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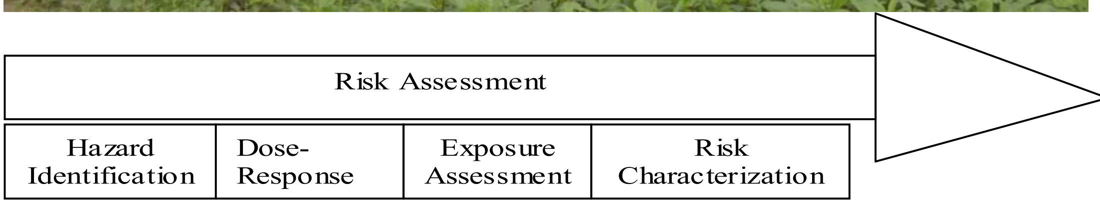


## Analysis of the Public Health Risks of Urban Wastewater Irrigation in Accra by Microbial Risk Assessment

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Master of Science Thesis
by
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**Delft**
**April 2007**

**To God be the Glory**

Dedicated to

My parents, Mr. and Mrs. Ahmed Ben Ibrahim, My siblings, Naseeya, Saeed and Abdul-Majeed, all relatives, colleagues and friends

## Abstract

The availability of permanent streams of sewage-contaminated urban wastewater emanating from various cities in developing countries has enabled small-scale farmers to diversify their cropping practices. In most cases, not only do the nutrients in the wastewater increase crop yields but also the practice is particularly lucrative during the dry season when wholesale market prices usually rise. However, the direct use of urban wastewater for irrigation in most cities such as in Accra, Ghana has potential health risks; this is as a result of the presence of various microbiological pathogens particularly in raw and partially treated urban wastewater.

The processes of Quantitative Microbial Risk Assessment (QMRA) and Hazard Analysis and Critical Control Points (HACCP) systems are partly used as tools to analyse pathogen risks leading to potential infections. These are carried out at various exposure points via the chain of events leading to the consumption of wastewater irrigated farm produce (lettuce as a case study). The analysis was based on estimation of pathogen exposure and human dose-response models. The study was in such a way that the estimated risk of infections (per day and ultimately per year) through the various potential exposure routes are compared with the reported water/food borne disease incidences in the Accra Metropolitan Area. Some reasons for differences between the reported cases and estimated infection risks are not limited to uncertainty in the estimated infection risks (system robustness), differences in host immunity for pathogen circulating in the environment and underreported cases of illnesses. Additionally, the reported cases of diseases could also be due to other food or water contamination related risks.

For realistic cost-effective measures in reducing infection risks or hazards due to wastewater irrigation in Accra to be made, a comprehensive cost-benefit analysis is required. However, some interventions (measures) to curb or reduce the hazards/risks due to urban wastewater irrigation in Accra were recommended. With the aid of sensitivity analysis, semi-quantitative microbial risk assessment and ranking of potential risk by exposure points some measure to reduce the risk of infection and subsequent illness thereof were proposed. These were not limited to retention/with-holding of wastewater at each farm site for couple of days before irrigation, protective clothing by farmers, fencing of wastewater storage sites and various forms of washing of lettuce before consumption among others. These recommended measures are in line with the research activities outlined within the EC funded SWITCH project. Furthermore, Goal 7 (targets 9 & 10) of the Millennium Development Goals (MDG's) reiterated the need for ensuring environmental sustainability particularly in developing countries such as Ghana. Goal 6 (target 8) of the MDG's also highlighted the need to halt and begin to reverse the incidence of malaria and other major diseases.


Keywords: quantitative microbial risk assessment, hazard analysis and critical control points, pathogens, exposure points, infections/diseases, urban wastewater, irrigation

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## List of Abbreviations

AfDB = African Development Bank

AMA = Accra Metropolitan Assembly (Area)

CSIR = Council for Scientific & Industrial Research

DHS = Department of Health Services, State of California

EPA = Environmental Protection Agency

FAO = Food and Agriculture Organization

GBC = Ghana Broadcasting Company

HACCP = Hazard Analysis and Critical Control Points

ICSMF = International Commission on Microbiological Specifications for Food

IRCWD = International Reference Centre for Waste Disposal

IWMI = International Water Management Institute

IWRM = Integrated Water Resources Management

MDGs = Millennium Development Goals

QMRA = Quantitative Microbial Risk Assessment

SWITCH = Sustainable Water Management Improves Tomorrow's Cities'Health

UN = United Nations

WHO = World Health Organisation

# 1 Introduction

## 1.1 General

The use of urban wastewater for irrigation is being going on for a long time now and the major driving forces of this practice include water scarcity, wastewater as a resource as well as population growth and urbanization (Carr, 2003). A case study in Pakistan by the International Water Management Institute enumerated the benefits of using urban wastewater in agriculture as a combined strategy for the following:

*Direct benefits*

- conservation of water
- recycling of nutrients, thereby reducing the need for farmers to invest in chemical fertilizer, and
- provision of a reliable water supply to farmers particularly in low-income dry areas;

*Indirect benefits*

- prevention of pollution of rivers, canals and other surface water that would otherwise be used for the disposal of the wastewater, and
- the disposal of municipal wastewater in a low-cost and hygienic way (van der Hoek et al., 2002)

Colossal volumes of mostly raw and in some few cases partially treated wastewater from the cities in developing countries including Ghana pollute natural water bodies such as rivers, streams, shallow dugout wells and other drains. These polluted sources are used in and around these cities for irrigation and other purposes. Carr (2003) reported the following facts:

- Median percentages of wastewater treated by effective treatment plants, Africa (0%), Asia (35%), Latin America and Caribbean (14%), North America (90%) and Europe (66%);
- 10% of the world's population thought to consume foods produced with wastewater irrigation;
- 20 million hectares in 50 countries are irrigated with raw or partially treated wastewater;
- Wastewater is an important resource in urban agriculture.

Having recognised the benefits of the use of urban wastewater for irrigation, there is the need for careful assessment of the health risks of irrigation with such waters for the farmers and communities exposed to the wastewater as well as the consumers of wastewater irrigated produce due to pathogenic microbial contamination. The accrued benefits would then have to be weighed against the risks involved in such activities. International guidelines for waters (WHO, 2003b, 2004) as well as other national guidelines strongly advocate a systems approach to managing risks and place pathogens as the highest priority hazards. Nonetheless suitable tools are not yet readily available to support agencies in assessing pathogen risks in the context of a systems analysis (Ashbolt et al., 2004). Within the limited data and information available, the concept of microbial risk assessment models for wastewater irrigation is used in this study to estimate the daily

risk and eventually the annual risk of enteric infection associated with such practices in Accra Metropolitan Area in Ghana.

The pursuit of environmental sustainability is the seventh of eight goals of the Millennium Development Goals (MDGs). The eight goals range from halving extreme poverty/hunger to combating major diseases and providing universal primary education, all by the target date of 2015. These form a blueprint agreed to by all the world's countries and the world's leading development institutions in September 2000. Achieving environmental sustainability requires carefully balancing human development activities while maintaining a stable environment that predictably and regularly provides resources such as freshwater, food, clean air, wood, fisheries, and productive soils and that protects people from floods, droughts, pest infestations, and disease. Therefore, environmental sustainability is necessarily a fundamental objective in the pursuit of the seven other Millennium Development Goals (UN Millennium Project 2005).

The above emphasize the need for the provision of soil nutrients to impoverished small-scale farmers, reliable water for agriculture as well as safe drinking water and sanitation to deprived communities (risk reduction in terms of water related diseases). These apart from being essential component of the targets of the MDGs, also form part of target benefits of the SWITCH project. The SWITCH project aims to achieve a paradigm shift in urban water management to get sustainable, healthy and safe urban water systems. It is a 5-year project financed by the European Commission to develop, apply and demonstrate a range of solutions for sustainable urban water management in 9 cities. Accra is one of the demonstration cities of this project.

## 1.2 Background

Irrigation with urban wastewater in and around cities in many developing countries is a wide spread reality (Bradford et al., 2003) and the city of Accra in Ghana is not an exception. An average of 280 million $m^3$ of wastewater is generated daily in the country and wastewater irrigated urban farming takes place in open spaces (especially lowlands or inland valleys) close to water sources. Open space urban farming is intensive, all-year-round and market-oriented. The plot size in urban areas range from 0.01 – 0.2 ha while that of peri-urban ranges from 0.1 – 0.8 ha (IWMI).

Accra the capital city of Ghana currently has close to two million inhabitants out of which less than 15% is served by conventional sewerage network and sewage treatment plant. This led to an increasing use of individual on-site sanitation facilities and subsequent discharge of high volume of raw wastewater, resulting in an increase in pollution of natural water bodies in the city (AfDB, 2006). These polluted sources being used for irrigation in and around Accra city poses a high public health risks through microbial crop contamination, especially when it concerns food that are consumed raw such as exotic vegetables e.g. lettuce, cabbage, carrot, cucumber, spring onions and green pepper among others. In order to protect the public against pathogenic gastro-intestinal infection contracted through consuming unwholesome food, Accra Metropolitan

Assembly enacted a by law. It states that "No crops shall be watered or irrigated by the effluent from a drain from any premises or any surface water from a drain which is fed by water from a street drain". However, there is no enforcement due to financial and personnel constraints (Obuobie et al., 2006).

According to the World Health Organization (WHO, 1989), the potential health risk is only based on the number of pathogens in the wastewater while the actual health risk depends on three more factors namely:

- The time pathogens survive in water or soil;
- The dose in which pathogens are ineffective to a human host; and
- Host immunity for pathogen circulating in the environment.

Sustainable risk reduction measures have been identified as one of the important aspects of an integrated water resources management (IWRM) approach, which looks at the whole urban water cycle. More so when other approaches such as the banning wastewater irrigation or restricting the types of crops irrigated (Drechsel et al., 2006). The aforementioned measures are in line with the research activities outlined within the EC funded SWITCH project. Furthermore, Goal 7 (targets 9 & 10) of the Millennium Development Goals also reiterated the need for ensuring environmental sustainability particularly in developing countries such as Ghana.

## 1.3 Case Study Area

Accra, which lies in the Greater Accra and administrative region, is the capital city of Ghana. It covers an area of about 230 to 240 km2 (Obuobie et al., 2006). With an annual population growth rate of about 3.4 % in its current administrative boundary, Accra has an estimated population of 1.66 million (Ghana Statistical Service, 2002). It is interesting to note that about 60 percent of the city's population lives in slums (informal settlements) in its centre while the middle and upper class moves to its periphery. Obuobie at al., 2006 further reported that geographically, Accra lies within the coastal-savanna zone (refer to figure 1.1 for the location map of Accra) with low annual rainfall averaging 810 mm distributed over less than 80 days (Table 1.1). The rainfall pattern of the city is bimodal with the major season falling between March and June, and a minor rainy season around October. Rain usually falls in intensive short storms and gives rise to local flooding where drainage channels are obstructed. Mean temperatures vary from 24 ºC in August (the coolest) to 28 ºC in March (the hottest). Natural drainage systems in Accra include streams, ponds and lagoons (e.g., Songo, Korle and Kpeshie). Floodwater drains and gutters are used for grey water, and often drain into the natural system, polluting heavily the lagoons and Accra's beaches.


