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EFFECTS OF QUALITY OF IRRIGATION WATER ON THE QUALITY OF SELECTED VEGETABLES IN THE KUMASI METROPOLIS

BY

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A THESIS PRESENTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF PHILOSOPHY (MPHIL.) POSTHARVEST TECHNOLOGY

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DECLARATION

I hereby declare that this work submitted to the School of Graduate Studies, Kwame Nkrumah University of Science and Technology Kumasi Ghana as a thesis for the Masters of Philosophy (Postharvest Technology) Degree is the result of my own original work and that this thesis has not been presented for any degree in this university or elsewhere, except for the literature references to other peoples work, which I have duly acknowledged.

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DEDICATION

This work is dedicated to my children Abraham Nkeamoroh, Monica A. Gyimah, Pascaline A. Gyimah, Pascalina A. Gyimah and Lois A. Gyimah and also to my late cousin Mr. Emmanuel Kofi Kumah.

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ABSTRACT

The research was carried out in five vegetable growing locations in the Kumasi metropolis to assess the effects of the quality of irrigation water on the quality of three different vegetables which were cabbage, carrots and green pepper. The objectives of the study were to identify the quality of the sources of irrigation water used in vegetable cultivation and determine the effect the water has on the vegetables in terms of microbial and pesticide contamination, and also determine microbial load content of vegetables in some markets where vegetables from the study area are sold. A field survey was first carried out where one hundred and twenty respondents were interviewed. They comprised of vegetable farmers, vegetable sellers, vegetable consumers, food sellers, agrochemical sellers and agricultural extension officers. The results obtained showed that the sources of water for irrigating vegetables in the Kumasi metropolis are dugouts and rivers/streams. Some farmers treated the water before use (filter or add some pesticides). Vegetables are mostly harvested by vegetable sellers and carried to the market. From the results, most consumers wash their vegetables with salt solution while majority of food vendors wash vegetables with only water. Laboratory test was carried out on the irrigation water and the vegetables from the growing sites and markets to determine the pesticide residue and microbial load content. The results showed that, only DDT and chlorpyrifos were detected in the irrigation water in very low values while thirteen pesticide residues were detected in the vegetables from the field. Total coliform, faecal coliform and Ecoli counts were also detected in the irrigation water, vegetables from the field and from the market. Irrigation water from KNUST had the highest total coliform count, while water from Ramseyer had the lowest. Also, carrot recorded the highest levels of total coliform, faecal coliform and E.coli, followed by green pepper and the lowest being cabbage.

On the average, vegetables from Ramseyer had the highest total coliform, faecal coliform and E.coli levels while Kwadaso had the lowest total coliform and faecal coliform counts and KNUST recording the lowest E.coli count. The results also showed that microbial contamination is higher in vegetables from the markets than from the field which is also higher than that of the irrigation water. Dry matter and moisture content were also determined and it revealed that carrot contains 11.34% dry matter, green pepper contains 5.55 and cabbage contains 6.38%, this shows that really, vegetables contain more moisture than dry matter content. The study revealed that microbial and pesticide contamination of vegetables does not depend on only irrigation water.

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LIST OF ABBREVIATIONS

CFU	-	Coliform Forming Unit
DDD	-	Dichloro Diphenyl Dichloroethane
DDE	-	Dichloro Diphenyl Dichloro Ethylene
DDT	-	Dichloro Diphenyl Trichloroethane
E.coli	-	Eschericha-coli
FAO	-	Food and Agriculture Organisation
MPN	-	Most Probable Number
MRU	-	Maximum Residual Level
POP	-	Persistent Organic Pollutant
UEW	-	University of Education Winneba-Kumasi campus
USEPA	-	United State Environmental Protection Agency

CHAPTER ONE

1.0 INTRODUCTION

Vegetables are edible plants or their parts intended for cooking or eating raw. They are important items in the human diet because they supply nutrients such as vitamins and minerals which are often lacking in most of the staple foods (Tweneboah, 2000). Vegetables constitute an indispensable constituent of human diet in Africa. They may be consumed raw or as cooked complement of the major staples like cassava, cocoyam and plantain (Afolabi and Oloyede, 2010). Vegetables are very useful to man in many ways including nutritional, economic and even medicinal.

Urban irrigated vegetable production has gained roots in most of our cities in Ghana. Most of the vegetable farms are sited around or near surface water bodies which are used for irrigating the vegetable crops. These water bodies are usually filled by runoff water, most of which may contain pollutants from domestic waste, industrial waste and sewage from health facilities.

The postharvest quality of horticultural crops can strongly be influenced by preharvest practices on the field, therefore if the water used is polluted it may affect the postharvest quality of the vegetables produced which may lead to postharvest challenges such as food poisoning which can result in serious health problems such as diarrhoea, dysentery and cholera among the populace. It was reported by Gyampah (2014), that the US has put a ban on export of vegetables from Ghana to their region because they have identified some vegetables from Ghana that did not meet their quality standards.

Vegetables are important sources of nutrients in the human diet. They are more frequently eaten raw (Norman, 1992). Nurudeen (2010) reported that most vegetable farmers in Tamale use polluted water to irrigate their crops. This has prompted the researcher to also assess the quality of some vegetables produced in some areas in the Kumasi metropolis under irrigation. Although some researchers have done some study on the effects of irrigation water on the quality of vegetables in some cities in Ghana including Kumasi, their focus was on lettuce.

The research finding that will emerge from this study will provide information on safety of consuming vegetables produced in the study area. It may create awareness to farmers of the negative effects on the consumers of their produce and so make them seek more information and education on the kind of water to use for irrigation, the need to treat surface water before using it to irrigate their crops, and also the need to adhere to good production practices.

The research will also provide qualitative data on the water used and the vegetables produced in Kumasi which will be useful for policy formulation, monitoring, evaluation and institutions of intervention for safer vegetable production and challenge them to come out with corrective measures for more efficient irrigation practice.

1.2 MAIN OBJECTIVE

The main objective of this study was to assess quality of the sources of irrigation water and their effect on the quality of three vegetables (carrot, cabbage, and green pepper) cultivated in some selected areas in the Kumasi metropolis.

1.3 SPECIFIC OBJECTIVES

1. To identify the sources of water used for irrigating vegetable crops in the

Kumasi metropolis.

2. To determine the physical quality of vegetables produced.
3. To determine the microbial contaminants and pesticide residue present in the water and in the vegetables from the production site, the microbial contaminants on the vegetables from the market.
4. To determine the postharvest treatment of vegetables before serving or consuming.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 URBAN VEGETABLE PRODUCTION

Central to urbanisation phenomena are qualitative and quantitative changes in urban food demands. These changes challenge food production, rural urban linkages, transport and traditional market chains, specialized urban and peri – urban farming systems appear, like large scale poultry production or urban and peri – urban agriculture (Obuobie *et al*., 2006). Young people in search of stable employment migrate to Dar es, Salaam, Addis Ababa, Lilangwe, Maputo and smaller cities throughout the region but often are disappointed by the lack of job opportunity (AVRDC – the world vegetable center, 2013)

AVRDC – The world vegetable center (2013), explained further that, in addition to providing employment for youth and improving incomes, labour intensive peri-urban vegetable production can lead to greater diversity in diets – an urgent and vital need in target countries where micronutrient and malnutrition is widespread. Also, land in peri- urban corridors with an adequate supply of water as well as good transport connection that allows produce to reach cities within two-three hours has potential for the production of fresh vegetables.

2.2 THE NEED FOR IRRIGATION IN VEGETABLE PRODUCTION.

According to Cornelius and Obeng-Ofori (2008), rapid urbanisation with its effects on life style, work organization, food preference and hence food demand will require significant adjustment in food production and marketing and food security policies. Irrigation as defined by Hanson *et al.*, (1980), is the application of water to soil for the purpose of supplying the moisture essential for plant growth. However, a broader and more inclusive definition is that, irrigation is the application of water to the soil for any number of the following eight purposes.

- To add water to the soil to supply the moisture essential for plant growth
- To provide crops insurance against short duration drought
- To cool the soil and atmosphere, thereby making more favourable environment for plant growth
- To reduce the hazard of frost
- To wash out or dilute salt in the soil
- To reduce hazard of soil piping
- To soften tillage pans and clods
- To delay bud formation by evaporative cooling

Most cultivated plants require a continuous supply of water to produce crops. Except in the seed stage, water, is the major portion of a plant's composition and is necessary for all vital functions (wolf, 2003). Wolf, (2003) sated further that, even in regions receiving excess of water, there are times when irrigation can provide extra return but the grower must know precisely when these periods occur.

Norman (1992) also stated that in the savanna zones, water availability is vital due to the lower rainfall, irrigations, is therefore very essential. The need to irrigate is usually driven by the necessity to meet water needs of the crop from year to year. Crop irrigation is vital throughout the world in order to supply water requirement not satisfied by rainfall, to provide the world's ever growing population with enough food (USGS Water Science School, 2014). However, the amount of water that has to be added to promote ideal growth will vary with crop, stage of growth of the crop, soil conditions, present water content and depth of rooting (wolf 2003).

Wolf (2003) further stated that there will be a response to irrigation at most stages of growth if the plant is under severe stress from lack of water but response at the critical

period can be obtained even if stress is mild. The critical point varies at different stages of growth. For many plants, period of seed germination and seedlings development is critical. Relatively small reduction in available water at flowering or period of fruit development and enlargement can also seriously limit yield of many plants. The need for irrigation has been brought forcibly to the attention of farmers throughout the world because of severe droughts that have affected much of the area. Although sufficient rainfall may be available for growing crops in normal years, it has been found through costly experience that short periods without rainfall have ruined crops which would otherwise have brought ample returns to the farmer
(Hanson *et al.,* 1980).

2.3 TYPES OR METHODS OF IRRIGATION

Vegetable crops differ in which method of irrigation can be used economically in their production. Three types of irrigation are commonly used in Alabama: Sprinkler, Big gun and Trickle or Drip irrigation (Kemble and Sanders 2007)

According to the USGS Water Science School (2014) many different irrigation methods are used worldwide, including center-pivot, Drip, flood, Furrow, Gravity, Rotation, Sprinkler, Sub- irrigation, travelling Gun, supplemental and surface irrigation
AgriEngineers.com – Types of irrigation (2006) also identified the types of irrigation as ditch or furrow irrigation, terracing, overhead (sprinkler) irrigation, center pivot irrigation, lateral move irrigation, drip or trickle irrigation, sub-irrigation and hand watering.

2.4 SOURCES AND QUALITY OF WATER USED FOR IRRIGATING VEGETABLES.

Water for irrigation is usually taken from the nearest convenient and dependable source available such as streams, rivers, lakes and underground water (Tweneboah 2000).

Basically rain and snow are the sources of all water. That portion which is not used at the point where it falls flows over the surface of the land and seep into the ground and augments the ground water supply. Therefore, the rain or snow which is not used becomes a potential source of surface or underground water for irrigation (Hasen *et al.*, 1980). Hasen *et al.*, (1980) stated further that irrigation water may also come from waste water which is water that is not used consumptively by agriculture, industry and municipalities.

Many water bodies near urban areas are highly polluted. This is the results of both garbage dumped by individuals and dangerous chemicals legally or illegally dumped by manufacturing industries health centers, schools and market places (eschool today 2010).

Sources of water for irrigation according to the Northeast Region Certified Crop Adviser (NRCCA) (2010) can include surface water sources, ground-water sources, municipal water supplies, grey-water sources and other agriculture and industrial process wastewater.

Farm water comes from a number of different sources and so its quality varies, water sources include dams, wells, rivers, town water, channels and recycled water.

According to Obuobie *et al.* (2006), the most common sources of water for urban irrigation in Kumasi is the use of stream and rain water highly polluted with domestic grey water. A report by Nurudeen, (2010) stated that some vegetable farmers in Tamale are using polluted water that runs through gutters and big drains in some parts of the metropolis to irrigate their vegetables.

The quality of irrigation water available to farmers and other irrigators has considerable impact on what plants can be successfully grown, the productivity of these plants and water infiltration and other soil physical conditions (Bauder *et al.,* 2014). According to Bauder *et al.,* (2014), soil scientist, use the following categories to describe irrigation water effects on crop production and soil quality.

- Salinity hazard – total soluble salt content
- Sodium hazard – relative proportion of sodium to calcium and magnesium ions
- PH – Acid or base
- Alkalinity - carbonate and bicarbonate
- Specific ion – chloride, sulfate, boron, and nitrate

Another potential irrigation water quality impairment that may affect suitability for cropping system is microbial pathogens. Water from various sources may be of unsuitable quality for its intended use for irrigation, stock, household or other farm activities (Ourimbah, 2011).

Similarly, Michael (2006) also stated that whatever may be the source of irrigation water, viz river, canal, tank, open well or tube well, some solute salts are always in it. However, the nature and quantity of dissolved salts depend upon the source of water.

According to park *et al.*, (2010) humans impact water quality in various ways. Nutrients, pathogenic and pharmaceutical waste can be introduced from treated and untreated sewage. Metal and chemical waste can be released as by -products of industrial and mining operations. Fungicides, herbicides and pesticides are applied for agricultural purposes. Birkenshow and Bailey (2013) also stated that most water sources are suitable for the whole range of crops and systems but physical quality is critically important. The two main aspects of water quality are its chemical and microbiological properties, other factors can occasionally affect quality especially from rivers and reservoir sources.

2.5 EFFECT OF WATER QUALITY ON HUMAN HEALTH

Water can contain substances that are harmful to life. These include metals such as mercury, lead, cadmium, pesticides, organic toxins and radioactive contaminates (United Nation Environmental programme global environment monitoring system (GEMS)/ water programme, 2008).

According to edugreen.teri.res.in/explore/water/health.html, exposure to polluted water can cause diarrhoea, skin irritation, respiratory problems and other diseases depending on the pollutant that is in the water body.

Many areas of groundwater and surface water are now contaminated with heavy metals, POPs (Persistent Organic Pollutants) and nutrients that have an adverse effect on health (edugreen.teri.res.in/explore/water/health.html).

