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HELMITH CONTAMINATION OF CABBAGE ON TWO WASTEWATER IRRIGATED FARMS IN THE KUMASI METROPOLIS

BY

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DECLARATION

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

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DEDICATION

This work is dedicated to my daughter Akosua OwireduwaahYeboah

ABSTRACT

The use of wastewater in vegetable farming is a common practice in many urban and suburban areas of Ghana. This study assessed helminth contamination of cabbage irrigated with wastewater on two major vegetable farms in the Kumasi Metropolis .cabbage samples were collected from the two farms as well as water samples from the source water and analyzed in the laboratory.

They were *Ascaris lumbricoides,* Hookworm*, H. nana, H.diminuta, S.heamatobium*, *Shistosomamansoni, C.sinensis S.stercolari* and *Trichuris trichiura*. Helminths encountered in the wet season were relatively higher in numbers than those observed in the dry season. The dry season had different species of helminthes as compared to the wet season. It was also observed that most farmers know the implications of the use of wastewater in irrigation on their health and consumer but since there are no regulations on the use of wastewater they tend to ignore it.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

As safe water sources become scarce and more polluted as a result of urbanization, the use of wastewater in urban agriculture may produce many benefits but may also lead to crop and soil contamination with pathogens that may endanger farmers and consumers. The use of wastewater in agriculture is a common practice and is increasing as a result of the rising water scarcity worldwide (Scott *et al*., 2004). The growing water scarcity threatens economic development, sustainable human livelihoods, environmental quality, and a host of other societal goals in countries and regions around the world.

Urban population growth, particularly in developing countries, places immense pressure on water and land resources; it also results in the release of growing volumes of wastewater, most of it untreated. Many West African studies have reported high levels of pathogen contamination in irrigation water; and on both farm and market vegetables (Faruqui *et al.,* 2004; Amoah *et al.,* 2005) which far exceed the ICMSF standards. On farms, vegetables grown with untreated wastewater and poorly composted manures are more prone to microbiological contamination (Beuchat, 2002).

In Ghana, high levels of faecal contamination have been reported in irrigation water and on vegetables grown in cities (Amoah *et al*., 2007a). Wastewater use in agriculture is a low-cost method of its disposal or management. Wastewater contains a lot of nutrients both macro and micro, which increases crop yields without the use of artificial fertilizer but it may contain toxic components such as heavy metals and other chemicals as industries expand into urban areas, and this has led to the change in the composition of wastewater

from being predominantly organic. The consumption of street food by urban poor has been cited as cause for high incidence of diarhoea diseases (King *et al*., 2000; Mensah *et al*., 1999).

In the last two decades, there has been a noticeable increase in the use of wastewater for the irrigation of crops in arid and seasonally arid areas of both industrialized and developing countries such as Ghana (Hussain *et al*., 2001).

In many developing countries, untreated or partially treated wastewater is usually used to irrigate the cities' own food, fodder, and green spaces. Irrigation with untreated wastewater can cause a major threat to public health, food safety, and environmental quality. High contamination levels, especially pathogens, have been recorded in most irrigation water sources as well as on irrigated vegetables (Fattal *et al.*, 2002). Wastewater has been implicated as an important source of health risk for chronic, low-grade gastrointestinal disease as well as outbreaks of more acute diseases including cholera. A primary exposure route for the urban population in general is the consumption of raw vegetables that have been irrigated with wastewater (Fattal *et al.*, 2002).

1.2 **PROBLEM STATEMENT**

Wastewater flown from drains into streams is very common in the Kumasi metropolis, and these are usually used for irrigation, mostly in a diluted form mixed with surface runoff and/or stream water (Cornish *et al.*, 2001). The WHO (1989) standards for irrigation water requires that water used for irrigation of crops must contain < 1 egg per litre of helminth eggs and <1000 faecal coliforms per 100 ml of water. Even though the discharged wastewater does not meet the above standard, they are still used to irrigate mainly vegetable crops in the Metropolis.

In addition, the use of wastewater in agriculture is not restricted in Ghana; therefore, all types of edible crops are irrigated with it, thereby putting both the consumer and the farmer at risk. Also, many of these vegetables irrigated are eaten raw, putting the consumer of street foods at further risk. It is against this background that this study was conducted to investigate the helminth contamination of cabbage grown on two wastewater irrigated farms in the Kumasi metropolis.

1.3 JUSTIFICATION

Quite a large number of the urban populations consume street foods which have raw vegetables such as cabbage as their basic ingredients. Food borne pathogens are killed when they are adequately cooked but vegetables are usually eaten raw, making the recent high patronage of fast foods with vegetables as its basic ingredient and their means of cultivation a subject of interest.

1.4 OBJECTIVES OF THE STUDY

The main objective of the study was to assess the helminth contamination of cabbage grown on two wastewater irrigated farms in the Kumasi metropolis.

The specific objectives were to:

i. dentify the types of helminth eggs in the wastewater samples from Sisa and Wiwi streams.
ii. determine the number of helminth eggs per litre of water from the Sisa and Wiwi streams.
iii. determine the number and types of eggs present in fresh cabbage cultivated on the two wastewater irrigated farms.

iv. iv. determine the number and types of eggs present in blanched cabbage cultivated on the two wastewater irrigated farms.

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CHAPTER TWO

LITERATURE REVIEW

2.1 WASTEWATER REUSE IN URBAN AGRICULTURE IN GHANA

Wastewater is any water that has been adversely affected in quality by anthropogenic influence. It comprises liquid waste discharged by domestic residences, commercial properties, industry, and / or agriculture and can encompass a wide range of potential contaminants and concentrations.

Urban and peri-urban agriculture (UA) is an activity that involves production, processing, and marketing of food and other products on land and water in urban and peri-urban areas. UA involves application of intensive production methods and (re)use of natural resources and urban waste to increase yields of a diversity of crops and livestock (UNDP, 1996). This is an open-space vegetable farming which is carried out in both the rainy and the dry seasons. More than 15 kinds of vegetables are cultivated, all of which are sold. The most perishable (often nontraditional) vegetables, such as lettuce, are usually grown and often harvested during the year (with only supplementary irrigation during the dry season). The use of polluted water for vegetable farming is more widespread in the more populated cities where safe water is scarce and is used for domestic purposes. From a general survey among open-space farmers carried out in 2002, it was found that about 84% of nearly 800 farmers farming in and close to Accra and almost all 700 farmers in Tamale used polluted water for irrigation, at least during the dry seasons (Keraita and Drechsel, 2007a).

Typical urban vegetable farm sizes range from 0.1– 0.2 ha and they increase in size along the urban–rural gradient. As production is market oriented, farming is input and output intensive, particularly in terms of the use of water and such other farm inputs as poultry

manure, pesticides and fertilizers. Most of those engaged in urban agriculture are migrants from rural areas and have experience in farming.

2.2 DIRECT USE OF TREATED WASTEWATER

It is the use of treated wastewater where control exists over the conveyance of the wastewater from the point of discharge from a treatment work to a controlled area where it is used for irrigation.

Many countries in the Middle East make use of wastewater stabilization ponds to remove pathogens from wastewater. The effluent from the ponds is used for irrigation. To describe such a situation the term reclaimed water is often used, meaning water that has received at least secondary treatment and is used after it flows out of a domestic wastewater treatment facility. It must be noted that in many cases wastewater can only be considered partially treated to the design standard because the levels of wastewater production far exceed treatment capacity.

2.3. INDIRECT USE OF WASTEWATER

This is the planned application to land of wastewater from a receiving water body. Municipal and industrial wastewater is discharged without treatment or monitoring into the water courses draining an urban area.

Irrigation water is drawn from rivers or other natural water bodies that receive wastewater flows. There is no control over the use of water for irrigation or domestic consumption downstream of the urban centre. As a consequence, many farmers indirectly use marginal quality water of unknown composition that they draw from many points downstream of the urban centre. In other cases the water is abstracted at one or two well defined sites for use in a formal irrigation system.

2.4 CULTIVATION OF CABBAGE *(Brassica spp.)*

Cabbage is from a group of plants known as the Cole crops. The word "Cole" means stem. Cole crops are from the family *Cruciferae*, a large family which contains many vegetables. It is also called the mustard family. The family name comes from the Latin word for "cross" and was given to members of this family because the flowers are cross 10 shaped. Cabbage is one of the most common "Cole" crops, which thrives well in cool weather (Tiwari *et al*., 2003). It requires 60 to 100 days from sowing to reach market maturity depending on the variety (www.aces.edu). The optimum temperature range for cabbage production is 15 to 20°C; growth stops when temperatures reach above 25°C. The minimum temperature is 0°C (freezing), but cold hardened varieties can tolerate temperatures as low as -10°C. Young plants less than six millimeters in diameter can tolerate both colder and warmer temperatures better than older plants (Bewick,1994).

High temperatures and low moisture can lead to low yields in cabbage. Poor environmental conditions during growth can lead to poor quality of harvest product. These conditions can also lead to long stems in the head and can cause the outer leaves to drop (Bewick, 1994). Higher temperatures can induce "bolting" in cabbage, but varieties differ in their susceptibility to this disorder. Bolting is the process in which the plant switches from vegetative growth (heading) to reproductive growth (formation of flowers and seeds). This switch becomes evident when seed stalks appear, making the heads unmarketable (www.aces.edu).

The nutritional value of 100 g of edible portion contain 1.8 g protein, 0.1 g fat, 4.6 g carbohydrate, 0.8 mg iron, 14.1 mg sodium, besides the enrichment in vitamins A and C (Tiwari *et al.*, 2003).

There is a large variety of cabbage cultivars available to growers. For fresh market, total yield is an important consideration, but quality considerations are foremost in cultivar selection. The size and the shape of the head are very important. Cabbage cultivars are classified by maturity, shape, leaf texture, and colour. Cabbage can be grown on a wide range of soils (mineral, sand and muck soils); but the crop is sensitive to soil acidity. The optimum pH is 6.0 to 6.5, and at pH greater than 7. Cabbage is a heavy user of nitrogen and potassium and requires frequent side dressing. Cabbage is considered a hard crop on the land, and many growers will rotate to other crops that do not have such high fertility requirements.

Irrigation is an essential element of a successful vegetable production operation and is critical to the consistent production of quality produce. Cabbage is a fast-growing, shallow-rooted crop whose roots penetrate only 12 to 15 inches into the soil. Although cabbage is relatively drought tolerant, adequate soil moisture levels should be maintained to maximize yields. The most critical period for irrigation is following direct seeding or transplanting and during head development. Any stress related to lack of water during these periods can lead to small head size (reduced yields), growth cracks, or tip burn. Any of these problems will result in loss in their marketability and value (www.aces.edu). Cabbage is irrigated by sub-surface irrigation (Bewick, 1994), and over head watering can irrigation in urban cities in developing countries (Keraita and Drechsel, 2006). On deeper sands it is a perfect crop for drip irrigation (Bewick, 1994). Regardless of the method used, cabbage requires about one inch of penetration of water in soil per week. The supply of water should be even throughout the growing season to prevent cracking of the heads (Bewick, 1994).

2.5. WATER RE-USE FOR IRRIGATION

Water reuse programs worldwide face a number of technical, economic, and regulatory challenges related to the long-term environmental, agronomic, and health impacts of the recycling of reclaimed water. Also, the economic benefit of water reuse in irrigation is difficult to determine, and must be weighed against environmental costs, making the decisions of wastewater engineers, administrators, and planners even more difficult.

2.5.1 Why Irrigation with Reclaimed Water is growing so fast

Four main reasons are responsible for the fast growth of wastewater irrigation: a. Reclaimed water serves as an extra source of water available for the rural sector for irrigation. This source is especially important in regions with limited water resources, where the increasing water demand by the urban sector (usually due to a combination of population growth and increasing living standards) is replenished by reducing the water supply to the agricultural sector. The supply of treated wastewater is quantitatively reliable for the farmers, since it depends neither on precipitation nor on the water balance of the whole region.

b. Irrigation adds significant polishing treatment to the effluents via break-down of xenobiotic compounds in the soil, evaporation of volatile compounds, pathogens die-off, biological degradation of remaining organic matter, and other processes.

c. Surprisingly, disposal of the treated effluents *via* irrigation may be the cheapest disposal alternative (for both construction and operational costs) when compared with disposal via discharge to rivers or lakes.

d. Disposal of the treated effluents through irrigation may also be the alternative with the minimal impact on the environment.

2.5.2. Irrigation in Kumasi

Kumasi has a semi-humid, tropical climate with a total average annual rainfall of approximately 90% of the annual total fall between March and October. November to march is the main dry season. Small scale irrigation of horticultural crops in the dry season is widespread in many of the villages within a 40 kilometer radius of Kumasi. In other areas, farmers draw water either from a series of pools in the dry season or from shallow hand dug wells. It is postulated that water drawn from the shallow wells is often of better quality than in the river.

2.5.3 Source of Municipal and Industrial Effluents

Between 250–350 m^3 of sewage and night soil are collected daily by vault emptying trucks. Recently they are discharged into poorly maintained waste stabilization ponds which have a very short retention time and results in untreated sewage passing directly into the Subin River. Even with effective waste stabilization ponds, much of the domestic sewage and industrial effluent from Kumasi continues to be discharged directly into streams passing through the city.

A research conducted by Salifu and Mumuni (1998) reported that Kumasi metropolitan area has sewage for less than 4% of its residents. About 40% of the residents depend on public toilet (improved pit latrines, aqua privies and pan latrines),15% depend on septic tanks (most without soak–aways), less than 10% have household improved pit latrines and 35% use the free areas such as bushes, refuse dumps and along river banks.

