbage plays an important role in the diet of many African communities and a large number of families owe their living on cabbage farming, and marketing. About 90% of the perishable vegetables are produced in closest market proximity due to their fragile nature and the common lack of cold transport and storage. These vegetables are a preferred cash crop, which can lift poor farmers out of poverty. On the other hand, farmers have huge problems finding in and around the cities unpolluted water sources for irrigation. Raw cabbage salad is not only in a very fortifying and nourishing meal but at the same time it is helpful, it prevents discomfort and diseases, dissolving even Calculi and curing Asthma diseases of the chest, bronchitis and others.

Sauerkraut or sour cabbage is a purifying remedy which cleanses the blood, cures Anaemia, ulcers, burns, infections, constipation and other diseases. It is also recommended for those who suffer from Jaundice, anaemia, and poor blood as it strengthens the blood stream. In certain ailments such as burns, ulcers, etc., it is applied as poultice. Considering the importance of cabbage to urban dwellers and the population at large there is urgent need to take a closer look at their production and possible risk contamination.

The population of Africa is estimated to triple by 2050 and this will be primarily in the urban and peri-urban areas or communities. In Ghana the urban population is also estimated to be 44% which is expected to increase rapidly as a result of 6 to 9% growth rates of her peri urban areas (UN-Habitat, 2001).

Basically, 85% of wastewater generated from urban centres worldwide ends up in the environment in its untreated form. In Ghana only a minor share of the wastewater is treated and less than 5% of the population has sewerage connections (Obuobie *et al.*, 2006).

Information on health risk effects from consumption of cabbage produced in Ghana, particularly those irrigated with wastewater has been speculative and subjective. The few studies conducted so far concentrated on the pathogenic aspect by examination of the exterior parts of the edible plants (Obuobie *et al.*, 2006). These studies assessed the bacteriological implications of consumption of such produce, if not properly washed in a fresh state.

1.2 Justification

As part of ensuring the protection of the health of the population, it is important to asses the water used for irrigated vegetable production and the carry over effect to the vegetables, using laboratory analyses in order to obtain information such as the concentration of certain pathogenic micro-organisms or, to establish their presence or absence (Razzolini and Nardocci, 2006).

In Tamale, water is an important source of enteric pathogens to vegetables because it is used in agricultural irrigation. This presents high risk to farm workers and to consumers of food products irrigated with wastewater (Strauss, 1985). The extent of the pollution increases if the vegetable's edible plant parts are near the ground (Minhas and Samra, 2004). Understanding the microbiology of the water used in vegetable production is therefore necessary to establish the potential risks that farm workers and consumers of these food products are exposed to. Without studies on the ecology of enteric pathogens in soil, a true characterization of public health risk as a result of direct or indirect exposure to soils will be impossible (Santamaria and Toranzos, 2003).

Virtually, little or no such studies have been conducted in the Tamale Metropolis to determine the quality of irrigation water used to irrigate cabbage. Information available is mere perceived problems associated with the consumption of cabbage in the Metropolis.

1.3 Research Hypothesis

The study was carried out on the basis of the following hypothesis:

$H_{o:}$ The quality of irrigation water has no effects on cabbage.

$H_{a:}$ The quality of irrigation water has effects on cabbage.

1.4 Main Objective

The overall objective of this study was to do an exploratory study to get an indication of the level of microbial pollution in selected irrigation waters from the Tamale Metropolis.

1.4.1The Specific Objectives were to:

1. To identify the main source of water for irrigating cabbage in the Tamale Metropolis (TM)
2. To determine the quality of water used for irrigating cabbage in the TM
3. To determine the effects of different sources of water on the postharvest quality of cabbage in the TM

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Importance of Vegetables

Fresh and minimally processed vegetables provide most of our daily requirements for vitamins, minerals and fibre. Their role in reducing the risk of lifestyle associated illnesses such as heart disease, diabetes and cancer has resulted in a further increase in their desirability and consumption. In order to benefit significantly from these health properties, the World Health Organization (WHO) recommends an intake of 400g, or five to nine portions, of fresh fruits and vegetables per day (Matthews, 2006).

The World Health Organization has issued reports claiming that correct fresh produce intake alone could save 2.7 million lives a year and that 31% of heart disease cases are due to an insufficient intake of such foods (Johnston *et al.*, 2006). As a result of the WHO recommendations (WHO, 2006a), fruit and vegetable consumption increased by at least 29% per capita in the United States between 1980 and 2000 (Matthews, 2006).

An increase in salad bars and a trend towards healthier living has resulted in a much wider consumption of fresh salad products and healthier foods, and consumer demand is forcing shops to stock fresh produce that is prepared to a ready-to-eat level and also low in or completely free of preservatives (Johnston *et al.*, 2006). A concern related to this increase in fresh produce consumption is the increased exposure to potentially pathogenic bacteria as well as an increase in the total number of bacteria that are ingested, both of these increasing the chance of infection (Harris *et al.*, 2003).

Competition amongst producers, as a result of an increased demand for fresh produce, has led to a wide variety and availability as well as a generally high quality. Developments are constantly being made to prolong the shelf-life of the produce by better refrigeration, packaging materials as well as modified atmosphere packaging. The minimal processing that the produce is exposed to means that the pathogens transferred to the produce in the field remain and survive any washing, processing or packaging that the produce is exposed to. These microbes may even multiply if the storage conditions are within the growth range of those that are present (Francis *et al.*, 1999).

It has been shown in the literature that many Ghanaian waters that are drawn from for agricultural irrigation purposes are heavily polluted and have high pathogenic loads (Obuobie *et al*, 2006). In several cases fresh produce is irrigated using this water (Germs *et al*., 2004). Concern has arisen that there could be a carryover of pathogens from the polluted urban water to the fresh produce during irrigation and that should the bacteria survive on this produce, the risk of infection for the consumer could be high.

The increase in consumption of contaminated produce can only increase the infection rate if carryover of pathogens takes place (Suslow *et al*., 2003). While posing a threat to the health of consumers, outbreaks of associated illnesses would damage the trust of the public, thereby affecting the credibility as well as the sales of all similar produce (Johnston *et al*., 2006). Outbreaks could also result in legal battles which could potentially lead to producers losing their export licences as well as possible rejection by the local market (Suslow *et al*., 2003). For Ghana, such outbreaks could be disastrous considering that this agricultural sector is one of great economic importance and would therefore not welcome such a setback.

Consumer awareness is a slow process and the public cannot be relied on to wash or cook fruits and vegetables sufficiently to destroy any pathogens that may be present (Bruhn, 2006). With a growing fresh produce market the food and agricultural industries are facing new challenges that require attention especially in terms of protecting the consumer against microbiological hazards (Garrett *et al*., 2003).

2.2 Irrigated Urban Agriculture

In many cities of Sub Saharan Africa (SSA) as in other developing regions, 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).

In many cases, this production is for subsistence needs to reduce household expenses while contributing to the daily diet. Subsistence production appears to expand during economic crises and helps many poor households who spend from 60% to 80% of their limited income on food (Smith, *et al.*, 1996). The United Nations Development Program estimated in 1996 that 800 million people are engaged in urban agriculture worldwide. Of these, 200 million are considered to be market producers employing150 million people on full-time basis (Smith *et al.*, 1996).

Market-oriented production is usually informal and takes place on open urban spaces, preferably in inland valleys and lowlands with water access or close to streams and drains, which allow dry season production of highly valuable crops with corresponding profits. Also peri-urban areas often attract highly specialized irrigated systems even for foreign export taking advantage of the proximity of city airports and harbours. Examples are pineapple farmers around Accra in Ghana or Basil leaf farmers on the beaches of Lomé in Togo. Also irrigated ornamental and flower production is a common and profitable Urban and Peri-urban Agriculture (UPA) system although high investment costs are needed (Drechsel *et al.*, 2006).

Depending on cultural specifics and production system these activities can have a very specific gender involvement with women in charge of production and/or marketing and often it is the only source of family income. A survey in 13 countries of West Africa showed that in 16 of 20 cities, men are mostly involved in open-space urban vegetable farming while in most cases, women dominated the vegetable retail sector (Drechsel *et al.*, 2006).

Open space urban agricultural production can become a profitable venture if market proximity is combined with water availability for irrigation. This permits dry season production and supports intensive year round production. Different sources of water are used for urban and peri-urban Agriculture in Sub Saharan Africa. In Lagos, for example, peri-urban farming depend solely on the Fadama wetland where farmers are able to cultivate continuously throughout the year using water from flowing rivers, ponds, dug wells or wash bores.