Eschool today (2010), also states that, in many poor nations there is always outbreak of cholera and other disease as a result of poor drinking water treatment from contaminated water. Farmers who pull water from ponds, streams, canals and ditches must consider the quality of water. Regardless of the irrigation source, it is important to test your water regularly. This will provide a snapshot of water quality at the time of testing and will allow growers to document changes over time. It may also pinpoint periods during the growing season when water quality may be a suspect (Allen 2006). In addition, one important agricultural practice is to protect and maintain safe irrigation water resources. For example, maintenance of wells and ponds and prevention of polluted run-off from entering water sources will help reduce the risk of contamination.

A research conducted by Watch *et al.,* (2002) on quality of vegetables, reported that post- harvest quality is threatened by various factors including poor quality irrigation water which could result in internal contamination of vegetables. A report by Drechsel *et al., (*2006) stated that, it is possible to introduce restriction to ensure that waste water is not used to irrigate high risk crops such as leafy vegetables that are eaten raw. Public awareness campaign for example through media might steer consumer demand for safer produce and influence farmers decision making. The author added further that political recognition and sustainability of irrigated urban and peri-urban vegetable farming is mostly constrained by the use of waste water. This notwithstanding, the best approach to reduce this health risk was to follow world Health Organization guidelines for use of waste water in Agriculture.

The use of watering cans increase crop contamination more especially on leafy vegetables through spraying with droplets on the leaves of vegetables. Writing on water quality, Drechsel and Varma (2007), indicated that the recognition of informal irrigated urban farming requires the institutionalization of risk reducing interventions. This has to consider the perception of all the actors along the contamination path way from farmers to the traders and consumers. Irrigation practices that reduce exposure to polluted water and effective vegetable washing before consumption are some of the ways to reduce the health risk.

Other than increase in urban food demands, the upsurge of urban population has far out placed sanitation infrastructure and service delivery (pay and Bernard, 2014).

They stated further that, basically, 85% of wastewater generated from urban centers worldwide ends up in the waste environment in its untreated form. Also in Ghana, only a minor share of the faecal sludge and water are really treated and less than 5% of the population has sewerage connections. Michael (2006) also stated that the main soluble constituents in water are calcium, magnesium, sodium and sometimes potassium as cations and chlorides, sulphate, bicarbonate and sometimes carbonates as anions. However, ions of some other elements such as lithium, silicon, bromine, iodine, copper, nickle, cobalt, fluorine, bronze, zirconium, titanium, vanadium, barium, Rubidium , ceasium , arsenic , antimony , bismuth , beryllium , chromium , manganese, lead , molybdenum ,selerium and phosphate and organic matter are present in micro quantities. These element usually do not affect the quality of irrigation water as far as the total salt concentration is concerned but some ions as selenium molybdenum and fluorine, if absorbed by plant in excessive amounts may prove harmful to the animal life when taken by them through drinking water, feed or forage. Also, a report by Farid *et al.*, (2012) in their study on arsenic contaminated irrigation water and its carried over effect on vegetables stated that, if arsenic contaminated water is used for irrigation, it may create hazard both in soil environment and in crop quality. Additionally, wastewater irrigation of vegetables and fodder may serve as the transmission route for heavy metals in the human food chain (scott *et a*l., 2004).

2.6. AGROCHEMICAL USE IN VEGETABLE PRODUCTION

Agrichemical (or agrochemical), a contraction of agricultural chemicals is a generic term for the various chemical products used in agriculture (http://encarta.msn.com/encnet/refpages). A similar view is expressed by Carnevale *et al.*, (1991) that agrochemicals include a broad range of compound used for fertilizing crops, controlling pests, enriching feed and promoting the health and production of livestock and poultry.

Many people use agrochemicals these days for various reasons, Stiling (1985) observed that population explosions that have occurred in recent decades will continue until 2100 with global population increase from 6 billion to 11.5 billion by the end of the 21st century. Furthermore, the average increase in living standards in some regions where there is strong and rapid economic growth means an increase in global food needs. Yet there are only two ways of increasing production, increase cultivated land area and improving productivity per acre (Stiling 1985).

2.6.1 Fertilizer Used In Vegetable Production

If not the most important, mineral fertilizers are one of the most important of the discoveries in modern chemistry (voisin, 1965). Voisin (1965) explained further that, when well applied, they maintain and even raise soil fertility, increase crop yield and improve feeding value of agricultural products.

On a similar note, Lockhart and Wisemen (2010) are also of the view that if good crops are to be continuously removed from a field or farm, there should be at least much nutrients returned to the soil as have been removed in the crops According to Messiaen (2013) chemical fertilizers are in two forms: simple fertilizer, the most concentrated are urea, ammonium nitrate, triple super phosphate and potassium sulphate.

Compound fertilizers: the majority of fertilizers available are of this type. They contain nitric or ammoniacal nitrogen, water soluble or nitric acid, soluble phosphoric acids, and potassium sulphate or chloride.

Organic manures, composts, green manures and crop residues according to William *et al.,* (1991) have a special place in vegetable farming. Apart from supplying plants with nutrients required for high yields of vegetables, organic manure plays another significant role. Carey (1991) also observed that the aim of every producer is to ensure a decent and increasing income not necessarily by maximizing production per acre. Carey (1991) reported further that as long as land is available it may be appropriate to increase to cultivated land area than to make use of agri-products (fertilizers and pesticides). Nevertheless practically, in every region of the world, farmers are faced on one hand with limited availability of arable land and on the other hand a decrease in the fertility of soil, and the only medium and long term solution according to Carey (1991) is to increase productivity per acre and reduce postharvest losses.

2.6.2 Pesticides Used In Vegetable Production

Pesticide according to Abbey *et al.,* (2001) is the general name for all chemicals used in controlling pests. Abbey *et al.,* (2001) explained further that pesticides are given different names depending on the type of pest being controlled, Example, nematicides to control worms (nematodes), fungicides to control fungi, and
insecticides to control insects.

Farming systems with high specialized intensity are today hard to imagine without the use of chemical plant protection agents (Heitefuss, 1989). The discovery of organic pesticides provided man with new and powerful weapons for his incessant war against insect pests, diseases and weeds. (Mathews 1979). The author stated further that, since the introduction of DDT, MCPA, and 2, 4-D in the 1940s, pesticides have played a major role in crop protection and the control of vector – borne diseases.

2.7 EFFECTS OF AGROCHEMICALS USE IN VEGETABLE PRODUCTION

Insecticides used to control vegetable insect pests come in several different forms. Dust baits and granules are dry forms used as purchased (Bessin *et al.*, 2014). Most vegetable farmers spray their crops against pest attack using different types of pesticides (Osei 2004). Osei (2004) listed them as follows;Insecticides: unden, thiodan, karate, 2,5 EC, actellic perfection

Fungicides: topsin, dithane M45, captan, benlate.

After a few years of chemical plant protection, practical experience had already shown that negative effect could also be associated with the unbalanced and excessive application of these agents (Heitefuss, 1989).

According to Debra and pollard, (2007) A study published in May 2007 in the peer – reviewed online journal, co-authored by Professor Hayes and Academics from Kyushu University in Japan, showed that Atrazine and its related herbicides cause cancer and reproductive problems. Improper use of agricultural chemicals, caranevale *et al.*, (1991) observed, can pose environmental and health risk to farm workers and consumers. Indiscriminate use of chemicals such as pesticides, leave residues which contaminate the soil, surface ground water or even crops and other vegetables (Awuku *et al*,. 1991)

According to Osei (2004), the following are some health hazards associated with the use of pesticides.

- Some pesticides that find their way into the human body are able to mimic some natural hormones causing a wide range of diverse effects.
- When carelessly used, they may result in acute or long – term side effect.
- Death may result from the intake of poisoned food.

Other problems include increasing secondary pests.

With regards to pesticide toxicity, Heitefuss (1989) stated that an important first requirement is that toxicologically critical amounts of the compound should not be present as residue on harvested produce, food or fodder. Recent outbreak of E-coli o157:H7, on spinach grown in California has put the spotlight on leafy green production and emphasized the need for good agricultural practices (Allen 2006). According to Allen (2006), manure and improperly managed compost may act as reservoir for pathogenic bacteria like E-coli. Poultry manure which represents 75% of the organic fertilizer used generally contains faucal coliforms (1.30 x 10%) and enterococci (3.4 x 10 %), (Westcot, 1997)

Amoah *et al.,* (2005) also stated that vegetables cultivated with manure are highly infested by bacteria, indicating contamination from faecal sources.

2.8 HARVESTING OF VEGETABLES

To maintain the quality of vegetables, they must be harvested at the right stage, and handled properly (Norman 1992). According to Norman (1992), no definite rule for time of and stage of harvesting exists since this varies with each crop depending on weather conditions, distance to market, consumer requirement and use for which the crop is required. Different methods are used in harvesting agricultural crops depending on the type of crop and its uses (either for the market, storage or processing), the physical location of the harvestable portion of the crop (either below or above the ground), the planting methods, the climatic conditions, the economic value of the other parts (either to be discard or retained), the size of the farm and labour availability (Cornelius and Obeng ofori, 2008).

Beuchat (1995) also stated that, vegetables can become contaminated with pathogenic microorganisms during harvesting through faucal materials, human handling, harvesting equipment transport containers, wild and domestic animals, air, transport vehicles, ice or water. However, harvesting at the appropriate time and keeping the harvested produ ce under controlled environmental conditions will help to retard growth of postharvest spoilage and pathogenic microorganism (Brackett 1992). The care taken during harvesting is repaid later because fewer bruises and other injury, means less diseases and enhanced value (Jobling 2002). According to a study conducted on urban agriculture in Ghana, harvesting of vegetables is done by traders who are often women (Hope *et al.*, 2008)

2.9 STORAGE AND PROCESSING OF VEGETABLES

Temperature is the most important factor that influences the deterioration of harvested commodities (Kader and Rolle 2004). According to Gorny (2001), the more closely optimum storage conditions of vegetables are adhered to throughout the supply chain, the longer is the postharvest life span. Most fresh fruits and vegetables have a storage life of few days under even the best environmental conditions (Agriculture and consumer protection, 1989). With the exception of leafy greens, fresh fruits and vegetables have a natural protective coating and should not be washed before storing as washing will hasten deterioration (www.cpm.ca/files/CPMATonestorageguide-Eglish.pdf)

Once harvested, fruits and vegetables must be stored under proper conditions, the most important of which are temperature and humidity (www.gordwing.cornell.edu/factsheet/Vegetables/Storage.pdf)/

2.10 QUALITY OF VEGETABLES IN THE URBAN MARKET

To producers, high yields, good appearance ease of harvest and the ability to withstand long-distance shipping to the markets are important quality attributes.

Appearance, firmness, and shelf-life are important from the point of view of wholesale and retail marketers. Consumers on the other land, Judge the quality of fresh ornamentals and vegetables on the basis of appearance (including freshness) at the time of initial purchase (Kader and Rolle, 2004). The authors stated further that a number of factors threaten the quality of fruits and vegetables. These include naturally occurring toxicants, such as glycoalkaloids in potatoes; natural contaminants such as fungal toxins (mycotoxins and bacterial) and bacterial toxins, and heavy metals(cadmium, lead, mercury); environmental pollutants, pesticides residues; and microbial contamination .As the availability of vegetables, particularly to urban population, presents, many challenges, issues such as assured availability of safe and good quality vegetables at affordable prices continue to be a major challenge (The Vegetable initiative for urban clusters, 2011). While health authorities and scientists regard microbial contamination as the number one safety concern, many consumers rank pesticide residues as their most important safety concern (Kader and Rolle, 2004). A study conducted by Ensink *et al.,* (2007) revealed that vegetables from the market harbored higher E. coli concentration with a (geometric) mean concentration of 14.3

E.coli per gram (95% Cl: 10.0-20.1) than vegetables from the field. Observations revealed that lettuce is the only crop commonly washed in irrigation water. Farmers after working walk into the water sources when collecting irrigation water and wash their boots, feet and hands in the same sources in which the market women wash the vegetables (Hope *et al.*, 2008).

Nuama, (2007) reported that a lot of vegetables have been found to contain poisonous chemicals. Vegetables such as tomato, carrot, cabbage and lettuce have higher concentrations of persistent organic pollutants (POPs). A similar report by

Gyampah, (2014) also stated that, the European Union has put a ban on export of vegetables from Ghana to their region. According to the report, the ban was put in place after EU authorities identified some vegetables from Ghana that did not meet their quality standards. According to Sangsore (2007), research indicates that raw vegetables can contain pathogenic bacteria, viruses, worms, fungi and high level of faecal pollutants found along the drains use in watering the vegetables. A research conducted by Drechsel *et al.*, (2006) points to the fact that faecal coliform level of vegetables in Tamale ranged from 4.0 x 10^8 to 7.5 X 10^8 for the three vegetables (cabbage, lettuce and spring onions). They also stated that total coliform and faecal coliform levels are lower in Kumasi as compared to Accra and Tamale. Drechsel *et al.*, (2006) further stated that farmers in their quest to control pests and diseases use banned chemicals such as DDT, Endosulfan, Lindane and chlorphyrifos. Most of these chemicals are highly toxic and persist in the environment causing serious threat to the health of producers and consumers.

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CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 STAGES OF RESEARCH

The research was carried out in two progressive stages. The first stage involved a field survey through the use of questionnaire to solicit information from farmers, vegetable sellers, food venders or fast food sellers, agrochemical sellers, agricultural extension officers and some individual buyers or consumers. The second stage involved laboratory analysis of dry matter/moisture content, microbial contaminants and pesticide residue.

3.2 BACKGROUND OF THE STUDY AREA

Kumasi is the capital town of Ashanti region of Ghana, lying in the middle belt of the country with a population of 2069,350 (2013estimate). The city occupies an area of 254km^2, Kumasi features wet and dry climate with relatively constant temperature throughout the year. There are two rainy seasons, the main season falls between March and July while the minor season is between September and November, with average annual rainfall of 1400mm. It experiences harmattan during the low sun months; from December to February. The harmattan is the primary source of the dry season *(*paradiseintheworld.com/Kumasi-ghana*)*

Due to the location of Kumasi in the country, it is suitable for the cultivation of many food crops such as maize, cassava and plantain and also some local and exotic vegetables including garden eggs, okra, tomato, carrot, cabbage and lettuce. Kumasi is alternatively known as the garden city because of its many beautiful species of plants and flowers which indicate its support of growth of a variety of crops. The main occupations in Kumasi are professional occupations such as services and manufacturing. Some markets in Kumasi where most of the vegetables produced are sold are central market which is the largest market in the city, Abinchi market, Asafo market, Bantama market and some smaller markets in the suburbs. Although, vegetables are produced in many parts of Kumasi, this study was centered on production at Gyinyase, Kwadaso Agricultural College, Ramseyer Institute, University of Education-Tanoso and Kwame Nkrumah University of Science and Technology. The study was also limited to cabbage, carrot, and green pepper.