2.6 SOURCES OF WATERBORNE PATHOGENS

The potential for contamination of the Regional Water Supply by waterborne pathogens poses a direct risk to human health. Elevated levels of pathogens in a water supply increase

the risk of waterborne disease. Humans are the primary source of waterborne pathogens; however, infected domestic animals and wildlife can also be sources of pathogenic organisms. Potential routes of exposure from human or animal faeces to the water supply include run-off from roads, changing water levels in streams and the reservoir shoreline, and direct defecation into the reservoir (Aramini *et al.*, 1997). Roads in the watershed area used by animals and humans have also been shown to be a potential route of contamination (Aramini *et al*., 1997). Pathogenic micro-organisms in surface water supplies can include parasites (e.g., Giardia, Cryptosporidium), viruses (e.g., Hepatitis A, coxsackie viruses), and bacteria (e.g., *E. coli*, Salmonella, Shigella) (Fox, 1999; Schaub and Roberson, 1997). Table 1 gives organism numbers in waste water per litre.

Table 1: Excreted organism concentrations in wastewater (per litre)

Bacteria	**Organism Numbers in wastewater (per litre)**
Campylobacter jejuni	$10–10^4$
Salmonella spp.	$1–10^5$
Shigella spp	$10–10^4$
Vibrio cholerae	$102–10^5$
Helminths	
Ascaris lumbricoides	$1–10^3$
Ancylostoma/Necator	$1 - 10^3$
Trichuris trichiura	$1- 10^2$
Schistosoma mansoni	ND
Protozoa	
Cryptosporidium parvum	$1–10^4$
Entamoeba histolytica	$1–10^2$
Giardia intestinalis	$102–10^5$
Viruses	
Enteric viruses	$105–10^6$
Rotavirus	$102–10^5$

Sources: Feachem *et al*., (1983); Yates & Gerba, (1998).

2.6.1 Pathogens isolated or associated with Vegetables

Spoilage bacteria, yeasts, and moulds dominate the microflora on vegetables, but the occasional presence of pathogenic bacteria, parasites, and viruses capable of causing human infections has also been documented (Beuchat, 1996). All types of produce have potential to harbour pathogens (Brackett, 1999) but *Shigella* spp., *Salmonella* spp.,

enterotoxigenic and enterohaemorrhagic *Escherichia coli*, *Campylobacter* spp., *Listeria monocytogenes, Yersinia enterocolitica*, *Bacillus cereus*, *Clostridium botulinum*, viruses, and parasites such as *Giardia lamblia*, *Cyclospora cayetanensis*, and *Cryptosporidium parvum* are of greatest public concern (Beuchat, 1996). Vegetables can become contaminated with pathogenic microorganisms while growing in fields, orchards, vineyards, or greenhouses, or during harvesting, post-harvest handling, processing, distribution, and preparation in food service or home settings (Beuchat, 2002).

2.6.2 Potential transmission of waterborne diseases

There is a serious concern about the potential transmission of diseases through wastewater irrigation, mainly in those countries without experience on this practice. The concern is based on serious considerations, but the experience gained by those countries where wastewater reuse in irrigation is a common practice allowed the development of a series of criteria to avoid this problem. These criteria include:

- Guidelines on the quality of the effluents and the required treatment system.
- Limitations on the types of crops that can be irrigated with effluents of different qualities.
- Limitations on the technology used for irrigation (flood, sprinklers, drip irrigation, etc.).

Better sewage treatment, storage and disinfection technologies have been developed during the last 10 years.

There are two main "schools" regarding the quality standards or guidelines for wastewater reuse in irrigation – the so called "WHO-World Bank" and the "California" schools -

which have different and somewhat contradictory recommendations. But wastewater irrigation practice continues to increase around the world in spite of these contradictions.

2.6.3. Pathogen die-off before consumption

The interval between final irrigation and consumption reduces pathogens (bacteria, protozoa, and viruses) numbers by approximately 1 log unit per day (Petterson and Ashbolt, 2003). The precise value depends on climatic conditions, with more rapid 30 pathogen die-off (approximately 2 log units per day) in hot, dry weather and less per day in cool or wet weather without much direct sunlight (approximately 0.5 log unit per day).

Helminth eggs can remain viable on crop surfaces for up to two months, although few survive beyond approximately 30 days (Strauss, 1996). The reduction potential die off rates should therefore be taken into account when selecting the combination of wastewater treatment and other health protection measures.

2.7. HELMINTHS

2.7.1. Roundworms (Nematodes)

Adult and larval roundworms are bisexual, cylindrical worms. They inhabit intestinal and extra-intestinal sites. Platyhelminths and nematodes that infect humans have similar anatomic features that reflect common physiologic requirements and functions. The outer covering of helminths is the cuticle or tegument. Prominent external structures of flukes and cestodes are acetabula (suckers) or bothria (false suckers). Male nematodes of several species possess accessory sex organs that are external modifications of the cuticle. Internally, the alimentary, excretory, and reproductive systems can be identified.

Tapeworms are unique in lacking an alimentary canal. This lack means that nutrients must be absorbed through the tegument. The blood flukes and nematodes are bisexual. All other flukes and tapeworm species that infect humans are hermaphroditic.

2.7.2 Tapeworms (Cestodes)

Adult tapeworms are elongated, segmented, hermaphroditic flatworms that inhabit the intestinal lumen. Larval forms, which are cystic or solid, inhabit extra-intestinal tissues. Anatomically, cestodes are divided into a scolex, or head, which bears the organs of attachment, a neck that is the region of segment proliferation, and a chain of proglottids called the strobila. A characteristic feature of adult tapeworm is the absence of an alimentary canal, which is intriguing since all of these adult worms inhabit the small intestine. The strobila elongates as new proglottids form in the neck region. The segments nearest the neck are immature (sex organs not fully developed) and those more posterior is mature.

2.8. RELATIVE HEALTH RISK FROM WASTEWATER USE

The discussion in the previous sections show that a broad spectrum of pathogenic microorganisms including bacteria, viruses, helminths and protozoa is present in wastewater and they survive for days, weeks and at times months in the soil and on crops that come in contact with wastewater. Early approaches to measuring the health risk from these pathogenic micro-organisms centred on detection. Based upon the fact that these micro-organisms could survive, detection in any of these environments was sufficient to indicate that a public health problem existed. It was then assumed that such detection showed evidence that a real potential for disease transmission existed (Shuval *et al.*, 1997). Throughout the years a number of standards and guidelines have been developed on this

zero-risk approach. This led to standards for wastewater use that approached those of drinking water especially where vegetable crops were being grown (Table 2).

Table 2: Survival times of selected excreted pathogens in soil and on crop surfaces at 20-30°C

Pathogen	Survival time	
	In soil	**On crops**
Viruses		
Enteroviruses[a]	<100 but usually <20 days	<60 but usually <15 days
Bacteria		
Faecal coliform	<70 but usually <20 days	<30 but usually <15 days
Salmonella spp.	<70 but usually <20 days	<30 but usually <15 days
Vibrio cholera	<20 but usually <10 days	<5 but usually <2 days
Protozoa		
Entamoeba histolytica cysts	<20 but usually <10 days	<10 but usually < 2 days
Helminths		
Ascaris lumbricoides eggs	Many months	<60 but usually <30 days
Hookworm larvae	<90 but usually <30 days	<30 but usually <10 days
Taenia saginata eggs	Many months	<60 but usually <30 days
Trichuris trichiura eggs	Many months	<60 but usually <30 days

[a] Includes polio-, echo-, and coxsackieviruses.

Whether a person becomes infected actually depends on a number of additional factors, each of which adds to or diminishes the actual risk of infection. Feachem *et al*. (1983), and Shuval *et al*. (1986), reviewed these factors and found several that are important for determining the relative health risk during wastewater use. These include the excreted load, latency, persistence, multiplication, infective dose, host responds and non-human host (Table 3). Shuval *et al*. (1986) developed a theoretical epidemiological model based on the above factors. The model looked at their relationship to the probability that one of the four enteric pathogen groups described earlier would cause infections in humans through wastewater irrigation. The factors considered were necessary to cause a high probability of infection and were found to be long persistence in the environment; low minimal infective dose; short or no human immunity; minimal concurrent transmission through other routes such as food, water and poor personal or domestic hygiene; and long latent period and/or soil development stage required.

The Shuval model shows that helminth diseases, if they are endemic, will be very effectively transmitted by irrigation with raw wastewater.

Table 3: Effectiveness of enteric pathogens to cause infections through wastewater irrigation related to their epidemiological characteristics

Enteric pathogens	Persistence in environment	Minimum infective dose	Immunity	Concurrent routes of infection	Latency/soil development stage
Viruses	Medium	Low	Long	Mainly home contact and food or water	No
Bacteria	Short/Medium	Medium/High	Short/Medium	Mainly home contact and food or water	No
Protozoa	Short	Low/Medium	None/Little	Mainly home contact and food or water	No
Helminths	Long	Low	None/Little	Mainly soil contact outside home and food	Yes

Source: Shuval *et al*. (1986).

2.9. PATHOGENS THAT REACH THE FIELD OR CROP

All the pathogens discussed in the previous section have the potential to reach the field. From the time of excretion, the potential for all pathogens to cause infection usually declines due to their death or loss of infectivity. The ability of an excreted organism to survive outside the human body is referred to as its persistence. For all the organisms, survival is highly dependent on temperature with greatly increased persistence at lower temperatures. The first exposure of excreted pathogenic organisms outside the body is usually in water. This blend with freshwater is often referred to as sewage. This sewage is then subjected to treatment prior to discharge, used directly for crop production or discharged to a watercourse where indirect use then occurs downstream.

There are many studies on the survival or persistence of excreted organisms in water and sewage. A summary is shown in Table 4. Many bacterial populations decline exponentially so that 90 to 99 percent of the bacteria are lost relatively quickly. Survival of bacteria, like

many other organisms, depends greatly on how hostile the environment is including other micro-organisms in the water that might provide competition or predation. Bacteria often survive longer in clean water than in dirty water but survival in excess of 50 days is most unlikely and at 20-30°C, 20-30 days is a more common maximum survival time. Viral survival may be longer than bacterial survival and is greatly increased at lower temperatures. In the 20-30°C range, two months seems a typical survival time, whereas at around 10°C, nine months is a more realistic figure. There is evidence that virus survival is enhanced in polluted waters, presumably as a result of some protective effect that the viruses may receive when they are adsorbed onto suspended solid particles in dirty water.

2.9.1 Survival times of excreted pathogens in freshwater and sewage at 20-30°C

Protozoal cysts are poor survivors in any environment. A likely maximum in sewage or polluted water would not exceed that shown in Table 4 for *Entamoeba histolytica*. Helminth eggs vary from the very fragile to the very persistent. One of the most persistent is the *Ascaris* egg which may survive for a year or more. The major concern for this helminth is that the soil is its intermediate host prior to reinfecting humans. The survival times shown in Table 4 may be altered by the type or degree of wastewater treatment given the sewage water prior to use or discharge to a water body. Different treatment processes remove pathogens to varying degrees. What is not well understood in wastewater treatment systems is whether the treatment process produced an elevated level of hostile environment that accelerated the death of the organism or whether the treatment process had little effect on excreted pathogens and simply allowed the necessary time for natural die-off to occur independent of the treatment process. The critical factor to consider for wastewater use is that most wastewater treatment plants were designed to reduce organic pollution of rivers and lakes and rarely are designed to remove all risks from pathogenic

organisms. Therefore, regardless of the level of treatment provided, some pathogenic organisms will reach the agricultural fields when the water is used.

In instances where the sewage water has not received treatment, the level of pathogenic organisms is likely to be higher whether the use is occurring directly from raw sewage or from raw sewage that has been blended with other water supplies. In both instances, pathogenic organisms will reach the agricultural fields. These pathogenic organisms, as with treated sewage, have the potential to contaminate both the soil and the crop depending upon how the irrigation water is used. The critical element is to understand that whether treated, partially treated or untreated water is used, pathogenic organisms are present and the used site must be managed in a manner that minimizes or eliminates the potential for disease transmission.

Table 4: Survival times of excreted pathogens in freshwater and sewage at 20-30°C

Pathogen	**Survival time (days)**
Viruses[a]	
Enteroviruses[b]	<120 but usually <50
Bacteria	
Faecal coliform[a]	<60 but usually <30
Salmonella spp.[a]	<60 but usually <30
Shigella spp.[a]	<30 but usually <10
Vibrio cholera[c]	<30 but usually <10
Protozoa	
Entamoeba histolytica cysts	<30 but usually <15
Helminths	
Ascaris lumbriocoides eggs	Many months

a. In seawater, viral survival is less, and bacterial survival is very much less than in freshwater.

b. Includes polio-, echo-, and coxsackieviruses.

c. *V. cholera* survival in aqueous environments is still uncertain.

Source: Feachem *et al*. (1983).

2.9.2 Pathogen survival under agricultural field conditions

The literature on survival times of excreted pathogens in soil and on crop surfaces has been reviewed by Feachem *et al*. (1983) and Strauss (1985). As expected there was wide variability in reported survival times which reflects the influence of environmental and analytical factors. Table 6 describes several factors affecting survival time of bacteria in soil. Many of these factors may also affect survival of other pathogenic organisms. Knowledge of the survival of pathogens in soil and on the crop allows an initial assessment of the risk of transmitting disease via produced foodstuff or through worker exposure.

Pathogens survive on crop surfaces for a shorter time than in the soil as they are less well protected from the harsh effects of sunlight and desiccation. Nevertheless, survival times can be long enough in some cases to pose potential risks to crop handlers and consumers, especially when survival times are longer than crop growing cycles as is often the case with vegetables. While the length of the crop growing cycle is important, equally important is the length of time since the last irrigation cycle (potential exposure cycle). WHO (1989), points out that excreted pathogens, if they do enter an irrigated area with the irrigation water, have the potential to remain infectious for a considerable period of time thus steps must be taken to interrupt this infection cycle.