Figure 1. 1: Location Map of Accra
Source: www.southtravels.com/africa/ghana/map.html

Table1. 1: Mean annual climate data of Accra

| Rainfall (mm) | Tempe-rature ($^0$C) | Relative humidity (%) | Sunshine duration (hrs) | Wind velocity (km/day) | Potential evaporation (mm) |
|---|---|---|---|---|---|
| 810 | 27.1 | 81 | 6.5 | 251 | 1504 |

Source: Agodzo et al., 2003

The Accra Metropolitan Area is made up of six sub metros namely Okaikoi, Ashiedu Keteke, Ayawaso, Kpeshie, Osu Klotey and Ablekuma (refer to figure 1.2).

Most of the open spaces in Accra are used for the cultivation of food crops like corn, okra, tomatoes and other vegetables. Fertilizers and insecticides are used in these areas. Constant felling of trees, bad farming practices and annual burning has altered the vegetation from "dry forest" and greatly depleted the fertility of the soil. Most animals have been pushed inland because for the rapid expansion of settlements in the Metropolitan area. Many species of snakes (some venomous) and lizards are found throughout the Metropolitan area. Apart from the above-mentioned fauna a great number of domestic animals - donkey, sheep, and goat, chicken are kept domestically in the metropolitan area.

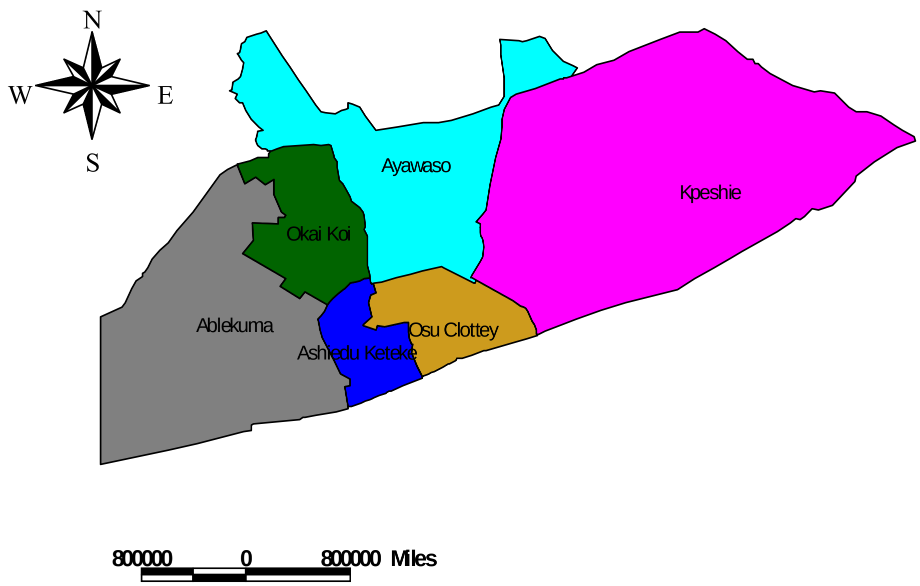


Figure 1. 2: Map of Accra Metropolitan Area showing the six sub-metros
(Source: Accra Metropolitan Health Service)

### 1.3.1 Geology & Soil of the Study Area

***Geology:*** The geology of AMA consists of Precambrian Dahomeyan schists, granodiorites, granites gneiss and amphibolites to late Precambrian Togo series comprising mainly quartzite, phillites, phylitones and quartz breccias. Other formations found are the palaeozoic accraian sediments - sandstone, shales and interbedded sandstone-shale with gypsum lenses. The coastline of Accra comprises a series of resistant rock outcrops and platforms and sandy beaches near the mouth of the lagoons (ghanadistricts.com).

***Soils:*** Generally speaking, the soils in the metropolitan area can be divided into four main groups: drift materials resulting from deposits by wind blown erosion; alluvial and marine motted clays of comparatively recent origin derived from underlying shales; residual clays and gravels derived from weathered quartzites, gneiss and schist rocks, and lateritic sandy clay soils derived from weathered Accraian sandstone bedrock formations. However, according to the information available at the Soil Research Institute in Accra, specific local soil distributions characteristics of the study are described below (also refer to figure 1.3):

1) Adawso-Bawjiase/ Nta-Ofin Association: This is made up of well drained, yellowish brown to reddish brown, iron stone concretionary and gravely sandy

clay loam (Adawso Series). Deep reddish brown to red gravely free sandy clay loam to clay (Bawjiase Series) – Suitable for maize, cassava, yam, pineapple, sunflower and tree crops. The lowland soils such as Nta and Ofin series are good for vegetables and sugarcane.

2) Alajo Association – These soils are deep plastic concretionary clays to clay loams.
3) Ayensu – Chichiwere Association – Mainly occupy levees and terraces along the Densu and Ayensu Rivers. They are deep, greyish brown, imperfect to poorly drained medium to heavy textured soils. Suitable for maize, vegetables etc.
4) Chuim – Gbegbe Association: Consist of red loams to clays, over quartz pepples, on upper slopes (Chuim Series) and Yellowish brown sandy clay (Gbegbe series). Suitable for sweet potatoes, cassava and groundnuts.
5) Fete – Bediesi Association: Very shallow, skeletal, well drained red loamy sands (Korle series). Excessively drained sketal rocky brash (Fete series); Red concretionary clays, Bediesi series. The lower to valley bottoms are occupied by alluvial sands (Krabo series) and sandy clays (Bejua series).
6) Keta series: Pale grey brown, loose sand (Keta series) suitable for coconut cultivation.

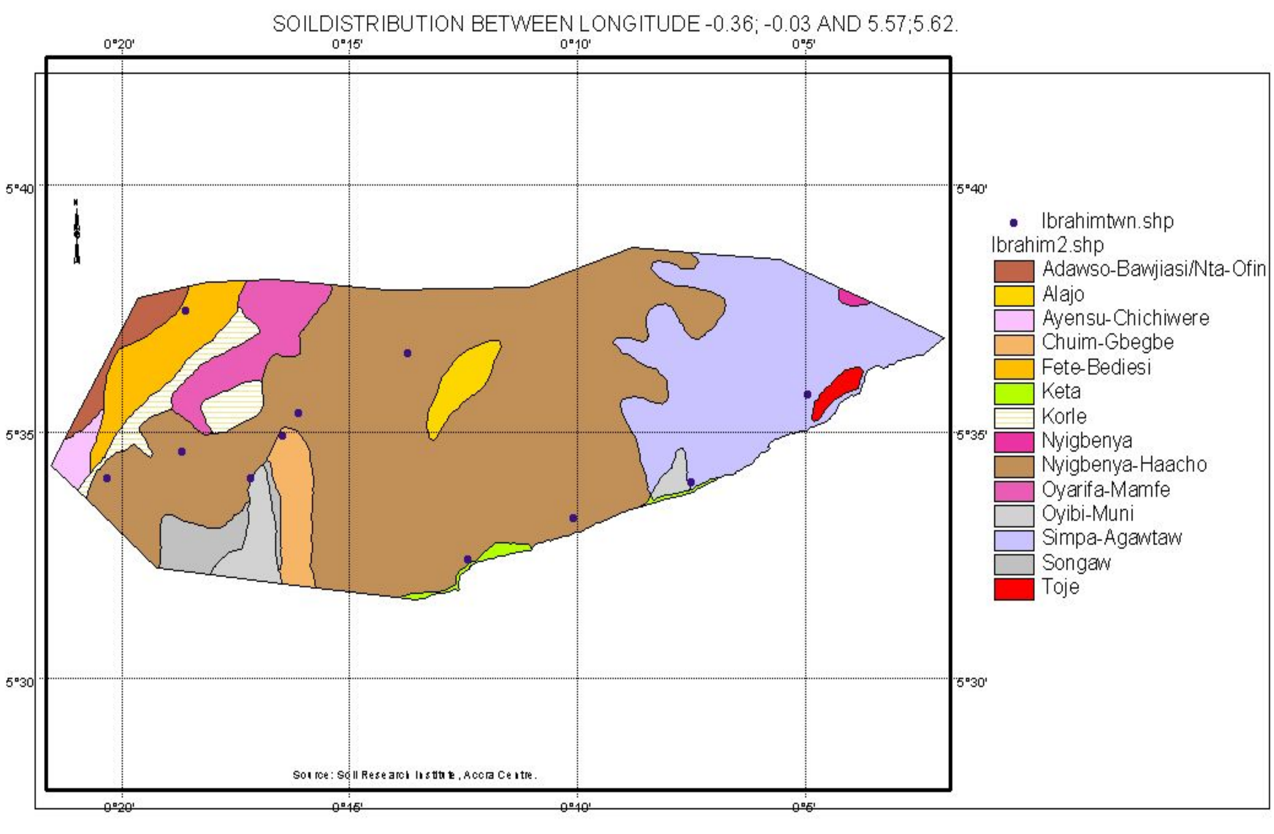


Figure 1. 3: Local Soil Distribution Types within the Study Area
Source: Soil Research Institute, Accra

7) Korle Consociation: Shallow excessively drained, loamy topsoil overlying red clay loam. Suitable for pasture.

8) Nyigbenya – Hacho Association: Mainly upland soils made up of moderately shallow, well drained to moderately well drained gravely and medium textured soils. Suitable for cassava, sugarcane and mangoes.
9) Oyarifa – Mamfe Association – Deep, reddish brown to red, sandy clays (Oyarifa series); and red, clay loams having abundant nonstone concretions and gravels (Mamfe series). Good agricultural soils for maize, cassava, groundnuts, tobacco, pineapple, yams and vegetables.
10) Oyibi – Muni Association – Deep, poorly drained silty clay loams or fine sandy loams very compact (Ada series); compact mottled red clays on marshes and creeks liable to flooding (Oyibi series) and sticky blue and grey alluvial clays or black liquid mud over mangrove (Muni and Truku series). Suitable for sugarcane
11) Simpa – Agawtaw Association: Grey, hard clay pan soils, very difficult to develop (Agawtaw series) and deep upland, sandy loams (Simpa series). Suitable for vegetables.
12) Sungaw Consociation: Deep, heavy clouddy clays with gypseous and calcareous layers and brackish waters (Sungaw series).
13) Toje Consociation: Very deep, red sandy loam to sandy clay loam soils. Very suitable for cultivation of maize, tree crops and vegetables.

### 1.3.2 Sanitation and Wastewater Generation & Disposal

The state of sanitation in Accra is currently not satisfactory since it is characterized by choked drains, indiscriminate waste disposal and uncollected refuse in central waste containers to mention few. These drains and sewers are mostly opened constituting major health hazard. Many factors account for this state of affairs. Notable among them are:

- Poor conceptualization of sanitation
- Lack of adequate sanitary facilities
- Ignorance and irresponsibility of individuals, households and communities
- Lack of community action
- Springing up of unauthorized temporary structures
- Continuously increasing number of squatters
- Indiscriminate hawking
- Lack of regular budgetary allocation for sanitation (ghanadistricts.com)

An estimated amount of 280 million $m^3$ wastewater generated within Ghana is mainly from domestic sources as the city's industrial development is concentrated along the coastline where wastewater, treated or untreated, is disposed of into the ocean. Domestic wastewater collection and disposal in Accra is done using the following:

- Underground tanks such as septic tanks and aqua-privies, either at industrial facilities or at the community level and then transported by desludging tankers to treatment works or dumping sites
- Sewerage systems
- Public toilets
- Pit and improved latrines (Keraita and Drechsel, 2005)

According to Keraita and Drechsel (2005), less than 5% of the households in Accra are connected to piped sewerage systems, while 21% use floodwater drains (gutters) as open sewerage that ends up in nearby water bodies. Some of the metropolitan dwellers discharge their faecal waste into septic tanks while kitchen and other wastes from the home are usually directed into the nearest open drain. As the majority of the urban drains are open, they often serve as defecating areas for households that do not have adequate sanitation facilities.