3.3 FIELD SURVEY

A field survey was conducted to seek the views of farmers, sellers and consumers on the handling and treatment of vegetables. Questionnaires were used and a total of 120 respondents comprising of 30 vegetable growers, 25 vegetable sellers, 20 food venders, 20 consumers or home users, 20 agrochemical sellers and 5 agricultural extension officers randomly selected. Five communities were also purposively sampled as the study area based on the vegetables produced, and three vegetables made up of one root vegetable, one fruit vegetable and one leafy vegetable were also purposively selected for the study . The questions centered on

1. The sources of water used.
2. The quality of the water
3. Agrochemical usage
4. Postharvest handling and treatment of the vegetables

3.4. LABORATORY ANALYSIS

This was the second stage of the study where samples of the water used to irrigate the vegetables were collected at random from each study area into bottles and stored under room temperature over- night and then transported with the vegetable samples which were also randomly picked from the farms (each vegetable put into a separate polythene bag) to the Ghana Standard Authority laboratory in Accra. The water and vegetable samples were analysed to determine the presence of microbial (total coliform salmonella, faecal coliform and E-coli) and chemical contaminants, and dry matter/moisture content of the vegetables. Vegetables were also selected at random from three randomly selected local markets for microbial load analysis at the microbiology laboratory at Kwame Nkrumah University of Science and Technology in Kumasi.

3.4.1 Determination of Dry Matter and Moisture Content

This method was based on moisture evaporation used by Pousga et al. (2007). In this method, empty crucibles were washed dried in an oven and in a desiccator for cooling. The weight of each crucible was taken. Hundred grams (100 g) of each sample of vegetable was weighed into a sterile crucible; weight of the crucible and sample were taken (in triplicate). This was transferred into an oven and set at 100ºC and less than 100 mm Hg for approximately 5 hours after which the crucible and content were removed from the oven, covered, cooled in desiccator, and weighed. Then the weight was measured using a measuring scale balance. It was transferred back into the oven for another one hour and then reweighed. The process continued until a constant weight was obtained. The difference in weight between the initial weight and the constant weight obtained was taken as the moisture content. The loss in weight multiplied by 100 over the original weight is percentage moisture content.

The formula used is presented below:

$$\text{Moisture content (g/100g)} = \frac{\text{lost in weight } (W_2 - W_3) \times 100}{\text{Original weight of sample}}$$

Where W1= weight of empty crucible,

W2 = weight of crucible plus weight of vegetables before drying,

W3 = final weight of crucible plus weight of vegetables, after drying

% Total solid (Dry matter) = 100 - percentage moisture

3.4.2 Determination of Total and Fecal Coliform

The presumptive test method (PMT) was used to determine the total and fecal coliform in the samples. Maximum recovery diluent was added to 3.0g of each sample and homogenized for 20 minutes. 1ml of the diluted sample was then incubated into three tubes containing double lauryl triptose broth. The dilutions were then inoculated into three tubes each containing single strength of lauryl tryptose broth and incubated at 37^0c for 24 hours. This was done to check the lowest dilution that will produce gas. Gas produced in any of the double and single strength tubes were sub-cultured into Ecoli broth (EC broth) and incubated in a water bath at 44^0c for 48 hours. The production of gas in any of the tubes in the EC broth confirms the presence of fecal coliform.

3.4.3 Determination of E-coli

The indoline test method was used where gas produced in the E- coli broth tube was sub- cultured into tryptone water and incubated at 44^0c for 48 hours. 0.5ml of kovac's reagent was then added. A red coloration in alcoholic phase, confirmed the presence of E- coli.

3.4.4 Determination of Salmonella

25g of each sample was added to 225ml of peptone water and homogenized for 24 hours. The Rappaport –vissiliadis soya broth and incubated in a water bath at 41.5^0c for 24 hours and then 1ml into muller- kanffman tetrathimate novobiocin broth (MKTTn) at 37^0c for 24 hours. The culture was then streaked into broth bismorth sulphite agar (BSA) and xylose Lysine Desoxycholate agar (XLD) and incubated for 24 hours at 37^oc. Black colonies on the agar would have indicated the presence of salmonella. Meaning there was no indication of salmonella.

3.4.5 Determination of Pesticide Residue

A multi-pesticide residue test was run using the Quick, Easy, Cheap, Effective, Rugged Safe (QuEChERS) mini multi pesticide method. In this method, representative sample of the vegetables were cut into pieces of 3 x 3cm and blended using Warren blender. 10g of the comminuted homogenous sample was put into a 50ml centrifuge tube. 10ml acetonile was added and vortex for 1 minute. After that a mixture of 4g magnesium sulphate anhydrous, 1g sodium chloride, 1g trisodium citrate dehydrate and 0.5g Disodium hydrogencitrate sesquihydrate were added to each sample and immediately vortex for a further1 minute and centrifuged for 5 minutes at 3000U/minute. 6ml aliquot of the extract was transferred into a Polypropylene (PP) centrifugation tube which contained 150mg of PSA (Primary Secondary Amine) 900mg magnesium sulphate. 4ml of the cleaned extract was put into a round bottom flask and acidified with 40µl of 5% formic acid solution in acetonitrile. The filtrate was concentrated below 40^{o}c on a rotary evaporator to dryness. The acidified extract was reconstituted in ethyl acetate and transferred into a 2ml standard opening vial for quantitation. The determination of the analyte was then done with the gas chromatography technique.

3.4.6 Experimental Design

The study was conducted using a 3 x 5 factorial experiment laid out in completely randomized design. The experimental factors were three types of vegetables (cabbage, carrot, and green pepper) and sources of water from five communities (Gyinyase, Kwadaso, Tanoso, Ramseyer and Kwame Nkrumah University of Science and Technology), and also 3 x 3 factorial experiment for three vegetables against three community markets, was also used and laid out in completely randomized design.

3.4.7 Data collection on survey and field experiment

Data was collected from the survey based on the questionnaire on sources of water, physical quality of water, and vegetables, treatment of water before use, treatment of vegetables before selling or consumption. Data was also collected from the laboratory analysis on dry matter content, microbial and chemical contamination of irrigation water and vegetables.

3.4.8 Data Analysis

The data obtained from field survey was analysed with the Statistical Package for Social Scientist (SPSS), to perform descriptive analysis such as frequencies and percentages and the results presented in tables and graphs. Data obtained from the laboratory results was analysed using Statistix version 9.0 software, to perform analysis of variance (ANOVA).

CHAPTER FOUR

4.0 RESULTS

4.1 SURVEY RESULTS

4.1.1 General Overview of Respondents

From the field survey, out of 120 respondents, 20 (16.7%) were Agrochemical sellers, 20 (16.7%) were consumers, 20 (16.7%) were food vendors, 30 (25%) were vegetable farmers, 25 (20.8%) were vegetable sellers and 5 (4.2%) were agriculture extension officers (Table 4.1).

Table 4.1: General overview of respondents

Respondents	Frequency	Percentage
Vegetable farmers	30	25.0
Vegetable sellers	25	20.8
Food vendors	20	16.7
Consumers	20	16.7
Agrochemical sellers	20	16.7
Agriculture extension officers	5	4.2
Total	120	100.0

4.1.1.2 Age distribution of respondents

23.4% of vegetable farmers were between the ages of 20-29 years, 33.3% were between the ages of 30-39 years, 26.7% were between the ages of 40-4 9 years, 10% were between the ages of 50-59 years and 6.7% were above 60 years (Fig. 4.1). The modal age of vegetable farmers was 30-39 years.

Only 4% vegetable sellers were below 20 years, 20% were between the ages of 20-29 years, 48% were between the ages of 30-39 years, 20% were between the ages of 4049 years, 8% were between the ages of 50-59 years. 45% food vendors were between the ages of 20 to 29 years, 50% were between 30 to 39 years, and 5% was between 50 to 59 years. For the consumers, 15% were below 20 years, 20% were between the ages of 20 and 29 years, 55% were between the ages of 30 and 39 years, and 10% were between the ages of 40 and 49 years. The minimum age of agro chemical sellers was 22 years and the maximum age was 51 years. The average age of agro chemical sellers was 33 years with the modal age being 28 years (Fig. 4.1).

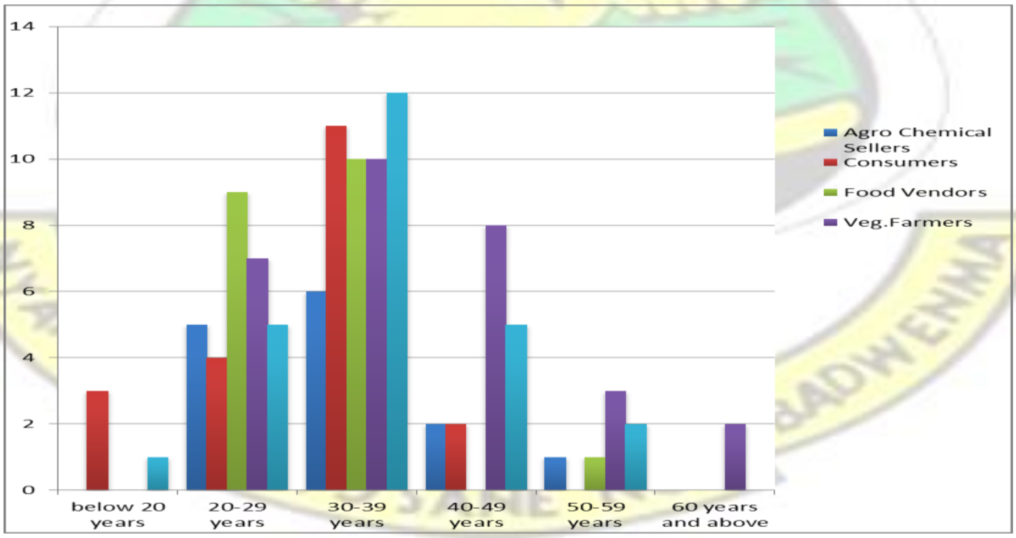

Figure 4. 1: Age distribution of respondents

4.1.1.3 Gender of vegetable farmers

Most vegetable farmers, 27 (90%) were males and 3 (10%) were females. This indicates that males are more into vegetable farming than females. (Table 4.2)

Table 4.2: Gender of farmers

Gender	Frequency	Percentage
Male	27	90.0
Female	3	10.0
Total	30	100.0

4.1.1.4 Educational background of respondents

Figure 4.2 shows that 8 vegetable farmers had no formal education, 13 had basic education, 5 had secondary education, and 4 had tertiary education. This represents 26.7%, 43.3%, 16.7%, and 13.3% respectively. Out of the 25 vegetable sellers studied, 64% had no formal education, 24% had basic education, and 12% had secondary education. 15% of food vendors had no formal education, 55% had basic education, 25% had secondary education, and only 5% had tertiary education. It was revealed from the study that 30% of the consumers had no formal education, 40% had basic education, and 30% had secondary education. 5% agrochemical seller had no formal education, 35% had Middle School education, 45% had secondary school education, and 15% had tertiary education.

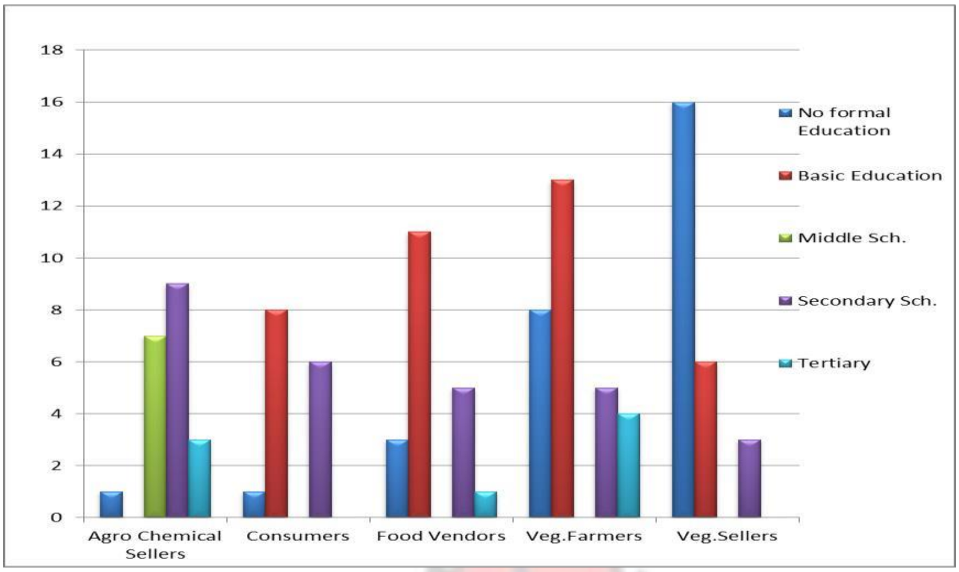

Figure 4. 2: Educational background of respondents

4.1.1.5 Practice and use of irrigation water by farmers

All vegetable farmers in this survey practiced irrigation. 30% used stream/river water for irrigation, 60% used water from dugouts, 6.7% used stream/ river and dugout, and 3.3% used pipe borne water (Table 4.3).

Table 4.3: Sources of irrigation water used by farmers

Source of water	Frequency	Percentage
Stream/river water	9	30.0
Dug out	18	60.0
Stream/river and Dug out	2	6.7
Pipe borne	1	3.3
Total	30	100.0

4.1.1.6 Water treatment practiced by vegetable farmers

From Table 4.4, 43.3% of vegetable farmers did not treat water before using it for irrigation. However, 56.7% of the farmers treated the water before using for irrigation of which 36.7% treated the water by filtering, 3.3% put it down to settle, 10.0% sieved with a net and 6.7% add some pesticides 16.7% of respondents admitted that the water they use for irrigation is also used for domestic purposes, 3.3% admitted that the water is used for only irrigation and 80% admitted that it is also used for mixing pesticides. 11 (36.7%) of respondents confirmed that they use their sources of water because it is the only water available, 18 (60) use their source of water because it is affordable, and 1 (3.3%) use the source of water because it is safe for humans.