2.3 The Challenge of Irrigated Urban and Peri Urban Agriculture (UPA)

Irrigated urban and peri- urban vegetable production appears as one of the most productive and income generating farming systems in Africa despite often marginal soils, insecure tenure and its informal character. The success, which is steered by the large urban market and demand for high value crops, also require high inputs in the form of water, nutrients and pesticides. While pesticide and fertilizer/manure can be bought, it is difficult to find sites with proper, reliable and cheap water access. In this situation, farmers often make use of typical urban 'resources' like water from streams or drains, exposing urban farming to urban pollution. Most farmers are not aware of their personal risk involved with the use of polluted irrigation water, or other health threats of higher priority like malaria. And in many cases, wastewater is the only reliable water source throughout the year (Keraita *et al*., 2002).

Due to low industrialization, the contamination is seldom through heavy metals but through faecal matter. Studies from Ghana, Senegal and Kenya confirmed that the bacteriological contamination of urban water sources generally exceeds irrigation standards, and can contribute significantly to crop contamination (Niang *et al*., 2002). Other problems can be soil and groundwater pollution or salinisation. Thus, despite all its benefits in terms of food supply, nutrition, employment, and poverty alleviation, urban vegetable production poses human health and environmental risks which makes it struggle for official recognition, not to mention support, especially in Sub-Saharan Africa with its complex urban sanitation problems (Obuobie *et al*., 2006).

The tendency of many local governments now is to formulate more diversified and regulatory policies that seek to actively manage the health and other risks through an integrated package of measures, with the involvement of the direct stakeholders in the analysis of problems and development of workable solutions. In March 2002, the Dakar declaration was signed by seven mayors and city councillors from West Africa in support of the development of the urban agriculture sector, well recognizing the potential problems of wastewater use (Niang *et al*., 2002).

However, recognition is not yet action. To support the important role of irrigated urban and peri-urban agriculture, city authorities will have to work with their farmers to find the right balance between health risk mitigation and livelihood security. There are many options also in situations where better municipal water treatment is not possible in the near future thus no possibility to meet the common irrigation water quality guidelines (Drechsel *et al*., 2006). Instead of banning urban farmers, authorities could for example allocate areas with safer water sources for farming as done in Cotonou.

2.4 Risk Associated with the Consumption of Contaminated Cabbage

According to Neill *et al* (1994) there have been three known outbreaks of food poisoning traced back to the consumption of cabbage. Two outbreaks of *E. coli* in coleslaw occurred in the United States, one in Indiana in 1998 and the other in Ohio in 1999. The cause was attributed to unwashed cabbage used in producing coleslaw. An outbreak of Listeria occurred in Nova Scotia in 1981 where the cause was traced back to a cabbage field fertilized with sheep manure.

2.5 Methods of Irrigation

The microbial quality of irrigation water is of importance as poor quality water can lead to the introduction of pathogens onto produce during pre and postharvest activities. Because of this problem, indirect or direct contamination of produce from water of persistent pathogens on harvested vegetables has been long recognized as a potential hazard (WHO, 2005). Though reports on direct evidence of foodborne illness due to contamination of fresh produce during "commercial" production are more limited, many of these crops have been implicated in foodborne illnesses. Already in 1987 Garcia *et al.* (1987), showed that under commercial conditions of 181 irrigation samples and 859 vegetables irrigated with the same water source in Spain were contaminated with *Salmonella typhimurium; S. kapemba; S. london*and *S. blockey*serotypes.

Different irrigation methods have been found to correlate with the level of microorganisms present on produce (FDA, 1998). It has also been reported that the transfer of microorganisms from irrigation water to produce is dependent on the nature of the produce (Beuchat and Ryu, 1997). Spray irrigation could be expected to increase the risk of contamination in comparison to drip irrigation or flooding because leafy vegetables provide large contact surfaces for water and for the attachment of microorganism (Sadovski *et al*., 1978).

Other popular methods are drip irrigation, subsurface drip irrigation or furrow irrigation; all of which result in minimal splashing of water and thus minimal exposure of the edible produce to potentially-contaminated water (Johnston *et al*., 2006). These methods could then be used in cases where contamination of produce is a real threat and contact between the water and the produce is preferred to be kept to a minimum. Irrigation choices should also take factors such as water quantity, cost, soil type, slope of the field and the type of crop rotation system into account. These factors must be weighed up against the likelihood of pathogen contamination and a decision must be made for each specific situation (Mena, 2006).

Different researchers have evaluated the presence or persistence of pathogens conveyed to crops by spray irrigation, irrigation by sewage effluent or drip irrigation (Sadovski *et al.*, 1978; Garcia *et al.*, 1987). It was found that carry-over varied and was depended upon the level and nature of environmental stress. Carry-over was correlated to target population densities in the source water and spatial orientation relative to the point source. The level of organic matter in the water also impacted the survival of pathogens.

Irrigation water polluted with manure has also been implicated in the outbreaks of enterohaemorrhagic *E. coli* 0157:H7 infections (Kim *et al*., 2006). The infections were associated with lettuce and other leaf crops and they are occurring with increasing frequency (Mahmoud *et al*., 2007). However, it has been found that *Salmonella* became undetectable on effluent-irrigated lettuce five days after irrigation was terminated, but *E. coli* indicator strains persisted (Mukherjee *et al*., 2004). It was reported by Matthews, (2006) that in the USA spray/overhead irrigation resulted in a greater number of lettuce plants‟ testing positive for *E. coli* O157:H7 at harvest following a single exposure to the pathogen. Similarly in Nigeria lettuce and carrots were positive for *Salmonella*, *Vibrio* spp. and *E. coli* following irrigation with water that tested positive with the same pathogens (Matthews, 2006). Mahmoud *et al.*, (2007) reported that strawberries tested positive for the presence of *E. coli* after both irrigation by drip and overhead methods were use.

Contaminated irrigation and surface run-off waters and the use of sewage as a fertilizer can also be sources of pathogenic microbes that contaminate fruits and vegetables in the field (Beuchat and Ryu 1997). It was also found that with sewage contamination between 84 and 100% samples were contaminated with either *L. monocytogenes*or *L. innocua*during a two year sampling period. *Salmonella* was also present in more than 50% of irrigation water samples contaminated with raw sewage or primary treated chlorinated effluents (Wang *et al.*, 1996).

It has been found that cholera and typhoid microbes can also be transferred during the irrigation of vegetables with untreated wastewater. Therefore, in areas where rivers are known to test positive for such pathogens, the method of irrigation as well as the option of water treatment should be critically considered.

Farming conditions and practices play a critical role in the contamination of produce and it is usual for the level of contamination to have dropped substantially from when it is harvested to the time of consumption (Francis *et al.*, 1999). Temperature is one of the most important factors that influence the growth, survival or decay of bacteria on produce after harvest. Each group of bacteria has its own growth criteria and therefore different bacteria will react differently under the presiding conditions (Peleg, 2000). In contrast to the usual decay patterns, *Listeria monocytogenes*as well as non-proteolytic strains of *Cl. botulinum*and *Aeromonas*are psychrotrophic and *Aeromonas* have been found to increase by 1 log value after 7 days at 3-4°C (Francis *et al.*, 1999). This means that there is still a chance for some of the contamination pathogens to multiply on produce after harvest.

2.6 Water Quality

When assessing the safety of produce the term, water quality is based on the pathogenic load of the water as a measure of quality (WHO, 1989). This term is more generally used when determining the efficacy of a treatment process on a water sample. In the case of produce safety it is the pathogenic load that is determined, rather than measuring chemical parameters (Carr, 2005). Water quality as described above is important as it dictates for what purposes the water is suitable (WHO, 1989). There are five different categories into which pathogens are classified according to their survival characteristics. Categories 1, 3, 4 and 5 include the nematodes, helminths, protozoa and viruses while Category 2 contains the bacteria. These bacteria are consider those that are infective immediately upon excretion but can still multiply outside of the host and generally have a higher median infective dose than the other four pathogen categories (Carr, 2005). More recently thermo tolerant *E. coli* evaluation has become one of the major tools used world-wide to determine the microbial quality of water (WHO, 2006b).

The high usage of fresh water could create problems if this water was to become heavily microbially contaminated especially as there are no alternative water resources available. It is therefore of utmost importance that the microbial quality of Ghana's fresh water resources be maintained.

2.6.1 Water Standards

In order to be able to ensure that water will be sufficiently safe for its intended use, it has been necessary to construct a set of guidelines for a variety of uses and all water should comply with the regulations and guidelines pertaining to its intended use.

In terms of the microbiological quality of water, guidelines for faecal coliforms are given, depending on the method used, as the maximum permissible number of colony forming units per 100 ml water (cfu.100 ml^{-1}) (WHO, 1989). Both the World Health Organization (WHO) and the Environmental Protection Agency (EPA) have guidelines for the quality of irrigation water. They both recommend that water used for the irrigation of fresh produce should have a faecal coliform load of less than 1 000 cfu.100 ml^{-1} (WHO, 1989). This applies to all water being used for the irrigation of crops, irrespective of its source.