Apart from some industrial and other private institutions such as hotels having functional wastewater treatment plants, none of the metropolitan ones are in operation at the time of visits. Although, more than half of all wastewater treatment plants in Ghana are in and around Accra (EPA, 2001). A few years ago, a large modern biological treatment plant started operation at Accra's Korle Lagoon; but, it handles only about 8% (one third of its capacity) of Accra's inner-city wastewater from domestic and industrial sources. Only about 10% of the Accra's wastewater is collected for some kind of treatment (Keraita and Drechsel, 2005). Most of the wastewater generated in Accra is discharged directly into the ocean due to its location on the coast. In the same vain, wastewater flows from drains into streams, which are usually used for irrigation. Thus apart from cases where farmers use wastewater directly from drains and broken sewers without further dilution, especially in the dry season wastewater is mostly used in a diluted form mixed with surface runoff and/or stream water (Cornish et al., 2001).

### 1.3.3 Population Distribution and Income Levels in the Study Area

#### 1.3.3.1 Population Distribution of Accra

With a population of 1,658,937 people (2000 National Population Census), Accra, Ghana's capital since 1877, is today one of the most populated and fast growing Metropolis of Africa with an annual growth rate of 3.36%. However, the census population figures do not show the daily generation of people into Accra. It is estimated that the city accommodates between 2.5 million to 3 million people in terms of socio-economic activities aside the residential dimension captured by the 2000 National Population Census (2000 National Population Census). Tables 1.2 and 1.3 give the population distribution for Accra.

Table 1. 2: Age-Sex Structure Of The Accra Metropolitan Assembly (2000)

| Population Cohort | Male Population | Female Population | Total Population | Total % |
|---|---|---|---|---|
| 0-4 | 91852 | 95523 | 187375 | 11.30 |
| 5-9 | 90677 | 97887 | 188564 | 11.37 |
| 10-14 | 84224 | 94779 | 179003 | 10.79 |
| 15-19 | 89473 | 98657 | 188130 | 11.34 |
| 20-24 | 93762 | 93060 | 186822 | 11.26 |
| 25-39 | 84269 | 85598 | 169867 | 10.24 |
| 30.34 | 64528 | 65026 | 129554 | 7.81 |
| 35-39 | 51588 | 52750 | 104334 | 6.29 |
| 40-44 | 42464 | 41755 | 84219 | 5.08 |
| 45-49 | 35335 | 31477 | 66812 | 4.03 |
| 50-54 | 25548 | 23887 | 49435 | 2.98 |
| 55-59 | 18414 | 15096 | 33510 | 2.02 |
| 60-64 | 13603 | 12608 | 26211 | 1.58 |
| 65+ | 31636 | 33461 | 65097 | 3.91 |
| **Total** | **817373** | **841564** | **1,658,937** | **100.00** |

Source: Ghana Statistical Service

It will be realized from the above information given that 51% of the population are females and the rest 49% males. This gives a sex ratio of 1:1.04 males to females.

Table 1. 3: Population by sex and sub-metro

| | | **Sex** | | **Sex ratio** | |
|---|---|---|---|---|---|
| ***Sub-metro*** | ***Population*** | ***Male*** | ***Female*** | ***Males to 100 females*** | ***Sub-metro share of region's population*** |
| Ablekuma | 518,112 | 253,458 | 264,654 | 95.8 | 17.8 |
| Ashiedu Keteke | 88,717 | 41,766 | 46,951 | 89.0 | 3.1 |
| Osu Clottey | 96,634 | 47,314 | 49,320 | 95.9 | 3.3 |
| Kpeshie | 387,013 | 191,203 | 195,810 | 97.6 | 13.3 |
| Ayawaso | 335,394 | 168,009 | 167,385 | 100.4 | 11.5 |
| Okaikoi | 233,067 | 115,623 | 117,444 | 98.4 | 8.0 |
| **Total** | **1,658,937** | **817,373** | **841,564** | **97.1** | **57.2** |

Source: Ghana Statistical Service

### 1.3.3.2 Income Levels in Accra

In respect of varying characteristics and income levels of residents of the Metropolis, Accra has been stratified into 4 income zones/classes to enable viable determination of level of poverty. The stratification is based upon housing characteristic and environmental conditions

of the residential suburbs of the city (ghanadistricts.com). This has been adopted by the AMA and gazetted in the Local Government Bulletin of the Assembly of January, 2002. In most cases, various classes of income levels are kind of overlapped or randomly distributed with all the six sub-metros; although dealers in urban vegetables (including farmers. sellers, street food vendors as well as vegetable consumers) are believed to be mostly from the middle and low income level/class but they also known to be scattered within all the six sub-metros. AMA identifies the following ***(refer to the map of Annex 1)***:

***1st Class Residential Area***
Cantonments, Kanda Estate, Tesano, Airport Residential Area, Ringway Estates, East Ridge, Police Headquarters Area, North Labone, Roman Ridge, Burma Camp, Kuku Hill, Zoti Area, Asylum Down, Dzorwulu, Teshie-Nungua Estates, East Legon, Ablemkpe, south Shiashie, North Dzorwulu, Nungua East, Cantonments, East Cantonments, Independence Avenue, T/Junction, Ridge, Dansoman (these are mostly located in Osu Klottey sub-metro and outskirts of AMA).

***2nd Class Residential Area***
South Kaneshie, Kokomlemle, W/Okponglo, Lartebiokorshie, Link Road, Osu, Accra new Town, South Labadi, Mataheko, Akokorfoto, Alajo, Darkuman, New Abossey Okai, Teshie new Town, Asylum Down, Akweteman, Sahara, Chorkor, Sakaman, Labadi-Aborm, East Legon, North Kaneshie, Apenkwa, Odawna, Nii Boi Town, Old Dansoman, Achimota, Tesano, North Labone, Nungua, Mantseman, Avenor, Dansoman, Ablemkpe, Kwashieman, Agbogbloshie, Osu, South Amanhoma, Osu Ako-Adjei Estates, Sempe New Town, Tesano, East Legon (Okponglo), Kotobabi, Odorkor, Okaishie, South Odorkor (these are mostly located in Ablekuma, Okai Kwei, Ahsiedu-Keteke sub-metros).

***3rd Class Residential Area***
Sukura, Nima, Aborfu, Bubuashie, Mamobi, Mampose, Gbegbeyise, Shiabu, Zabramaline, New Mamprobi, New Fadama, Chemuna, North Labone, Korle gonno, Osu Alata/Ashante, Alajo, South Shiashie, Avenor Area, Dansoman Amanhoma, Osu Ako-Adjei, Nungua-Zongo, Kotobabi, Odorkor, Darkuman (these are mostly located in Ayawaso and Ablekuma sub-metros).

***4th Class Residential Area***
Teshie Old Town, Nungua Old Town, Asere, Bukom, Chorkor, UssherTown, Abossey Okai, Zongo (these are mostly located in Kpeshie, Ashiedu-Keteke submetros).

### 1.3.4 Health Characteristics of the Study Area

#### 1.3.4.1 Health Services

Generally there are several levels and categories of health facilities within the metropolitan area. The categories include government, quasi-government, mission and private. The levels comprise of hospitals, health centres/health post and clinics. Table 1.4 shows the list of health facilities under each sub in Accra metropolis as provided by the Accra Metropolitan Health Service (27 in total).

Table 1. 4: Sub-metros with corresponding health facilities

| **Sub-metro** | **Hospitals/clinics** |
|---|---|
| Kpeshi Submetro | 1. LA General Hospital<br>2. Airport Clinic |
| Ayawaso Submetro | 1. Maamobi Polyclinic<br>2. Mallam Atta Clinic<br>3. Nima Government Clinic<br>4. Nima 441 PHC Clinic<br>5. James Camp Clinic<br>6. 37 military hospital<br>7. Legon hospital |
| Okai Koi Submetro | 1. Kaneshie Polyclinic<br>2. Achimota Hospital<br>3. Manna Mission |
| Ashiedu Keteke Submetro | 1. PML Hospital<br>2. Ussher Polyclinic<br>3. Makola Clinic<br>4. Fire Service Clinic |
| Ablekuma Submetro | 1. Mamprobi Polyclinic<br>2. Dansoman Health Centre<br>3 Korle Gonno (Korle bu) |
| Osu Clottey Submetro | 1. Adabraka Polyclinic<br>2. Civil Servant Clinic (Mental Hospital)<br>3. Castle Clinic<br>4. TUC Clinic<br>5. Parliament Clinic<br>6. Stadium Clinic (Trust Hospital)<br>7. Ridge Hospital<br>8. Police Hospital |

Source: Accra Metropolitan Health Service

#### 1.3.4.1 Incidences of Diseases

According to the information obtained from the metropolitan health service, the major health problems of AMA are essentially communicable diseases due to poor environmental sanitation, ignorance, and poverty. Table 1.5 presents reported cases of some of these diseases.

Table 1. 5: Reported incidences of some communicable diseases in AMA

| Year | Tyhpoid | Cholera | Diarrhoea | Infectious Hepatits | Intestinal Worms | Skin Diseases & Ulcers | Malaria |
|---|---|---|---|---|---|---|---|
| 2002 | 2350 | 760 | 26741 | 213 | 6759 | 30861 | 265917 |
| 2003 | 1620 | 20 | 24439 | 167 | 4255 | 32999 | 233070 |
| 2005 | 2037 | 1084 | 32765 | 169 | 3870 | 36535 | 302478 |

Source: Accra Metropolitan Health Service

Songsore et al. (2005) hinted that the first important point to make is that the environmental route to disease causation looms large within the entire metropolitan area affecting both the wealthy and the poor. It further revealed that the morbidity profile suggests that the major health problems still remain preventable and communicable diseases associated with deprivations in income, social capital and environmental assets. This is confirmed by the commonly reported diseases at the various health centers within the metropolis (refer to Annex 2). It is worth noting that since the introduction of cholera in the country in 1970, the disease has become endemic with seasonal outbreaks that coincide with the onset of the rainy season. The prevalence of water/food borne diseases in the study area gives an indication of the occurrences of pathogenic microorganisms in the various discharged sewage, which eventually mix up with urban run-offs. It is even more worrying in the current situation where none of the metropolitan sewage treatment plants is operational.

Considering only the medical centers/ hospital with in the AMA, under-reported cases of diseases could be estimated at approximately 19% (as 5 out of the 27 registered hospitals/clinics having been reporting to the metropolitan health office within the years of consideration, refer to Annex 2). Underreported cases were not available when AMA health office was contacted; hence an underreported case of 54% community-based surveys reported in China was used (WHO, 2007); that of AMA could be more than that taking into account numerous private clinics that don't report disease incidences to the AMA not to mention sick individuals that do not even visit hospitals/clinics for treatment. 73% (19 + 54) underreported cases was therefore used for the study area as none of that of African countries could be found as at the time of searching.