Table 5: Factors affecting survival times of enteric bacteria in soil

Soil factor	Effect on bacterial survival
Antagonism from soil microflora	Increased survival time in sterile soil
Moisture content	Greater survival time in moist soils and during times of high rainfall
Moisture-holding capacity	Survival time is less in sandy soils than in soils with greater water-holding capacity
Organic matter	Increased survival and possible re growth when sufficient amounts of organic matter are present
pH	Shorter survival time in acid soils (pH 3-5) than in alkaline soils
Sunlight	Shorter survival time at soil surface
Temperature	Longer survival at low temperatures; longer survival in winter than in summer

Source: Shuval *et al*. (1986)

CHAPTER THREE

MATERIAL AND METHODS

3.1 STUDY AREA

The study was conducted at Ahinsan and Wiwiso in the Kumasi metropolis of Ghana's Ashanti region (Figure 1). It is located in the Rain Forest Region about 250 kilometres (by road) northwest of Accra. Kumasi is approximately 480 km north of the equator and 160 km north of the Gulf of Guinea. It is popularly known as "The Garden City" or "heart beat" of Ghana because of its many beautiful species of flowers and plants. Kumasi is the capital town of Ashanti Region and the second largest city in Ghana with a population of one million and an annual growth rate of about 6 % (Ghana Statistical Services, 2002).

It features a tropical wet and dry climate, with relatively constant temperatures throughout the course of the year. Kumasi is noticeably wetter than nearby Accra, averaging around 1400 mm of rain per year.

The city almost features two different rainy seasons, a longer rainy season from March through July and a shorter rainy season from September to November. In actuality, the month of February through to November is one long wet season, with a relative lull in precipitation in August. Similar to the rest of West Africa, Kumasi experiences the harmattan during the "low sun" months. The city's vantage location coupled with the availability of social amenities such as good road network, electricity, schools, hospitals, water, large market centres etc have made it the hub of trade in the Ashanti Region.

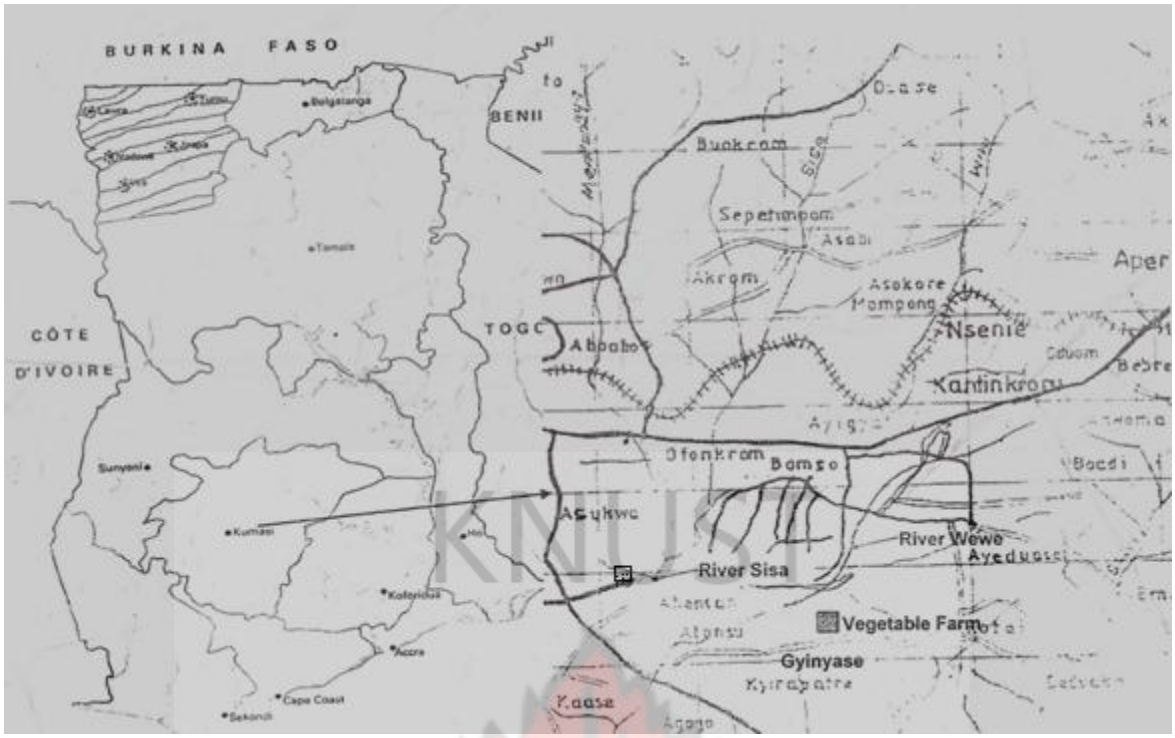

Figure 1 Map of Ghana showing the study areas

3.2 SAMPLING SITES

The study was conducted around Kwame Nkrumah University of Science and Technology (KNUST) at Wiwiso and Ahensan in the Kumasi metropolitan area. Four sites were chosen, two along each of the Sisan and Wiwi streams.

Wiwi site was located along Okodee road on the KNUST campus whereas shallow well 1 was located about 100 metres from the Wiwiso Metropolitan Assembly School. Sisa site at Ahinsan was a source of water for irrigating vegetables such as cabbage, spring onions, carrots and lettuce. Shallow well 2 was also at Ahinsan about 200 metres from Sisa site 1. The Wiwi stream takes its source from Abirem and Sisa from Duase all in Kumasi.

3.3 COLLECTION OF SAMPLES

Collection of samples was done twice a week in the mornings. Triplicate water samples were collected from each site into a separate well cleaned plastic container (1 Litre). Each sample was stirred to obtain a homogeneous mixture before samples were taken.

The samples were transported unpreserved to the laboratory within 1 hour. The sample collection was done over a period of 4 months, from late December 2011 to early February 2012 for the dry season, and from March 2012 to April 2012 for the wet season. In each season eight samples were collected and the helminths in each of the samples were counted per litre.

Cabbage samples were taken randomly after harvest from two farms twice in a week for five weeks after harvest. Five cabbage samples were blanched wand the rest were in their raw state.

3.4 WATER SAMPLE PREPARATION

The sedimentation procedure outlined by Bouhoum and Schwartzbrod (1989) was used. The sample was allowed to sediment for 1-2 hours. An open-topped, straight-sided container was used for sedimentation, since it makes removal of the supernatant easier and permits thorough rinsing of the container. Ninety percent of the supernatant for each of the samples was removed using a suction pump. The sediment was carefully transferred into one or more centrifuge tubes, and centrifuge at 1000 g for 15 min and the supernatant was removed. More than one centrifuge tube was used; therefore all the sediments were transferred into one tube, and recentrifuged at 1000 g for 15 minutes. The pellet was suspended in an equal volume of acetoacetic buffer, pH 4.5. Two volumes of ethyl acetate were added, and the solution was mixed thoroughly by shaking. The sample was centrifuged at 1000 g for 15 min. The sample was separated into three distinct phases. All the non-fatty, heavier debris, including helminthes eggs, larvae and protozoa, were at the bottom layer. Above this was the buffer, which was clear. The fatty and other material formed a thick dark plug with the ethyl acetate at the top of the sample. The volume of the pellet containing the eggs was recorded, and then poured off. 1 ml was suspended in 5 volumes of zinc sulfate solution. The pellet was re-suspended in five volumes of zinc

sulfate solution. The volume of the final product (X ml) was recorded. The sample was mixed thoroughly by hand. An aliquot with a Pasteur pipette was quickly removed and transferred to a McMaster slide for final examination. The full McMaster slide was left to stand on a flat surface for 5 minutes before examination to allow all the eggs to float to the surface. The McMaster slide was placed on the microscope stage and examined under 10× or 40× magnifications. And all eggs seen within the grid in both chambers of the McMaster slide was counted. The number of eggs per litre was calculated from the following equation:

$$N = AX \div PV$$

where:

N = number of eggs per litre of sample

A = number of eggs counted in the McMaster slide or the mean of counts from two or three slides

X = volume of the final product (ml)

P = volume of the McMaster slide (0.3 ml)

V = original sample volume (1liter)

It was assumed that eggs are uniformly distributed in the final processing stage. A multiplication step was therefore used to convert the number of eggs found to eggs per litre.

3.5 CABBAGE SAMPLE PREPARATION

For the cabbage samples, five raw cabbage heads were taken and their leaves were removed layer by layer. The layers were sampled by 10% weight and washed under running tap for 2 min and I litre of the water used to wash it was collected and sedimented. Five (5) other samples also had their layers removed. The layers were sampled by 10%

weight, weighed and blanched for two minutes at 80^{o}C and one litre was measured from the water used in cooking the cabbage layers and sedimented. The sedimentation procedure outlined by Schwartzbrod (1989) was used.

3.6 IDENTIFICATION AND COUNTING OF EGGS

The identification and counting of eggs was done under the light microscope at both ×100 and ×400 magnification. Specific eggs were easily identified on the basis of their morphological shapes and sizes. Comparison were made with the described egg characteristics according to WHO (1994).

3.7 QUESTIONNAIRE

Fifty vegetable farmers were sampled randomly and interviewed in order to gain information on their educational levels, health complaints, time of hand washing, the use of protective clothing, knowledge of risks associated with wastewater use and the method of watering their vegetables.

3.8 STATISTICAL ANALYSIS

The data collected on the amount of eggs counted for the sampling period for both streams, and the shallow wells were subjected to a two-way analysis of variance (ANOVA). Differences were tested on seasons (dry and wet), type of stream (Wiwi and Sisan), the kind of Helminth eggs, and more importantly, the weeks within which the data was collected, to determine whether there was a significant difference between them.

CHAPTER FOUR

RESULTS

4.1 TYPES OF HELMINTHS ENCOUNTERED

Generally, nine parasites were encountered in the Wiwi and Sisan streams, the two shallow wells (1 and 2) and cabbage samples. They were: *Ascaris lumbricoides, Trichira trichuira,* Hookworm, *Hymenolepis nana, Hymenolepi diminuta, S. sterioralis, S. heamatobium, S. mansoni* and *C. sinensis.*

4.2 Mean number of Helminths in the Wiwi Stream

The Table 6 below shows the specific types of helminthes encountered in the Wiwi stream in the dry season. The table also shows the mean number of eggs, the range and the standard deviation of the means. From the table, *C. sinensis* had the highest mean of 3.5 helminth per week, followed by Hookworm (2.25), *A. lumbricoides* (1.63), *S. mansoni* (1.13) and *S. haematobium* (1), *Trichuris trichiura* (0.75), *Hymenolepis diminuta* (0.38), and *S. stercoralis* and *H. nana* with means of 0.25.

Table 6: Types and number of helminths enumerated in the Wiwi stream during the dry season

Types of Parasites encountered	**Number of helminths per week**								Mean no. of helminths	S.D
	Wk 1	Wk2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8		
Ascaris lumbricoides	2	1	2	2	2	2	2	2	1.63	0.33
Trichuris trichiura	1	1	0	1	1	1	1	1	0.75	0.33
Hookworm	2	1	2	3	3	3	3	3	2.25	0.71
S. stercoralis	2	1	1	2	1	1	1	1	0.25	0.43
Hymenolepis diminuta	4	4	3	4	4	2	4	5	0.38	0.83
Hymenolepis nana	2	1	1	1	1	1	1	2	0.25	0.43
S.haematobium	1	1	1	1	1	1	1	1	0	0.0
S .mansoni	1	1	1	1	1	1	2	1	1.13	0.33
C. sinensis	3	4	3	3	4	3	3	5	3.50	0.71
Total									10.14	

In the wet season, Hookworm (with 2.5 eggs/litre) were the highest helminths enumerated in the Wiwi stream, followed by *Ascaris lumbricoides* (2.25). No helminths were recorded for *S. haematobium, S .mansoni* and *C. sinensis* (Table 7).

Table 7: Types and number of helminths enumerated in the Wiwi stream during the wet season

Types of helminths encountered	Number of helminths per week								Mean no. of helminths	S.D
	Wk 1	Wk2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8		
Ascaris lumbricoides	2	1	2	3	3	3	2	2	2.25	0.66
Trichuris trichiura	1	1	0	1	1	1	1	1	0.88	0.33
Hookworm	2	3	0	3	3	3	3	2	2.5	0.51
S. stercoralis	2	1	2	2	1	1	0	1	1.25	0.66
Hymenolepis diminuta	0	0	1	0	0	1	2	1	1.38	0.48
Hymenolepis nana	1	1	1	2	0	1	1	2	1.13	0.60
S.haematobium	0	0	0	0	0	0	0	0	0	0
S .mansoni	0	0	0	0	0	0	0	0	0	0
C. sinensis	0	0	0	0	0	0	0	0	0	0
Total									9.39	

4.2.1 Mean number of Helminth in the Sisan Stream

Table 8 indicates that *Hymenolepis diminuta* had the highest mean number of helminths (2.875), followed by *Ascaris lumbricoides* (2.75), *Trichuris trichiura* (1.5), *S. haematobium* and *S. mansoni* both with mean number of helminths of 1.25, *Hymenolepis nana* (1.125), *S. stercoralis* (1) and Hookworm (0.5). Helminths of *C. sinensis* were not recorded in Sisan stream in the dry season.

Table 8: Types and number of helminths enumerated in the Sisan stream in the dry season

Types of helminths encountered	Number of helminths per week								Mean no. of helminths	S.D
	Wk 1	Wk2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8		
Ascaris lumbricoides	3	1	3	3	3	4	3	2	2.75	0.83
Trichuris trichiura	1	2	2	2	1	2	1	1	1.5	0.5
Hookworm	1	0	0	1	0	1	0	1	0.5	0.5
S. stercoralis	1	1	1	1	1	1	1	1	0.13	0
Hymenolepis diminuta	3	4	4	3	3	3	1	2	2.38	0.93
Hymenolepis nana	1	1	1	2	1	1	1	1	0.25	0.33
S.haematobium	2	1	1	1	2	1	1	1	1.25	0.43
S .mansoni	1	1	1	2	1	1	2	1	0.63	0.43
C. sinensis	0	0	0	0	0	0	0	0	0	0
Total									9.39	

Table 9: Types and number of helminths enumerated in the Sisan stream in the wet season

Types of helminths encountered	Number of helminths per week								Mean no. of helminths	S.D
	Wk 1	Wk2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8		
Ascaris lumbricoides	4	5	3	3	3	2	1	3	3	1.118
Trichuris trichiura	3	2	2	2	1	2	1	2	1.875	0.600
Hookworm	0	1	0	0	0	0	0	1	0.25	0.43
S. stercoralis	0	0	0	0	0	0	1	1	0.13	0.33
Hymenolepis diminuta	3	3	3	1	2	2	3	1	2.38	0.86
Hymenolepis nana	1	0	0	0	0	0	1	0	1.25	0.43
S.haematobium	2	1	1	1	2	1	1	1	1.25	0.43
S .mansoni	0	0	0	1	1	1	1	1	1.25	0.48
C. sinensis	0	0	0	0	0	0	0	0	0	0
Total										

Table 9 above shows the mean number of parasites recorded for each type of helminth in the Sisan stream for the wet season. Helminths of *Ascaris lumbricoides* were the highest with 3 helminths per litre, followed by *Hymenolepis diminuta* (2.88), *Trichuris trichiura* (1.88*), S. haematobium* (1.25), *S. stercoralis* (1), *S .mansoni* (0.63), Hookworm and *Hymenolepis nana* (0.25*). C. sinensis* were not detected.