Table 4. 4: Forms of water treatment by vegetable farmers

Forms of treatment	Frequency	Percentage
No treatment	1	43.3
Put water down to settle	1	3.3
Sieve with net	14	46.7
Add some pesticides	2	6.7
Total	30	100.0

4.1.1.7 Mode of fertilizer and application of respondents

All 30(100%) of the farmers used fertilizer. 5 (16.7%) used organic fertilizers only, and 25 (83.3%) used both organic and inorganic fertilizers Also, 27 (90%) of farmers used pesticides and 1 (3.3%) of farmers did not use pesticides. This study revealed that, 7 (23.3%) farmers poured the remains of agrochemicals on farm after use, 8 (26.6%) poured remains into nearby bush, 2 (6.7%) poured remains near the water bodies, 7 (23.3%) left remains for later use, 3 (10.0%) managed to use all the chemicals and 1 (3.3%) had no excess.

Table 4.5: Types of fertilizers used by vegetable farmers

Fertilizer type	Frequency	Percentage
Organic	5	16.7
Both	25	83.3
Total	**30**	**100.0**

4.1.2 Demographic Characteristics of Vegetable Sellers

4.1.2.1 Gender of vegetable sellers

All thirty (100%) vegetable sellers in this survey were females (Table 4.6).

Table 4.6: Gender of vegetable sellers

Gender	Frequency	Percentage
Male	0	0.00
Female	30	100
Total	**30**	**100.0**

4.1.2.2 Maintaining freshness of vegetables

Results fromTtable 4.5 shows that 8 (32%) spread vegetables in the open air, 1 (%) kept them in water, 4 (16%) sprinkled water on them, 3 (12%) covered them in baskets and 9 (36%) left them in sacks.

Table 4.7: Maintaining freshness of vegetables by vegetable sellers

Maintaining Table **freshness**	**Frequency**	**Percentage**
Spread them in the open air	8	32.0
Sprinkle water on them	4	16.0
Put them in water	1	4.0
Cover them in baskets	3	12.0
Leave the undisplayed ones in sacks	9	36.0
Total	25	100.0

4.1.2.3 Cleaning of packaging materials

It could be inferred from table 4.8 that 15 (60%) of vegetable sellers cleaned their packaging materials before every packaging, 4 (16%) once every month, and 6 (24%) said anytime they felt like cleaning.

Table 4.8: How often vegetable sellers clean their packaging materials

Frequency of cleaning	Frequency	Percentage
Before every packaging	15	60.0
Once every month	4	16.0
Anytime I feel like cleaning	6	24.0
Total	25	100.0

4.1.3 Demographic Characteristics of Food Vendors

4.1.3.1 Gender

Results from the study showed that 6 (30%) of vendors were males and 14 (70%) were females.

Table 4.9: Gender of food vendors

Gender	Frequency	Percentage
Male	6	30.0
Female	14	70.0
Total	20	100.0

4.1.3.2 Treatment of vegetables by food venders

It could be inferred from table 4.10 that 5 (25.0%) of the respondents washed vegetables with salt solution, 1 (5%) washed with vinegar solution and 14 (70.0%) washed with only water.

Table 4.10: Treatment of vegetables by food venders

Treatment	Frequency	Percentage
Wash with salt solution	***5***	25.0
Wash with vinegar solution	1	5.0
Wash with water only water	14	70.0
Total	20	100.0

4.1.4 Demographic Characteristics of Consumers

4.1.4.1 Gender of consumers

Results from Table 4.11 shows that 4 consumers representing 20% were males while 16 representing 80% were females.

Table

4.11: Gender of vegetable consumers

Gender	Frequency	Percentage
Male	4	20.0
Female	16	80.0
Total	20	100.0

4.1.4.2 Treatment of vegetables by consumers

Table 4.12 shows that 5 (25%) of the consumers washed vegetable with only water, 12 (60%) washed with salt solution, 1 (5%) washed with vinegar solution and 2 (10%) used charcoal and water

Table 4.12: Treatment of vegetables by consumers

Gender	Frequency	Change
Wash with only water	5	25.0
Wash with salt solution	12	60.0
Wash with water and vinegar	1	5.0
Use charcoal and water	2	10.0
Total	20	100.0

4.1.5 Demographic Characteristics of Agrochemical Sellers

4.1.5.1 Gender

Results from the study revealed that 16 (80%) of them were males while 4 (20%) were females. (Table 4.13).

Table 4.13: Gender of agrochemical sellers

Gender	Frequency	Percentage
Male	16	80.0
Female	4	20.0

Total	20	100.0

4.1.5.2 Types of Agro chemicals sold

Out of the 20 agrochemical seller sampled for the study, 19 (95%) sold all kinds of agrochemicals and only one (5%) sold fertilizers only.

Table 4.14: Types of agrochemicals sold by respondents

Type sold	Frequency	Percentage
All types are available	19	95.0
Fertilizers	1	5.0
Total	20	100.0

4.1.5.3 Education on correct handling and consequences of agrochemicals

It could be inferred from table 4.15 that 11 (55%) of the agrochemicals had been educated and 9 (45%) had not been educated on correct handling and consequences of agrochemicals.

Table 4.15: Education of agrochemical sellers on correct uses of agrochemicals

Education	Frequency	Percentage
Yes	11	55.0
No	9	45.0
Total	20	100.0

4.1.5.4 Source of education

According to results in table 4.16, 5 (45.4%) of the sellers who had been educated on correct usage of agrochemicals received their education from MOFA, 2 (18.2%) received theirs from NGOs, and 4 (36.4%) received theirs from colleague sellers.

Table

4.16: Sources of education on correct handling of agrochemicals

Education	Frequency	Percentage
MOFA	5	45.4
NGOs	2	18.2
From colleagues	4	36.4
Total	11	100.0

4.1.5.5 Educating farmers on correct usage of agrochemicals

All 20 (100%) agrochemical sellers confirmed that they educate farmers on how to use agrochemicals. (Table 4.17).

Table 4.17: Educating farmers on correct handling of agrochemicals by agrochemical sellers

Educate	Frequency	Percentage
Yes	20	100.0
No	0	0.00
Total	20	100

4.1.5.6 Access to banned chemicals

Results from table 4.18 show that 1(5.0%) of the sampled agrochemical sellers had access to banned agrochemicals while 19(95%) had no access to banned agrochemicals.

Table 4.18: Access to banned agrochemicals

Access	Frequency	Percentage
Yes	1	5.0
No	19	95
Total	20	100.0

4.1.5.7 Expired agrochemicals

According to results in table 4.19, 5 respondents representing 25% admitted that Sometimes, some of the agrochemicals expire and 15 respondents representing 75% said their chemicals do not expire.

Table 4. 19: Expiring of agrochemicals at the shop

Expire	Frequency	Percentage
Yes	5	75.0
No	15	25.0
Total	20	100.0

4.1.6 Information from agricultural extension officers

4.1.6.1 Vegetables cultivated in Officer's district

Information provided by Agricultural extension officers showed that the list of vegetables below are cultivated in their districts; lettuce, cabbage, spring onion, green pepper, okra, garden eggs, tomatoes, carrot, eggplant and French beans.

4.1.6.2 Sources of water for irrigation

Out of the 5 extension officers, 1 (20%) testified that farmers in his district used harvested rain water for irrigation, 3 (60%) testified that farmers used streams/rivers, and 1 (20%) testify that farmers used streams/rivers and shallow wells. (Table 4.20)

4.20: Source of water for irrigation responded by extension officers

Source of water	Frequency	Percentage

Table

Harvested rain water	1	20.0
Stream/rivers	3	60.0
Stream/rivers and shallow wells	1	20.0
Total	5	100.0

4.1.6.3 Types of agrochemicals farmers use

All the five (100%) extension officers admitted that farmers in their areas used both organic and inorganic agrochemicals.

Table 4.21: types of agrochemicals used by farmers as responded by extension officers

Agrochemicals	Frequency	Percentage	
Organic only	0	0.00	
Inorganic only	0	0.00	
Both organic and inorganic	5	100.0	
	5	100.0	al

4.2. LABORATORY RESULTS

4.2.1 Moisture and Dry Matter Content of Vegetables from Production Sites

4.2.1.1 Dry matter content

The Effects of location and vegetable on dry matter content are recorded in Table 4.22. Dry matter content was significantly highest in green pepper from Kwadaso. Cabbage from Kwadaso had the least dry matter but was similar to the dry matter content in cabbage from Tanoso.

Dry matter content was very high in vegetables from Kwadaso, whiles the least was in vegetable from Gyinyase. They recorded mean value of 8.23, 7.97, 7.70, 7.53 and 7.27 respectively. Their impact were significantly different ($p<0.01$) from one another except that of KNUST and Tanoso.

Table 4.22: Effects of location and vegetable on dry matter content (%)

Location	**Vegetable**			
	Carrot	**Cabbage**	**G. pepper**	**Mean**
Gyinyase	6.10	5.40	10.30	7.27
KNUST	6.50	6.60	10.00	7.70
Kwadaso	6.10	4.90	13.70	8.23
Ramseyer	6.40	5.40	12.10	7.97
Tanoso	6.80	5.20	10.60	7.53
Mean	6.38	5.50	11.34	

HSD (1%) : Location = 0.02 ; Vegetables =0.14 ; Location x Vegetable = 0.43

4.2.1.2 Moisture content

From Table 4.23 green pepper from Kwadaso had the highest level of moisture content as compared to the lowest found in carrots sampled from the same site. Both recorded a moisture level of 95.10% and 86.30% respectively. Green peppers from Tanoso contained 94.80% moisture which was not different ($p>0.05$) from the ones from Gyinyase and Ramseyer with an equal moisture level of 94.60%, and as well as when compared to the highest. Cabbage sampled from Kwadaso had a moisture level of 93.90% which was different ($p<0.05$) from the same kind of vegetable from KNUST and Remseyer that recorded the same moisture of 93.50% not different

($p>0.05$) from 93.4 and 93.20 percent in green pepper and cabbage from KNUST and Tanoso respectively. Also, the 93.90% moisture has a similar effect as 93.80% in cabbage from Gyinyase. In the declining order of moisture, carrots from KNUST, Gyinyase, Tanoso, and Ramseyer recorded 90.00%, 89.70%, 89.40%, and 87.90% for which 89.70% moisture content had statistically similar effect as 90.00% and 89.70%

Table 4.23: Effects of location and vegetable on moisture content (%)

Location	Vegetables			
	Cabbage	G. pepper	Carrot	Mean
Gyinyase	93.8	94.60	89.70	92.7
KNUST	93.5	93.4	90.00	92.3
Kwadaso	93.9	95.1	86.30	91.8
Ramseyer	93.5	94.6	87.90	92.0
Tanoso	93.2	94.8	89.40	92.5
Mean	93.58	94.5	88.66	

HSD (1%): location = 0.189 ; Vegetables = 0.129 ; location x Veg = 0.399

4.3 MICROBIAL LOAD ON VEGETABLES

4.3.1 Microbial Load on Vegetables Samples from Selected Production Sites

4.3.1.1 E. coli

From Table 4.24, cabbage from Gyinyase, KNUST and Kwadaso; Carrots from KNUST and UEW – Kumasi; and KNUST's green pepper showed no detectable *E. coli* contaminant. However, the result indicated the effect of 0.04 – 0.29 *E. coli* (log MPN/g) in carrots from Kwadaso and Gyinyase; green pepper from Ramseyer, UEW – Kumasi and Kwadaso; and UEW – Kumasi's cabbage was not different (p>0.01). These low levels of *E. coli* were different from 1.08 log MPN per grams (the highest) detected in carrots from Ramseyer. Gyinyase's green pepper and Ramseyer's cabbage *E. coli* detected ranged from 0.13 to 0.23 log MPN per grams. However, their difference was insignificant ($p<0.01$) and hence, cause an effect of a same magnitude. Green pepper from Gyinyase and cabbage from Ramseyer recorded 0.63 and 0.49 *E. coli* microbes (log MPN/g) respectively with the same effect.

Table 4.2[1]: Effects of location and vegetable on level of Ecoli (log MPN/gram)

Locations	**Vegetable**			
	Cabbage	**G. pepper**	**Carrot**	**Mean**
Gyinyase	0.00	0.63	0.04	0.22
KNUST	0.00	0.00	0.00	0.00
Kwadaso	0.00	0.29	0.04	0.11
Ramseyer	0.49	0.06	1.08	0.54
UEW-M	0.16	0.11	0.00	0.09
Mean	0.13	0.22	2.23	

HSD (1%) : Vegetables = 0.144 ; locations = 0.210 ; locations x vegetables = 0. 42 pepper 2.07 log MPN per grams compared to carrot and cabbage which had 1.82 and

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[1] .3.1.2 Faecal coliforms

The effect of levels of faecal coliforms varied significantly ($p<0.01$) at the selected locations (Table 4.25). Carrot from Kwadaso recorded no level (0.00 log MPN per grams) of faecal coliform. However, Green pepper from KNUST, Kwadaso and Ramseyer as well as cabbage from Gyinase and carrot from UEW-Kumasi had high levels of faecal coliforms (3.04 log MPN per grams) each.

Ramseyer had the highest mean value of 2.43 log MPN per grams, KNUST came second with 2.09 log MPN per grams, followed by UEW Kumasi (1.71 log MPN per grams), Gyinyase (1.62 log MPN per grams) and Kwadaso having the lowest count of 1.41 log MPN per 100g. Similarly, more faecal coliforms were detected on green

1.67 log MPN per grams respectively.