The current guidelines for *E. coli* in irrigation water are not more than 100 organisms.100 mL^{-1}(WHO, 1989; WHO, 2006b). From the literature there is no clear indication as to how the value of <1000 *E. coli* per 100 ml was reached but it is considered as a very conservative maximum. However, it is yet to be tested at what point and in what quantity carryover of pathogens from irrigation water to fresh produce takes place. It is interesting to note that the permissible load of *E. coli* on raw fruits and vegetables is zero per g product. Therefore if *E. coli* present in irrigation water is carried over onto produce, the produce should be considered as suspect.

There are no many published limits or guidelines available for the total number of microorganisms and where limits do exist, the values vary greatly. The total number of microorganisms is determined by performing an aerobic colony count (ACC) on a water sample. Since the organisms detected are not necessarily harmful to the produce or to the consumer, the value obtained from this test is used to indicate number of possible pathogens or spoilage bacteria. Further tests should be performed if more specific information is required regarding the different microorganisms present.

However, if the ACCs are high, there is a greater chance that there are corresponding high levels of spoilage organisms or pathogens. Similarly, a low total load usually reflects very low levels of spoilage organisms or pathogens, if there are any. The result for the ACC can, therefore, in broad terms serve as an indication of contamination. In literature, recommended limits for ACCs range from 2.9 to 7.3 log cfu.g-1.

When assessing the safety of food, the lag time, exponential growth phase and the decay/survival rates of the organisms present on the products are important.

In terms of food spoilage, a product is considered to be spoiled when its microbial load exceeds 1 x 105-7 organisms per g (Geldreich, 1996). This limit does not make an allowance for the presence of pathogens. The infective doses of pathogens can be as low as 1-103 organisms, so a product can appear to be unspoiled while it is actually carrying dangerous levels of pathogens. The infectivity of the *Escherichia coli* pathogenic strains is substantially higher than that of the other strains. As few as 100 EHEC organisms can cause infection (WHO, 2006b). For this reason, it is important to test the quality of irrigation water and fresh produce regularly; although in practice it is not always possible (WHO, 2006b). Clearly, the microbially contaminated water can pose a big threat to food safety if produce is unknowingly being infected with pathogens while being sold. For this reason, WHO has drawn up a set of standards that dictate the legal maximum loads for different pathogens that can be present on a product (WHO, 2006b). While national and international standards and regulations are published and enforced by, or should be, official authorities, there are also certain standards that are set by the industry itself.

The benefit of such industry standards is that they are usually manageable and deal with food safety problems faced in the specific industry through the sharing of information. The role of inspections and certifications by third party groups is a further means of insurance and assurance for retail food companies. It also provides a guaranttee of a certain level of quality to the client and prevents each client from independently needing to inspect the supplier prior to purchase (Michaels and Todd, 2006).

2.7 Sources of Contamination

The two main categories of contaminants are chemical and microbiological with the latter being the focus of this particular study. For this reason, further discussions will only include aspects of microbiological contamination. However, chemical contamination is equally important and the health risks, both short-term and chronic are serious and not to be neglected. The origin of chemical contamination and methods of detection differ greatly from microbiological contaminants and are thus generally studied separately.

Most of the microbiological contaminants posing a threat to the health of consumers originate from humans or animals, with the majority of these being of faecal origin or transferred through faeces (Harris *et al*., 2003). According to Jamieson *et al.* (2004) and Maciorowski *et al.* (2007) contamination of water can be divided into two major mechanisms namely point-source and non-point source contamination. Point-source contamination emanates from a clearly identifiable point such as animal feedlots as well as from runoff from storage facilities. Non-point-source contamination can be from different sources or even many points. For example this type of contamination can occur, at the site of manure application, at a surface level, at the site where the manure is actively combined with the soil, and at the site where the origin of the manure is from livestock, (Jamieson *et al.*, 2004; Maciorowski *et al.*, 2007).

The use of manure as a fertilizer has increased in popularity as consumers are seeking fresh produce that has been produced without harmful or chemically loaded pesticides and fertilizers (Suslow *et al.*, 2003). The alternative to fertilizer is manure and its use in the field is increasing mainly as a result of consumers "organic" trends to enhance health. Ironically' it is only for conventional fertilizers that the microbiological safety can be assured and the use of fertilizer is, in fact, much less risky than manure. Manure is likely to be loaded with bacteria present in animal faeces and the risk of contamination of irrigation water is high. Thus a potential hazard does exist for the carry-over of potential pathogens to fresh produce directly or indirectly through contaminated irrigation water.

Another pathway for faecal contamination is through direct contact with human sewage. Biosolids, or sewage sludge are what remains after the liquid phase of sewage has been removed for treatment. This has been used as a fertilizer or added to nutritious slurries for crops (Minhas *et al.*, 2006). However, this has been recognized to be potentially heavily loaded with pathogens and has been outlawed by the British Retail Consortium (Coetzer, 2006). While animal manure is a problematic contaminant that is very difficult to control, contamination of rivers and water systems with human faeces is an enormous problem that is on the increase. Human faeces is entering river systems through failing sewage pipes and treatment plants, illegal release of untreated sewage and the close proximity of informal settlements with no sanitation facilities to river resources which become the obvious dumping ground for the generated waste (Barnes and Taylor, 2004). Until these informal settlements are provided with functioning sanitation facilities and are trained to use them properly, little change for the better can be expected and these communities have no option but to continue dumping their waste into gutters and nearby water bodies.

While informal settlements are responsible for some faecal pollution and even waste dumping, they are, by far not the only guilty party. For example, it was reported by Barnes, (2003) that a winery downstream of the Kayamandi settlement was dumping cellar and production effluent into the rivers. Depending on the fermentable carbon load of this type of pollution it might result in increased fermentation in the rivers. The acidity and conditions of the water would therefore also be changed, thereby allowing organisms which would not normally be able to survive in river water to grow and multiply.

When considering the increasing pollution of Ghana water bodies and the downward trend in water quality, it is clear that the situation will hardly improve unless a control body or regulatory agency takes charge and enforces the quality standards of water bodies from which water is drawn from for irrigation.

While fruits and vegetables are in the field, polluted water is one of the major threats for product contamination. The produce can be exposed to water during both irrigation and application of pesticides, and the water used for these purposes can be drawn from gutters, streams, open ditches or canals, dams or ponds, or reservoirs.

Alternatively, if available, municipal water can be used but the quality of this water cannot always be relied on (Johnston *et al.*, 2006).

Another source of contamination is the land on which the produce is grown. In some cases, farms have been acquired without knowledge of its previous purpose and if it was used for animals, or was even loaded heavily with manure, then the reservoir that has built up in the soil can potentially contaminate the produce (Coetzer, 2006). In the case of farms positioned near rivers, the land use upstream is also important for the safety of the plot. For example, during times of flooding, contaminants that are carried by the river from various sources upstream can be washed onto land that the river does not usually reach and result in unexpected and irreversible contamination.

Contamination of fresh produce can also take place postharvest (Harris *et al.*, 2003). In a food safety review, Harris *et al.* (2003) reported that numerous microbial pathogens have been isolated from fresh fruits and vegetables but not all were linked to produce associated illnesses. Many of the isolated organisms have the potential to under the right conditions cause illnesses. Vehicles of postharvest microbial transmission include harvesting equipment, packing house conditions, unhygienic workers, processing plants and even pests (in the field or postharvest) (Matthews, 2006; WHO, 2006b). In the packing house, transmission of pathogens through practices such as washing can occur if the water is not properly disinfected, filtered or replaced on a regular basis. It is thus important that, producers acknowledge the role that the origin and pollution level of the irrigation water can play in the safety of the end product.

2.8 Coliforms

Coliforms are defined as being Gram-negative, non-spore forming, rod-shaped facultative anaerobes that are part of the family *Enterobacteriaceae* (Leclerc *et al.*, 2001). Coliforms are also characterised by their ability to ferment lactose at 35°C, resulting in gas formation. Approximately 10% of all intestinal microorganisms including *E. coli* fall into the coliform group. However, this group is not exclusive to intestinal bacteria and it has thus been broken down into smaller sub-groups in order for the intestinal bacteria to be able to be classified separately.

2.8.1 Total Coliforms

There are several other genera not part of the coliforms that can ferment lactose and possess beta-galactosidase and can yield false total coliform reactions. A major limitation of using the coliforms as indicator is the classification which presents major problems as a result of the high degree of character variation extending from the lactose positive/negative variations to the highly reactive *Enterobacter*genus.