## 2 Problem Statement

Streams, dugout wells as well as other drains polluted with raw (most of the time) and partially treated wastewater have been the sources of irrigation water in urban city of Accra for the cultivation of perishable crops/vegetables which are mostly consumed raw. These sources of irrigation water are increasingly becoming polluted especially with faecal matter (pathogens) due to poor and inadequate sanitation infrastructure in the urban areas (Cornish and Kielen, 2004; Keraita et al., 2003; Keraita and Drechsel, 2004). The practice has health implications, which need to be addressed (IRCWD, 1985; Shuval et al., 1986; Mara and Cairncross, 1989). Furthermore, adequate spotting of where to invest the limited available budgets for optimum benefits remains a difficulty.

In view of the potential health risks to vegetable farmers, their families, nearby communities and various groups of customers it is necessary to investigate the important exposure points.

# 3 Research Objectives

## 3.1 General Objective of the research

The overall objective of this research is to assess the microbial risks of urban wastewater irrigation in Accra and to suggest sustainable risk management approach while maximizing the health benefits. This is towards achieving the MDG's in particular goal number seven that's on Environmental Sustainability.

## 3.2 Specific Objectives of the research

The specific objectives include:

- To identify the sources of wastewater, the farm locations and types of crops irrigated with urban wastewater including the markets and the categories of the consumers in Accra (i.e. the buyers);
- To identify potential exposure sites/points so as to rank the infection risk of the various points;
- To compare the estimated microbial risks of infection with the reported disease incidences in Accra Metropolitan Area; and
- To suggest some cost-effective interventions (measures) to curb the hazards/risks due to such activities.

## 3.3 Research Questions

In order to achieve the set objectives, the following research questions have been formulated for this research study:

- What are the possible sources of wastewater used for urban irrigation in Accra? Furthermore, where are such farms located in the city and what type of crops are being cultivated? What about the markets where the produce are being sold as well as the categories of buyers (customers).
- What percentage of such food crops is brought from outside Accra and what percentage of these crops are irrigated with wastewater.
- What are the potential exposure points/ sites of contamination/infections?
- What are the differences between the estimated infection risks as a result of urban wastewater irrigation in Accra and the reported disease incidences? What could be the reason for these differences if there are any?
- What are some of the cost-effective intervention (measures) to curb the hazards/ risks due to wastewater irrigation activities in Accra?

# 4 Literature Review

This section provides a comprehensive literature review on public health (microbial) risks of the use of urban wastewater for irrigation purposes. Quite a number of publications related to the subject matter were used for a clear insight and knowledge of different approaches, concepts, definitions and assessment methods.

## 4.1 The Use of Urban Wastewater for Irrigation

Wastewater from urban areas is a non-conventional water resource for irrigation, saving on the use from fresh water resources. Thus, it contributes to agricultural water demand management. Wastewater contains large quantities of nutrients, but also provides a health risk hazard for individuals exposed to the water, if not properly treated beforehand. In some countries like Tunisia, strict regulations as part of the enabling environment control the use of wastewater. Agricultural products irrigated with it are not meant for consumptive use. In Accra, capital of Ghana, nearly all vegetables are irrigated with wastewater. In Bolivia's city of Cochabamba, the use of treated wastewater as an additional resource to control overall demand is complicated by the location of wastewater treatment plants in the downstream part of the peri-urban area (Vehmeija and Wolters, 2004). Recent wastewater use practices range form the piped distribution of secondarily treated wastewater (i.e. mechanical and biological treatment) to peri-urban citrus fruit farms (e.g. city of Tunis) to farmers illegally accessing and breaking up buried trunk sewers from which raw wastewater is diverted to vegetable fields (e.g. city of Lima) (Strauss and Blumenthal, 1990). It is worth mentioning that agricultural reuse of wastewater is practiced throughout South America and in Mexico. It is also widespread in Northern Africa, Southern Europe, Western Asia, on the Arabian Penisula, in South Asia and in the United States (Shuval et al., 1986; Strauss and Blumenthal, 1990; Asano, 1998; Bahri, 1998; and Khouri et al., 1994).

In a publication by Strauss in August 2000 entitled "Human Waste (Excreta and Wastewater) Reuse", it was estimated that in the order of 10% of the world's wastewater is being used for irrigation (Strauss, 2000). 100% of the wastewater from the cities of Santiago (Chile) and Mexico City are used for irrigation, constituting some 70% and 80%, respectively of the irrigation waters used in the surrounding agricultural zones during the dry season. In South Africa, in the order of 15 – 20% of the wastewater is reused in agriculture (Khouri et al., 1994). Farmers have for long been utilising wastewater, whether treated or raw, in a legal or illegal manner, to compensate for scarce or costly fresh water resources. In contrast to this, planners and decision makers have become aware of the need to make wastewater reuse part of urban strategic sanitation and infrastructure planning more recently only. The recommended revised guidelines for safe use of wastewater in agriculture by the World Health Organization (WHO, 2004) took into account all available epidemiological and microbiological data, which are summarized in table 4.1.

Table 4. 1: Recommended revised microbial guidelines for the use of treated wastewater in agriculture

| Category | Reuse Condition | Exposed Group | Irrigation | Nematodes | FC | Wastewater treatment |
|---|---|---|---|---|---|---|
| **A** | A1* | Workers, consumers and public | Any | $\leq 0.1$ ($\leq 1$) | $\leq 10^3$ | |
| **B** | B1* | B1 Workers (but no children <15 years), nearby communities | (a) Spray/Sprinkler | $\leq 1$ | $\leq 10^5$ (no standard) | |
| | B2* | B2 as B1 | (b) flood/furrow | $\leq 1$ | $\leq 10^3$ (no standard) | As for category A |
| | B3* | B3 Workers including children <15 years, nearby communities | Any | $\leq 0.1$ ($\leq 1$) | $\leq 10^3$ (no standard) | As for category A |
| **C** | C1* | Non | Trickle, drip or bubbler | Not applicable | Not applicable | |

Source: WHO (2004)

**For A1***
Reuse Condition: *Unrestricted irrigation (vegetable and salad crops eaten uncooked, sports field, public parks)*
Wastewater treatment: *Well designed series waste stabilization ponds, sequential batch-fed wastewater storage and treatment reservoirs or equivalent treatment*

**For B1***
Reuse Condition: *Restricted irrigation (cereal crops, industrial crops, fodder crops, pasture and trees)*
Wastewater treatment: *Retention in stabilization ponds in series including one maturation pond or in sequential wastewater storage and treatment reservoirs or equivalent treatment*

**For C1***
Reuse Condition: *Localized irrigation of crops in category B if exposed to workers and public does not occur*
Wastewater treatment: *Pre-treatment as required by irrigation technology, but not less than primary sedimentation*

The faecal coliform guideline (e.g. 1000FC/100ml for food crops eaten raw) was intended to protect against risks from bacteria infections, and the intestinal nematode egg guideline was intended to protect against helminth infections (and also serve as indicator organisms for all of the large settlable pathogens including amoebic cysts). The exposed groups that each guideline was intended to protect and the wastewater treatment expected to achieve the

required microbiological guideline were clearly stated. Wastewater stabilization ponds were advocated as being both effective at the removal of pathogens and the most cost-effective treatment technology in many circumstances (Blumenthal et al., 2000).

## 4.2 Wastewater Microbiology (Pathogens)

According to Bitton (2005) in the third edition of "Wastewater Microbiology", several pathogenic microorganisms and parasites are commonly found in domestic wastewater as well as in effluents from wastewater treatment plants. The four categories of pathogens encountered in the environment are (Leclerc et al., 2002):

**Pathogens & non-pathogens**

***1. Bacterial pathogens***: Some of these pathogens (e.g. *Salmonella, Shigella*) are enteric bacteria. Others (e.g. *Legionella, Mycobacterium avium, Aeromonas*) are indigenous aquatic bacteria. Wastewater bacteria, which are not necessarily pathogens (in fact most are not) have been characterized and belong to the following groups (Dott and Kampfer, 1998):

- Gram-negative facultatively anaerobic bacteria, e.g. *Aeromonas, Plesiomonas, Vibrio, Enterobacter, Escherichia, Klebsiella and Shigella*.
- Gram-negative aerobic bacteria, e.g. *Pseudomonas, Alcaligenes, Flavobacterium, Acinetobacter*.
- Gram-positive spore forming bacteria, e.g. *Bacillus spp*.
- Nonspore-forming gram-positive bacteria, e.g. *Arthrobacter, Corynebacterium, Rhodococcus*.

The faeces of a healthy person contain large numbers of bacteria (> $10^{10}$/g), most of which are not pathogenic. Pathogenic or potentially pathogenic bacteria are normally absent from a healthy intestine unless infection occurs. When infection occurs, large numbers of pathogenic bacteria will be passed in the faeces thus allowing the spread of infection to others. Diarrhoea is the most prevalent type of infection, with cholera the worst form. Typhoid, paratyphoid and other *Salmonella* type diseases are also caused by bacterial pathogens (Feachem, 1983, Rose, 1986 and Shuval *et al*., 1986a).

***2. Viral pathogens***: These are also released to aquatic environment but are unable to multiply outside their host cells. Their ineffective dose is generally lower than for bacterial pathogens. Approximately 140 types of enteric viruses may contaminate water and wastewater. Virus presence in the community wastewater reflects virus infections among the population (Bitton, 1980a). Numerous viruses may infect humans and are passed in the faeces (> $10^9$/g). Five groups of pathogenic excreted viruses are particularly important: adenoviruses, enteroviruses (including polioviruses), hepatitis A virus, reoviruses and diarrhoea-causing viruses (especially rotavirus) (Feachem *et al*., 1983; Rose, 1986 and Shuval *et al*., 1986a).

***3. Protozoan parasites***: These are also released to aquatic environment as cysts or oocysts, which are quite resistant to environmental stress and to disinfection, and do not multiply outside animal/human hosts. Some of the major waterborne pathogenic protozoa affecting humans are not limited to *Giardia lamblia, Entamoeba histolytica, Cryptosporidium, Cyclospora, Balantidium coli and Microsporidia* among others (Bitton, 2005). Many species of protozoa can infect humans and cause diarrhoea and dysentery.

***4. Helminth parasites***: Although these are not generally studied by microbiologists, their presence in wastewater, along with bacterial and viral pathogens and protozoan parasites is nonetheless of great concern as regards human health (Bitton, 2005). It is estimated that about 63% of the Chinese population is infected with one or more helminth parasites, particularly with *Ascaris lumbricoides, Trichuris trichiura*, and hookworms *Ancylostoma duodenale* and *Necator americanus*. Most of these infections are acquired by the food-borne route (Hotez et al., 1997; Xu et al., 1995).

The direct detection of pathogenic bacteria and viruses, and cysts of protozoan parasites requires costly and time-consuming procedures, and well-trained labour. These requirements led to the concept of indicator organisms of faecal contamination.