Table 4.25: Effects of location and vegetable on the level of faecal coliform (log MPN/gram)

Location	Vegetables			
	Carrot	**Cabbage**	**G. pepper**	**Mean**
Gyinyase	1.34	3.04	0.49	1.62
KNUST	2.32	0.90	3.04	2.09
Kwadaso	0.00	1.20	3.04	1.41
Ramseyer	1.64	2.60	3.04	2.43
UEW-K	3.04	1.34	0.75	1.71
Mean	1.67	1.82	2.07	

HSD (1%) : Vegetables = 0.016 ; locations = 0.023 ; locations x vegetables = 0.048

4.3.1.3 Total coliforms

From Table 4.26, total coliforms detected at different production sites related to the vegetables samples; carrot, cabbage and green pepper varied significantly ($p<0.01$) Green pepper from Gyinyase specifically had the highest total coliform count of 3.30 log MPN per grams while Cabbage from Kwadaso had no detectable coliform. Carrot from KNUST showed a trace of 3.23 coliforms in log MPN per grams but was not different from that from Kwadaso with a total of 3.20 coliforms in log MPN per grams. In a similar effect, cabbage sampled from UEW – Kumasi recorded a total of 3.18 coliforms in log MPN per grams and was not different from the coliforms detected in carrots from Kwadaso (3.20 log MPN/g) and Ramseyer (3.15 log MPN/g). Also, green pepper and cabbage from UEW – Kumasi and Gyinyase had total coliforms of the same effect with 1.46 and 1.45 log MPN per grams. Except these, the rest of the interaction means varied significantly ($p<0.01$) from one another within the range of 0.00 – 3.30 log MPN per grams.

The total number of coliforms on vegetables from Ramseyer was highest, followed by KNUST, UEW Kumais, Gyinyase and the least, at Kwadaso. The total coliforms count at those specific locations were, 2.54, 2.23, 1.80, 1.76 and 1.50 log MPN per grams respectiv The total number of coliforms found on carrot was more than that recorded on green pepper and cabbage which had mean values of 2.18, 1.95 and 1.77 log MPN per grams respectively.

Table 4.26: Effects of location and vegetables on the level of total coliform (log MPN/gram)

Location	Vegetables			
	Cabbage	G. pepper	Carrot	Mean
Gyinyase	1.45	3.30	0.54	1.76
KNUST	2.51	0.95	3.23	2.23
Kwadaso	0.00	1.30	3.20	1.50
Ramseyer	2.72	2.76	3.15	2.54
UEW-K	3.18	1.46	0.77	1.80
Mean	1.77	1.95	2.18	

HSD (1%) : Vegetables = 0.015 ; locations = 0.021 ; locations x vegetables = 0.045

4.3.2 Microbial Analysis on Market Vegetables Samples

4.3.2.1 Total coliforms

The effect of market on total coliform of vegetable showed significant differences (Table 4.27). The highest total coliforms were recorded in cabbage from Kwadaso (9.65 log cfu) followed by cabbage from Atonsu (9.32 log cfu). The least total coliform was recorded in green pepper from Tanoso (6.38 log cfu).

The vegetable samples from the three market centres recorded total coliforms significantly different ($p<0.01$) from one another. Vegetables from Kwadoso (8.08 log cfu) had the highest total coliforms, followed by those from Atonsu (7.22 log cfu) and then the least from Tanoso (6.47 log cfu). Cabbage recorded significantly the highest level of total coliforms (8.45 log cfu), carrot had total coliform of 7.06 log cfu while the least was recorded in green pepper (6.26 log cfu).

Table 4.27: Effect of market and vegetable on level of total coliform (lof/cfu)

Market	Vegetable			
	cabbage	**G. pepper**	**Carrot**	**Mean**
Atonsu	9.32	5.96	6.38	7.22
Tanoso	6.38	5.86	7.18	6.47
Kwadaso	9.65	6.96	7.62	8.08
Mean	8.45	6.26	7.06	

HSD (1%) : Vegetables = 0.020 ; locations = 0.020 ; locations x vegetables = 0.044

4.3.2.2 Faecal coliforms

From Table 4.28, the effect of market and vegetable on faecal coliform showed significant differences. Cabbage from Kwadaso (7.96 log cfu) recorded the highest level of faecal coliform while green pepper from Atonsu recorded no level of faecal coliforms (0.00 log cfu).

There were more faecal coliforms detected on vegetables from Kwadaso compared to Tanoso and Atonsu which had contamination levels of 6.39, 5.96 and 4.18 log cfu, respectively.

Table 4.28: Effect of market and vegetable on level of faecal coliform (log cfu)

Market	Vegetables			
	Cabbage	**G. pepper**	**Carrot**	**Mean**
Atonsu	7.17	0.00	5.36	4.18
Tanoso	6.96	4.95	5.96	5.96
Kwadaso	7.96	5.36	5.86	6.39
Mean	7.37	3.44	5.73	

HSD (1%) : Market = 0.022 ; Vegetables = 0.022 ; market x veg = 0.048

4.3.2.3 E. coli

From Table 4.29, significant differences were observed for interactions between vegetables and markets. There were no detectable levels of E. coli contaminations on Green pepper from Atonsu, Tanoso and Kwadaso markets as well as carrot and cabbage from Tanoso. However, the highest E. coli level was recorded in cabbage from Kwadaso (5.62 log cfu).

Kwadaso and Atonsu recorded 3.41 and 3.32 *E. coli* on vegetables in log cfu while Tanoso showed no *E. coli* contaminants. These mean *E. coli* detected on vegetables were significantly different each other.

Table 4.29: Effect of market and vegetable on level of Ecoli (log cfu)

Market	**Vegetable**			
	Cabbage	**G. pepper**	**Carrot**	**Mean**
Atonsu	5.36	0.00	4.60	3.32
Tanoso	0.00	0.00	0.00	0.00
Kwadaso	5.62	0.00	4.60	3.41
Mean	3.66	0.00	3.07	

HSD (1%) : Market = 0.014 ; Vegetables = 0.014 ; market x veg = 0.031

4.3.4. MICROBIAL LOAD IN IRRIGATION WATER

4.3.4.1 Total Coliforms in Irrigation Water

Irrigation water from the production locations contains some level of coliforms (Table 4.30). The total number of coliforms in irrigation water from KNUST was highest (1.11 log MPN/100mL) unlike the lowest level of 0.11 log MPN/100mL found in irrigation water from Ramseyer. The level of coliforms in irrigation from UEW Kumasi (0.13 log MPN/100L) was not different (p>0.01) from the 0.11 log MPN/100mL. Total coliforms of 0.62 and 0.34 log MPN/100mL were detected in water used as irrigation water from Kwadaso and Gyinyase respectively. These were significantly different (p<0.01) from the highest and lowest levels detected (Table 4.30).

4.3.4.2 Faecal Coliforms in Irrigation Water

Faecal coliforms in the irrigation water from the various production sites ranged from 0.04 – 0.49 log MPN/100mL (Table 4.30). Irrigation water from both Gyinyase and KNUST recorded the least faecal coliforms of 0.04 log MPN/100mL while Kwadaso's irrigation water contained the highest level of 0.49 log MPN/100mL. Also the irrigation water from Ramseyer and UEW Kumasi had the same level of faecal coliforms of 0.09 log MPN/100mL. These mean contamination levels were significantly different (p<0.01) from one another with respect to their effect (Table 4.30).

4.3.4.3 E. coli in Irrigation Water

E. coli was highest in irrigation water from Kwadaso (0.49 log MPN/100mL) and lowest from Ramseyer (0.02 log MPN/100mL) while UEW – Kumasi had no detectable *E. coli* in irrigation water used for vegetable production (Table 4.30). 0.04 log MPN/100mL E. coli was found in Gyinyase and KNUST irrigation water and its effect was not different from 0.02 log MPN/100mL (Table 4.30).

Table 4.30: Level of microbial contamination in irrigation water at production sites (MPN/100mL)

Locations	Total coliforms	Faecal coliforms	*E. coli*
KNUST	1.11	0.04	0.04
Kwadaso	0.62	0.49	0.49
Gyinyase	0.34	0.04	0.04

UEW – Kumasi	0.13	0.09	0.00
Ramseyer	0.11	0.09	0.02
HSD (1%)	0.053	0.053	0.032

4.4.1 CHEMICAL RESIDUES ON THE QUALITY OF VEGETABLES

The sampled vegetables from the selected production sites or locations were analysed for the following chemical residues: Pirimiphos-methyl, fenitrothion, chlorpyrifos, profenofos, p,p'-DDE, bifenthrin, lambda-cyhalothrin, permethrin, cyfluthrin, cypermerthrin, fenvalerate, deltamethrin, and fenpropathrin.

The vegetables from the five sties showed no detectable level of pirimiphos-methyl and fenitrothion residues except in cabbage from Kwadaso which had less than 0.01mg/kg (Table 4.31). Insignificant level of chlorpyrifos was found on fresh carrots sampled from KNUST; and cabbage from Kwadaso, KNUST and Gyinyase with 0.01, 0.02 and less than 0.01 mg/kg residual levels respectively. Less than 0.01 mg/kg bifenthrin was found in fresh carrot from all the sampling sites except Gyinyase and cabbage from Ramseyer and KNUST. Green pepper had no level of the chemical residue (Table 4.31).

Very insignificant amount of lambda-cythalothrin was detected on UEW – Kumasi's cabbage and carrots from Kwadaso and Gyinyase with less than or a level of 0.01 mg/kg. Similarly, the vegetables showed no detectable amount of permethrin residue except less than or 0.01 mg/kg found in cabbage from KNUST, Kwadaso and Ramseyer (able 4.32). Less than 0.01 mg/kg cyfluthrin was detected in fresh carrots from UEW – Kumasi and cabbage from Kwadaso and Gyinyase (Table 4.32). Likewise, <0.01 mg/kg of cypermethrin was detected in all the sampled vegetables except in green pepper from Kwadaso, KNUST and Gyinyase (Table 4.32).

Table 4.31: The amount and kind of chemical residues in vegetables from five production site

Location	Pesticides/Veg.Mg/Kg	Pirimiphosmethyl	Fenitrothion	Chlorpyrifos	Profenofos	Bifenthrin	Lambdacyhalothrin	Permethrin
KNUST	Fresh Carrots	Nd	Nd	Nd	Nd	Nd	Nd	Nd
KNUST	Green Pepper	Nd	Nd	<0.01	Nd	<0.01	Nd	Nd
KNUST	Cabbage	Nd	Nd	0.02	Nd	<0.01	Nd	<0.01
Kwadaso	Fresh Carrots	Nd	Nd	Nd	Nd	<0.01	0.01	Nd
Kwadaso	Green Pepper	Nd	Nd	Nd	Nd	Nd	Nd	Nd
Kwadaso	Cabbage	<0.01	<0.01	0.01	0.01	Nd	Nd	<0.01
Gyinyase	Fresh Carrots	Nd	Nd	Nd	Nd	Nd	0.01	Nd
Gyinyase	Green Pepper	Nd	Nd	Nd	Nd	Nd	Nd	Nd
Gyinyase	Cabbage	Nd	Nd	<0.01	Nd	Nd	Nd	Nd
UEW Kumasi	Fresh Carrots	Nd	Nd	Nd	Nd	<0.01	Nd	Nd
UEW Kumasi	Green Pepper	Nd	Nd	Nd	Nd	Nd	Nd	Nd
UEW Kumasi	Cabbage	Nd	Nd	Nd	Nd	Nd	<0.01	Nd
Ramseyer	Fresh Carrots	Nd	Nd	Nd	Nd	<0.01	Nd	Nd
Ramseyer	Green Pepper	Nd	Nd	Nd	Nd	Nd	Nd	Nd
Ramseyer	Cabbage	Nd	Nd	Nd	Nd	<0.01	Nd	<0.01

*Nd=not detected

Table 4.32: The amount and kind of chemical residues on vegetables from five production sites

Location	Pesticides/Vegetables Mg/Kg	Cyfluthrin	Cypermerthrin	Fenvalerate	Fenpropathrin	Deltamethrin	p,p'-DDE
KNUST	Fresh Carrots	Nd	<0.01	Nd	Nd	Nd	Nd
KNUST	Green Pepper	Nd	Nd	0.01	<0.01	Nd	Nd
KNUST	Cabbage	Nd	<0.01	<0.01	Nd	0.04	0.03
Kwadaso	Fresh Carrots	Nd	<0.01	Nd	Nd	Nd	Nd
Kwadaso	Green Pepper	Nd	Nd	0.01	<0.01	Nd	Nd
Kwadaso	Cabbage	0.01	<0.01	<0.01	Nd	<0.01	0.02
Gyinyase	Fresh Carrots	Nd	<0.01	Nd	Nd	Nd	Nd
Gyinyase	Green Pepper	Nd	Nd	0.02	<0.01	Nd	Nd
Gyinyase	Cabbage	<0.01	<0.01	<0.01	Nd	0.06	0.04
UEW Kumasi	Fresh Carrots	<0.01	<0.01	Nd	Nd	Nd	Nd
UEW Kumasi	Green Pepper	Nd	<0.01	<0.02	Nd	Nd	Nd
UEW Kumasi	Cabbage	Nd	<0.01	<0.01	Nd	0.05	0.04
Ramseyer	Fresh Carrots	Nd	<0.01	Nd	Nd	Nd	Nd
Ramseyer	Green Pepper	Nd	<0.01	<0.01	0.01	0.05	<0.05
Ramseyer	Cabbage	Nd	<0.01	Nd	Nd	Nd	Nd

*Nd = not detected

Carrots from all the sites showed no detectable level of fenvalerate unlike green pepper which had 0.01 to 0.02 mg/kg, and cabbage of less than 0.01 mg/kg from all sites except at Ramseyer with no detectable amount. Fenpropathrin was only detected in green pepper from all the sites except UEW – Kumasi (Table 4.32).

4.5.1.1 Deltamethrin and p,p'-DDE in cabbage

Deltamethrin and p,p'-DDE were only detected in cabbage from the various production area or sites (table 4.32). They ranged from <0.01 – 0.06 mg/kg and 0.02 – 0.05 mg/kg respectively. The highest residual level of both chemicals were detected in cabbage from Gyinyase (0.06 mg/kg) and Ramseyer (0.05 mg/kg) while the lowest in those from Kwadaso (<0.01, 0.02 mg/kg) respectively (Table 4.32). The amount of deltamethrin in cabbage from Gyinyase, Ramseyer, UEW – Kumasi, and KNUST were insignificant with respect to their effect. However, their effect varied significantly ($p<0.01$) from the level detected in the ones from Kwadaso. In order of decreasing level, they had 0.06, 0.05, 0.05, 0.04 and <0.01 mg/kg respectively (Figure 4.3).

Also, the residual levels of p, p'-DDE in cabbage from the five sampling sites were not significantly different ($p>0.01$) except between the highest (0.05 mg/kg) and lowest (0.02 mg/kg) detected the ones from Ramseyer and Kwadaso respectively (as indicated on Figure 4.3).