2.8.1.1 Faecal (thermotolerant) Coliforms

The 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. This temperature tolerance is specific to those coliforms many of which are adapted to survive within the intestine of a warm-blooded host. Beside *E. coli,* several species of the genera *Klebsiella, Enterobacter*, *Citrobacter*, *Hafnia*, *Pantoea*, *Raoultella*and *Serratia*also fall into the faecal coliform group and many are thermotolerant (Leclerc *et al.*, 2001). However, members of these genera are also present in the environment and their presence in water and produce is not necessarily related to faecal contamination (Alonso *et al.*, 1999). Thus, the specificity of faecal coliforms as indicators of faecal pollution varies considerably depending on environmental conditions. While the presence of faecal coliforms is often indicative of faecal pollution, more specific tests have been developed to detect which coliforms are present.

2.8.1.2 Escherichia coli

The *Escherichia coli* group is one of the most common indicator organisms and is used particularly for the detection of faecal contamination, especially in drinking water. The presence of *E. coli* is never beneficial to a consumer and always points to the possibility of faecal contamination. Its presence, therefore, should not be ignored if it is detected in a sample.

Escherichia coli is of the family *Enterobacteriaceae* and most strains are normal inhabitants of the intestinal tract and are practically always present in faeces and thus also in faecally contaminated water. This has resulted in the almost universal use of *E. coli* as the standard indicator for faecal contamination (Francis *et al*., 1999). There are also several reports in the literature confirming the presence of *E. coli* and other thermotolerant coliform bacteria in the environment. Not all strains are harmless and major pathogenic strains like *E. coli O*157:H7, have been identified in several MPF-related food outbreaks. According to Francis *et al*. (1999), if ingested, this strain can result in haemorrhagic colitis, gastroenteritis and kidney failure, while it less commonly results in thrombocytopenic purpura and haemolytic uremic syndrome (Gil and Selma, 2006). Serious cases can even result in death. The monitoring of faecal matter in rivers and on the MPFs is therefore of great importance since there is very little control possible over animal faeces entering the river (Francis *et al*., 1999).

E. coli has been reported to be the most sensitive thermotolerant coliform to environmental stresses and does not usually grow outside the human or animal gut. In contrast, it has also been reported that the general survival ability of *E. coli* increases upon exposure to one environmental stress which indicates that it is able to activate survival mechanisms when it is threatened (Maciorowski *et al*., 2007). *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. The number of *E. coli* present in an environment was found to increase logarithmically with an increase in oxygen, indicating that *E. coli* requires high levels of oxygen for metabolism and therefore grows better under conditions of high atmosphere (Maciorowski *et al*., 2007).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was carried out in the Tamale Metropolis and its suburbs. Five sampling sites were selected in the Metropolis, which have different irrigation water bodies ranging from treated to untreated water. The total stretch of sampling sites was about 12 km. The total area investigated was about 15 km^2. The five sampling sites were the following communities:

- Nobisco
- Lamashegu
- Gumani
- Waterworks
- Choggu

The main crops irrigated in the Metropolis during the dry season were vegetables. The vegetables cultivated using these water sources does not constitute the only source for local consumption in the metropolis

Figure 3.1 Map Of Tamale Metropolis

Predominantly, leafy vegetables are grown in the metropolis during the dry season. The type of vegetables cultivated were cabbage, tomatoes, amaranthus and lettuce with the total area under cultivation in many acres. The exact production area for cabbage was however not known.

3.2 Site Selection

Five different sites namely Nobisco (pipe), Builpela (dam), chefurigu (dam), Gumani (gutter/ drain) and Waterworks (well/dugout) were chosen and monitored over five months. A total of twenty-five (25) samples were taken during the period with five samples from each site. The sampling sites used in this study were chosen with farmers' participation to represent cabbage producing areas from which irrigation water is drawn.

3.3 Socio-Economic and Health Survey

A cross sectional socio-economic and health survey was carried out by administering questionnaires in the metropolis (local dialect) to assess the health risk of farmers and consumers. The questionnaire was also administered to establish the main source of water for irrigation and the postharvest quality of cabbage regarding its shelflife, absence of defects, size, weight, and development of rots among others. The questionnaire also sought information on handling practices during harvesting, washing, packaging, and storage. The information collected from the survey was used to establish associations with the microbiological results. The questionnaire included open and close-ended questions about the occupation, family size, source of cabbage, intake of raw salads, disease pattern etc.

Ten producers at every production site were randomly selected and interviewed with a well structured questionnaire. This represented 50% of the total population of cabbage producers in the metropolis that use irrigation water. The questionnaire was also administered at random to target consumers in restaurants, hotels, fast foods, guesthouses and the open market. In all, 50 consumers were contacted and interviewed.

3.4 Sampling Frequency

Water samples were taken from all the five sites on a monthly basis starting from January to May, 2011.Sampling of irrigation water was carried out in the morning at the time when farmers irrigate their cabbage.

3.5 Sampling Method

Sampling was carried out according to clusters with additional precautions taken to ensure both accuracy of the samples and safety of the sampler. Water bottles were sterilized to kill all pathogens that might be present. The water samples were taken from as close to the edge of the water source in the case of the dams. The sample bottles were submerged 30 cm under the water with the neck of the bottle facing upwards. Once the bottle was submerged, the cap was removed and the bottle filled with water. The cap was replaced while the bottle was still submerged and the closed bottle was then placed upright into the pre-chilled cooler-box for transportation back to the laboratory. Pipe water was collected directly from the water hose used by the farmers for irrigation.

An insulated cooler-box containing frozen ice-blocks was used to keep the samples at refrigerator temperature (4°C) until they were analysed in the laboratory. The specimen (water and cabbage) were prepared by indicating the location, the date samples were taken and the appearance of the water for each site and placed into the cooler box. The appearance of the water (i.e. cloudy, translucent, opaque, brown, milky) and any accompanying odours were recorded for each specimen. The appearance of the cabbages (size, weight, rots and defects) were also recorded.

3.6 Washing and Sterilization

To avoid microbial contamination, materials used for microbiological analysis were sterilized under laboratory conditions using standard procedures. All glassware, sample bottles and equipment for the test were thoroughly cleaned with detergent and hot water, rinsed with hot water to remove all traces of residual washing compounds and finally rinsed with distilled water.

3.7 Media preparation

MacConkey agar was dissolved in 1 litre of distilled water and heated to dissolve. Melted 20.5g plate count agar (MacConkey agar) was used as the medium, it was cooled to a temperature of 42^0c. MacConkey agar is a selective and differentiation medium for the detection of Enterobacteriaceae.

3.8 Microbial Examination

3.8.1 Most Probable Number Method (MPN)

The Most Probable Number (MPN) was used to estimate faecal coliforms and total coliforms present in the specimens (Oblinger *et al.*, 1975)

Five petri dishes were arranged on a table according to the number of specimen. A sterilized pipette was then used to pick 1ml of each specimen with the Petri dish lifted high enough to insert the pipette. The petri dish was again lifted and the MacConkey agar poured into the petri dish and swirled for a uniform mixture. The petri dishes were then covered, inverted and placed into an incubator for the coliforms to form colonies. The specimens were then left in an incubator for 24 hours. Counting of both the faecal and total coliforms was subsequently carried out using magnifying lens and a tally counter and the results recorded.

3.9 Cabbage Microbial Analysis

During each visit, 2 to 3 cabbages heads were harvested at random from different locations on the field and immediately put into boxes without washing. The samples were then transported in boxes made of insulating material. The temperature of the cabbages was not monitored. The cooler boxes were delivered to the Ghana Water Company Microbiology Laboratory, Tamale for examination. Samples were stored at normal room temperature in cardboard boxes or on metal shelves of a walk-in cooler until analyses began.

The wash method was adopted for microbiological analysis of cabbage following the standard procedure adopted by Feenstra *et al*. (2000). A cabbage of known weight free from soil contamination was washed with 1 litre of sterile water and the wash water was screened for faecal coliforms,

The physical appearance, size, weight, development of rots, absence of defects and shelflife were some of the parameters monitored and recorded.

3.10 Data Analysis

The survey data was analyzed using Statistical Package for Social Sciences version 17. (SPSS). Analysis of Variance was also used. The results were presented in tables and charts.

CHAPTER FOUR

4.0 RESULTS

4.1 Socio-Demographic Characteristics of Respondents

The socio-demographic characteristics of respondents were gender, age and education.

4.1.1 Gender Backgrounds of Respondents

The research revealed that out of 50 respondents who were interviewed, 43 respondents representing 86% were males whiles 7 respondents representing 14% were females. Those sampled were producing cabbage using irrigation in the Tamale Metropolis.

Table 4.1 illustrates the gender distribution of farmers who are into cabbage irrigation in the study area.

Table 4.1. Gender Distribution of Respondents

Gender	Frequency	Percentage (%)
Male	43	86
Female	7	14
Total	**50**	**100**

Source: Field work, May, 2011.