4.2.2 Mean number of Helminth in Shallow Well 1

The types and number of parassites enumerated in the Shallow Well 1 in the dry season are presented in Table 10 while Table 11 shows those for the wet season. In the dry season, this well was dominated by *Ascaris lumbricoides* with mean of 2.27, followed by *Hymenolepis nana* (1.38), *Trichuris trichiura* (1.25), and *S. haematobium, S. mansoni*, Hookworm and *S. stercoralis,* with mean of 1.13. *Hymenolepis diminuta and C. sinensis* were not detected in the samples (Table 10).

Table 10: Types and number of helminths enumerated in shallow well 1in the dry season

Types of helminths encountered	**Number of helminths per week**								**Mean no. of helminths**	**S.D**
	Wk 1	Wk2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8		
Ascaris lumbricoides	3	4	3	2	3	2	2	2	2.27	0.70
Trichuris trichiura	2	2	1	1	1	1	1	1	1.25	043
Hookworm	1	1	1	1	1	2	1	1	1.13	0.33
s. stercoralis	1	1	1	1	1	1	1	2	1.13	0.33
Hymenolepis diminuta	0	0	0	0	0	0	0	0	0	0
Hymenolepis nana	1	2	1	2	1	2	1	1	1.38	0.48
S.haematobium	1	1	1	1	1	1	2	1	1.13	0.33
S .mansoni	2	1	1	1	1	1	1	1	1.13	0.33
C. sinensis	0	0	0	0	0	0	0	0	0	0
Total									9.42	

Similarly, *Ascaris lumbricoides* were the highest enumerated in Shallow Well 1 in the wet season with a mean of 5.13. This was followed by Hookworm (2.88), *Trichuris trichiura* (2.63), *C .sinensis* (1.38), *S. haematobium* (0.75), *S. mansoni and Hymenolepis diminuta* (0.13). *Hymenolepis nana and S. stercoralis* were not detected during this period (Table 11).

Table 11: Types and number of helminth enumerated in shallow well 1in the wet season

Types of helminths encountered	Number of helminths per week								Mean no. of helminths	S.D
	Wk 1	Wk2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8		
Ascaris lumbricoides	4	6	6	5	5	4	5	6	5.13	0.78
Trichuris trichiura	2	3	4	3	3	2	2	2	2.63	0.70
Hookworm	3	4	3	3	2	3	3	2	2.88	0.60
S. stercoralis	0	0	0	0	0	0	0	0	0	0
Hymenolepis diminuta	0	0	0	0	1	0	0	0	0.13	0.33
Hymenolepis nana	0	0	0	0	0	0	0	0	0	0
S.haematobium	0	1	0	0	1	1	1	2	0.75	0.66
S .mansoni	0	0	0	0	0	0	1	0	0.13	0.33
C. sinensis	1	2	1	1	1	2	1	2	1.38	0.48
Total									13	

4.2.3 Mean number of Helminth in Shallow Well 2

According to Table 12, *Ascaris lumbricoides* were the highest enumerated with mean of 2.25, *C. sinensis and Hymenolepis diminuta* were not recorded in the samples from this well.

Table 12: Types and number of helminths enumerated in shallow well 2 in the dry season

Types of Parasites encountered	Number of helminths per week								Mean no. of helminths	S.D
	Wk 1	Wk2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8		
Ascaris lumbricoides	2	2	2	2	3	2	3	2	2.25	0.43
Trichuris trichiura	1	1	1	1	2	1	3	2	1.5	0.71
Hookworm	1	1	1	1	1	1	1	1	1	0
S. stercoralis	1	1	1	1	1	1	2	1	1.13	0.34
Hymenolepis diminuta	0	0	0	0	0	0	0	0	0	0
Hymenolepis nana	2	1	1	1	1	1	1	1	1.13	0.33
S.haematobium	1	1	1	1	2	1	1	2	1.25	0.43
S .mansoni	1	1	1	1	1	1	2	1	1.13	0.33
C. sinensis	0	0	0	0	0	0	0	0	0	0
Total									8.39	

Table 13: Types and number of helminth enumerated in Shallow Well 2 in the wet season

Types of Parasites encountered	Number of helminths per week								Mean no. of helminths	S.D
	Wk 1	Wk2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8		
Ascaris lumbricoides	4	3	4	4	5	4	5	4	4.13	0.60
Trichuris trichiura	4	3	3	3	3	3	3	3	3.13	0.33
Hookworm	2	2	3	2	2	2	3	3	2.38	0.48
S. stercoralis	0	0	0	0	0	0	0	0	0	0
Hymenolepis diminuta	1	0	0	0	0	0	0	0	0.13	0.33
Hymenolepis nana	0	0	0	0	0	0	0	0	0	0
S.haematobium	1	0	1	0	0	0	1	2	0.63	0.70
S .mansoni	0	0	0	0	0	0	0	0	0	0
C. sinensis	0	0	0	0	0	2	0	0	0.25	0.66
Total									10.65	

Ascaris lumbricoides (4.13) again, were the highest number of helminthes recorded in the water samples from this well in the wet season. This was followed by *Trichuris trichiura* (3.13), Hookworm (2.38), *S. haematobium* (0.63), *C. sinensis* (0.25) *and Hymenolepis diminuta* (0.13). No helminths were recorded for *S. stercoralis* and *Hymenolepis nana* (Table 13).

4.3 PARASITE LOADS IN THE WET AND DRY SEASONS

Figure 2 shows that samples from the Wiwi stream recorded higher numbers of Hookworm, *H. diminuta, H. nana, S. haematobium, S .mansoni* and *C. sinensis* in the dry season than in the wet season. However, *Ascaris lumbricoides* numbers in this stream were higher in the wet season.

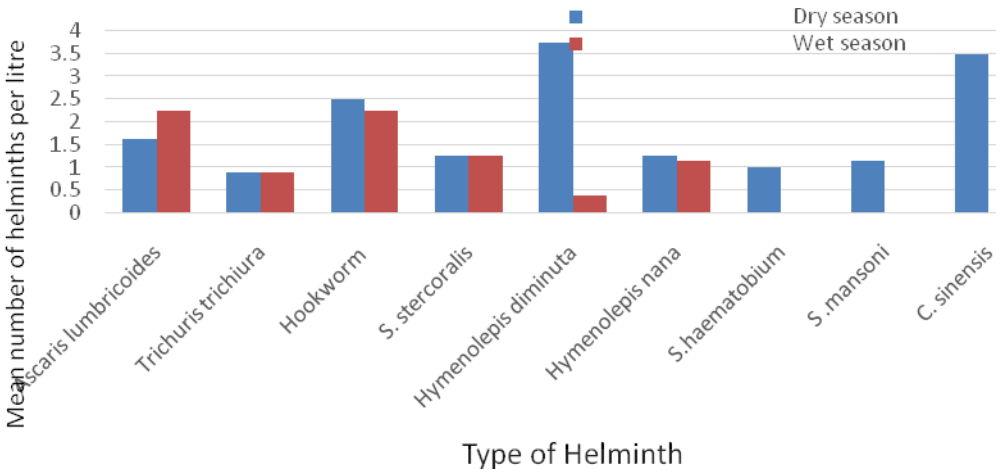

Figure 2 Comparison of mean number of Helminth encountered in the Wiwi stream in the wet and dry season

Similarly, higher numbers were recorded in the dry season for samples from the Sisan stream. Hookworm and *S. stercoralis* were the only exception (Figure 3).

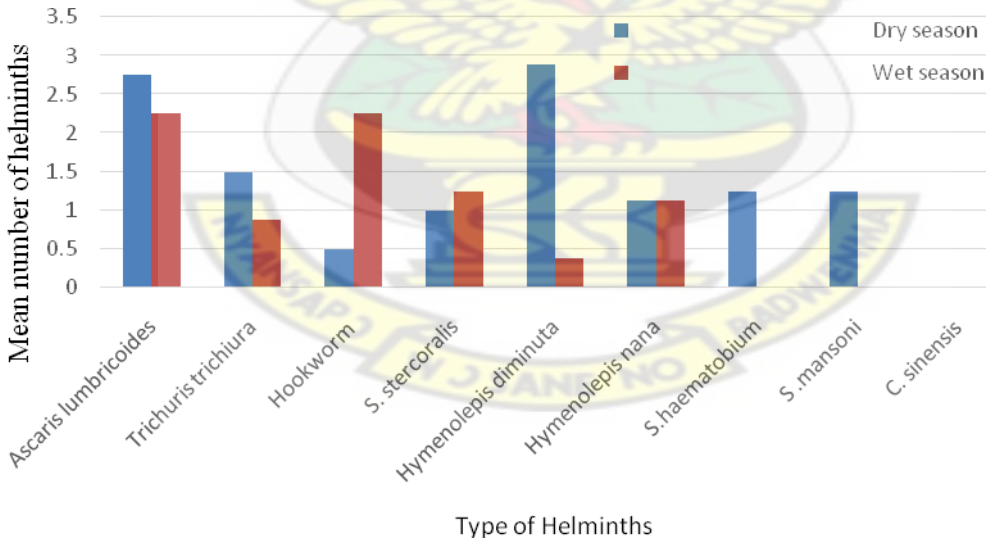

Figure 3 Comparison of mean number of Helminths encountered in the Sisan stream in the wet and dry seasons.

In the Shallow Well 1, *Ascaris lumbricoides*, *Trichuris trichiura*, Hookworm, *H. diminuta* and *C. sinensis* were higher in the wet season. *H. nana, S. haematobium, S .mansoni* and *S. stercoralis*, on the other hand were higher in the dry season (Figure 4).

Shallow Well 2 showed results similar to Shallow Well 1. *Ascaris lumbricoides, Trichuris trichiura,* Hookworm, *H. diminuta* and *C. sinensis* were higher in the wet season whereas *H. nana, S. haematobium, S .mansoni* and *S. stercoralis* were higher in the dry season (figure 5).

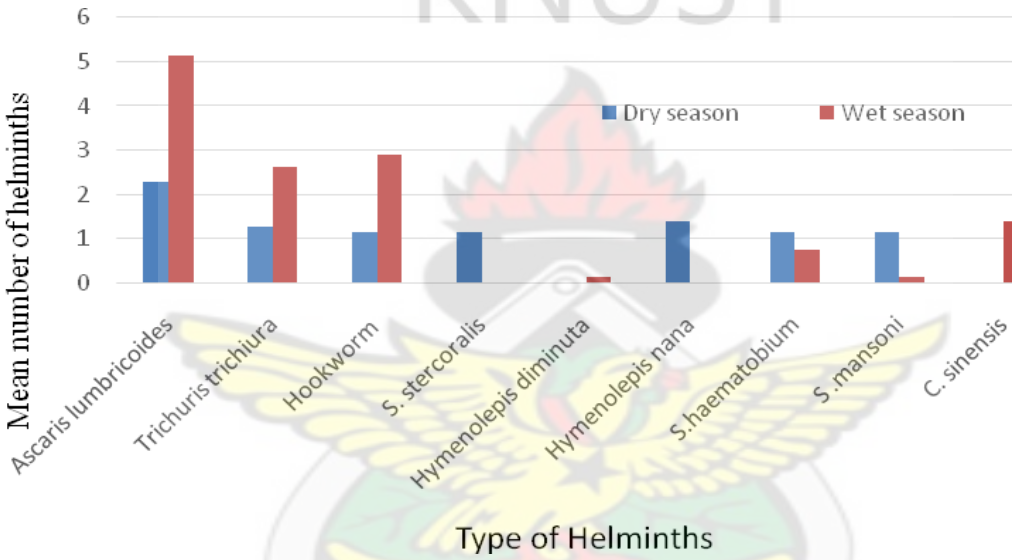

Figure 4 Comparison of mean number of Helminths encountered in the Shallow Well 1 in the wet and dry seasons.

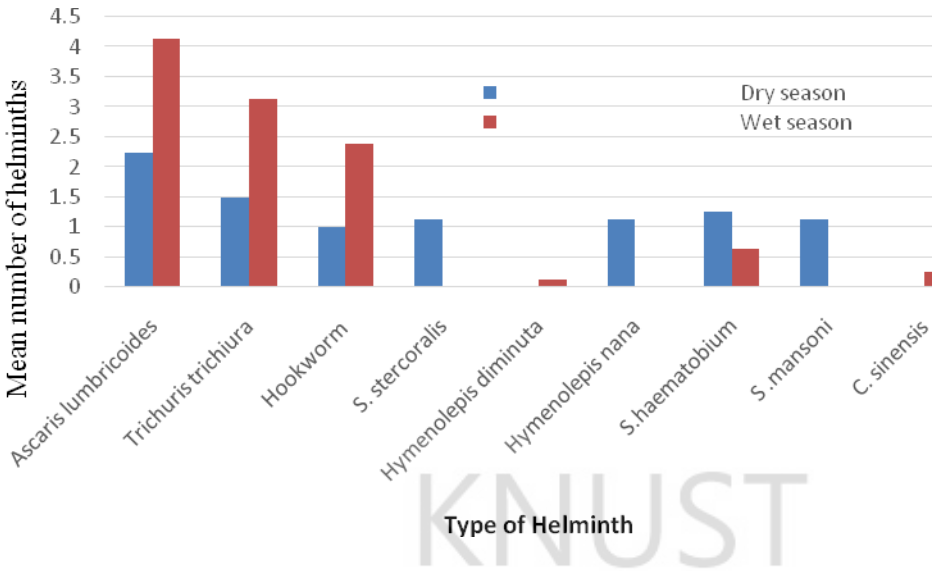

Figure 5 Comparison of mean number of Helminths encountered in the Shallow Well 2 in the wet and dry seasons.