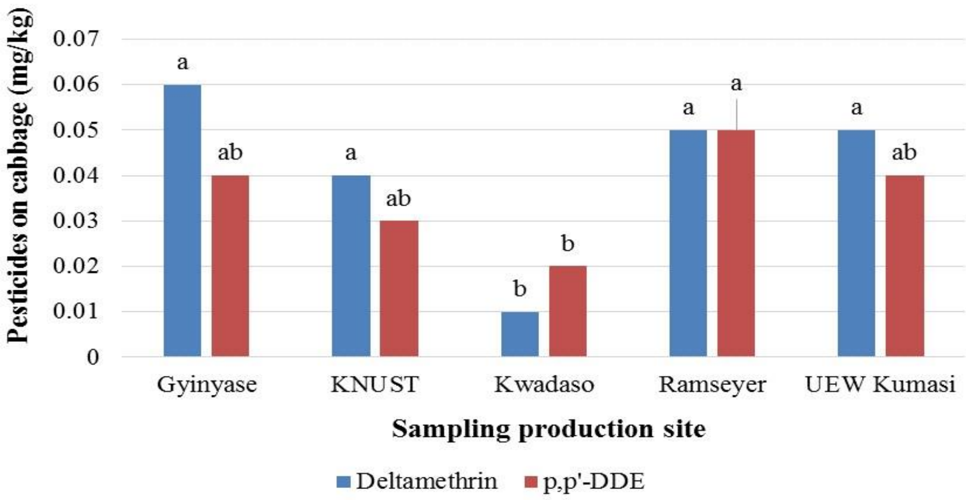

Figure 4.3: The level of Deltamethrin and p, p'-DDE residues on cabbage from selected production sites

4.5.2 Level of Chemical Residues in Irrigation Water from the Selected Sites

Irrigation water from the selected sites showed no detectable residual amount of endrin, dieldrin, methoxychlor, chlorfenvinphos, lambda-cyhalothrin, perimethrin, cyfluthrin, cypermethrin except DDT and chlorpyrifos. Water samples from Ramseyer, KNUST and Gyinyase showed less than 0.01 ug/L of DDT which are very insignificant. Chlorpyrifos was only detected in irrigation water from Gyinyase at a level of <0.01 ug/L.

CHAPTER FIVE

5.0 DISCUSSION

5.1 FIELD SURVEY

5.1.1 Demographic Characteristic of Farmers

5.1.1.1 Gender and Age of famers

The findings from this study revealed that most of the vegetable farmers in the Kumasi Metropolis are males.it was also revealed that most of the farmers engaged in vegetable farming are between the ages of 30 and 39 years. This information shows that most of the vegetable farmers in the Kumasi Metropolis are in their youthful age. This conforms to the statement made by the AVRDC-The World Vegetable Centre (2013) that young people in search for stable employment migrate to the cities throughout the sub-region but are often disappointed by the lack of job opportunities and most of them find their way into urban agriculture. However, it contradicts a statement by Barimah (2008) that Ghana's agriculture is in the hands of the aging farmers and the population of the youth engaged in agriculture is very low.

5.1.1.2: Level of education of farmers

The results indicate that majority of the vegetable farmers have attained basic school education which means they can read simple instructions on labels of chemicals they use during production. This reduces the risk of wrong application methods, overdose and wrong concentration.

5.1.1.3 Sources of water for vegetable farming

Vegetable farming largely depends on irrigation. The results indicated that most of the vegetable farmers draw water from dug-outs wells to irrigate their vegetable crops. This could be attributed to the fact that there are no permanent irrigation facilities for the vegetable farmers to use. During the rainy season, they depend on the streams and rivers most of which dry up during long dry seasons. This confirms the statement made by Keriata *et al.,* (2002) that, farmers draw water from dug-out wells and streams. It also confirms a statement made by Hasen *et al.,* (1980) that, basically rain and snow are the sources of all water. That portion which is not used at the point where it fall flows over the surface of the land and seep into the ground and augments the ground water supply. Therefore the rain and snow which is not used become a potential source of water or ground water for irrigation. However, it contradicts a statement by Drechsel *et al.,* (2006) that famers in three major cities of Accra, Kumasi and Tamale draw water from drains and sometimes treated waste water. It is also in contrast with the report by Nurudeen (2010), that some vegetables farmers in Tamale are using polluted water that runs through drains and big gutters in some parts of the metropolis to irrigate their vegetables.

5.1.1.4 Treatment of water before using for irrigation

It was revealed by the study that a greater percentage of farmers treated their water in different ways before using it to irrigate their crops. This practice could reduce the risk of contaminating the vegetable crops through irrigation.

5.1.

1.5 The use of fertilizers in vegetable production

Application of plant nutrients is a practice that helps farmers to maximize yield. However, there are certain basic factors that one must consider when applying fertilizer. The result of this study revealed that organic manure is the most the widely used fertilizer for cultivation of vegetables and the commonest organic manure used is poultry droppings. This might be due to abundance of organic fertilizer (poultry dropping) in the study area and could account for the presence of faecal coliform and E.coli in both the water and vegetables because organic manure is the main source of faecal contamination, confirming a statement by Allen (2006) that manure and improperly managed compost may act as reservoir for pathogenic bacteria like E. coli. It also confirms a statement by Amoah *et al.*, (2005) that vegetables cultivated with manure are highly infested by bacteria, indicating contamination from faecal sources.

5.1.1.6 Pesticide use and the Types Used by farmers

Pest attack is one of the problems that confront farmers in Ghana and Kumasi is no exception. In order to minimize cost and losses due to pest attack, farmers of vegetables in the Kumasi metropolis use a lot of pesticides. This study revealed that most farmers use Lambda, Diaten, Golan, Attack and Sanfocide to control pests. Most of the chemicals mentioned were detected in the vegetables. This could be attributed to the low level of formal education among farmers in the study area making it difficult to understand things written on the labels of chemicals. The implication is that farmers may not use the right dosage or concentration during application. Most farmers do not also observe the correct harvest interval. Thus pesticides are applied frequently until crops are harvested. This exposes consumers to the adverse effect of pesticide residue.

5.1.2. Demographic Characteristics of Vegetable Sellers.

5.1.2.1. Age and gender of vegetable sellers.

The results revealed that most of the vegetable sellers in the various markets in the Kumasi metropolis fall within the age range of 30-39 years. This age range is within the active youthful group. This is probably due to the hard work involved in harvesting vegetables in the farms (which is mostly done by the vegetable sellers), packaging and conveying to the roadsides to be transported to the markets. It was also revealed that all the vegetable sellers are females. This may be due to the fact that food ingredients including vegetables are sold by women in most of our markets in Ghana. This confirms a statement by Kwei (2007) that in Ghana, women are found working in the informal sector, from small-scale farming activities, selling on table tops at markets to venturing into micro enterprises. It is estimated that women make up about 85% of the wholesale and retail trading businesses.

5.1.2.2 Level of formal vegetable sellers.

It was revealed that a greater percentage of the seller do not have any formal education. Those who have some formal education just have basic education, with only a few attaining secondary education and low level of formal education is the reason why most Ghanaian women are engaged in the informal sector as stated by
Kwei (2007).

2.3 Handling of vegetables by sellers

Among the vegetable sellers selected for this study most of them cleaned their packing materials. But some cleaned after a long period of use. Others use water in the farm which is used for irrigation to clean their packing materials. Some sellers do not clean their packing

5.1.

materials at all. Refusing to clean materials used for packing vegetables gives a tendency of transferring dirt, germs and other microbial organisms from the packaging materials to the vegetables making them unhealthy and unsafe for consumption. In order to ensure freshness of vegetables, most sellers spread the vegetables in the open air while others sprinkle water over them. This is probably because consumers look at the appearance and the freshness of the vegetables before buying. This confirms a statement made by Kader and Rolle (2004) that consumers judge the quality of fresh ornamentals and vegetables on the basis of appearance (including freshness) at the time of initial purchase.

5.1.3 Demographic Characteristic of Food Vendors

5.1.3.1: Age and gender of food vendors.

The results revealed that majority of the food vendors in the study area are within the age range of 30-39. This is closely followed by the age range of 20-29. All these age groups are the active working group. This may be due to the fact that there is so much heat involved in the preparation of food (cooking) which most of the aged cannot withstand. It may also be as a result of rural –urban migration where most of the youth move to the cities to find jobs. Most of them end up selling food in the markets and road sides. It was also revealed that majority of the food vendors are females only a small percentage are males. This may be due to the fact that most of the males are rather engaged in production and construction firms.

5.1.3.2: Educational background of vendors

This study reveal that majority of food vendors in the Kumasi metropolis have only basic education which is either primary school or junior high school level. At this level of education most people cannot read and write so most of them who end their education at this level are usually engaged in petty trading which includes selling of food. This could also be due to the high economic activities in the metropolis. The youth who have no other jobs find food selling a lucrative business.

5.1.3.3: processing and storage of vegetables by vendors

It was revealed by this study that majority of the food venders washed vegetables with only water. Only a few washed with salt solution and vinegar. By washing the vegetables with salt solution, they may probably have it in mind that the vegetables contain some contaminants which cannot be removed by washing with only water. This is in conformity with a statement by Ensink *et al*., (2007) that vegetables from the market harboured higher E-coli concentration with a mean concentration
(geometric) of 14.3 E.coli per gram.

Majority of the food vendors admitted that they use all the vegetables the same day just after buying from the market. The few who do not use the vegetables the same day leave them in the open space for fresh air and use within two or three days. This confirms a statement by the Agriculture and Consumer Protection (1989), that most fruits and vegetables have a storage life of few days even under the best environmental condition.

4Demographic Characteristic of Consumers in the Kumasi Metropolis

5.1.4.1 Age and gender of consumers

It was revealed by the result that majority of the consumers fall within the age range of 30-39 years, which is within the active working group. This probably is due to awareness created on the nutritional value of vegetables in the life of human beings. As stated by the Vegetable

5.1.

Nutritional Facts (2009) that vegetables are low in calories and fats but contain good amount of vitamins and minerals. Therefore the health of these people could be a determining factor on the Gross Domestic Product (GDP) of the nation.

It was also revealed that majority of the consumers are females who mostly buy and prepare food for their families. This will help improve the health condition of families or people in the country which is in conformity with a study conducted by the U.S Centre for Disease Control (2010), which revealed that plant rich diet of fruits and vegetables is associated with a decreased risk of chronic diseases including heart attack and stroke.

5.1.4.2. Educational back ground of consumers

It was revealed by this study that majority of the consumers of vegetables have attained secondary education followed by those who have attained tertiary education. It could be deduced from the results that level of formal education has an impact on the choice of the diet. This is a positive impact of education on the country and it conforms to the popular statement that "education is the key to national development"

5.1.4.3 Postharvest treatment of vegetables by consumers in the Kumasi Metropolis.

Improper handling of vegetables can create conducive environmental conditions for pathogenic organisms to attack vegetables. It is therefore very important for farmers and consumers to adopt proper postharvest handling methods aiming at minimizing postharvest contamination and losses. It was revealed by the study that the commonest method of treating vegetables is by washing with salt solution. This probably is due to the educational level of the consumers. Most of them can read and write so are aware of the risk involved in consuming contaminated food.

5.1.5 Demographic Characteristics of Agrochemicals Seller in the Kumasi Metropolis.

5.1.5.1 Age and gender of Agrochemical sellers.

The minimum age of agrochemical sellers in the Kumasi Metropolis according to the results of this study was 22 years and the maximum age was 51 years. The average age of agrochemical sellers was 33 years with the modal age being 28 years. This means that most agrochemical sellers are in the youthful age. This is normal because people who are 20 years or below may either be in school or may be too young to work and at age 60 and above, they may be old and not strong enough to do hard work. The results also show that nobody above 51 years sells agrochemicals, this may be due to the health hazards posed by exposure to agrochemicals since at the age above 51 one's immune system is not as strong as that of younger people to be able to stand the risk of exposure to agrochemicals. The result also indicated that more males are into the agrochemical business than females. Although, many females are engaged in trading in other commodities, from this study, more males are in the agrochemical business than females. This can be because females are afraid of the chemicals especially when they are pregnant or cannot handle agrochemicals when nursing children.

5.1.5.2 Level of education of agrochemical sellers

The result from this study revealed that majority of the sampled population have secondary education .It indicated that almost all the sampled population have some level of education. Such people may be able to read labels of agrochemicals. Yet a small percentage (5%) of sellers has no formal education and will not be able to interpret instructions on label to farmers

5.1.5.3Education on the correct handling of agrochemicals

Results from this study revealed that not all sampled population of agrochemical sellers have been educated on the correct handling of agrochemicals. Meanwhile some of the agrochemical sellers have low educational background and so cannot read and understand agrochemical labels. If such people are not given proper education, their activities become a source of danger to the community. Agrochemical sellers also educate farmers on the correct use of agrochemicals, meaning that farmers are likely to receive incorrect information from some of the sellers, which can result in misuse of agrochemicals by farmers and this will produce negative rippling effect with fatal consequences on the community and nation as a whole.

5.1.5.4 The use of banned and expired agrochemicals

According to the results of this study, some agrochemical sellers have access to banned agrochemicals which they sell to farmers to use on crops. Some sellers also confirmed that they sometimes sell expired agrochemicals to farmers. Although the number of sellers who sell these expired and banned agrochemicals is not great, it is still dangerous to the consumers of produce on which such agrochemicals will be used.

5.1.6 Response from Agriculture Extension Officers

According to result of this study, agriculture extension officers have confirmed that farmers cultivate vegetables in the areas. They confirmed that the farmers who cultivate vegetables irrigate their crops. Majority of the agricultural officers have confirmed that vegetable farmers in their area use stream, river, well or harvested rain as their source of water to irrigate their vegetables. It was also revealed that agricultural extension officers are aware that vegetable farmers use various agrochemicals during production. According to the officers, farmers use weedicides, pesticides and fertilizers. It was also revealed that agricultural extension officers educate farmers on good agronomic practices and that farmers also consult them on good production practices.

5.2 LABORATORY ANALYSIS

5.2.1 Dry Matter and Moisture content of vegetables:

Vegetables are known to contain more water than dry matter content. The result of this study is therefore in conformity with the statement made by Kemble and Sanders (2007) that vegetables contain 80-95 % water. However the percentage of moisture variation at the different study sites may be attributed to the fact that the moisture level of the soil at the different locations are not the same and could have an impact on the moisture and dry matter contents of the vegetables. Although vegetables contain a higher percentage of moisture, the amount may be determined by the type of vegetable and area of cultivation. This also means that irrigating vegetables with contaminated water may have an adverse effect on the postharvest quality of the vegetables.