4.1.2 Age of Respondents

The age distribution of respondents in the communities is shown in figure 4.1. Majority of the respondents are within the age group of 41-50 years. This represents 64.0% of the respondents. Eleven (11) respondents, representing 22.0% fall within the age group of 31-40 years where as 10% of the respondents are above 50 years.

However, only two (2) of the respondents representing 4.0% are within the age group of 21-30 years. The age profile rises to 41-50 years and declines

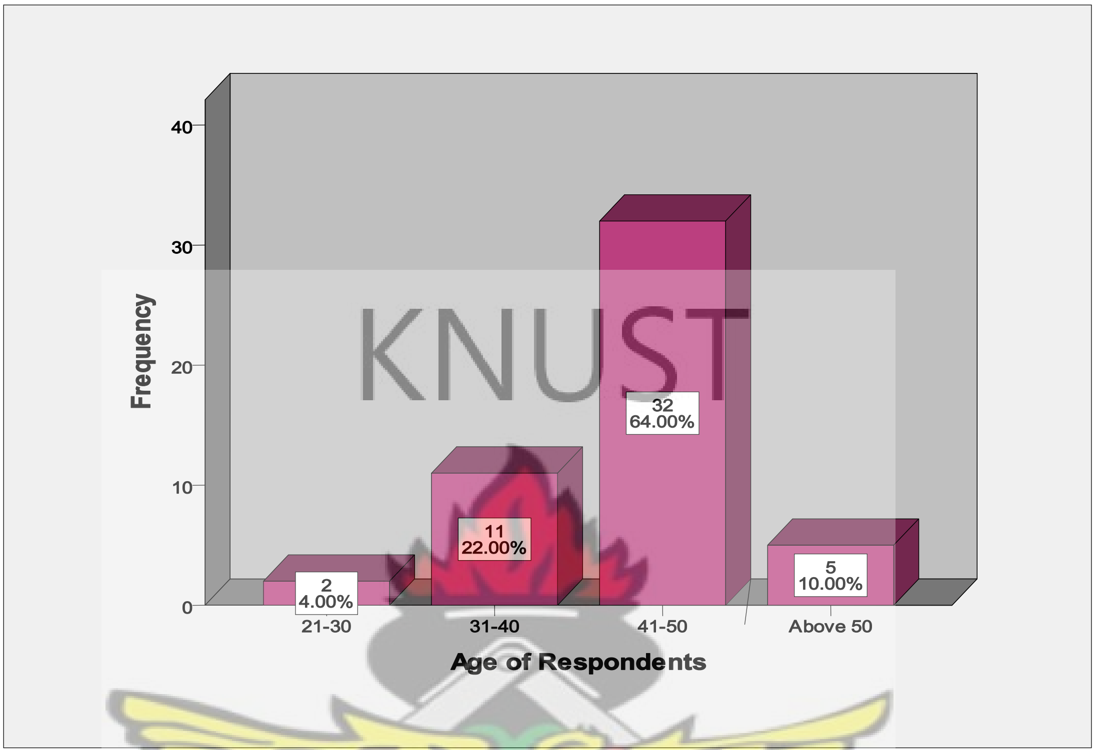

Figure 4.1 Age Distribution of Respondents.

Source: Field work, May, 2011.

4.1.3 Educational Background

From Table 4.2, out of the fifty (50) respondents, forty (40) of them which represent 80% had no formal education, 16% represented by eight (8) respondents had basic education. Also 2 respondents representing 4% had secondary education and none of them had tertiary education.

Table 4.2 Educational Background of Respondents.

Educational background of Respondents	Frequency	Percentage (%)
No Formal Education	40	80.0
Basic	8	16.0
Secondary	2	04.0
Tertiary	0	00.0
Total	**50**	**100.0**

Source: Field work, May, 2011.

4.2 Methods of Irrigation

Table 4.3 shows the methods and technologies used in irrigating the cabbage in the study area. Thirty four percent (34 %) of the respondents used watering cans for irrigation, 12% use buckets and the remaining 54% used rubber hose for irrigating their cabbage.

Table 4.3 Methods of Irrigation Used in Tamale Metropolis

Method	**Frequency**	**Percentage (%)**
Watering cans	17	34.0
Buckets	6	12.0
Rubber hose	27	54.0
Total	**50**	**100.0**

Source: Field work, May, 2011.

4.3 Main Source of Water for Irrigating Cabbage

The results obtained after administering the questionnaires clearly showed that the main source of water used for irrigating cabbage in the metropolis is pipe water. Thirty one (31) respondents representing 62% (majority of respondents) use pipe water for irrigation in the study area. Dam water was nextwith 13 respondents, representing 26%.Five percent (5%) and two percent (2%) use gutter /drain and well water, respectively (Figure 4.2).

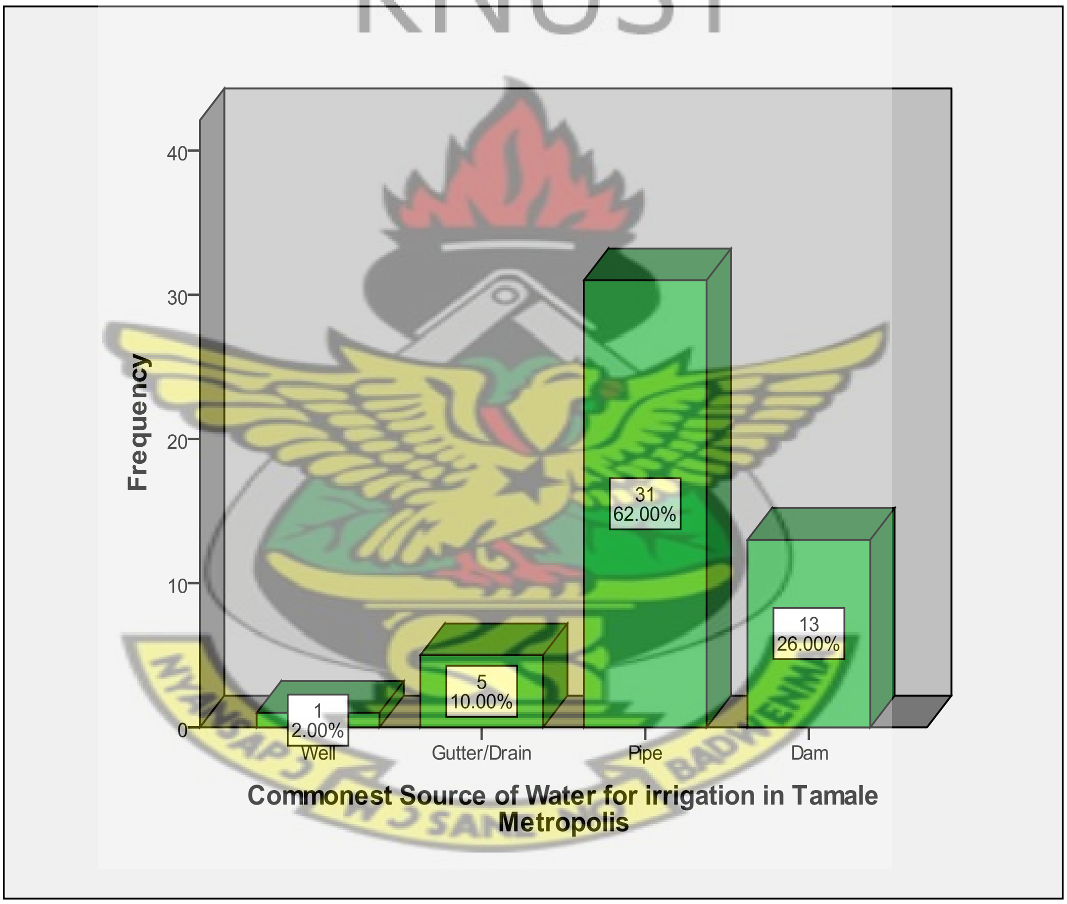

Figure 4.2 Sources of Water for Irrigating Cabbage.

Source: Field work, May, 2011.

4.4 Effects of Different Water Sources on the Postharvest Quality of Cabbage

4.4.1. Weight of cabbage

The weights of the cabbage varied according to the water source. (Table 4.4)

Table 4.4 Effects of Water Sources on the weight of Cabbage

Source	Weight of cabbage at each point/kg					Average weight/kg
	P1	P2	P3	P4	P5	
Nobisco pipe	2.1	2.3	2.5	2.0	2.1	**2.2**
Builpela dam	2.6	2.7	2.7	2.5	2.3	**2.6**
Gumani Gutter	3.7	3.4	3.0	3.4	3.8	**3.5**
Waterworks well	2.2	2.4	2.4	2.1	2.6	**2.3**
Chefurigu dam	2.4	2.5	2.6	2.3	2.3	**2.4**

Source: Field Work, May, 2011.