Table 4. 2: Advantages and limitations of reference pathogens selected/required for modelling in risk assessment

| **Pathogen Group** | **Ref. pathogen** | **Advantages** | **Limitations** |
|---|---|---|---|
| Viruses | Rotavirus | 1. Highly infectious and therefore a conservative model<br>2. Dose-response relationship available<br>3. Endemic throughout the world, and maybe<br>4. particularly important in developed countries | High infectivity may result in overestimation of risk for less infectious viruses such as echovirus |
| | Hepatitis A | 1. Persistent in the environment and to disinfection<br>2. Important disease throughout the world with serious health consequences | 1. Not necessarily reflective of more infectious viruses<br>that cause gastroenteritis<br>2. No dose-response model available<br>3. Not as prevalent in sewage as rotavirus, NLV or adenovirus |
| | Adenovirus | 1. One of the most numerous culturable virus groups in wastewater<br>2.Not as virulent as rotavirus and may better represent enteric viruses in dose-response models | |
| Bacteria | ETEC (e.g. *E. coli* O157:H7) | 1. Highly infectious and relatively persistent in the environment<br>2. Resulted in a number of waterborne outbreaks | 1. Generally not isolated by standard methods for *E. coli*. Numerous enterotoxigenic (ET) strains possible and regionally variable.<br>2. Limited dose-response model available |

| | | | |
|---|---|---|---|
| | *Campylobacter jejuni* | 1. Major water and food borne pathogen<br>2. Sequelae described | 1. Difficult to culture from environmental waters, as may form dormant cells<br>2. Many *Campylobacter*-like environmental organism of unknown health impact |
| | *Salmonella* spp. (nontyphoid) | 1. Major water and food borne pathogen<br>2. Relatively easy to detect in water | 1. Complex methods to enumerate from waters<br>2. Vast range of serogroups, many may not be human pathogens |
| | *Vibrio cholerae* (Cholera-types) | Major pathogen of wet developing regions of the world | 1. No dose-response model available<br>2. Difficult to culture from environmental waters, as may form dormant cells or grow in waters<br>3. Various environmental strains are not human pathogens |
| | *Helicobacter pylori* | Potential waterborne pathogen, although weak epi evidence to date | 1. Environmental growth & forms of this pathogen are poorly understood<br>2. No occurrence data in sewage/excreta<br>3. No dose-response model available |
| Protozoa | *Cryptosporidium* | | |
| | *Giardia lamblia* | | |
| Helminths | *Ascaris lumbricoides* | 1. Major helminth pathogen<br>2. Highly persistent in soil/excreta<br>3. Good methods for estimating numbers | No dose-response model available |

Source: Petterson and Ashbolt (2002)

### 4.2.1 Microbial hazards in reclaimed water

The use of reclaimed water (i.e. untreated, partially treated or even treated sewage) could be hazardous to health due to the presence of microbial pathogens. Sewage is the primary source of hazardous microorganisms; environmental microorganisms such as Legionella spp and mycobacteria may also be present, and may multiply within recycled water systems. Healthy individuals do not normally excrete pathogens. Pathogen density in sewage effluent is therefore highly variable and depends on the incidence of infection in the contributing

population (WHO guidelines, 2005). Reported numbers of pathogens and indicator organisms in sewage are shown in table 4.3.

Table 4. 3: Numbers of microorganisms detected in raw sewage

| Organism | Numbers in sewage (per litre) |
|---|---|
| **Bacteria** | |
| *Escherichia coli* ( indicators) | $10^5$–$10^{10}$ |
| Pathogenic *E. coli* | Low |
| *Enterococci*(indicators) | $10^6$–$10^7$ |
| *Shigella* | $10^1$ –$10^4$ |
| *Salmonella* | $10^3$–$10^5$ |
| *Clostridium perfringens* (indicator) | $10^5$–$10^6$ |
| **Viruses** | |
| Enteroviruses | $10^2$–$10^6$ |
| Adenoviruses | $10^1$–$10^4$ |
| Noroviruses | $10^1$–$10^4$ |
| Rotaviruses | $10^2$–$10^5$ |
| Somatic coliphages (indicators) | $10^6$–$10^9$ |
| F–RNA coliphages (indicators) | $10^5$–$10^7$ |
| **Protozoa and helminths** | |
| *Cryptosporidium* | 0–$10^4$ |
| *Giardia* | $10^2$–$10^5$ |
| Helminth ova | 0–$10^4$ |

Source: Feacham et al (1983), Geldreich (1990), NRC (1996), Bitton (1994)

Protozoa and enteric viruses in sewage are of greater concern than enteric bacteria for two main reasons. First, protozoa and enteric viruses are more difficult than bacteria to remove or inactivate by standard sewage treatment processes. Second, ingestion of low numbers of these organisms (compared with most enteric bacteria) can lead to illness. In developed countries with high standards of health, endemic immunity to enteric viruses is low (Havelaar and Melse 2003, Asano and Levine 1998). In such countries, norovirus is probably the most common cause of infectious diarrhoea (Lopmam et al 2003), whereas, in children, rotavirus is the most common cause of diarrhoea and can even cause fatalities (Havelaar and Melse 2003).

## 4.3 Potential Microbial Contamination Routes and Patterns in Wastewater Irrigation

From the previous section, there is obviously a risk of disease transmission through the use of untreated wastewater for vegetables irrigation. In Mexico, the irrigation of vegetable crops with domestic wastewater showed that the highest bacteria contamination was observed in leafy vegetables such as lettuce (37,000 total coliforms/100g and 3,600 faecal coliforms/100g) and spinach (8,700 total coliforms/100g; 2,400 faecal coliforms/100g).

Vegetable crops were highly contaminated with *Giardia* cysts following irrigation with wastewater. Coriander showed the highest cysts load. Similarly, vegetables were shown to become contaminated with *Cryptosporidium* oocysts and *Giardia* cysts following irrigation with poor quality wastewater effluents (Armon et al., 2002).

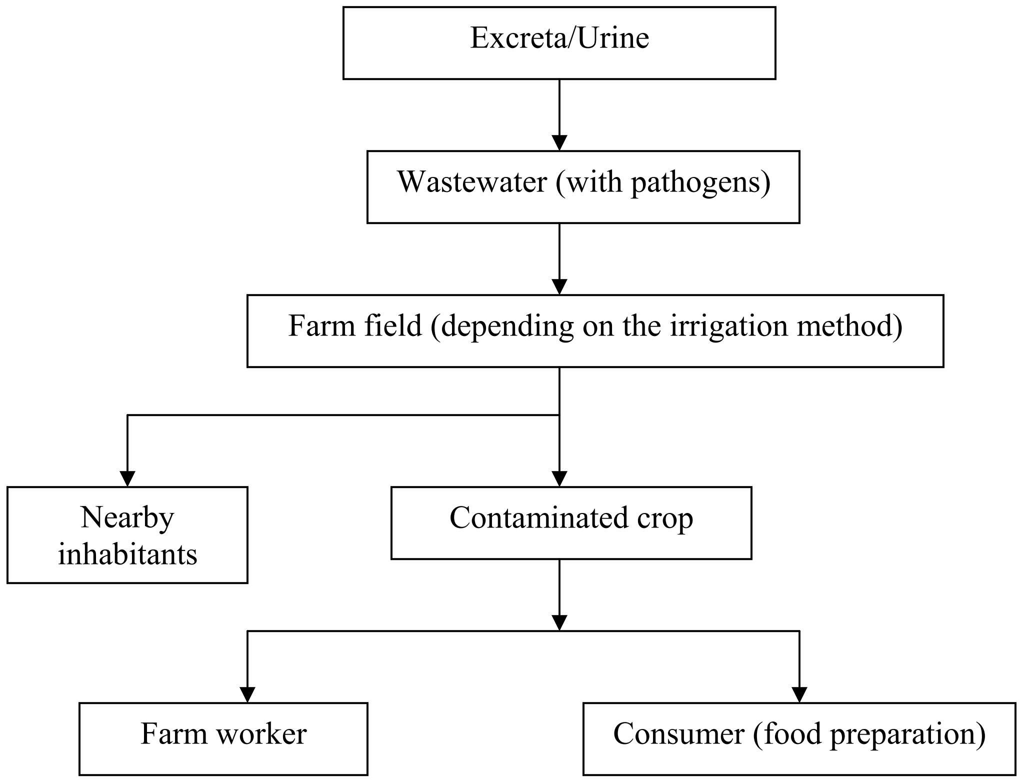


Figure 4. 1: Potential Pathogen Contamination Routes
*(Modified from Bitton, 2005)*

As depicted in figure 4.1, all the pathogens discussed in section 4.2 have the potential to reach the crops on the field and subsequently the farm workers, nearby inhabitants and the consumers. 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. There are many studies on the survival or persistence of excreted organisms in soil and on crop surfaces. A summary is shown in table 4.4.

Table 4. 4: Typical Pathogen Survival Rates at 20° to 30°C in Various Environments*

| **Pathogen** | **Freshwater and Wastewater** | **Survival Time in Days**** | |
|---|---|---|---|
| | | **Crops** | **Soil** |
| **Bacteria** | | | |
| Fecal coliforms*** | <60 but usually <30 | <30 but usually <15 | <120 but usually <50 |
| *Salmonella* (spp.)*** | <60 but usually <30 | <30 but usually <15 | <120 but usually <50 |
| *Shigella**** | <30 but usually <10 | <10 but usually <5 | <120 but usually <50 |
| *Vibrio cholerae***** | <30 but usually <10 | <5 but usually <2 | <120 but usually <50 |
| **Protozoa** | | | |
| *E. histolytica* cysts | <120 but usually <15 | <10 but usually <2 | <20 but usually <10 |
| **Helminths** | | | |
| *A. lumbricoides* eggs | Many months | <60 but usually <30 | <Many months |
| **Viruses** | | | |
| Enteroviruses*** | <120 but usually <50 | <60 but usually <15 | <100 but usually <20 |

* Adapted from Feachem et al. (1983).
** Includes polio, echo, and *Coxsackie* Viruses
*** In seawater, viral survival is less, and bacterial survival is very much less than in fresh water.
**** *V. Cholerae* survival in aqueous environments is a subject of current uncertainty.

Ron Crites and George Tchobanoglous, Small and Decentralized Wastewater Management Systems (United States: McGraw-Hill, 1998)

WHO (1989) concludes that "Available evidence indicates that almost all excreted pathogens can survive in soil... for a sufficient length of time to pose potential risks to farm workers. 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). E. coli O157:H7 contamination of lettuce through flood irrigation with contaminated water has been demonstrated. Cells of the pathogen were shown to penetrate into the stomata and junction zones of cut lettuce leaves, becoming entrapped 20 to 100 µm below the surface of the cut edge. Cells entrapped at subsurface locations were protected from sanitation from chlorine (Ethan et al., 2002).

## 4.4 Microbial Risk Assessment of Wastewater Irrigation

Most reported illness cases due to contact with contaminated wastewater or recreational waters have occurred where either the water has not been treated or where treatment processes have been either inadequate or have broken down (Mackenzie et al., 1994; Shuval, 1991). Factors that can have an influence on the risks associated with wastewater reuse include wastewater types (sources), method of application (irrigation type), potential for human contact (exposure), and treatment level (if available). International guidelines for

waters (WHO, 2003b, 2004) as well as other national guidelines strongly advocate a systems approach to managing risks and place pathogens as the highest priority hazards. Nonetheless, suitable tools are not yet available to support agencies in assessing pathogen risks in the contest of a systems analysis. Quantitative microbial risk assessment (QMRA) is now the preferred approach to assess pathogen risks at points of exposure, based on estimation of pathogen exposure and human dose-response models (Ashbolt et al., 2004).