4.4. HELMINTHS IN BLANCHED AND RAW CABBAGE

Figure 6 shows the varying difference between the mean number of helminths per liter observed in raw cabbage (mean = 2.863) and in blanched cabbage (mean = 0.550) cultivated on the two farms from which the samples were taken. *H .diminuta* was comparatively higher both in blanched and raw cabbage cultivated on the farm irrigated with Sisan stream with means of 4.250 and 1.750, respectively. *H. diminuta* was totally absent in blanched and raw cabbage watered with Wiwi stream. *T. tricuira* was also highly recorded in raw cabbage cultivated with wiwi and sisan with means of 4.50 and 3.75, respectively.

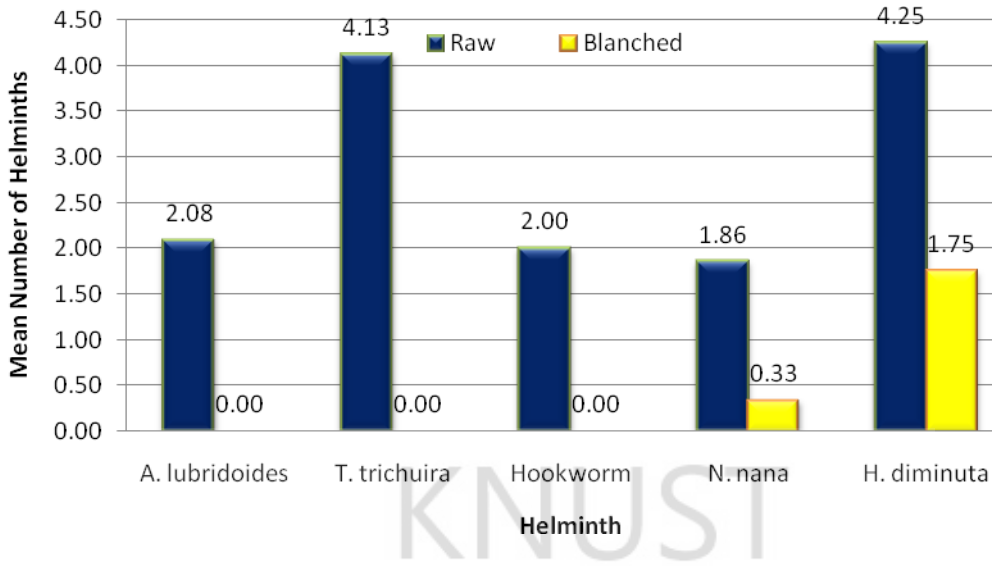

Figure 6: Mean number of helminth eggs in blanched and raw cabbage

Table 15: Means and standard deviations of helminths encountered in the raw and blanched cabbage samples

Helminths	Raw cabbage		Blanched cabbage	
	Mean number of helminths counted	S.D	Mean number of helminths counted	S.D
A. lumbricoides	2.6000	.89443	.8000	0.83666
T. trichiura	1.6000	.89443	.8000	0.83666
Hookworm	1.8000	.83666	1.2000	1.30384
s. stercoralis	0.4000	.54772	.2000	0.44721
H. diminuta	0.4000	.54772	.0000	0.00000
H. nana	1.6000	.89443	.4000	0.54772
S. haematobium	1.4000	.54772	.4000	0.54772
S. mansoni	0.8000	.83666	.0000	0.00000
C. sinensis	0.2000	.44721	.0000	0.00000
Total	1.2000	1.01354	.4222	0.72265

Total number of samples: raw 45.

Blanched 45

From the Table 15 above, the mean number of helminth in the raw cabbage samples are *A.lumbricoides* (2.6000) being the highest followed by Hookworm (1.8000), *T trichiura*

and *H. nana* (1.6000), *S.haematobium* (1.4000), S.mansoni (0.8000), *S.stercoralis* and, *H.diminuta* (0.4000), C.sinensis (0.2000)and a total mean of 1.2000.

The blanched cabbage samples recorded the following helminths; *A.lumbricoides* and *T. trichiura* (0.8000),Hookworm (1.2000), *H. nana* and *S.haematobium* (0.4000) *C.sinensis* and *S.mansoni* (0.0000) and a total mean number of helminths of 0.4222.

4.5 RESULTS OF THE QUESTIONNAIRE

4.5.1 Educational level of farmers

Fifty vegetable farmers were randomly selected and interviewed on farms along the Wiwi and Sisan streams. Of the fifty farmers interviewed, 48% were found to be illiterates, 30% had middle school leaving certificate (MSLC), 12% and10% had Senior High School and Junior High School certificates (Figure 7).

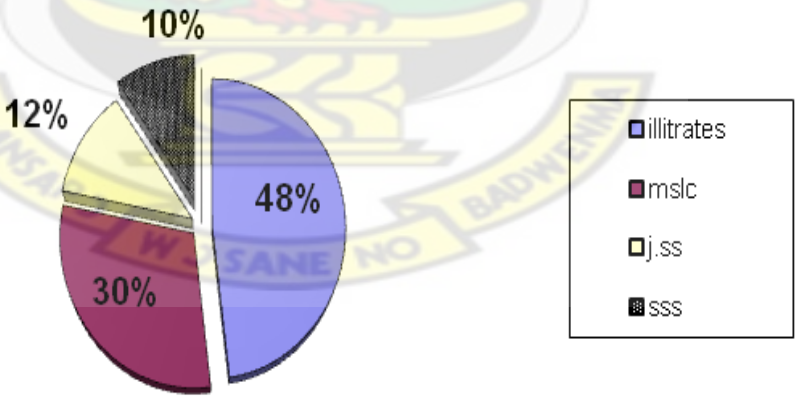

Figure 7: Educational level of vegetable farmers

4.5.2 Common sicknesses among vegetable farmers

Out of the fifty farmers sampled, diarrhea and body itching complaints were 40% each and that of stomach ache was 20% (Figure 8).

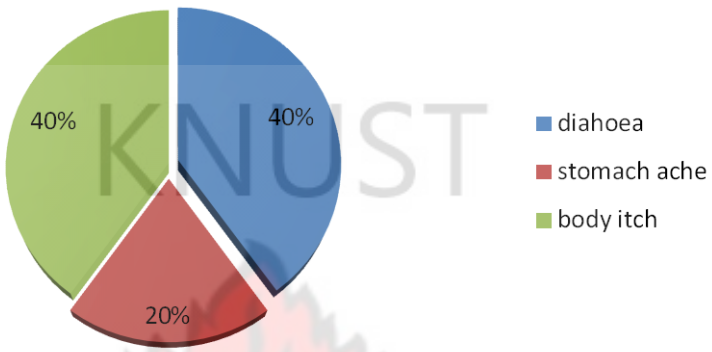

Figure 8: Common sicknesses among the vegetable farmers

4.5.3 Time of hand washing by farmers

According to Figure 5, 50% of the farmers sampled washed their hands at the end of the day before they go home; 40% washed their hands soon after watering their farms and 10% washed their hands at home after the day's work.

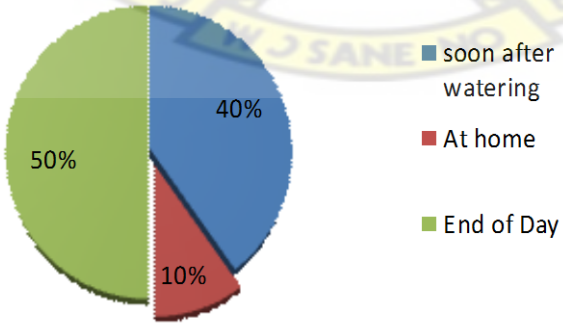

Figure 9 Time of hand washing by farmers

4.5.4 The use of protective clothing by farmers

All the farmers had Wellington boots but 42% of them wore them when working on the farm, 42% wore neither hand gloves nor wellington boots,16% only wore hand gloves (Figure 10).

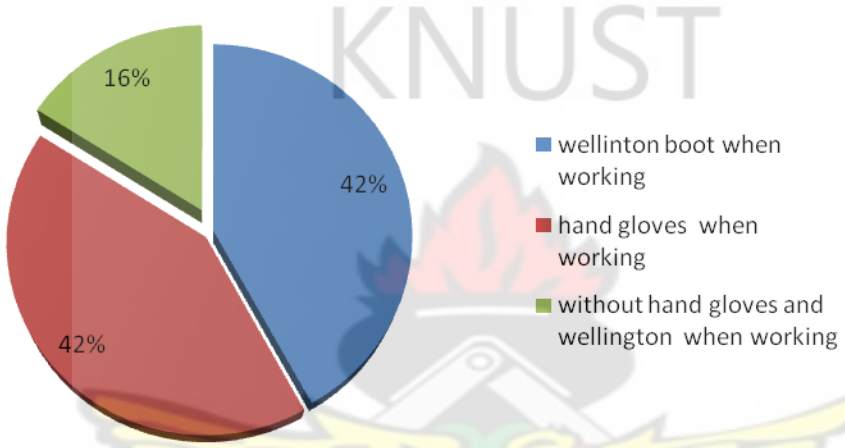

Figure 10 Use of protective clothing

4.5.5 Knowledge of health risk associated with wastewater use

80% of the vegetable farmers were aware that the wastewater used for watering their vegetables was contaminated with municipal and industrial waste but did not know its effect on their health.

20% were not aware of the fact that the wastewater was contaminated.

CHAPTER FIVE

DISCUSSION

5.1 HELMINTH ENCOUNTERED IN THE WATER SAMPLES

Nine different types of helminths were encountered in the two streams (Wiwi and Sisan) during sampling in the study. They were *Ascaris lumbricoides,* Hookworm*, H. nana, H. diminuta, S. heamatobium, Shistosoma mansoni, C. sinensis, S. stercolaris* and *Trichuris trichiura*. The occurrence of these pathogens in the water samples is an indication of faecal pollution of these water sources.

It was assumed that helminths were uniformly distributed in the final processing stage that is why a multiplication step was used to convert the number of helminths found to helminthes per litre. In this method, if only one helminth is detected in the sample, the final helminth count then, may be greatly exaggerated. In addition, a small sample size plus the sub-sampling stage makes the detection of very small number of helminths improbable. Hence, in all these experiments, large volumes of irrigated water were drawn to offset those anomalies (Ayres and Mara, 1996).

Although the identified helminth from the experiments were typically for each species, it is to be remembered that not all helminths were absolutely uniform in size and shape. In the present study, it is prudent to recognize that *Ascaris sum* (from pigs) and of *A. lumbricoides* (from humans) for example, are morphologically indistinguishable. Similarly, human whipworm, *Trichuris trichiura*, can only be separated from those of animal species by careful measurement. The *trichuris* species are all of similar colour and shape (Ayres and Mara, 1996).

5.1.1 Types of Helminths encountered in the Wiwi and Sisan Streams

Nine (9) different types of helminth were encountered in the Wiwi stream during sampling in the dry season. In the wet season, however, *S. haematobium, S. mansoni* and *C. sinensis* were absent in the water samples.

Eight (8) types of helminth were present in water samples from the Sisan stream in the dry season. They were *Ascaris lumbricoides*, Hookworm, *H. nana, H. diminuta, S. heamatobium, Shistosoma mansoni, S. stercolaris* and *Trichuris*. *C. sinensis* were absent. These same types of helminths were present in the samples in the wet season. *C. sinensi* were, again, absent in the samples.

The presence of helminth in a water body indicates contamination from human or animal source. The Wiwi stream is slow-moving and weedy. It is close to a school urinal and children bathe in the water. On most of the visiting days, faeces were found at the banks of the river and also there was a refuse dump near the stream. Again, drains from nearby houses discharge their sewage directly into the stream. Also, sewage from the halls of residence of the Kwame Nkrumah University of Science and Technology discharge directly into this stream. Domestic animals were also seen grazing at the banks of the stream. All these anthropogenic activities are believed to have contributed differently and severally to the different numbers and types of Helminth eggs encountered in the samples from the Wiwi stream.

The environmental conditions existed at the Sisan site were not different from the Wiwi site, except that the stream was a slow-moving. These unsanitary conditions such as dumping of refuse, free range places of convenience and livestock feeding around and along the water sources and the channeling of municipal waste into these rivers may have led to the presence of helminths in them. Also, runoffs from unsanitary sites may have

washed human and animal faecal matter into the water sources by rains. Again, people who live along the streams and their activities may have led to the discharge of sewage directly into the streams.

Wastewater, especially domestic wastewater effluent, contain pathogens which can cause the spread of diseases when not managed properly. Pescod and Arar (1988) and FAO (1992) reported that most helmniths are found in natural waters as a result of the discharge of effluent, activated sludge, sewage, excreta and faeces from cattle, rodents, man, etc. These pathogens finally reach the agricultural field when waters are used for irrigation and helminthes have the potential to contaminate both the soil and the crop and also pose health risks to the handlers.

The mean number of eggs recorded for the specific species were relatively higher in the dry season than in the wet season for most types of helminths (Figure 2 and 3). This may be attributed to runoff water resulting from heavy rains in the wet season washing away some of the helminth from the streams. Another possible reason which could have accounted for the deferring distribution of the parasites in the streams is the differences in the environmental conditions that existed at the time of sampling (Feachem *et al*., 1983). The wet season may have provided favorable conditions for the survival of predators to attack specific types of helminths in the water.