P=Point of sample collection

4.4.2 Development of Rots and Defects

Most of the cabbages were observed to have a lot of defects and the farmers claimed that this was due to excessive heat at the time of planting. According to the farmers heat is normally accompanied by some red tiny insects that feed on the leaves of the cabbage. In some cases the situation was so serious that the leaves of the cabbages never form heads.

4.4.3 Shelflife

From the interview conducted with most consumers in the open market, restaurants, hotels, guesthouses and fast-foods, different responses were obtained. Forty four percent (44%) of the respondents indicated that cabbage can be stored for maximum of 2-4 weeks, 24% showed that at maximum, cabbage can be stored for 2 weeks and the same percentage was also recorded for 4-8 weeks. The remaining respondents (8%) revealed that cabbage can be stored for 8-16 weeks. It was observed that consumers do not store cabbage beyond16 weeks.

Table 4.5 the Storage Life of Cabbage

	Consumers					
	Hotels	**Market**	**Fast foods**	**Guesthouses**	**Restaurants**	**Total**
>16wks	N	N	N	N	N	0 (0%)
8-16wks	1	2	N	1	N	4 (8%)
4-8wks	2	1	3	3	3	12 (24%)
2-4wks	6	3	5	4	4	22 (44 %)
2 wks	1	4	2	2	3	12 (24%)
Total	10	10	10	10	10	**50**

Source: Field Work, May, 2011.

N=None

4.5 Risk Associated with the Consumption of Cabbage

The descriptive statistics revealed that 32 producers representing 64% and 43 consumers also representing 86% showed that the consumption of cabbage may be associated with some level of risk from contamination. However, 18 producers and 7 consumers representing 36% and 14% respectively revealed that the consumption of cabbage is not associated with any risk.

Table 4.6 Response about the Risks of Cabbage Consumption

Risk associated with the consumption of Cabbage	Target group		TOTAL
	producers	Consumers	
YES	32 (64%)	43 (86%)	75
NO	18 (36%)	7 (14%)	25
TOTAL	**50 (100%)**	**50 (100%)**	**100**

Source: Field Work, May, 2011.

4.6 Quality of Water Used for Irrigating Cabbage

From Table 4.4, it is evident that pipe water recorded zero for both TC and FC for all months except the month of January where 1cfu m/l was recorded for FC. However, the rest of the sources recorded values above the recommended standard by WHO and EPA. The well water like pipe water recorded low figures but there were still significant difference between the pipe water and the well water.

Table 4.7 Total Coliforms (TC) and Faecal Coliforms (TF) Content of Irrigation Water Sources

Month	Coliforms	Pipe	Builpela Dam	Gutter/Drain	Well	Chefurigu Dam
January	TC	1cfu m/l	138cfm/l	148 cfu m/l	20cfum/l	105cfu m/l
	FC	1cfu m/l	98cfum/l	102 cfu m/l	18cfu m/l	100cfu m/l
February	TC	None	81cfum/l	306 cfu m/l	65cfu m/l	105cfu m/l
	FC	None	67cfum/l	204 cfu m/l	60cfu m/l	75 cfu m/l
March	TC	None	45cfum/l	272 cfu m/l	20cfu m/l	46cfu m/l
	FC	None	30cfum/l	168 cfu m/l	20cfu m/l	28 cfu m/l
April	TC	None	66cfum/l	254cfu m/l	69cfu m/l	78cfu m/l
	FC	None	58cfum/l	128 cfu m/l	65cfu m/l	72 cfu m/l
May	TC	None	TNC(∞)	TNC (∞)	TNC (∞)	TNC (∞)
	FC	None	TNC(∞)	TNC (∞)	TNC (∞)	TNC (∞)

Source: Field work, May, 2011.

TNC= Too Numerous to Count

4.7 Microbial Analysis of cabbage

From Table 4.8, it was realised that after washing the cabbages with sterilised water and screening for faecal coliforms, the pipe water was found not to have any infection, the Builpela dam and Chefurigu dam had a total of 29 cfu m/l and 41cfu m/l respectively. The Gumani gutter/drain was found to have the highest infection value of 74 cfu m/l.

Table 4.8 Faecal Coliforms content of washed cabbage

Month	Nobisco pipe	Builpela dam	Gumani gutter	Waterworks well	Chefurigu dam
May	0cfu m/l	17cfu m/l	31cfu m/l	8cfu m/l	23cfu m/l
April	0cfu m/l	12cfu m/l	43cfu m/l	5cfu m/l	18cfu m/l
Total	**0 cfu m/l**	**29 cfu m/l**	**74 cfu m/l**	**13cfu m/l**	**41 cfu m/l**

Source: Field work, May, 2011.

4.8 Findings of the Study

The findings of the work were based on the data collected for analysis and interpretation.

4.8.1 Key Findings of the Study

The commonest source of water for irrigation in the metropolis is pipe water used in Nobisco and some parts of Waterworks. The least was well water. The findings also revealed that apart from pipe water, the rest were heavily polluted and are above the recommended water quality standard (10 cfu mL^{-1}) for irrigation by World Health Organization (WHO) and Environmental Protection Agency (EPA).

4.8.2 Other Findings of the Study

The field survey together with the data analysis revealed that, gender, age and educational background have influence in cabbage irrigation farming in the study area. The research also indicated that both producers and consumers of cabbage are consciously aware of some level of contamination along the production consumption path -way. The quality of cabbage produced in the study area with irrigation water has some physical defects. The findings also revealed that both producers and consumers are aware that irrigation water has effects on postharvest quality of cabbage.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Socio-Demographic Characteristics of Respondents

Gender plays a vital role in every farming community in the Northern Region. Generally, men are engaged in farming than women. The rational for male domination is simply that they are family heads and are the sole providers of food. Women on the other hand are house wives and are responsible for processing, preserving and marketing of farm produce.The descriptive statistics from the research revealed that 86% of those involved in cabbage production were males whiles 14% were females. This is in agreement with the report by Drechsel *et al* (2006) that, in 16 out of 20 cities in West Africa, men are mostly involved in open-space urban vegetable farming while in most cases; women dominated the vegetable retail sector. Almost all the people in the metropolis who sell vegetables in the market and on the streets are women.

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 41-50 years dominated with a percentage of (64%). Many of the producers between 21-30 years and 31-40 years were people who are still at school going age and people who are seeking white colour jobs, respectively. The informal nature of urban and peri-urban irrigated vegetable farming could also account for the low participation of the youth. The area under cultivation is fragmented and small in size.

This explains the reasons why low figures were recorded for those age groups.

It was also found that, those who were engaged in cabbage irrigation farming had little or no education. 80% of the producers were illiterates. This is typical in Africa where Agriculture is considered to be for those who are not educated. This phenomenon is seriously affecting agricultural productivity since most of our illiterate farmers are not aware of good agronomic practices and many other issues regarding postharvest handling and storage of farm produce especially perishable vegetables.

The results obtained from the study indicated that there are five main sources of water used for irrigation in the Tamale Metropolis with pipe water as the main source of irrigation water. This finding contradicts the report by Keraita *et al*., (2002) that wastewater is the only reliable water sources for irrigation throughout the year in urban areas. However, the use of potable water for urban/peri-urban crop production in Ghana is constrained by high tariffs, making it uneconomical and non viable (Sonou, 2001). Many producers complained about the cost on tariffs and the irregular supply of water in the Metropolis. Unfortunately, there are no large and reliable rivers with tributaries passing through the Tamale Metropolis along which many farms are situated. As a result of the inaccessibility to river water as well as the unavailability supply of treated water, for irrigation cabbage farmers rely heavily on other sources of water.

5.2Methods of Irrigation

5.2.1Watering Cans

This is the second to rubber hose irrigation method used in all the study areas in the metropolis. It is also the best one for fragile leafy vegetables. Farmers use watering cans of 15liters to fetch and manually carry water from a water source, mostly shallow dug wells and dams, to the fields, followed by watering of crops through the spout or shower head of the can simulating an overhead irrigation method. The 1cfu m/l recorded in the pipe water for the month of January could be due to leakage of the pipe lines or from the water hose as farmers come into contact with it.

5.2.2 Bucket Method

Regarding this method, bowls and buckets are used to fetch water, usually from a dam, gutter or dugout. It is then manually carried to the fields where it is either applied directly or put in a drum to be applied later. This practice mostly involved children carrying buckets as 'head loads' and is commonly done in the peri-urban areas. Here male farmers involved family members and take advantage of the traditional role of women and children in transporting water. Farms are comparatively far from the water source than where watering cans are used, but normally are less than 50m. The manner of watering either overhead or to the roots is determined by crop height and type. Farmers using buckets and watering cans come in contact with water mainly by stepping in it while fetching, or water splashing on them while carrying and during watering. Crop contamination is very high due to the combination of the facts that crops have large surface area and are irrigated through overhead application

5.2.3 Rubber Hose

Majority of cabbage producers (54%) in the metropolis use this method for irrigation. Usually this method uses pipe water as the source. The rubber hose is connected to the mouth of the pipe and the pipe opened to allow the water flow. 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. With the flood irrigation method the topography of the field has to be taken into consideration. See appendices.