In general, the process of risk assessment entails four steps illustrated by figure 4.2.

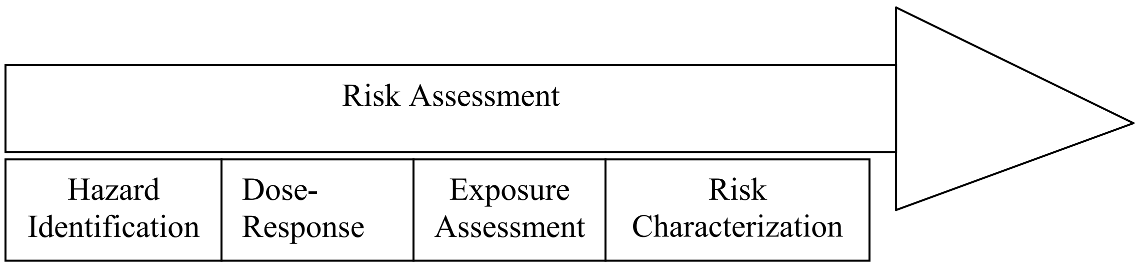


Figure 4. 2: Process of Risk Assessment

Source: National Guidelines for Water Recycling (Managing Health and Environmental Risks; Draft for Public Consultations), October 2005

***Hazard Identification:*** All pathogens that are excreted in faeces could potentially be found in wastewater (Westrell et al., 2004). Hazard identification involves two main aspects; (1) the identification of microbial hazards and reference pathogens that are used as surrogates for the various types of microorganism. (2) Potential variability of concentration of hazards (Marsden, 2005).

***Dose – Response:*** Information on relationships between doses of organisms and responses in the form of incidences or likelihood of illness is generally obtained from investigations of outbreaks or from experimental human-feeding studies (WHO 2004; Teunis et al., 2004; Haas et al., 1999; Messner et al., 2001). In general the doses associated with illness are much lower for viruses and protozoa than for bacteria. Ingestion of 1 – 10 virus particles or protozoan cysts can result in illness. In contrast, ingestion of 103 to more than 106 bacteria (depending on the type of bacterial pathogen) might be required to cause illness. Shigella, typhoid salmonellae and haemorrhagic E. coli are notable exceptions to these figures (WHO 2004; Teunis et al., 2004; Haas et al., 1999) requiring fewer organisms to cause diseases.
Risk assessments are normally based on data and dose-response models developed for human-feeding studies. Lognormal, beta-poison and exponential distributions can be used to determine probability of infection following exposure to different doses of the pathogens (Haas et al., 1999). Hunter et al. have proposed two models of the infection process (2003); namely the exponential model (equation 1) and the beta-Poison model (equation 2).

$$\text{Probability}_{\text{infection}} = 1 - \exp(-rD) \quad \ldots\ldots (1)$$

Where D = pathogen dose; r = fraction of pathogens that survives to produce an infection

$$\text{Probability infection} = 1 - (1 + (D/ID50\ (2\text{-}1/\alpha\text{-}1))^{-\alpha} \quad \ldots\ldots (2)$$

Where D = pathogen dose; α and ID are parameters of the beta-distribution used to describe variability in survival Estimates of daily risk may be extrapolated to yearly risk. When $P_1^*$ and $P_n^*$ are the probabilities of infection after a single (e.g. daily) exposure and after repeated exposures (n times a daily exposure) respectively:

$$P_n^* = 1 - (1 - P_1^*)^n \sim n * P_1^* \qquad (3)$$

The latter simplification is valid as long as $P_1^* << 1$ (Haas et al., 1999)

***Exposure Assessment:*** Exposure assessment generally focuses on the public or consumers; for example;

- Consumers of foods irrigated with recycled water;
- Users and passers-by of municipal areas irrigated with recycled water;
- Occupiers of homes supplied with recycled water through dual re-circulation system

In terms of volume and frequency, the main route of exposure to microbial hazards from recycled water is ingestion. However, some uses of recycled water can involve production of sprays and aerosols. For these uses, microorganisms with potential to cause respiratory illness (e.g. certain types of adenoviruses and enteroviruses) may be significant hazards (Draft guidelines, 2005). The doses of pathogens for various exposures can be estimated from the concentrations in raw sewage based on literature data or in the case of treated sewage, the removal, inactivation or growth at different stages (Westrell et al., 2004).

***Risk Characterization:*** This is the final step of risk assessment. It integrates the information from hazard identification, dose – response and exposure assessment to estimate the magnitude of risks (Draft guidelines, 2005). The estimated results obtained may then be compared to the background endemic level of infection (secondary data from the relevant institution) in the studied community (Westrell et al., 2004).

## 4.5 Hazard Analysis and Critical Control Points

Hazard Analysis and Critical Control Points (HACCP) management system has been applied within food and drinking water production (FAO, 1997; WHO, 2003). According to Westrell et al., 2004, HACCP offers a preventive management and quality assurance approach rather than random monitoring of the end product. HACCP involves identification of critical points to control hazards and maintain best management practices throughout production and distribution. Criteria are established for each control point, which are monitored and corrective actions are established that should be carried out when critical limits are not met (FAO, 1997; WHO, 1999). In Westrell et al., 2004, the concept was applied on treatment, handling and reuse of wastewater and sewage sludge. By this approach, the "chain of production" of these fractions could be quality assured.

Table 4. 5: Procedure Used in HACCP/QMRA case study

| | |
|---|---|
| 1 | Draw out systems structure and define system boundary |
| 2 | Compile literature data on pathogens and treatment processes |
| 3 | Site visits with specific questions |
| 4 | Construct model with data from literature and site specific data |
| 5 | Examine exposure pathways through QMRA and site discussions with personnel |
| 6 | Rank exposures after highest risk |
| 7 | Choose control point(s) for each type of hazardous exposure |
| 8 | Describe parameters governing the performance of a certain control point |

(Adopted from Westrell et al., 2004)

Hazard identification and exposure assessment are common issues across qualitative and quantitative methods. Dose-response models and risk characterization are usually replaced with risk rankings in qualitative assessments. These rankings are generally derived from expert opinion summarizing (or from the results of quantitative estimations):

- Likelihood of possible risk pathways
- Severity of outcome from each pathway
- Numbers of people that may be impacted

Possible ranking schemes are numerous, but follow the generic structure indicated in the following tables:

Table 4. 6: Example of the use of a QMRA model with a HACCP approach to management

| **Possible qualitative risk assessment approach to rank or scale hazardous scenarios** | |
|---|---|
| **Step** | **Comment** |
| 1. Hazard Scenario | Identification of hazardous scenarios, such as raw wastewater irrigation, massive rainfall induced contamination of source water, filter breakthrough or loss of chemical disinfection system; i.e. not necessarily limited to a single pathogen. |
| 2. Likelihood | Ranking or scaling of how likely the event is e.g. # events per year |
| 3. Consequence | Ranking or scaling of the consequence, e.g. short-term injury or ill-health through to permanent disability or death |
| 4. Scale of effect | Consideration of the number of people affected by the hazard scenario |
| 5. Risk score | Different weightings may be given to (2) to (4) and summed to give a value for each hazard scenario |
| 6. Rank | Each hazard scenario is then ranked, to provide a priority list for risk management |

Source: Petterson et al., 2001

Table 4. 7: Descriptive terms for risk score calculation (Davison et al., 2002)

| Item | Definition | Weighing factor |
|---|---|---|
| Almost certain | Once a day | 5 |
| Likely | Once per week | 4 |
| Moderate | Once per month | 3 |
| Unlikely | Once per year | 2 |
| Rare | Once every five years | 1 |
| Catastrophic | Potentially lethal to large population | 5 |
| Major | Potentially lethal to small population | 4 |
| Moderate | Potentially harmful to large population | 3 |
| Minor | Potentially harmful to small population | 2 |
| Insignificant | No impact or not detectable | 1 |

Table 4. 8: Example of Simple risk scoring table for priotising risks (Davison et al., 2002)

| Severity of Consequences | | | | | |
|---|---|---|---|---|---|
| **Likelihood** | Insignificant | Minor | Moderate | Major | Catastrophic |
| Almost Certain | 5 | 10 | 15 | 20 | 25 |
| Likely | 4 | 8 | 12 | 16 | 20 |
| Moderate | 3 | 6 | 9 | 12 | 15 |
| Unlikely | 2 | 4 | 6 | 8 | 10 |
| Rare | 1 | 2 | 3 | 4 | 5 |

The risk score for a particular hazard = likelihood * severity of consequences

# 5 Methodology and Approach

In pursuit of the set objectives of this research study, an adopted approach and methodology for the study have been outlined as follows:

## 5.1 Map of the Study area

Using the area map of Accra Metropolitan Area (refer to figure 1.2) the various sites of the following were identified:

- Urban wastewater irrigation farm areas;
- Types of crops being cultivated;
- Markets locations for the produce; and
- Population distribution and income levels among others.

The metropolitan study area is made up of six sub-metros namely; Ablekuma, Ashiedu Keteke, Osu Clottey, Kpeshie, Ayawaso and Okaikoi. The entire study area could further be sub-divided in respect of varying characteristics and income levels of residents of the metropolis. This follows the population distribution pattern within the city as wealthy people live in sparsely populated and may not be at a high risk compared to the densely populated areas with low-income earners.

## 5.2 Desk Study and Field Work

Desk study in form of further literature search particularly studies on urban vegetable production and consumption in and around the study area. Most of the information used in this research study is obtained from IWMI, Accra office. Visits were made to some farm sites, markets and street food vending spots among others; this is to obtain additional information to complement the ones secured during desk study. Microsoft excel is also used for the estimations of dose (exposure) and infection risks.

## 5.3 Observations and Interviews/ Secondary data

Observational techniques coupled with descriptive studies are being used for this research; these are based on available secondary data gathered from interviewing various experts in some relevant institutions in Accra (refer to Annex 3 and table 5.1). These include the approximate number of farmers at each site, vegetable sellers (mostly women) and consumers. It also include various incidences of water/ food borne diseases reported in some health centers with in the sub-metros of Accra and possible determinants of the diseases in a defined population (as prescribed by Blumenthal et al., 2001). This is also aimed at identifying changes in morbidity and/or mortality in time or to compare the incidence or prevalence of diseases in different geographical areas. For instance, a series of descriptive studies of *Ascaris lumbricoides* infection in Jerusalem have shed light on the role of wastewater irrigation on vegetable and salad crops in the transmission of *Ascaris* infection (Shuval et al., 1985, 1986).

## 5.4 Conceptual Model (with exposure points) and Microbial Risk Assessment

The processes of Microbial Risk Assessment enumerated in Section 4.4 were partly used for this exercise. A range of points of potential exposure to pathogens were investigated; these exposures were obtained during discussions with the experts at the Accra office of the International Water Management Institute (IWMI). They were identified by a systematic on-site survey of the chain of events from wastewater generation and irrigated farms leading to the consumption of the produce (refer to figure 5.1).