5.1.2 Helminth encountered in the Shallow Wells

All the 9 types of Helminth encountered in the Wiwi and Sisan streams were also present in the two shallow wells used to irrigate vegetable farms in the study area. The presence of these parasites in the wells could be attributed to several sources in the study area. Shallow Well 1 is sited close to a bush about 50 metres away from the farms which is used as a place of convenience by the vegetable farmers and some of the natives of Wiwiso. Shallow

well 2 is also sited about 50 metres from a heap of cow dung and poultry droppings as in shallow well 1. It was also sited downstream of the Sisan site where children bathe in the water. These clearly show that the source of water used in irrigating these vegetable farms in the metropolis are highly susceptible to contamination by human activities.

The mean number of helminths encountered varied from the dry season to the wet season. *Ascaris lumbricoides, Trichuris trichiura,* Hookworm, *H. diminuta* and *C. sinensis* were higher in the wet season whereas, *H. nana, S. haematobium, S .mansoni* and *S. stercoralis* were higher in the dry season. The dry season, which is characterized by high temperatures and low or no rainfall may have contributed to the decrease in helminth numbers in most of the types in the shallow wells.

In all, nine helminths were identified in this study which sought to analyse the health hazards posed by water sources used for the irrigation of vegetable crops in the Kumasi metropolis.

In shallow well 1,the mean number of helmiths are higher in the wet season with the exception of *S.stercoralis,H nana* S.*haematobium* and *s. mansoni* with means lower in the wet season than in the dry season. In the dry season, this may be due to the harsh weather conditions in the dry season. The dry season, characterized by high temperatures and low or no rainfall, may have contributed to the decrease in helminth egg numbers (Feachem *et al*., 1983). Helminth vary from very fragile to very persistent; thus helminths have wide varying persistence in the environment. Their survival in the environment may result from environmental influence and the ability of the species to persist.

The high numbers in the wet season may be due to the favourable weather condition which may have contributed to the disposal of parasite, caused by low temperatures and high rainfall. The high rainfall may also have washed down faecal matter from the unhygienic

and unsanitary sites along the banks of the river into the wells. Runoffs from other faecal polluted areas entering the water sources may also have contributed to the high number of helminths in the wet season.

5.1.3 Helminth encountered in the raw and blanched cabbage

The main factors influencing die–off rates of helminth are temperature, dryness and uv light. Die-off rates increase in proportion to the level or intensity of these variables. The mean number of helminthes recorded for raw cabbage as compared to the blanched sample shows that *S. mansomi* and *C. sinensis* died after the application of the 80^{o}C heat to the sample for 2minutes. *Ascaris lumbricoides* which had the highest mean number of (2.6) dropped to (0.8) after the application of heat because it is said to be one of the resistant types of helminths. Hookworm had a mean number of 1.8 and after blanching had 1.2, which may also be due to the resistant nature of it.

5.2 FARMERS EDUCATIONAL LEVEL, HEALTH COMPLAINTS AND DAILY FARM PRACTICES

Epidermiological studies by WHO (1989), and Cifuentes (1993), have shown that, there is a risk of infection for people exposed to wastewater and it is highest for roundworm such as *Ascaris lumbricoides*, whipworm *trichuris trichiura* and hookworm *Ancylostoma duodenale* and *nectar americanu*. The major concern is that the soil is the 'intermediate host' for most helminths reinfecting humans. WHO (1989) concludes that available evidence indicates that almost all excreted pathogens can survive in soil for sufficient length of time to pose potential risk to farm workers.

The incidence of disease such as diarrhea, stomach ache and body itch which are associated with contamination of drinking water and food and direct contact with the body by water re-used for vegetable irrigation may be due to lack of or inadequate personal

hygiene practices such as hand washing with detergents and clean water on the farm. Most of the farmers interviewed washed their hands at home with or without soap after closing from farm work. Those who washed their hands after work on the farm used the same source of waster.

It was realized that the farmers did not protect themselves adequately during the watering process. They claimed they do not feel comfortable in wellington boots and hand gloves. They also said the protective clothing slowed down their work. Some felt it was not important wearing them; others think it is too expensive to purchase them.

Though most of the farmers were illiterates, their knowledge about health risks associated with the use of wastewater for farming was very high because of the education they have being receiving from agriculture extension officers who visit their farms periodically.

The persistent re-use of this water for vegetable irrigation is due to the availability of the water source throughout the year, the water source being very close to them and at no cost.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Analyses of cabbage and irrigation source water samples have revealed that nine (9) different types of Helminths were present in the samples. They included: *Ascaris lumbricoides*, Hookworm, *H. nana, H. diminuta, S. heamatobium, S. histosomamansoni, C. sinensis, S. stercolaris* and *Trichuris trichiura*. The occurrence of the different species of helminth in the water sources is an indication of faecal pollution of these water sources which are used in the irrigation of vegetables in the Kumasi metropolis.

The study also revealed that Helminths encountered in the wet season were relatively higher in numbers than those observed in the dry season. Also, blanching the cabbage at 80^{o}C for 2 minutes greatly reduced the helminth counts.

Helminth levels in the two streams and their respective shallow wells were above the WHO standard for irrigational purposes.

Majority of the farmers were aware of the danger posed to their health and those of their consumers by the use of such water to irrigate their vegetables. However, their persistent use of this water for vegetable irrigation is due to the availability of the water source throughout the year, and also, the water source being very close to them and at no cost.

6.2 RECOMMENDATION

Ensuring food safety to protect public health and promote economic development remains a significant challenge in developing countries where wastewater is used in vegetable farming. Guideline information on the best ways to maximize wastewater reuse and reduce

potential health risk in the increasing waning water resources while maintaining food safety is needed.

It is recommended that:

1.Vegetable farmers using wastewater should be educated on the benefits of the various interventions and encouraged to adopt them to reduce on–farm contamination.

2. Street kitchen vendors should be educated and encouraged to use improved washing methods during food preparation.

3. Further studies should be carried out on Quantitative Microbial Risk Assessment (QMRA) to quantify the actual risk of disease associated with consumption of wastewater – irrigated vegetables and calculate Disability Adjusted Life Year (DALY), values appropriate for Ghanaian communities.

4. Vegetable crop eaten raw should be irrigated with treated water

5. Farmers and sellers should be advised not to use wastewater to wash vegetables after harvesting.

6. Farmers should be encouraged to use protective clothing during farm work to reduce hookworm infection

7. The following should be included during further studies on helminth infestation in wastewater irrigation

- Epidermiological studies should be carried on information on waste water.
- Proper sanitation practice should be enforced in the surrounding of the vegetable farms.

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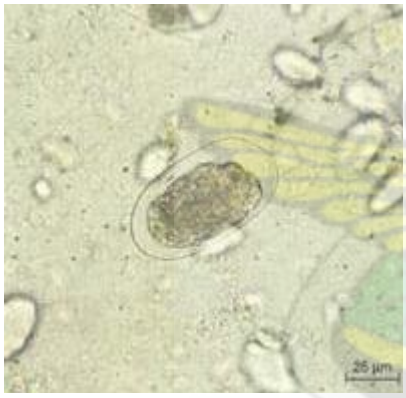
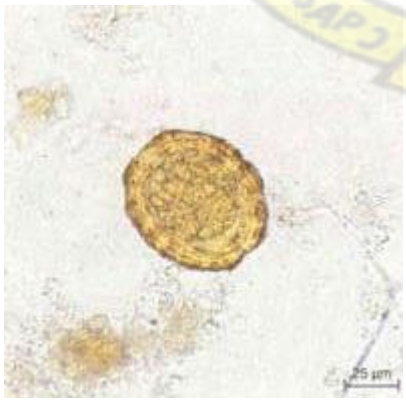
APPENDICES

Trichuris trichiura

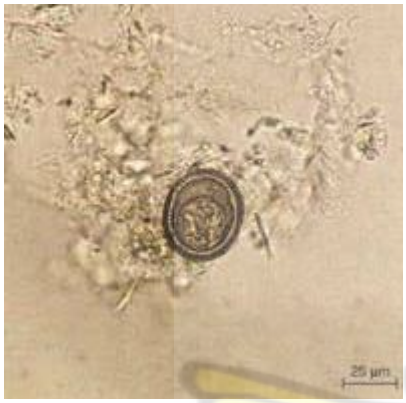


Hookworm

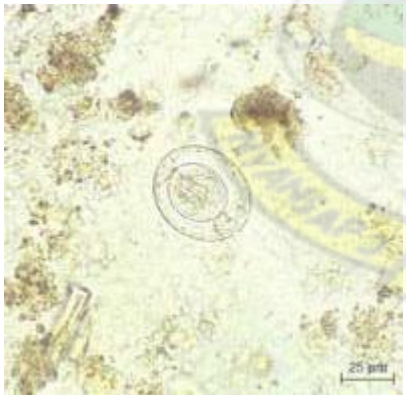


Ascaris lumbricoides

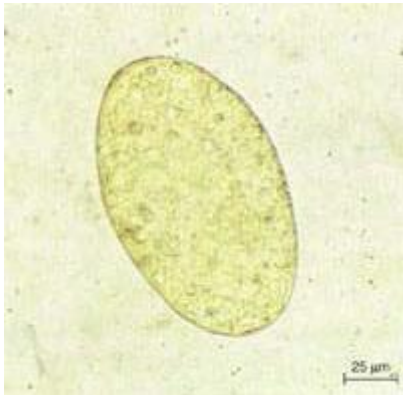
Hymenolepis diminuta



Taenia sp.



Hymenolepis nana



Fasciola hepatica

Schistosoma haematobium

Schistosoma mansoni

NB: The values provided in bracket indicate infertile eggs.

RAW CABBAGE 1(Farm1) wiwi	**No. of helminth eggs/lit**		**Raw cabbage (farm 2) sisan**	
Ascaris lumbricoides	4		Ascaris lumbricoides	3
Trichuris trichiura	1		Trichuris trichiura	1
Hookworm	5		Hookworm	4
Shistosoma haematobium	2		Shistosoma haematobium	2
Shistosoma mansoni	*2*		Shistosoma mansoni	*1*
2				
Ascaris lumbricoides	3		Ascaris lumbricoides	5
Trichuris trichiura	1		Trichuris trichiura	2
Hookworm	3		Hookworm	4
Shistosoma haematobium	2		Shistosoma haematobium	3
Shistosoma mansoni	*2*		Shistosoma mansoni	*2*
3				
Ascaris lumbricoides	4		Ascaris lumbricoides	5
Trichuris trichiura	1		Trichuris trichiura	2
Hookworm	5		Hookworm	3
Shistosoma haematobium	1		Shistosoma haematobium	2
Shistosoma mansoni	*2*		Shistosoma mansoni	*2*
4				
Ascaris lumbricoides	5		Ascaris lumbricoides	4
Trichuris trichiura	1		Trichuris trichiura	1
Hookworm	5		Hookworm	4
Shistosoma haematobium	1		Shistosoma haematobium	2
Shistosoma mansoni	*2*		Shistosoma mansoni	*2*
5				
Ascaris lumbricoides	3		Ascaris lumbricoides	*1*
Trichuris trichiura	1		Trichuris trichiura	*3*
Hookworm	3		Hookworm	*2*
Shistosoma haematobium	1		Shistosoma haematobium	*1*
Shistosoma mansoni	*2*		Shistosoma mansoni	*1*
BLANCHED CABBAGE				
1				
Ascaris lumbricoides	1(1)		Ascaris lumbricoides	1
Trichuris trichiura	0		Trichuris trichiura	0
Hookworm	0		Hookworm	0
Shistosoma haematobium	0		Shistosoma haematobium	0

Shistosoma mansoni	*0*		Shistosoma mansoni	*0*
2				
Ascaris lumbricoides	2(1)		Ascaris lumbricoides	2
Trichuris trichiura	0		Trichuris trichiura	0
Hookworm	0		Hookworm	0
Shistosoma haematobium	0		Shistosoma haematobium	0
Shistosoma mansoni	*0*		Shistosoma mansoni	*0*
3				
Ascaris lumbricoides	1(1)		Ascaris lumbricoides	1
Trichuris trichiura	0		Trichuris trichiura	0
Hookworm	0		Hookworm	0
Shistosoma haematobium	0		Shistosoma haematobium	0
Shistosoma mansoni	*0*		Shistosoma mansoni	*0*
4				
Ascaris lumbricoides	(1)		Ascaris lumbricoides	1
Trichuris trichiura	0		Trichuris trichiura	0
Hookworm	0		Hookworm	0
Shistosoma haematobium	0		Shistosoma haematobium	0
Shistosoma mansoni	*0*		Shistosoma mansoni	*0*

Although s.mansoni was not present in the waste water used, it was found in the raw cabbage.