The level of coliforms contamination on the cabbage however depended on the method of irrigation used. The results indicated that watering cans and buckets are employed in the study area making it an overhead irrigation method. This explains why most of the cabbages 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 leafy vegetables provide large contact surfaces for water and for the attachment of microorganism.

The findings is also in line with the report by Francis *et al* (1999) that farming conditions and practices play a critical role in the contamination of farm produce.

5.3 Effects of the Different Water Sources on the Postharvest Quality of Cabbage

The weights of the cabbage at maturity varied for the five water sources. The cabbages produced with pipe water were the smallest in size with an average of 2.2kg. Those cabbages produced with dam water and well water were almost the same in size. The cabbage produced with gutter water was found to be the biggest among all the five sources with an average weight of 3.5kg. On the average most of the cabbages weighed 3kg -5kg. It is therefore clear that the source of water used for irrigation had an effect on the size and weight of the cabbage produced in the study area.

The development of defects and rots also followed the same trend. Defects and rots where found to be common with cabbages produced with the gutter/ drain water.

Cabbage irrigated with pipe water had the least defects, followed by the well water and then the two dams.

The study revealed that both producers and consumers are aware of possible contamination and its subsequent risk to their health would prefer to have quality produce. However, considering the educational level of the producers and the general behaviour of consumers in Ghana, change in attitude may be very slow process. Bruhn, (2006) reported that consumer awareness is a slow process and the public cannot be relied on to wash or cook fruits and vegetables sufficiently to destroy any pathogens that might be present.

The findings also showed that water quality can affects the shelf life of cabbage and cabbaged produced with pipe water had longer shelflife than other sources.

5.4 Coliforms Count (Microbial Analysis)

The microbial analysis revealed that all the water from the metropolis, except pipe water, are not safe for use as irrigation water.

The high level of faecal coliforms contamination in the two dams especially the Chefurigu dam could be that, it has a lot of water deposited in it from many sources. Again, the two dams are located within settlement areas that have no access to toilet facilities. Animals also drink from the dams and therefore defecate around the dams basins. The high level of faecal coliforms detected also agrees with the report made by Barnes and Taylor (2004) that human faeces is entering water bodies through failing sewage pipes and treatment plants, illegal release of untreated sewage and the close proximity of informal settlements with no sanitation facilities to water bodies which become the obvious dumping ground for the generated waste. The metropolis has no waste treatment plants and also the problem of inadequate toilet facilities could all account for the high level of contamination. The number of faecal coliforms found in all the water sources was above the recommended 10cfu mL^{-1} by World Health Organization and Environmental Protection Agency.

This agrees with the findings made by Obuobie *et al* (2006) that many Ghanaian waters that are drawn for agricultural irrigation purposes are heavily polluted and have high pathogenic loads.

Other studies in from Ghana, Senegal and Kenya have also shown which stated that the bacteriological contamination of urban water sources generally exceeds irrigation standards, and can contribute significantly to crop contamination (Keraita *et al.*, 2002,Niang*et al.*, 2002).Thus, despite all the benefits of urban cabbage irrigation farming in terms of food supply, nutrition, employment, and poverty alleviation, its production poses human and environmental risks which makes it struggle for official recognition, not to mention support, especially in Sub-Saharan Africa with its complex urban sanitation problems (Drechsel *et al.*, 2006; Obuobie *et al*.,2006)

However, the possibility of solving the high level of water contamination in the Metropolis seem to be a mirage as there are no proper drains, poor sanitation systems and inadequate sewage disposal. Drechsel *et al* (2006) reported that better municipal water treatment is not possible in the near future thus no possibility to meet the common irrigation water quality guidelines.

The results obtained after washing the cabbages as prescribed by Feenstra *et al* (2000) showed that the rate of prevalence followed the same trend as the sources of water. Which agrees with the findings by Garcia *et al* (1987), that under commercial conditions of 181 irrigation samples and 859 vegetables irrigated with the same water source in Spain were contaminated with *Salmonella typhimurium; S. kapemba; S. london*and *S. blockey*serotypes.

It was also found that, the high rate of infection could probably be due to the methods of irrigation. FDA, (1998) reported that different irrigation methods have been found to correlate with the level of microorganisms present on produce. As mentioned that rubber hose, watering cans, buckets and are the methods commonly used in the study area. Thus a large portion of the cabbages come into contact with during irrigation. The high rate of infection could be due to the nature of the produce as reported by Beuchat and Ryu (1997) that the transfer of microorganisms from irrigation water to produce is dependent on the nature of the produce.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

The findings of the study indicated that water sources such as those from gutters/drains, dams and wells were heavily polluted and not safe for irrigation purposes. It was also established that the main source of water used for irrigation in the Tamale metropolis was pipe water. However, cabbage farmers complained about the cost of water tariffs. Farmers in the metropolis use rubber hose, watering cans and buckets for irrigation.

The presence of coliform bacteria in the gutters, dams and wells is an important parameter for cabbage produced in the Tamale to be thoroughly washed with brine or vinegar before used. The research also indicated that both producers and consumers of cabbage are consciously aware of some level of contamination along the production consumption path -way. The quality of cabbage produced in the study area with irrigation water has some physical defects.

These waters are scheduled for irrigation but they cannot be recommended without antimicrobial treatment, because fruits and vegetables quality depend on the quality of irrigation water and other factors. While it is acknowledged that environmental conditions may affect the survival of pathogens on produce, these conditions are unpredictable and vary seasonally, or even daily.

In Tamale Metropolis, industrial contribution to water pollution is generally low. High levels of faecal contamination are mainly due to inadequate sanitation facilities in the city which leads to poor sanitation practices like open defecation, and broken down sanitation infrastructure. However, the studies were not sufficiently detailed to verify these observations. As water quality continues to deteriorate, especially in the metropolis, it is pertinent to counteract and improve the situation.

In view of limited private and public resources to mitigate nonpoint source pollution through improved infrastructure, educating the public about the dangers of indiscriminate solid and liquid waste disposal should be institutionalized.

In the mean time, the enforcement of standards through regular testing of produce will increase the safety of food for the consumer in the short-term, until the quality of our water is restored to safe levels.

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APPENDICES

Appendix 1 Questionnaire for the Assessment of microbial content of water used for irrigation and their effects on the postharvest quality of cabbage (*brassica oleracea var. capitata*) in the Tamale metropolis

A. Personal Background

01. What is your name?..

02. How old are you ☐☐

03. Sex? A. Male ☐

B. Female ☐

04. Are you married?

A. Yes ☐
B. No ☐
C. divorce ☐
D. Separated ☐
E. Others.............................

05. Do you have children?

A. Yes ☐
B. No ☐
C. Don't Know ☐
D. Others..

06. What is the sex of your children A. male ☐

B. female ☐

B. Educational Background

07. Have you ever attended school?

A. Yes ☐
B. No ☐
C. Others..

If **No**, skip question 8

08.What is your highest level of education?