5.2.2 Microbial load in Vegetables from the Production Sites

5.2.2.1 Total Coliform count

Total coliform count was higher at Ramseyer than the other four production sites. This may be attributed to the refuse damp very close to the stream used for irrigation and also a gutter running from the school and nearby houses directly into the stream. Kwadaso received the least total coliform count and this could be due to the fact that the area of cultivation is not very close to any residence as compared to the other locations. Difference in total coliform counts in the various cultivation sites of the study could also be attributed to difference production practices such as amount of organic manure usage and other environmental factors. On the part of vegetables, carrots recorded the highest mean value. It could also be inferred from the results that level of microbial contamination does not depend on the type of vegetable.

5.2.2.2 E.Coli

The level of E.coli was high in Ramseyer than all the other four sites selected for this study. Carrots also had the highest count as compared to the other two vegetables (cabbage and green pepper). The presence of E.coli in vegetables could be due to the use of organic manure as stated by Allen (2006) that manure and improperly managed compost may act as reservoir for pathogenic bacteria like E.coli.

5.2.2.3 Faecal Coliform count

Vegetables sampled from all the five locations showed the presence of faecal coliforms except for cabbage from Kwadaso. Unlike E.coli, which recorded lower values in the vegetable samples, the value of faecal coliform are quite high and that could be a treat to the health of consumers of vegetables from these location. The high values of faecal coliforms could be attributed to the deposit of human waste around the production sites and run-off from garbage and polluted water getting into contact with vegetables through irrigation, splashing and other on-farm agricultural activities. It could also be from the manure used since farmers at all the location use some organic manure. The results is in conformity with what was reported by Donkor *et al.,* (2009) that high levels of coliform and faecal coliform may be likely due to manure soil contamination. They explained further that these pathogenic bacteria, viruses, worms, fungi and high level of faecal pollution are found along the drains used in watering vegetables. However, comparing the level of faecal coliforms with previous study in some cities in Ghana including some other parts of Kumasi, It could be said that the values are comparatively low. For instance Drechsel *et a.,l* (2006) revealed that faecal coliform levels of vegetables in Tamale ranged from $40x10^8$ to $7.5x10^8$ for cabbage, lettuce and spring onions. In view of this, the statements by Drechsel *et al.,* (2006) that total coliform and faecal coliform levels are lower in Kumasi as compared to Tamale and Accra was confirmed. Carrots had more faecal coliform than green pepper and cabbage probably because carrot is in the soil and have direct contact with the soil; it becomes more contaminated than the above ground crops.

5.2.2.4: Microbial load count in irrigation water from the five locations Some levels of total coliform, faecal coliform and E.coli were detected in the samples of irrigation water from all the five locations. Water from KNUST recorded the highest value for total coliform while Ramseyer recorded the lowest value. On the part of E.coli the highest was recorded in water from Kwadaso while that of

UEW-Kumasi had none. Faecal coliform counts were highest in water from Kwadaso and the lowest was in KNUST and Gyinyase. Differences in the values recorded could be as a result of other environmental differences such as drainage from garbage and gutters. Microbial load counts detected in the irrigation water are lower than what was detected in the vegetables. This indicates that microbial contamination of vegetables does not come from only irrigation water. Other factors such as manure and method of watering can also determine the microbial contamination of vegetables. Because Drechsel and Varma (2007) stated that the use of watering cans increase crop contamination more especially through spraying with droplets on leaves of vegetables. Despite the low value of microbial load detected in irrigation water from the five location, the use of the water still pose a threat to consumers since the USEPA (2013) set the minimum coliform limit Rule (MCLR) for total coliform at zero because there have been water borne disease outbreaks in which researchers found very low levels of coliform, so any level indicates some health risks.

5.2.2.5 Pesticide residue in the vegetables and irrigation water from the five locations.

As many as thirteen pesticide residues were found in the vegetables from the five growing locations, although not all were in each vegetable sample. However, the levels detected were below the recommended maximum residual levels by FAO and WHO. This notwithstanding, consuming these vegetables still poses a threat to the health of consumers since most consumers take in vegetables in their raw state or just a little cooked. More pesticides were detected in cabbage from all five locations than carrot and green pepper. This could be attributed to the fact that it is a leafy vegetable and attracts a lot of insects and therefore cabbage is being sprayed with more pesticides and also more frequently than carrot and green pepper. Kwadaso recorded the highest number of pesticides in cabbage followed by KNUST. Ten and seven pesticides were detected respectively. Highest residual levels detected in cabbage from Kwadaso and KNUST are 0.02 for P'P-DDE and 0.04 for Deltamethrin respectively. Cabbage from UEW-Kumasi recorded the highest pesticide residual level being 0.05 for P'P-DDE and the lowest residual level was <0.01 for most of the pesticides in the three vegetables from all five locations. Meanwhile only DDT and Chlorpyrofos were detected in water samples. DDT was detected in water sampled from Gyinyase, KNUST and Ramseyer while chlorpyrifos was only detected in irrigation water from Gyinyase at a level of <0.01ug/L. This result therefore shows that irrigation water has very little impact on the quality of vegetables in terms of pesticide residue. The presence of pesticides in the vegetables could be attributed to direct contact with crops during spraying or by absorption from the soil. After spraying farmers may not wait for the recommended period before harvesting and that could be a cause of residues in the vegetable.

5.2.2.6: Microbial load count in vegetable samples from three markets

Microbial load levels are very high in vegetables samples from the three markets as compared to those from production sites. Total coliform levels from the three markets have almost tripled, with samples from Kwadaso market recording the highest for the three vegetables. Tanoso had the lowest values for cabbage and green pepper and Atonsu recorded the lowest value for carrot. The very high values detected in vegetables from the markets could be attributed to improper handling, storage, packaging materials, use of contaminated water in cleaning vegetables. Differences recorded in the vegetables from different markets could be attributed to difference in storage, packaging materials, transporting or even the hands of sellers.

The high values obtained for samples from the markets confirm studies conducted by Ensink *et a*l., (2007) which revealed that vegetables from the market harboured higher E.coli concentration (with a mean concentration of 14.3 E.coli per gram 95%) than vegetables from the field.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATON

6.1 CONCLUSION

Majority of the vegetable farmers in the Kumasi metropolis use water from dugouts and river/stream to irrigate their crops, however most of them treat the water before use.

Thirteen pesticide residues were detected in vegetables from the cultivation sites while only three pesticides residues were detected in the irrigation water. Pesticide residues detected in both the irrigation water and the vegetables were within the EU acceptable maximum residual levels.

The levels of microbial load and chemical residue detected in the vegetables are lower than those in the irrigation water indicating that irrigation water has little impact on microbial load and pesticide residue of vegetables cultivated in the study area. Notwithstanding the low values in microbial load and pesticide residue in the vegetables, continues consumption of these vegetables poses a threat to human health.

Microbial load in vegetables from market locations was higher than those from production sites. However, most consumers treat vegetables well before consuming them while most food venders wash vegetables with only water which is also a risk to people who consume vegetables served by food venders.

6.2 RECOMMENDATIONS

1. There is the need for further research in the study area to determine the level of microbial and chemical contamination of vegetables in different seasons of the year.
2. There should be proper education and monitoring on the production and post-harvest handling of vegetables to reduce the contamination of vegetables in the supply chain and ensure safety in consuming vegetables produced in the Kumasi metropolis.
3. There should be further studies to determine the main sources of microbial contamination of vegetables apart from irrigation water.
4. Awareness should be created on the risk of consuming contaminated vegetables.

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APPENDICES

Appendix I: EU Maximum Residual Level (MRL) of Pesticides in Vegetables.

Test Conducted	Carrot	Green Pepper	Cabbage
Fenpropathrin	0.01	0.01	0.01
Cyfluthrin	0.02	0.10	0.30
Cypermerthrin	0.05	0.10	1.00
Fenvalerate	0.02	0.05	0.10
Deltamethrin	0.05	0.05	0.10
P,P'-DDE	0.05	1.00	0.05
Pirimiphos-methyl	1.00	0.10	0.05
Fentrothion	1.00	1.00	0.01
Chlorpyrifos	0.10	1.00	1.00
Profenofos	0.05	0.10	0.05
Befenthrin	0.05	0.10	1.00
Lambda-cyhalothrin	0.02	0.05	0.20
Permethrin	0.05	0.10	0.05
P,P'DDT	0.05	1.00	0.05

Appendix II: Analysis of Variance Table of Microbial Load of Vegetables from growing sites.

Analysis of Variance Table for TC

Source DF SS MS F P mkt 2
11.5862 5.7931 37241.4 0.0000 veg 2 22.1046
11.0523 71050.5 0.0000 mkt*veg 4 12.4504
3.1126 20009.6 0.0000
Error 18 0.0028 0.0002
Total 26 46.1440

Grand Mean 7.2567 CV 0.17

Analysis of Variance Table for FC

Source DF SS MS F P mkt 2
24.738 12.3691 65483.5 0.0000 veg 2 70.136
35.0679 185654 0.0000 mkt*veg 4 30.939
7.7347 40948.4 0.0000
Error 18 0.003 0.0002
Total 26 125.816

Grand Mean 5.5100 CV 0.25

Analysis of Variance Table for Ecoli

Source DF SS MS F P mkt 2
67.906 33.9529 436538 0.0000 veg 2 69.456
34.7281 446505 0.0000 mkt*veg 4 34.796
8.6989 111843 0.0000
Error 18 0.001 0.0001
Total 26 172.159

Grand Mean 2.2422 CV 0.39

Analysis of Variance Table for Ecoli

Source	DF	SS	MS	F	P
Veg	2	0.09222	0.04611	2.96	0.0672
Loc	4	1.60621	0.40155	25.76	0.0000
Veg*Loc	8	2.42434	0.30304	19.44	0.0000
Error	30	0.46767	0.01559		
Total	44	4.59043			

Grand Mean 0.1936   CV 64.51

Analysis of Variance Table for Fcoli

Source	DF	SS	MS	F	P
Veg	2	1.2533	0.62664	3357.00	0.0000
Loc	4	5.8517	1.46293	7837.12	0.0000
Veg*Loc	8	41.6007	5.20009	27857.6	0.0000
Error	30	0.0056	0.00019		
Total	44	48.7113			

Grand Mean 1.8520   CV 0.74

Analysis of Variance Table for Tcoli

Source	DF	SS	MS	F	P
Veg	2	1.2449	0.62244	3836.97	0.0000
Loc	4	6.1944	1.54859	9546.12	0.0000
Veg*Loc	8	46.8549	5.85687	36104.0	0.0000
Error	30	0.0049	0.00016		
Total	44	54.2991			

Grand Mean 1.9682   CV 0.65

Analysis of Variance Table for EcoliT

Source	DF	SS	MS	F	P
Veg	2	0.01387	0.00694	2.54	0.0956
Loc	4	0.28332	0.07083	25.96	0.0000
Veg*Loc	8	0.41832	0.05229	19.16	0.0000
Error	30	0.08187	0.00273		
Total	44	0.79737			

Grand Mean 1.0844   CV 4.82

Analysis of Variance Table for DMC

Source	DF	SS	MS	F	P
Veg	2	297.408	148.704	10138.9	0.0000
Site	4	5.068	1.267	86.39	0.0000
Veg*Site	8	29.732	3.717	253.40	0.0000
Error	30	0.440	0.015		
Total	44	332.648			

Grand Mean 7.7400 CV 1.56

Analysis of Variance Table for MC

Source	DF	SS	MS	F	P
Veg	2	295.792	147.896	11676.0	0.0000
Site	4	4.932	1.233	97.34	0.0000
Veg*Site	8	29.748	3.718	293.57	0.0000
Error	30	0.380	0.013		
Total	44	330.852			

Grand Mean 92.247 CV 0.12

Completely Randomized AOV for Ecoli

Source	DF	SS	MS	F	P
Loc	4	0.52224	0.13056	1632.00	0.0000
Error	10	0.00080	0.00008		
Total	14	0.52304			

Grand Mean 0.1180 CV 7.58

Completely Randomized AOV for Fcoli

Source	DF	SS	MS	F	P
Loc	4	0.44100	0.11025	501.14	0.0000
Error	10	0.00220	0.00022		
Total	14	0.44320			

Grand Mean 0.1500 CV 9.89

Completely Randomized AOV for Tcoli

Source	DF	SS	MS	F	P
Loc	4	2.08164	0.52041	2365.50	0.0000
Error	10	0.00220	0.00022		
Total	14	2.08384			

Grand Mean 0.4620   CV 3.21

Appendix III Sample Questionnaire

SECTION A: THE VEGETABLE FARMERS

1. Location

………………………………………………………..………………

2. Gender

Male [ ]   female [ ]

1. Age

Below 20 years [ ]   20-29 years [ ] 30-39 years [ ]

40-49 years [ ]   50-59 years [ ] 60 years and above [ ]

2. Level of formal education

No formal education [ ] primary education [ ] middle school/JSS [ ] secondary education [ ]   tertiary education [ ]

3. List the vegetables you grow…………………..

…………………………………………………………………………

4. Do you irrigate your crops?

Yes [ ] no [ ]

5. If yes, what is the source of water you use?

Stream/river [ ] well [ ] dug-out [ ] borehole [ ] others, specify

…………………………………………………………………………

1. What is the physical quality of the water?

Clear and Clean [ ] Dirty [ ]

2. What other use does the water serve in this community?

For domestic use [ ] Drinking water for cattle [ ] for only irrigation [ ]

3. Why do you use this water for irrigation?

Because it is the only available source [ ] Because it is affordable [ ] Because it is safe for human use [ ]

6. Do you have access to water all year round? Yes [ ] No [ ]

7. Does the source of water affect your production or yield in any way? Yes [ ] No [ ]

If yes, how?...

8. Do you treat the water before use? Yes [ ] No [ ]

9. If yes, what form of treatment do you apply? Filter the water [ ] put down to settle [ ] others specify…………………………………..

10. Do you have any intension of improving upon the quality of the source of water you use? Yes [ ] No [ ]

11. If yes, what do you intend doing? Dig a borehole [ ] Dig a deep well and use a pump [ ] Dig a dam [ ] others, specify………..…………………………………...........