In the proposal, conceptual exposure points were to be developed for the various sectional division of Accra city (either based on the sub-metros or population/income levels distribution); however, the various exposure points identified are so randomly and in some cases chaotically sited that it is practically impossible to evaluate. Hence the whole study area is evaluated and analyzed while deductions are made for the various chosen areas based on the socio-economic conditions. Furthermore, evaluation and analysis were based on the percentage of wastewater-irrigated vegetables in Accra compared to that brought from outside Accra, which are mostly irrigated with relatively less polluted wastewater. The frequency of exposure, the approximate number of persons exposed at each point and the amount likely to be ingested per exposure were in most cases determined by estimation. The estimations and assumptions made are based on observation as well as secondary (mostly from IWMI) and literature data. The doses of pathogens of each exposure are estimated from the concentrations in raw sewage obtained from IWMI while the unavailable ones are based on literature data. For this research studies, within the limits of available data and information, disease risk as a result of wastewater irrigation and consumption in Accra is expressed semi-quantitatively and in most cases qualitatively based on the conditional probability of infection (Ashbolt et al., 2004). The final results are expressed as the probability of infections and eventually illness resulting from each exposure; these would be compared to the background endemic level of illness in Accra (obtained from reported cases of water/food borne diseases).

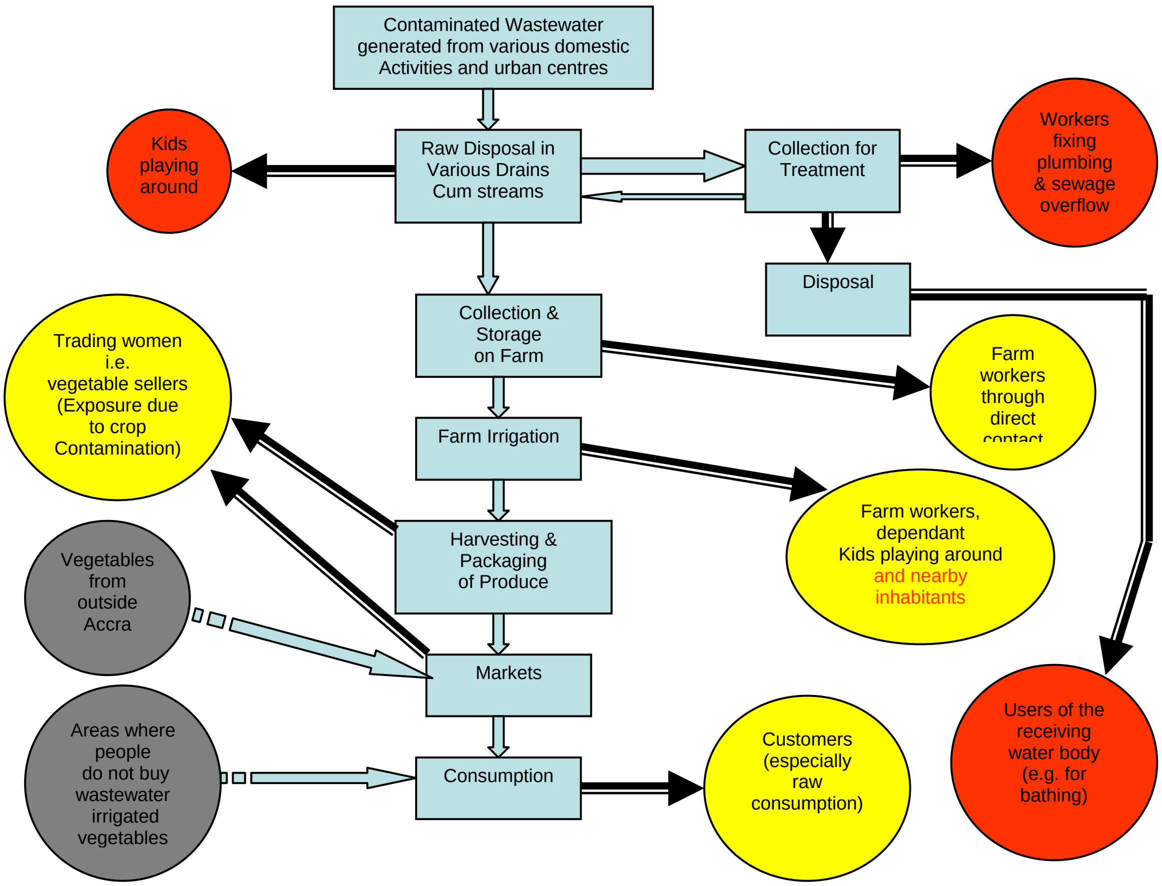


Figure 5. 1: Potential exposure points in chain of events leading to consumption

The exposures in yellow colour are the main focus of this research; refer to the research carried out by Ms. Isabella Lunani on Analysis of the Public Health Risk of Urban Water Systems in Accra by Microbial Risk Assessment for the ones in red colour. IWMI reported that about 65% of vegetables traded in Accra come from outside the city. Apart from few instances of non-wastewater irrigated vegetables sold at some of the supermarkets, it's difficult to identify areas where these types of vegetables are being sold.

In figure 5.1, the exposures in red colour are not considered because they are not within the scope of this research. Furthermore, none of the Accra Metropolitan wastewater/sewage treatment plants is functioning at the time of visits.

From personal observation and discussions with my local mentor at IWMI office in Accra, three major groups of people were identified to be at risk; these include:

- Agricultural field workers at various farm site and their immediate families especially those that help on the farms;
- Vegetable handlers (including market women and street food vendors); and
- Consumers of vegetables

Theoretically those living near the affected fields could potentially be at risk too but the fact is that sprinklers are not being used for wastewater irrigation. It is only the Dzorwulu farm site that sometimes uses this irrigation method with tap water. Furthermore, the fact that there are other major potential sources of air pollution rendered this particular source insignificant.

The table below summarizes some relevant information gathered regarding the various exposure routes:

Table 5. 1: Some Relevant Information Being Sought in Accra

| **Exposure Routes** | **Information being sought** |
|---|---|
| Urban Vegetable Farms | Location of farm sites, methods of irrigation, number of farmers (including members of family if involved), frequencies of irrigation, soil types, farm sizes, irrigation water storage systems, children playing near storage ponds, sources of irrigation water, microbial water quality, time of harvest after last irrigation, distance to the nearest inhabitants among others. |
| Urban Vegetable Markets | Number of major markets involved, approximate number of vegetable sellers, frequencies of sales, packaging/display systems, |
| Consumers (mostly through street food vendors) | Microbial quality of vegetables, preparation processes (of the vegetables before sales), approximate number of street food vendors, approximate number of customers, estimates of quantities consumed per purchase, frequencies of consumption (e.g. per week) |

The consumers of raw vegetables have mostly been traced to the members of the public from all parts of the city who patronize the various Street Food Vendors. A study by the International Water Management Institute (IWMI) estimated that only about 2% of the urban vegetables go directly to the various house holds (Obuobie *et al*., 2006).

Figure 5. 2: Some forms of food vending in Accra

### 5.4.1 Microbial Risk Analysis

The microbial risk analysis method deployed for this study is based on a combination of semi-quantitative and qualitative assessment approaches. Within the limit of available data and information, the principle of risk analysis previously described by Haas *et al.* (1999) was partially followed. Crude methods are used to obtain rough estimates of exposures and other parameters. A conceptual model showing possible process steps for wastewater irrigation of vegetable crops is given in figure 5.3.

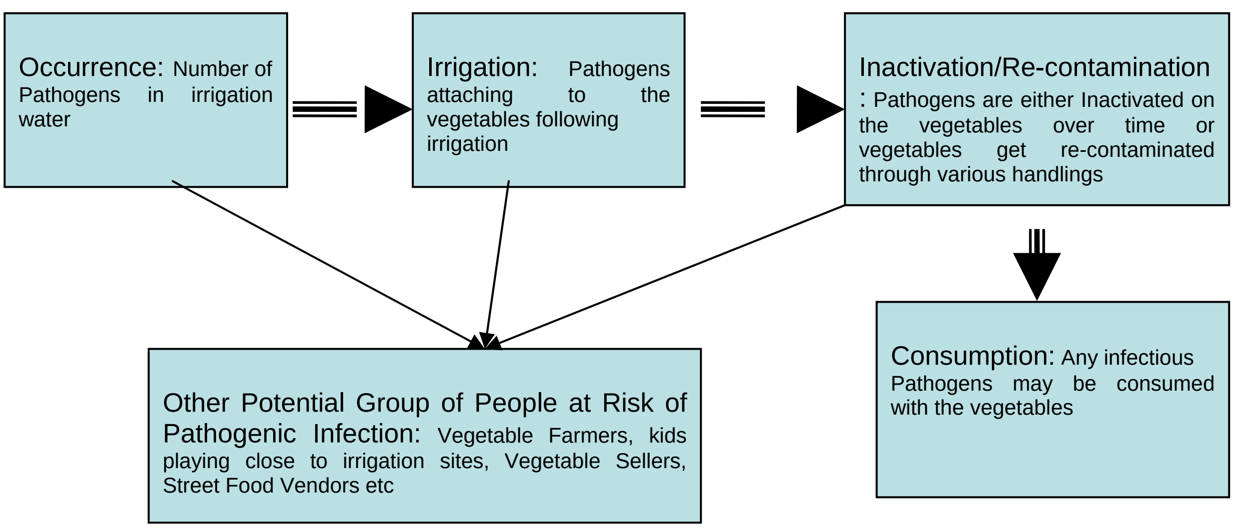


Figure 5.3: A conceptual model showing process steps for wastewater irrigation of vegetables

### 5.4.1.1 Semi-Quantitative Microbial Risk Assessment

Hazard analysis and exposure assessments were carried out to identify possible scenarios on a broad scale. However, it is worth emphasizing that the research limits the potential exposures only to those considered more likely and important within the context of the study area. Doses of selected pathogens identified were calculated (by estimation) and further used in a dose-response assessment in order to quantify the risks for infection. The stepwise procedure for the microbial risk assessment is further described in the following sections.

***1. Hazard Identification in the Study Area***

The first step in any microbial risk assessment is the identification of the pathogen hazards that are to be investigated. In this case, hazard was defined as the pathogen that causes water borne diseases. Due to the inadequate nature of sewage disposal mechanism within Accra Metropolis, all pathogens that are excreted in faeces (which can cause gastro-intestinal infections) could potentially be found in the city's wastewater. Such raw wastewater mixed with run-offs flows through the city's drains and drain-cum-streams is mostly used by the farmers for vegetable irrigation. It is simply not possible for a risk assessment to take into detailed consideration all potential pathogenic microorganisms. Rather, the most relevant pathogens affecting the study population are identified and targeted in the risk investigation (Ashbolt and Petterson, 2004). The results of hazard identification presented in section 6.6.1 were carried out through literature review including studies carried out on urban wastewater (with sewage and open drain-cum-streams) and crops (mostly vegetables) irrigated within Accra. As model organisms for the assessment, *Salmonella, Cryptosporidium, Ascaris lumbricoides, Hepatitis A* and *rotavirus* were selected as reference pathogens for bacteria, protozoa, helminthes and viruses respectively; these and others have been identified as causes of water/food borne diseases within Accra and have been detected in sewage (Mensah et al., 2002, Mensah et al., 2001, Newman, 2001 and Mills-Robertson et al, 2003). The choice of these pathogens was based on health significance within the metropolis and availability of data needed for the estimation (refer to tables 5.3 & 5.4 and Annexes 2).