A. Primary ☐
B. Secondary ☐
C. Tertiary ☐
D. Others...

PRODUCERS/FARMERS

09. What is your source of water for irrigation?

A. Well ☐
B. Gutter/stream ☐
C. Pipe ☐
D. Dam ☐
E. Others.................................

10. Do you think your source of water is clean for irrigation?

A. Yes ☐

B. No ☐

C. Others……………………………….

11. What is the physical quality of water used for irrigation?

A. Very good (colourless) ☐
B. Good (slightly turbid) ☐
C. Bad (green/very turbid) ☐

12. Does the source of water have an effect on the yield and quality of your vegetables?

A. Yes ☐

B. No ☐

C. DK ☐

D. Others………………………………..

13. What is the commonest source of water for irrigation in the Metropolis?

A. Well ☐
B. Gutter ☐

C. Pipe ☐
D. Dam ☐
E. Others……………………………

14. What water source do you consider best for irrigation?

A. Well ☐

B. Pipe ☐

C. Gutter ☐

D. Dam ☐

E. Others………………………

15. Do you have a regular source of water for irrigation?

A. Yes ☐
B. No ☐
C. Others......................................

16. What type of equipment do you use for irrigation?

A. Pumping machine ☐

B. Hand fetching ☐

C. Others…………………………

17. Do you think water quality affects postharvest storage of cabbage?

A. Yes ☐

B. No ☐

C. Others…………………..

18. Do you feel any stomach discomfort after eating the cabbage you produce?

A. Yes ☐

B. No ☐

C. Others……………….

19. Do you think the cabbage you produce have health hazards to consumers?

A. Yes ☐

B. No ☐

C. Others……………………..

20. Do you use your children as labour in your vegetable farm?

A. Yes ☐
B. No ☐
C. Others............................

21. What age bracket do you use as labour in your cabbage farm

A. 0 -17 years ☐

B. 18 – 60 years ☐

C. 61 ≥ years ☐

CONSUMERS

09. Do you like the type of cabbage in the market?

A. Yes ☐
B. No ☐
C. Others......................

10. If yes why…………………….if no why………………..

11. Where do you buy your cabbage from?

A. Producers ☐
B. Middlemen ☐
C. Market ☐
D. Others.......................................

12. Does the cabbage you buy store for long?

A. Yes ☐
B. No ☐
C. Others....................................

13. Do you think water quality affects postharvest storage of cabbage?

A. Yes ☐
B. No ☐
C. DK ☐
D. Others……………………

14. Do you feel any stomach discomfort after eating fresh/cooked cabbage you buy?

A. Yes ☐
B. No ☐
C. Others……………….

15. What is the commonest source of water for irrigation?

A. Well ☐
B. Gutter ☐
C. Pipe ☐
D. Dam ☐
E. Others……………………………

16. Do you like the appearance of the cabbage you eat?

A. Yes ☐
B. No ☐
C. Others..

17. Do you like the taste of the cabbage you eat?

A. Yes ☐
B. No ☐
C. Others..

18. Do you know the source of water used for irrigation?

A. Yes ☐
B. No ☐

19. Does the quality of water used for irrigation affect the quality of cabbage produced?

A. Yes
B. No
C. DK
D. Others....................................

20. What type of water would you prefer producers to use for irrigation?

A. Pipe borne water
B. Well water
C. Gutter water
D. Others...............................

21. Does the cabbage you buy store for long

A. Yes
B. No

22. Does the cabbage you buy have physical defects or rots?

A. Yes
B. No

Appendix 2. **Testing of Hypothesis**

The null hypothesis, the statement to be tested can either be accepted or rejected after comparing the test statistics to the critical value. The sample data contained in table 4.8 are the FC values of the various water sources.

Contingency Table for Computation of Test Statistics

Month	Nobisco pipe	Builpela dam	Gumani gutter	Waterworks well	Chefurigu dam	Marginal Row Totals
January	1	98	102	18	100	**319**
February	0	67	204	60	75	**406**
March	0	30	168	20	28	**246**
April	0	58	128	65	72	**323**
May	**0**	**∞**	**∞**	**∞**	**∞**	**∞**
Marginal Column Totals	**1**	**253**	**602**	**163**	**275**	**1,294**

Source: Field work, May, 2011.

Determining the Critical Value

The critical value was determined using the degree of freedom= (Rows-1) (Columns-1)

= (4 – 1) (5 – 1) = 12.

Given the alpha level (α=0.05), the chi-square table indicated 2.179 as the critical value (chi-square critical).

3.10.2 Computation of Test Statistics Using the Formula

The approximated expected cell frequencies are;

$X^2 = \Sigma\, [(fo\text{-}fe)^2]$, where *fo*represents the data obtained from the field, and *fe* is

represented as *fe*= (Row total) (column total)

Grand total

The expected frequency (*fe)* is therefore calculated as follows:

$Fe_{1,1} = \frac{(319)(1)}{1294} = 0.2465$ $\qquad$ $Fe_{2,1} = \frac{(406)(1)}{1294} = 0.3138$

$Fe_{1,2} = \frac{(319)(253)}{1294} = 62.3702$ $\qquad$ $Fe_{2,2} = \frac{(406)(253)}{1294} = 79.38023$

$Fe_{1,3} = \frac{(319)(602)}{1294} = 148.4065$ $\qquad$ $Fe_{2,3} = \frac{(406)(602)}{1294} = 188.8809$

$Fe_{1,4} = \frac{(319)(163)}{1294} = 40.1832$ $\qquad$ $Fe_{2,4} = \frac{(406)(163)}{1294} = 51.1422$

$Fe_{1,5} = \frac{(319)(275)}{1294} = 67.7937$ $\qquad$ $Fe_{2,5} = \frac{(406)(275)}{1294} = 86.2828$

$Fe_{3,1} = \frac{(246)(1)}{1294} = 0.1901$ $Fe_{4,1} = \frac{(323)(1)}{1294} = 0.2496$

$Fe_{3,2} = \frac{(246)(253)}{1294} = 48.0974$ $Fe_{4,2} = \frac{(323)(253)}{1294} = 63.1522$

$Fe_{3,3} = \frac{(246)(603)}{1294} = 114.6352$ $Fe_{4,3} = \frac{(323)(602)}{1294} = 150.2674$

$Fe_{3,4} = \frac{(246)(163)}{1294} = 30.9876$ $Fe_{4,4} = \frac{(323)(163)}{1294} = 40.6871$

$Fe_{3,5} = \frac{(246)(275)}{1294} = 52.2797$ $Fe_{4,5} = \frac{(323)(275)}{1294} = 68.6437$

Computation of Test Statistics

Cells	$fo_{i,j}$	$fe_{i,j}$	$(fo_{i,j} - fe_{i,j})$	$(fo_{i,j} - fe_{i,j})^2$	$\frac{(fo_{i,j} - fe_{i,j})^2}{fe_{i,j}}$
$Fe_{1,1}$	1	0.2465	0.7535	0.5678	2.3034
$Fe_{1,2}$	98	62.3702	35.6298	1269.4826	20.3540
$Fe_{1,3}$	102	148.4065	-46.4065	2153.5632	14.5112
$Fe_{1,4}$	18	40.1832	-22.1832	492.0943	12.2463
$Fe_{1,5}$	100	67.7937	32.2068	1037.2780	15.3005
$Fe_{2,1}$	0	0.3138	-0.3138	0.9229	2.9410
$Fe_{2,2}$	67	79.3802	-12.3802	153.2694	1.9308
$Fe_{2,3}$	204	188.8809	15.1191	228.5872	1.2102
$Fe_{2,4}$	60	51.1422	8.8578	78.4606	1.5341
$Fe_{2,5}$	75	86.2828	-11.2828	127.3016	1.4754
$Fe_{3,1}$	0	0.1901	-0.1901	0.0361	0.1899
$Fe_{3,2}$	30	48.0974	-18.0974	327.5159	6.8094
$Fe_{3,3}$	168	114.6352	53.3648	2847.8019	24.8423
$Fe_{3,4}$	20	30.9876	-10.9876	120.7274	3.8960
$Fe_{3,5}$	28	52.2797	-24.2797	589.5038	11.2760
$Fe_{4,1}$	0	0.2496	-0.2496	0.0623	0.2496
$Fe_{4,2}$	58	63.1522	-5.1522	26.5452	0.4203
$Fe_{4,3}$	128	150.2674	-22.2674	495.8371	3.2997
$Fe_{4,4}$	65	40.6871	24.3129	591.1171	14.5284
$Fe_{4,5}$	72	68.6437	3.3563	11.2647	0.1641
					139.4826

From the test statistics, the researcher finds that $\sum_{i=1}^{4}\sum_{j=1}^{5}\frac{(fo_{i,j}-fe_{i,j})^2}{fe_{i,j}} = 139.48$

Decision Making

The computed chi-square which is 139.48 when compared to the critical chi-square (2.179), it is quite obvious that the computed chi-square is greater than the critical value; therefore the researcher failed to accept the null hypothesis (H_o) that*; the quality of irrigation water has no effect on vegetables products.*

It is important to note that, if the null hypothesis is rejected based on the statistics, we cannot say that the null hypothesis is false. Failure to reject the null hypothesis does not prove that the null hypothesis is true; it means that the sample data does not provides enough evidence to disprove the null hypothesis (Douglas e*t al* 2000). On the other hand, if the researcher accepts the null hypothesis, it does not mean that the null hypothesis is true; the researcher has only been able to prove the null hypothesis base on the sample data.

Conclusion

Since the computed chi – square is greater than the critical chi – square, the null hypothesis was rejected in favour of the alternative hypothesis (H_a) which was earlier on stated as*; the quality of irrigation water has effect on vegetable products and a related health hazards to consumers of such products.*

As a result, the researcher can therefore theorized that, the quality of irrigation water has effect on cabbage and a related health hazards to consumers of such products.

Appendix 3. Builpela Dam

Appendix 4. A farmer washing vegetables in Chefurigu Dam

Appendix 5.A farmer irrigating cabbage with pipe water using a rubber hose

Appendix 6. A farmer irrigating cabbage with well water using watering cans