12. Do you use any form of fertilizer during production

Yes [ ] No [ ]

13. If yes, what type of fertilizer do you use? Organic [ ] Inorganic [ ] Both [ ]

14. List the inorganic fertilizers you use…………………………………….……

………………………………………………………………………..……………......

15. What are the organic fertilizers you use?

Cow dung [ ] Poultry manure [ ] Both [ ] Compost [ ]

others please specify……………………………..…………………………..

16. Do you use any pesticides or weedicides? Yes [ ] No [ ]

17. If yes, what are some of the pesticides or weedicides you use?......................................

………………………………………………………………………………..

18. Do you also use any plant extract? Yes [ ] No [ ]

19. If yes, what are the plant extracts you apply?...

…………………………………………………………………………………..

20. 26. Does the season have any influence on the application of agrochemicals?

Yes [ ] No [ ]

21. 27.If yes, state how the season influences or affects pesticide use

……………………………………………………………………………………

………………………………………………………………………

22. Do you always get the expected results or yield after applying agrochemical(s)? Yes [ ] No [ ]

23. 29. Give reason(s) for your answer if no to (28)

………………………………………………………………………………………………

…………………………………………………………………………………

24. 30. For how long have you been using fertilizers and other agrochemicals on this field?

Less than two years [ ] 2- 5 years [ ] 6-10 years [ ] more than 10 years [ ]

25. How often do you apply fertilizer? …………………………………………..

26. 32. How often do you apply pesticides? Any time there is the need to control pests [ ] Once in every cropping season [ ]

others specify………………………………………………………………….

27. What quantities of fertilizers and pesticides do you apply?

As directed by the extension agent [ ] As written on the container or label [ ] As directed by the seller [ ] anything goes [ ] depending on the condition of the crops [ ]

28. What is the source of water for applying agrochemicals?

Stream/river [ ] well [ ] dugout [ ] borehole [ ] others, specify………………

29. Who recommends agrochemicals for you? Colleague farmers [ ]

Agrochemical Sellers [ ] Extension Officers [ ] Media [ ] All the above [ ] **30.** Have you been educated on the correct use of agrochemicals?

Yes [ ] No [ ]

31. Who gave the education, If yes to (36)? Agrochemical Sellers [ ] Colleague farmers [ ] Extension Officers [ ] others specify

…………………………………………………………………………………….

32. How and where do you dispose of the excess agrochemicals?

Pour on the farm [ ] Pour into the nearby bush [ ] Pour into nearby water body [ ] others specify………………………………………………………….. ..…

………………………………………………………………………………………

33. How do you dispose of empty containers?

Burry in the farm [ ] Throw into the nearby bush [ ]

Throw into the other side of water [ ] Leave them on the farm [ ]

Others specify…………………………………………………...………………

………………………………………………………………………………………

34. How do you clean the application equipment after use?

Wash them in the water body [ ] Wash and pour into the bush [ ]

Wash and pour on the farm [ ] others specify ……………………………

35. Where and how do you sell your produce? To retailers on the field [ ] To retailers in the market [ ] directly to consumers [ ]

Others specify…………………………………………………………………

………………………………………………………………………………………

36. Who harvests the matured vegetables?

The farmer [ ] Casual labourers [ ] The retailers [ ] others, specify

………………………………………………………………………………………

SECTION B: THE VEGETABLE SELLER

1. Location……………………………………………………………………
…

………………………………………………………………………………………

2. Age

Below 20 years [ ] 20-29years [ ] 30-39 years [ ]
40 49 years [ ] 50-59 years [ ] 60 years and above

3. Gender

Male [ ] Female [ ]

4. Level of formal education

No formal education [ ] primary education [ ] middle school/ JSS [ ] Secondary education [ ]

Tertiary education [ ]

5. Which vegetables do you sell?...

....

6. For how long have you been selling vegetables? Less than one year [ ] 1-2 years [ ] 2- 5 years [ ] 6-10 years [ ] more than 10 years [ ] 7. Where do you get the vegetables to sell?

Grow them personally [ ] Buy from farmers [ ] Buy from the market [ ]

8. Which farm site are the vegetables grown?

………………………………………………………………………………………

9. Have you had the chance of visiting the farm?

Yes [ ] No [ ]

10. Do you know the source of water used to irrigate the vegetable crops on the field?

11. Yes [ ] No [ ]

12. If yes, what is your perception about the quality of the water? It is good for irrigation [ ] It should be treated before use [ ]

Others specify………………………………………………………………

13. Do you know the types of agrochemicals used by the farmers?

Yes [ ] No [ ]

14. If yes, what is your perception about the quality of the vegetables?

They are not safe for consumption if not properly treated [ ] They are safe for consumption [ ]

Others, specify…………………………………………………………..

15. How are harvested vegetables handled in the farm?

They are put in sacks [ ] They are put in baskets [ ] They are put in boxes [ ]

Others, specify ………………………………………………………………….

…………………………………………………………………

16. How are the vegetables transported from farm to the market?

Join commercial vehicles [ ] Hire a vehicle [ ] Use private vehicle [ ]

Others, specify …………………..…………………………………………….

…………………………………………………………………………………………

17. Do you clean your packaging materials?

Yes [ ] No [ ]

18. If yes, how often do you clean them?

Before every packing [ ] Once every month [ ] Any time I feel like cleaning [ ] others, specify………………………………………..…………………………

…………………………………………………………………………………………

19. How long does it take to sell the packs?

One day [ ] 2-5 days [ ] One week [ ] It depends on market conditions [ ] 20. How do you store unsold vegetables?

Leave them on tables [ ] Put them in the basket [ ] Put them in the sacks [ ]

Others specify……………………………………………………………..

21. How do you ensure that the freshness of the vegetables is retained? Cover them in the basket [ ] Spread them in the open air [ ]

Sprinkle water on them [ ] Others, specify………………………..

22. If you use water to maintain freshness, what is the source of the water?

23. Pipe borne water [ ] Stream/river [ ]

Others, specify……………………………………………………………….

24. Do you treat water before use? Yes [ ] No [ ]

25. If yes, what form of treatment do you give? Filtering [ ] Put it down to settle [ ] Others specify……………………………………………

26. If no why? The water will not have any side effect on the vegetables [ ] The consumers will clean the vegetables before use [ ]

Others specify……………………………………………

27. Have you been educated on the correct handling of vegetables?

Yes [ ] No [ ]

28. If yes, by who? Kumasi Metropolitan Assembly [ ] Ghana Health Service [ ] An NGO [ ] Vegetables growers [ ] Colleague sellers [ ]

29. How often do you receive this education? For only once [ ] Once every year [ ] Twice in the year [ ] Quarterly [ ]

30. Do you treat the vegetables before selling?

Yes [ ] No [ ]

31. If yes, what type of treatment is it?

Wash them [ ] Clean them with rags [ ]

Others, specify ……………………..…………………………….

SECTION C: FOOD VENDORS OR FAST FOOD SELLERS

1. Location…………………………………………………………………………
…

2. Age

Below 20 years [ ] 20-29 years [ ] 30-39 years [ ]

40-49 years [ ] 50-59 [ ] 60 years and above [ ]

3. Gender

Male [ ] female [ ]

4. Level of formal education

No formal education [ ] primary education [ ] middle school/JSS [ ] Secondary education [ ] Tertiary education [ ]

5. Which vegetables do you serve with your food?

………………………………………………………………………………………

6. Where are they bought or got from?

From growers [ ] From the market [ ] Grow them personally [ ]

7. Have you had the chance of visiting any vegetable farm?

Yes [ ] No [ ]

8. Do you know the sources of water used during cultivation?

Yes [ ] No [ ]

9. If yes, what is your perception about the quality of the water? It is good for irrigation [ ] It should be treated before use [ ]

Others, specify ……………………………………………………………

10. Do you know the agrochemicals sued during the cultivation of the vegetables?

Yes [ ] No [ ]

11. What is your perception about the quality of the vegetables?

They are safe for consumption [ ]

The water used does not have any bad effect [ ]

12. Do you treat the vegetables before selling or use? Yes [ ] No [ ]

13. If yes what type of treatment do you practice?

Wash with clean water [ ] Wash with salt solution [ ] Wash with warm water [ ] Wash with vinegar [ ] Others, specify ……………………………..…… 11. How do you process the vegetables before serving to customers? Slice and serve raw [ ] Slice and heat [ ] used for stew [ ]

Others, specify……………………………………………………………….

………………………………………………………………………………….

12. What equipment do you use for processing?

……………………………………………………………………………………………

………………………………………………………………………….

13. Do you clean the processing equipment?

Yes [ ] No [ ]

14. If yes how often do clean them?

Before and after every use [ ] Before use [ ] After use [ ] 15. Do you add anything to the vegetables before selling?

Yes [ ] No [ ]

16. If yes, what do you add?

Mayonnaise [ ] Ketchup [ ] Mayonnaise and ketchup [ ]

Others, specify ……………………………………………………………….
17. Do you use the vegetables the same day?
Yes [ ] No [ ]
18. If no, how do you store them before use?
Keep them in the refrigerator [ ] Leave them in the open air together [ ] Leave them in the open air separated [ ]
19. Do you sell all processed vegetables in the same day? Yes
Yes [ ] No [ ]
20. If no, what do you do with the unsold vegetables?
Keep them in the refrigerator [ ] Heat and store for the following day [ ] Consume at home [ ] Throw away [ ] Use to feed farm animals [ ]
Others please specify……………………………………………………………….

SECTION D: THE CONSUMERS.

1. Age
Less than 20 years [ ] 20-29 years [ ] 30-39 years [ ]40-49 years [ ] 50-59 years [ ] 60 years and above [ ]
2. Gender
Male [ ] Female [ ]
3. Level of formal education
No formal education [ ] primary education [ ] middle school/JSS [ ] Secondary education [ ]
4. Which vegetables do you normally purchase?
………………………………………………………………………………………………
…………………………………………………………………………………
5. Do you have any idea of where the vegetables were grown?
Yes [ ] No [ ]
6. Do you have any idea of the source of the water used to irrigate the vegetables?
Yes [ ] No [ ]
7. Do you treat the vegetables before use?
Yes [ ] No [ ]
8. If yes, what treatment do you apply?
Wash with water [ ] Wash with salt solution [ ] Wash with vinegar [ ]
Wash with hot water [ ] Heat for a few minutes [ ]
Others, specify………………………………………………………………………………
………………………………………………………………………………………………
9. Have you ever had any bad experience after taking vegetables?
Yes [ ] No [ ]
10. If yes, specify the experience you have had?
…………………………………………………..…………………………………
11. Did you trace the source of the problem?

Yes [ ]   No [ ]

SECTION E: THE AGRICULTURAL EXTENSION OFFICERS

1. Which vegetables are cultivated in your district?

…………………………………………………………………………………………

……………………………………………………………………………

2. What are the sources of water used by farmers to irrigate their vegetable crops?

Harvested rain water [ ] Streams/rivers [ ] Wells [ ] Bore holes [ ]

Dug-outs [ ] Others, specify ………………………………………………………

3. Which agrochemicals do the farmers mostly use?

…………………………………………………………………………………………

……………………………………………………………………………

4. Do the farmers know the consequences of the agrochemicals they use?

Yes [ ] No [ ]

5. Where do the farmers usually sell their produce?

…………………………………………………………………………………………

…………………………………………………………………………………………

……………………………………………………………………

6. What treatment is applied by farmers before selling the vegetables?

…………………………………………………………………………………………

……………………………………………………………………………

7. Do farmers consult you on cultural practices?

Yes [ ] No [ ]

8. Do you teach farmers the best agronomic practices?

Yes [ ] No [ ]

9. If yes, do they practice what you teach them?

Yes [ ] No [ ]

10. If no, why do they not practice what you teach them?

…………………………………………………………………………………………

……………………………………………………………………………

SECTION F: AGROCHEMICAL SELLERS

1. Age of Seller…………………………………………………………………………

2. Gender of Seller………………………………………………………………

3. Level of formal education

No formal education [ ] Primary school [ ] Middle school/JHS [ ] Secondary school [ ] Tertiary education [ ]

4. For how long have you been in the Agrochemical selling business?

Less than 2 years [ ] 2 to 5 years [ ] 6 to 10 years [ ]
11 to 15 years [ ] More than 15 year [ ]

5. What types of agrochemicals do you sell?

All types are available [ ] Fertilisers [ ] Pesticides [ ]
Herbicides [ ] Others, specify [ ]

6. Name some of the pesticides you sell.

……………………………………………………………………………………………
……………………………………………………………………………

7. Name some of the herbicides you sell.

……………………………………………………………………………………………
………………………………………………………………………………

8. How do farmers call the agrochemicals?

By their original names [ ] By describing [ ] They use local names [ ] All the above [ ] By presenting samples of containers or labels [ ]

Others, specify……………………………………………………………………

9. Do you educate farmers on the use of agrochemicals?

Yes [ ] No [ ]

10. How do you dispose off empty containers and some unsold or spilled agrochemicals?

By throwing them onto refuse dumps [ ] By throwing them into the bush[ ] Give them to farmers [ ] Re-use them for other agrochemicals [ ]

Others, specify……………………………………………………………………

11. Have you been educated on the correct handling of agrochemicals?

Yes [ ] No [ ]

12. If yes, who educated you?

MOFA [ ] Ministry of Health [ ] NGOs [ ] From Colleague Sellers [ ]

Others, specify……………………………………………

13. How often do you receive this education?

Just once [ ] Once every year [ ] Twice in the year [ ] Quarterly [ ] Any time there is a new product [ ] Others, specify………………………

14. Do you have access to any banned chemicals?

Yes [ ] No [ ]

15. If yes, what are some of these chemicals?

………………………………………………………………………………………

16. Are there instances where some chemicals get expired?

Yes [ ] No [ ]

17. If yes, what happens to the expired chemicals?

Sell to farmers at a reduced price [ ] Give to farmers as bonus [ ]

Others, specify……………………………………………………………………

18. At what farming season do farmers buy pesticide more?

Major season [ ] Minor season [ ]

19. Have you encountered any health hazards from handling of or exposure to agrochemicals? Yes [ ] No [ ]

If yes, specify……………………………………………………………………

20. Do you wear any protective clothing when handling agrochemicals?

Yes [ ] No [ ]