HELMINTHS RESULTS FOR BOTH RIVER WIWI AND SISAN SAMPLED

DRY SEASON DEC-FEB	RIVER WIWI	NUMBER OF HELMINTH EGGS	RIVER SISAN	NUMBER OF HELMINTH EGGS
WEEK 1 SAMPLE 1	*Ascaris lumbricoides*	2	*Ascaris lumbricoides*	2 (1)
	Trichuris trichiura	0	*Trichuris trichiura*	1
	Hookworm	1	*s.stercoralis*	1
	s.stercoralis	1(1)	*Hookworm*	0
SAMPLE 2	*Ascaris lumbricoides*	1	*Ascaris lumbricoides*	2
	Trichuris trichiura	1	*Trichuris trichiura*	1
	Hookworm	2	*Hookworm*	0
	s.stercoralis	1	*s.stercoralis*	1
WEEK 2 SAMPLE 1	*Ascaris lumbricoides*	1	*Ascaris lumbricoides*	1
	Trichuris trichiura	1	*Trichuris trichiura*	1
	s.stercoralis	1(1)	*s.stercoralis*	1
	Hookworm	0	*Hookworm*	1
SAMPLE 2	*Ascaris lumbricoides*	1	*Ascaris lumbricoides*	1
	Trichuris trichiura	0	*Trichuris trichiura*	2
	s.stercoralis	1	*Hookworm*	0
	Hookworm	1	*s.stercoralis*	1
	Hymenolepis nana			
WEEK 3 SAMPLE 1	*Ascaris lumbricoides*	1	*Ascaris lumbricoides*	3 (1)
	Trichuris trichiura	0	*Trichuris trichiura*	2
	Hookworm	1	*Hookworm*	0
	s.stercoralis	(1)	*s.stercoralis*	1
SAMPLE 2	*Ascaris lumbricoides*	3	*Ascaris lumbricoides*	2(1)
	Trichuris trichiura	0	*Trichuris trichiura*	1
	Hookworm	3	*Hookworm*	0
	s.stercoralis	1	*s.stercoralis*	1
WEEK 4 SAMPLE1	*Ascaris lumbricoides*	3	*Ascaris lumbricoides*	4 (1)
	Trichuris trichiura	1	*Trichuris trichiura*	1(1)
	Hookworm	3	*Hookworm*	0
	s.stercoralis	2	*s.stercoralis*	(1)
SAMPLE 2	*Ascaris lumbricoides*	3	*Ascaris lumbricoides*	2(1)
	Trichuris trichiura	1	*Trichuris trichiura*	2
	Hookworm	3	*Hookworm*	1
	s.stercoralislate	1	*s.stercoralis*	1
WEEK 5	*Ascaris lumbricoides*	2	*Ascaris lumbricoides*	1
	Trichuris trichiura	1	*Trichuris trichiura*	1

	Hookworm	3	*s.stercoralis*	0
	s.stercoralis	1	*Hookworm*	0
SAMPLE 2	*Ascaris lumbricoides*	3	*Ascaris lumbricoides*	4 (1)
	Trichuris trichiura	(1)	*Trichuris trichiura*	1
	Hookworm	3	*Hookworm*	0
	s.stercoralis	1	*s.stercoralis*	(1)
WEEK 6 SAMPLE 1	*Ascaris lumbricoides*	3	*Ascaris lumbricoides*	3(1)
	Trichuris trichiura	1	*Trichuris trichiura*	2
	Hookworm	3	*s.stercoralis*	(1)
	s.stercoralis	1	*Hookworm*	0
SAMPLE 2	*Ascaris lumbricoides*	3	*Ascaris lumbricoides*	2(1)
	Trichuris trichiura	1	*Trichuris trichiura*	1
	Hookworm	3	*Hookworm*	0
			s.stercoralis	(1)
WEEK 7 SAMPLE 1	*Ascaris lumbricoides*	1	*Ascaris lumbricoides*	1(1)
	Trichuris trichiura	1	*Trichuris trichiura*	1
	Hookworm	3	*Hookworm*	0
SAMPLE 2	*Ascaris lumbricoides*	3	*Ascaris lumbricoides*	2(1)
	Trichuris trichiura	1	*Trichuris trichiura*	1
	Hookworm	3	*Hookworm*	0
			s.stercoralis	(1)
WEEK 8 SAMPLE 1	*Ascaris lumbricoides*	1	*Ascaris lumbricoides*	1(1)
	Trichuris trichiura	0	*Trichuris trichiura*	1
	Hookworm	3	*Hookworm*	0
			s.stercoralis	(1)
SAMPLE 2	*Ascaris lumbricoides*	3	*Ascaris lumbricoides*	1
	Trichuris trichiura	1	*Trichuris trichiura*	1
	Hookworm	3	*Hookworm*	1
	s.stercoralis	1	*s.stercoralis*	(1)

HELMINTH EGGS (RESULTS FOR BOTH SHALLOW WELLS)

DRY SEASON DEC-FEB	**WIWI SHALLOW WELL**	**NUMBER OF HELMINTH EGGS/lit**	**SISAN SHALLOW WELL**	**NUMBER OF HELMINTH EGGS**
WEEK 1 SAMPLE 1	*Ascaris lumbricoides*	2	*Ascaris lumbricoides*	1
	Trichuris trichiura	2	*Trichuris trichiura*	1
	Shistosoma haematobium	2	*Shistosoma haematobium*	1
	Hymenolepsis diminuta	1	*Hymenolepsis diminuta*	0
	Hookworm	1	Hookworm	1
	s.stercoralis	(1)	s.stercoralis	1
	Hymenolepris nana	1	*Hymenolepris nana*	2
	C .sinensis	(1)	C .sinensis	0
WEEK1 SAMPLE 2	*Ascaris lumbricoides*	3	*Ascaris lumbricoides*	1
	Trichuris trichiura	1	*Trichuris trichiura*	1
	Shistosoma haematobium	1	*Shistosoma haematobium*	0
	Hymenolepsis diminuta	1	*Hymenolepsis diminuta*	1

	Hymenolepris nana	1	*Hymenolepris nana*	(1)
	S.stercoralis	2	s.stercoralis	(1)
	Hookworm	0	Hookworm	1
	C .sinensis	1	C .sinensis	0
WEEK 2 SAMPLE 1	*Ascaris lumbricoides*	3	*Ascaris lumbricoides*	1
	Trichuris trichiura	1	*Trichuris trichiura*	1
	Shistosomahaematobium	0	*Shistosoma haematobium*	2
	Hymenolepsis diminuta	0	*Hymenolepsis diminuta*	0
	Hookworm	2	*Hookworm*	1
	S .stercoralis	2	s.stercoralis	1
	Hymenolepris nana	1	*Hymenolepris nana*	(1)
	C .sinensis	0	C .sinensis	0
WEEK 2 SAMPLE 2	*Ascaris lumbricoides*	3(1)	*Ascaris lumbricoides*	1
	Trichuris trichiura	1	*Trichuris trichiura*	(2)
	Shistosoma haematobium	1	*Shistosoma haematobium*	2
	Hymenolepsis diminuta	1	*Hymenolepsis diminuta*	0
	s.stercoralis	(1)	*s.stercoralis*	(1)
	Hymenolepris nana	2	*Hymenolepris nana*	2
	C .sinensis	0	C .sinensis	0
	Hookworm	1(1)	Hookworm	1
WEEK 3 SAMPLE 1	*Ascaris lumbricoides*	1(1)	*Ascaris lumbricoides*	2(1)
	Trichuris trichiura	1	*Trichuris trichiura*	2
	Shistosoma haematobium	1	*Shistosoma haematobium*	0
	Hymenolepsis diminuta	0	*Hymenolepsis diminuta*	0
	s.stercoralis	(2)	*s.stercoralis*	1
	Hookworm	2	Hookworm	0
	Hymenolepris nana	3	*Hymenolepris nana*	2
	C .sinensis	0	C .sinensis	0
WEEK 3 SAMPLE 2	*Ascaris lumbricoides*	2(1)	*Ascaris lumbricoides*	3
	Trichuris trichiura	1	*Trichuris trichiura*	1
	Shistosoma haematobium	2	*Shistosoma haematobium*	1
	Hymenolepsis diminuta	0	*Hymenolepsis diminuta*	0
	Hymenolepris nana	1	*Hymenolepris nana*	2
	s.stercoralis	1(1)	*s.stercoralis*	1
	Hookworm	1	Hookworm	0
	C .sinensis	0	C .sinensis	0
WEEK 4 SAMPLE1	*Ascaris lumbricoides*	1(1)	*Ascaris lumbricoides*	3
	Trichuris trichiura	(1)	*Trichuris trichiura*	2
	Shistosoma haematobium	2	*Shistosoma haematobium*	1
	Hymenolepsis diminuta	2	*Hymenolepsis diminuta*	0
	s.stercoralis	1	*s.stercoralis*	(1)
	Hookworm	1	*Hookworm*	0
	Hymenolepris nana	1	*Hymenolepris nana*	1
	C .sinensis	0	C .sinensis	0
WEEK 4 SAMPLE 2	*Ascaris lumbricoides*	2(1)	*Ascaris lumbricoides*	3
	Trichuris trichiura	(1)	*Trichuris trichiura*	2

	Shistosoma haematobium	3	*Shistosoma haematobium*	2
	Hymenolepsis diminuta	0	*Hymenolepsis diminuta*	0
	s.stercoralis	2	*s.stercoralis*	(1)
	Hookworm	1	*Hookworm*	1
	Hymenolepris nana	2	*Hymenolepris nana*	1
	C .sinensis	0	C .sinensis	0
WEEK 5 SAMPLE 1	*Ascaris lumbricoides*	3 (1)	*Ascaris lumbricoides*	2
	Trichuris trichiura	2	*Trichuris trichiura*	1
	Shistosoma haematobium	3	*Shistosoma haematobium*	2
	Hymenolepsis diminuta	1	*Hymenolepsis diminuta*	0
	s.stercoralis	1	*s.stercoralis*	1
	Hookworm	2	*Hookworm*	1
	Hymenolepris nana	1	*Hymenolepris nana*	1
	C .sinensis	0	C .sinensis	0
WEEK 5 SAMPLE 2	*Ascaris lumbricoides*	1 (1)	*Ascaris lumbricoides*	3
	Trichuris trichiura	2		
	Shistosoma haematobium	0	*Shistosoma haematobium*	2
	Hymenolepsis diminuta	0	*Hymenolepsis diminuta*	0
	Hymenolepris nana	1	*Hymenolepris nana*	2
	s.stercoralis	1(1)	*s.stercoralis*	1
	Hookworm	2	Hookworm	2
	C .sinensis	0	C .sinensis	0
WEEK 6 SAMPLE 1	*Ascaris lumbricoides*	3	*Ascaris lumbricoides*	3
	Trichuris trichiura	2	*Trichuris trichiura*	2
	Shistosoma haematobium	2	*Shistosoma haematobium*	2
	Hymenolepsis diminuta	1	*Hymenolepsis diminuta*	0
	s.stercoralis	2	*s.stercoralis*	1
	Hymenolepris nana	1	*Hymenolepris nana*	1
	Hookworm	1	Hookworm	1
	C .sinensis	*0*	*C .sinensis*	0
WEEK 6 SAMPLE 2	*Ascaris lumbricoides*	4(1)	*Ascaris lumbricoides*	3
	Trichuris trichiura	1		
	Shistosoma haematobium	3	*Shistosoma haematobium*	2
	Hymenolepsis diminuta	0	*Hymenolepsis diminuta*	0
	Hymenolepris nana	2	*Hymenolepris nana*	2
	s.stercoralis	1	*s.stercoralis*	1
	Hookworm	2	Hookworm	1
	C .sinensis	*0*	*C .sinensis*	0
WEEK 7 SAMPLE 1	*Ascaris lumbricoides*	0	*Ascaris lumbricoides*	(1)
	Trichuris trichiura	0		
	Shistosoma haematobium	0	*Shistosoma haematobium*	1
	Hymenolepsis diminuta	1	*Hymenolepsis diminuta*	0
	Hymenolepris nana	1	*Hymenolepris nana*	2
	s.stercoralis	1	*s.stercoralis*	1
	Hookworm	2	Hookworm	1
	C .sinensis	*0*	*C .sinensis*	0
WEEK 7 SAMPLE	*Ascaris lumbricoides*	2	*Ascaris lumbricoides*	1(1)

2				
	Trichuris trichiura	0	*Trichuris trichiura*	1
	Shistosoma haematobium	0	*Shistosoma haematobium*	1
	Hymenolepsis diminuta	0	*Hymenolepsis diminuta*	1
	Hymenolepris nana	2	*Hymenolepris nana*	1
	s.stercoralis	1	*s.stercoralis*	1
	Hookworm	1	Hookworm	0
	C .sinensis	*0*	*C .sinensis*	0
WEEK 8 SAMPLE 1	*Ascaris lumbricoides*	1	*Ascaris lumbricoides*	2
	Trichuris trichiura	0	*Trichuris trichiura*	1
	Shistosoma haematobium	1	*Shistosoma haematobium*	0
	Hymenolepsis diminuta	1	*Hymenolepsis diminuta*	1
	Hymenolepris nana	0	*Hymenolepris nana*	1
	s.stercoralis	2	*s.stercoralis*	1(1)
	Hookworm	1	Hookworm	1
	C .sinensis	*0*	*C .sinensis*	0
WEEK 8 SAMPLE 2	*Ascaris lumbricoides*	2	*Ascaris lumbricoides*	3
	Trichuris trichiura	2	*Trichuris trichiura*	1
	Shistosoma haematobium	0	*Shistosoma haematobium*	0
	Hymenolepsis diminuta	1	*Hymenolepsis diminuta*	1
	Hymenolepris nana	1	*Hymenolepris nana*	2
	Hookworm	1	*Hookworm*	1
	s.stercoralis	1	*s.stercoralis*	1
	C .sinensis	0	C .sinensis	0

WET SEASON APRIL-MAY	RIVER WIWI	NUMBER OF HELMINTH EGGS	RIVER SISAN	NUMBER OF HELMINTH EGGS
WEEK 1 SAMPLE 1	*Ascaris lumbricoides*	3	*Hymenolepis nana*	2
	Trichuris trichiura	2	*Ascaris lumbricoides*	3 (1)
	Hookworm	3	*Trichuris trichiura*	1(2)
	Hymenolepis nana	1	*Hookworm*	0
	S. heamatobium	2	*S. heamatobium*	2
	Hymenolepis diminuta	0	*Hymenolepis diminuta*	0
	c.senensis	2	*c.senensis*	2
	Shistosoma mansoni	0	*Shistosoma mansoni*	0
SAMPLE 2	*Ascaris lumbricoides*	4(1)	*Hymenolepis diminuta*	0
	Trichuris trichiura	2	*Hymenolepis nana*	3
	Hookworm	0	*Ascaris lumbricoides*	(4)
	Hymenolepis nana	2	*Trichuris trichiura*	2
	S. heamatobium	1(1)	*Hookworm*	0
	Hymenolepis diminuta	0	*S. heamatobium*	1
	c.senensis	1	*c.senensis*	
	Shistosoma mansoni	0	*Shistosoma mansoni*	0
WEEK 2 SAMPLE 1	Ascaris lumbricoides	3	*Hymenolepis diminuta*	0
	Trichuris trichiura	1	*Hymenolepis nana*	1(2)
	Hookworm	3	*Ascaris lumbricoides*	5(1)
	Hymenolepis nana	1	*Trichuris trichiura*	1(2)
	S. heamatobium	(1)	*Hookworm*	0
	Hymenolepis diminuta	0	*S. heamatobium*	1
	c.senensis	2	*c.senensis*	1
	Shistosoma mansoni	0	*Shistosoma mansoni*	0
SAMPLE 2	Ascaris lumbricoides	4	*Hymenolepis diminuta*	0
	Trichuris trichiura	3	*Hymenolepis nana*	2
	Hookworm	3	*Ascaris lumbricoides*	2 (1)
	Hymenolepis nana	3	*Trichuris trichiura*	1
	S. heamatobium	2	*Hookworm*	0
	Hymenolepis diminuta	0	*S. heamatobium*	1
	c.senensis	1	*c.senensis*	
	Shistosoma mansoni	0	*Shistosoma mansoni*	0
WEEK 3 SAMPLE 1	*Ascaris lumbricoides*	1	*Hymenolepis diminuta*	0
	Trichuris trichiura	3	*Hymenolepis nana*	3
	Hookworm	1	*Ascaris lumbricoides*	1 (3)
	Hymenolepis nana	3	*Trichuris trichiura*	1(1)
	Hymenolepis diminuta	0	*Hookworm*	0
	S. heamatobium	(2)	*S. heamatobium*	0
	Shistosoma mansoni	0	*Shistosoma mansoni*	0

	c.senensis	(1)	*c.senensis*	0
SAMPLE 2	*Ascaris lumbricoides*	3(1)	*Hymenolepis diminuta*	0
	Trichuris trichiura	2	*Hymenolepis nana*	2
	Hookworm	2	*Ascaris lumbricoides*	1(1)
	Hymenolepis nana	2	*Trichuris trichiura*	2
	S. heamatobium	1	*Hookworm*	0
	Hymenolepis diminuta	0	*S. heamatobium*	1
	c.senensis	2	*c.senensis*	0
	Shistosoma mansoni	0	*Shistosoma mansoni*	0
WEEK 4 SAMPLE1	*Ascaris lumbricoides*	5	*Hymenolepis diminuta*	0
	Trichuris trichiura	2	*Hymenolepis nana*	0
	Hookworm	3	*Ascaris lumbricoides*	4 (1)
	Hymenolepis nana	1	*Trichuris trichiura*	3
	S. heamatobium	1	*Hookworm*	0
	Shistosoma mansoni	0	*S. heamatobium*	2
	c.senensis	1	*c.senensis*	1
	Hymenolepis diminuta	0	*Shistosoma mansoni*	0
SAMPLE 2	*Ascaris lumbricoides*	4	*Shistosoma haematobium*	2
	Trichuris trichiura	2	*Shistosoma mansoni*	1
	Hookworm	4	*Hymenolepsis diminuta*	0
	Hymenolepis nana	(2)	*Hymenolepris nana*	2
	S. heamatobium	1	*hookworm*	0
	Hymenolepis diminuta	0	*Trichuris trichiura*	0
	c.senensis	(1)	*c.senensis*	0
	Shistosoma mansoni	0	*Trichuris trichiura*	0
WEEK 5	*Ascaris lumbricoides*	3	*Ascaris lumbricoides*	3
	Trichuris trichiura	1	*Shistosoma haematobium*	2
	Hookworm	3	*Shistosoma mansoni*	1
	Hymenolepis nana	1	*Hymenolepsis diminuta*	0
	S. heamatobium	1	*Hymenolepris nana*	2
	Hymenolepis diminuta	0	*hookworm*	0
	c.senensis	2	*c.senensis*	0
	Shistosoma mansoni	0	*Trichuris trichiura*	0
SAMPLE 2	*Ascaris lumbricoides*	2	*Ascaris lumbricoides*	3
	Trichuris trichiura	3	*Shistosoma haematobium*	2
	Hookworm	2	*Shistosoma mansoni*	1
	Hymenolepis nana	(1)	*Hymenolepsis diminuta*	0
	S. heamatobium	0	*hookworm*	0
	Hymenolepis diminuta	0	*Trichuris trichiura*	0
	c.senensis	1	*c.senensis*	0
	Shistosoma mansoni	0	*Hymenolepis nana*	3
WEEK 6 SAMPLE 1	*Ascaris lumbricoides*	3	*Hymenolepris nana*	2
	Trichuris trichiura	4	*Ascaris lumbricoides*	3
	Hookworm	3	*Shistosoma haematobium*	2
	Hymenolepis nana	1(2)	*Shistosoma mansoni*	1
	S. heamatobium	(2)	*Hymenolepsis diminuta*	0
	Hymenolepis diminuta	0	*hookworm*	0
	Shistosoma mansoni	0	*Trichuris trichiura*	1

	c.senensis	2	*c.senensis*	1
SAMPLE 2	*Ascaris lumbricoides*	5	*Ascaris lumbricoides*	1
	Trichuris trichiura	2	*Trichuris trichiura*	2
	Hookworm	3	*Shistosoma haematobium*	0
	Hymenolepis nana	1(2)	*Shistosoma mansoni*	1
	S. heamatobium	1	*Hookworm*	0
	Hymenolepis diminuta	0	*Hymenolepis diminuta*	0
	Shistosoma mansoni	0	*Hymenolepis nana*	3
	c.senensis	1	*c.senensis*	0
WEEK 7 SAMPLE 1	*Ascaris lumbricoides*	3(1)	*Ascarislumbricoides*	2
	Trichuris trichiura	4	*Trichuris trichiura*	1
	Hookworm	3	*Shistosoma haematobium*	1
	Hymenolepis nana	2	*Shistosoma mansoni*	1
	S. heamatobium	2(1)	*Hymenolepis diminuta*	0
	Hymenolepis diminuta	0	*hookworm*	0
	Shistosoma mansoni		*Hymenolepis nana*	3
	c.senensis	2	*c.senensis*	
SAMPLE 2	*Ascarislumbricoides*	3(2)	*Ascaris lumbricoides*	1
	Trichuris trichiura	2	*Trichuris trichiura*	2
	Hookworm	1	*Shistosoma haematobium*	1
	Hymenolepis nana	4	*Shistosoma mansoni*	1
	S. heamatobium	0	*Hymenolepis diminuta*	0
	Hymenolepis diminuta	0	*hookworm*	0
	c.senensis	2	*c.senensis*	1
	Shistosoma mansoni	0	*Hymenolepis nana*	3
WEEK 8 SAMPLE 1	*Ascaris lumbricoides*	4	*Ascaris lumbricoides*	1
	Trichuris trichiura	4	*Trichuris trichiura*	2
	Hookworm	3	*Shistosoma haematobium*	1
	Hymenolepis nana	1(2)	*Shistosoma mansoni*	1
	S. heamatobium	(1)	*Hymenolepis diminuta*	0
	Hymenolepis diminuta	0	*hookworm*	0
	c.senensis	3	*c.senensis*	1
	Shistosoma mansoni	0	*Hymenolepis nana*	3
SAMPLE 2	*Ascaris lumbricoides*	3	*Ascaris lumbricoides*	2
	Trichuris trichiura	3	*Trichuris trichiura*	2
	Hookworm	3	*Shistosoma haematobium*	2
	c.senensis	2	*c.senensis*	
	Hymenolepis nana	3	*Shistosoma mansoni*	1
	Shistosoma mansoni	0	*Hymenolepis nana*	2
	S. heamatobium	1	*hookworm*	0
	Hymenolepis diminuta	0	*Hymenolepis diminuta*	0

HELMINTH EGGS (RESULTS FOR BOTH SHALLOW WELLS) WET SEASON				
	WIWI SHALLOW WELL	**NUMBER OF HELMINTH EGGS /lit**	**SISAN SHALLOW WELL**	**NUMBER OF HELMINTH EGGS**
WEEK1 SAMPLE1	Ascaris lumbricoides	6	Ascaris lumbricoides	3 (2)
	Trichuris trichiura	2	Trichuris trichiura	1(2)
	Hookworm	2(1)	Hookworm	2
	Hymenolepis nana	0	Hymenolepis nana	1
	S. heamatobium	0	*S. heamatobium*	0
	c.sinensis	1	c.sinensis	2
		1		
WEEK1 SAMPLE2	Ascaris lumbricoides	2	Ascaris lumbricoides	3
	Trichuris trichiura	2	Trichuris trichiura	1(3)
	Hookworm	3	Hookworm	1
	Hymenolepis nana	0	Hymenolepis nana	0
	S. heamatobium	0	*S. heamatobium*	1
	c.sinensis	1	c.sinensis	1(1)
WEEK2SAMPLE 1	Ascaris lumbricoides	4(1)	Ascaris lumbricoides	(2)
	Trichuris trichiura	4	Trichuris trichiura	(2)
	Hookworm	(3)	Hookworm	1(1)
	Hymenolepis nana	0	Hymenolepis nana	0
	S. heamatobium	1	*S. heamatobium*	0
	c.sinensis	2	c.sinensis	1
WEEK2 SAMPLE2	Ascaris lumbricoides	6	Ascaris lumbricoides	3 (1)
	Trichuris trichiura	2	Trichuris trichiura	1(2)
	Hookworm	2(2)	Hookworm	2
	Hymenolepis nana	0	Hymenolepis nana	0
	S. heamatobium	1	*S. heamatobium*	0
	c.sinensis	3	c.sinensis	1
WEEK3SAMPLE1	Ascaris lumbricoides	4	Ascaris lumbricoides	2 (1)
	Trichuris trichiura	3	Trichuris trichiura	(2)
	Hookworm	2(1)	Hookworm	3
	Hymenolepis nana	0	Hymenolepis nana	0
	S. heamatobium	0	*S. heamatobium*	0
	c.sinensis	1	c.sinensis	2
WEEK3 SAMPLE2	Ascaris lumbricoides	7	Ascaris lumbricoides	3 (1)
	Trichuris trichiura	4	Trichuris trichiura	1(2)
	Hookworm	2	Hookworm	3
	Hymenolepis nana	0	Hymenolepis nana	0
	S. heamatobium	0	*S. heamatobium*	1
	c.sinensis	1	c.sinensis	0
WEEK4 SAMPLE1	Ascaris lumbricoides	4(1)	Ascaris lumbricoides	2(1)
	Trichuris trichiura	3	Trichuris trichiura	3
	Hookworm	3	Hookworm	2

	Hymenolepis nana	0	Hymenolepis nana	0
	S. heamatobium	0	*S. heamatobium*	0
	c.sinensis	1	c.sinensis	0
WEEK 4SAMPLE 2	Ascaris lumbricoides	4	Ascaris lumbricoides	3 (1)
	Trichuris trichiura	3	Trichuris trichiura	1(2)
	Hookworm	3	Hookworm	1(1)
	Hymenolepis nana	0	Hymenolepis nana	0
	S. heamatobium	0	*S. heamatobium*	0
	c.sinensis	1	c.sinensis	0
WEEK5 SAMPLE1	Ascaris lumbricoides	5	Ascaris lumbricoides	3 (1)
	Trichuris trichiura	2	Trichuris trichiura	1(2)
	Hookworm	2	Hookworm	2
	Hymenolepis nana	(1)	Hymenolepis nana	0
	S. heamatobium	1	*S. heamatobium*	0
	c.sinensis	1	c.sinensis	1
WEEK5 SAMPLE 2	Ascaris lumbricoides	5	Ascaris lumbricoides	3 (2)
	Trichuris trichiura	2	Trichuris trichiura	2
	Hookworm	2(1)	Hookworm	1
	Hymenolepis nana	0	Hymenolepis nana	0
	S. heamatobium	0	*S. heamatobium*	0
	c.sinensis	1	c.sinensis	0
WEEK6 SAMPLE 1	Ascaris lumbricoides	4	Ascaris lumbricoides	3 (1)
	Trichuris trichiura	2	Trichuris trichiura	1(2)
	Hookworm	3	Hookworm	2
	Hymenolepis nana	0	Hymenolepis nana	0
	S. heamatobium	1	*S. heamatobium*	0
	c.sinensis	2	c.sinensis	(1)
WEEK6 SAMPLE 2	Ascaris lumbricoides	3	Ascaris lumbricoides	3 (1)
	Trichuris trichiura	2	Trichuris trichiura	1(2)
	Hookworm	1(1)	Hookworm	2
	Hymenolepis nana	0	Hymenolepis nana	0
	S. heamatobium	2	*S. heamatobium*	0
	c.sinensis	2	c.sinensis	2
WEEK7 SAMPLE1	Ascaris lumbricoides	6	Ascaris lumbricoides	3 (1)
	Trichuris trichiura	2	Trichuris trichiura	1(2)
	Hookworm	3	Hookworm	2
	Hymenolepis nana	0	Hymenolepis nana	0
	S. heamatobium	0	*S. heamatobium*	1
	c.sinensis	2	c.sinensis	1
WEEK7 SAMPLE 2	Ascaris lumbricoides	4	Ascaris lumbricoides	3 (2)
	Trichuris trichiura	2	Trichuris trichiura	1(2)
	Hookworm	3	Hookworm	3
	Hymenolepis nana	0	Hymenolepis nana	0
	S. heamatobium	1	*S. heamatobium*	1
	c.sinensis	2	c.sinensis	0
WEEK8 SAMPLE 1	Ascaris lumbricoides	7	Ascaris lumbricoides	3 (2)
	Trichuris trichiura	2	Trichuris trichiura	2(1)
	Hookworm	2	Hookworm	2
	Hymenolepis nana	0	Hymenolepis nana	0

	S. heamatobium	3	*S. heamatobium*	1
	c.sinensis	1	c.sinensis	2
WEEK 8 SAMPLE2	Ascaris lumbricoides	4(1)	Ascaris lumbricoides	2(1)
	Trichuris trichiura	2	Trichuris trichiura	1(2)
	Hookworm	1(1)	Hookworm	2(1)
	Hymenolepis nana	0	Hymenolepis nana	0
	S. heamatobium	1	*S. heamatobium*	2
	c.sinensis	1(1)	c.sinensis	1

*Sample taking was done for a period of 8weeks (2 months), 4 weeks in April and 4 weeks in May

*The values provided in bracket indicate infertile eggs.

*s. stercoralis was not present.

*c sinensis was rather present instead of s.stercoralis in the dry season.