***2. Exposure Assessment***

People may be exposed to hazards through different routes (i.e. hazard pathways) during urban wastewater irrigation, harvesting, marketing as well as consumption of especially uncooked exotic vegetables. In addition to the hazard pathways, there are likely to be numerous scenarios that increase or decrease pathogen risk. Some examples are not limited to heavy rain/storm events where wastewater/excreta is splashed on vegetable leaves or moved to areas normally protected from contact, the use of polluted water for washings and unhygienic nature of vegetable handling and sales points. Such scenarios may be manageable while others may not and hence the need to interface QMRA with the hazard analysis critical control point (HACCP) approach (Ashbolt & Petterson, 2004). This is done by identifying the higher risk pathways and events that management should focus on and potential target levels to control particular pathogens. The exposure to hazards were identified through discussions with the staff of IWMI (most especially my local mentor) as well as brief on-site surveys at some farm sites, markets and street food vendors. Some informal interviews were carried out for each of the identified groups. Most of the data and information used are obtained from Obuobie et al., 2006 and Amoah, 2004. Estimates of the number of farmers at each site, vegetable sellers, food vendors, daily vegetable consumers & quantity consumed were obtained from these sources. The rest

are the frequencies of exposures, concentrations of pathogens in wastewater, vegetables and other material that people could be exposed to, including incidences of diseases frequently complain about by the exposed groups. Probable percentage/ fraction reduction in pathogens before intake, some likely ingested volumes and other relevant data/information that were lacking are either estimated or assumed based on similar studies or literatures. Some of the findings are shown in Table5.2.

Table 5.2: Points of exposure with estimations on volume ingested, frequency and the number of persons affected

| Exposure | Volume ingested per exposure (ml or g)[1] | Frequency | Number of persons affected |
|---|---|---|---|
| a) Wastewater Irrigation Farmers: | | | |
| 1. Marine drive site | 1mL | 3 times per week for 8 months in a year | 98 |
| 2. Dzorwulu/Plant Pool site | Same as above | Same as above | 62 |
| 3. La site | Same as above | Same as above | 400 |
| 4. Korle-bu site | Same as above | Same as above | 80 |
| 5. GBC site | Same as above | Same as above | 26 |
| 6. CSIR and IWMI offices site | Same as above | Same as above | 38 |
| b) Children playing at various wastewater storage sites | 1mL | once per month | 337 |
| c) Harvest of vegetables (lettuce as a case study) | 1mL | 9 times per year | 40 |
| d) Sale of vegetables (permanent & mobile retailers) | 0.5mL | thrice per week | 421 |
| e) Street food vending | 3g (0.3mL) | 6 times per week | 5000 |
| f) Consumption of raw vegetables | 12g (1.3mL) | 3 times per week | 280,000 |

All figures used in table 5.2 are not always the same all year round; most are the available ones at the time of IWMI's research. Those of GBC and CSIR sites were estimated after brief interactions with some of the farmers. Most of the volumes ingested apart from the daily raw vegetable consumption are either estimated or assumed based on similar studies or literatures.

1mL volume likely to be ingested by each farmer per exposure is used as a default from routine/accidental ingestion figures by the WHO draft guideline 2005. The frequencies as well as the number of farmers affected were obtained from Obuobie et al 2006.

[1] Estimated irrespective of amount of wastewater used and contact time per exposure

Estimate of 1ml ingestion by children playing at the vicinity of wastewater flowing/storage site was used in a similar study by Westrell et al. (2004) for children playing at wetland inlet. The children's frequency of exposure was estimated based on discussions with some of the farmers. It is considered a rare event because according to them, apart from their own children (attending schools most of the time) engaging in some errands on the farms they don't entertain the presence of other kids within the farms vicinity. The affected number of children was estimated from Obuobie et al. (2006); its study on the profile of urban vegetable farmers in Accra revealed that about 60% of the farmers (approximately 704 in totals) are above 30 years. Assuming 80% of these are helped by a child once every month.

The estimated 1mL ingestion during harvest was used as a routine exposure from indirect ingestion via contact with vegetables as suggested by the WHO draft guideline, (2005). The frequency of exposure was deduced from the number of harvest of lettuce per year as investigated by Obuobie et al. (2006). Additionally, the number of persons affected during each harvest was obtained from the same source; the outcome of the investigation was that harvesting is mostly carried out by the wholesalers (refer to table 6.8). The daily consumption of raw vegetables, the frequency of exposure as well as the number of consumers were investigated by IWMI (also in Obuobie et al., 2006). According to the WHO Draft Guidelines, 2005, 100 g of lettuce leaves hold 10.8mL of water, therefore 12g will hold 1.3mL.

The number of persons affected through the sale of vegetables and food vending as well as frequency of sale of vegetables were also obtained from Obuobie at al. (2006); however, the frequency for street food vending was obtained from direct interaction with some of the vendors who indicated that in most cases, it's only on Sundays of every week that they don't sell food. Furthermore, it came to light during the discussions held with them that they also consume about a quarter of what their customers buy at a time (strictly on assumption). The estimated volume ingested by the permanent & mobile retailers was assumed to be half of the ingested amount during harvest; the assumption was that about half of the attached water would have been lost from the vegetables through processes such as evaporation/dehydration before getting to the markets.

For potentially exposed consumers or any other victim, the needed parameters to estimate the dose (i.e. exposure.) include the followings

- Concentration of indicators (to estimate the number of pathogens)
- Wastewater remaining on crops
- % die-off between harvest and consumption
- Consumption per exposure

Hence, dose per event could be estimated as below:

*Dose per event=pathogen concentration in source water/vegetable * log reduction * exposure (amount consumed)*

It is worth emphasizing that since the results of direct analysis of each pathogen concentration was not available, estimates of the reference pathogens were made taking into consideration the ratios of each pathogen to that of feacal coliform obtained from literature (see table 5.3).

Table 5. 3: Pathogens Indicator Ratio[2]

| Pathogen | Fecal Coliforms | Fecal Streptococci |
|---|---|---|
| *Virus* | $1:6x10^3$ | $1:10^3$ |
| *Salmonella* | $1:3x10^2 – 3x10^6$ $(3 * 10^4)$* | $1:5x10^1 – 5x10^3$ |
| *Shigella* | $1:6x10^3 – 3x10^6$ $(1.3 * 10^5)$* | $1:10^3 – 5x10^5$ |
| *Helminth* | $1:3x10^4 – 3x10^6$ $(3 * 10^5)$* | $1:5x10^3 – 5x10^5$ |
| *Protozoa cysts* | $1:1.5x10^4 – 3x10^5$ $(6.7 * 10^4)$* | $1:2.5x10^3 – 5x10^4$ |

Table adapted from DHS (DHS 1987).
* figures in brackets are the Geometric Means

Although due to other confounding factors including the prevailing local environmental conditions, other possible scenarios are also investigated, the following assumptions were made for worst case scenarios of the microbial risk assessment:

- Urban wastewater irrigation within Accra is carried out without any form of treatment; hence log reduction of pathogen is negligible.
- 100 g of lettuce leaves hold 10.8 mL water and other produce might hold up to about 2 to 3 mL per 100g (Draft Guidelines, 2005).
- All the pathogens in the hold-up water survive and are attached to the vegetable crops.
- A fraction of pathogens continue to be infectious until consumption.
- There is no formation/production of sprays and aerosols since sprinklers are not used for irrigation in Accra's urban vegetable farms. Pipe borne water being used in Dzorwulu site where this system of irrigation is partly practiced.
- No cross contaminations or additional contamination during harvest and marketing.
- Notwithstanding the presence of environmental conditions such as high temperature and humidity favouring log reduction, there is no significant pathogen die-off or reduction between harvest and consumption because in most cases, irrigation is carried out until the day of harvest (except some form of washings before consumption).

### 3. *Dose-Response Assessment*

This is vital to microbial risk assessment as it provides a link between exposure and the probability of potential infection. In order to estimate the probabilities of infection following potential exposures to the identified hazards within Accra, the dose-response relationships in Table 5.4 and Annex 4 are used.

According to Ashbolt and Petterson (2004), models for infection have been developed based on the "single hit" theory. The assumptions of the single hit model are: the inoculum (pathogens present n the wastewater or lettuce in this case), is known but for poisson uncertainty, that organisms act independently, individual probabilities of success do not depend on their numbers (independence) and that any single organism can start infection (Teunis *et al.*, 2002).

[2] **Source:** Pathogen Total Maximum Daily Load For The New River And Implementation Plan (May 23, 2002) Prepared by: Regional Board Staff Watershed Protection Branch of California Environmental Protection Agency Regional Water Quality Control Board Colorado River Basin Region

At present, there appears to be no information on the dose-response data for *Ascaris*. Therefore, there are no r estimates for this organism. The r- value of 0.0198 for *Giardia* another protozoan was used in estimating the probability of infection as they have the same infective dose, see table 5.4 (Brooks et al., 1991).

Table 5. 4: Dose –response relationships for reference organisms

| ***Organism type*** | ***Distribution*** | ***Model*** | ***Parameters*** |
|---|---|---|---|
| Enteric virus (rotavirus) | Beta-Poison | $P = 1 – (1 + d/N_{50} (2^{1/\alpha} – 1))^{-\alpha}$ or $P = 1 – (1 + d/\beta)^{-\alpha}$ | $\alpha = 0.27$ $N_{50} = 5.60$ $\beta = 0.42$ |
| Bacterium *(Campylobacter jejuni)* | Beta-Poison | $P = 1 – (1 + d/N_{50} (2^{1/\alpha} – 1))^{-\alpha}$ | $\alpha = 0.145$ $N_{50} = 896$ |
| Protozoan *(Cryptosporidium parvum)* | Exponential | P = 1 – exp (-rd) | r = 0.059 d = dose |
| Protozoan (*Giardia lamblia*) | Exponential | P = 1 – exp (-rd) | r = 0.0198 d = dose |
| Helminthes (*Ascaris lumbricoides)* | Not available (Exponential) | Not available (P = 1 – exp (-rd)) | r = 0.0198 |

Sources: Haas et al. (1999), Ashbolt & Petterson (2004) and Draft Guideline (2005)[3]

Detailed results and outcome of the semi-quantitative microbial risk assessment carried out are duly presented in section 6.6.1.

**4. Exposure assessment due to other confounding factors**

The earlier exposure assessments carried out leading to the estimation of the risk of infection were based on worst case scenarios. These involve some extreme assumptions made; however, there are some practices and activities (in form of preventive measures) undertaken by some of the exposed individuals as well as natural inactivation/die-off of some pathogens as a result of prevailing local environmental conditions. Taking some of these into consideration, the findings that have been summarized in table 5.5 are used for different scenarios to estimate infection risk. Further explanations are not limited to the following:

- Although urban wastewater irrigation within Accra is mostly carried out without any form of treatment; however, apart from the fact that some few farmers use pipe-borne water for irrigation, others use partially treated wastewater and dug-out pond. Therefore, log reduction of pathogen is a possibility.
- The above statement means that not all the pathogens in the hold-up water would survive to get attached to the vegetable crops.
- Not all attached pathogens would continue to be active or infectious until consumption. This is because when exposed on leaves (out of wastewater), not all

3 α and r are parameters describing probability of infection; d = dose; $N_{50}$ = median infective dose; P = probability of infection. Model parameters are as described in Haas et al (1999), except for Cryptosporidium where the data of Messner et al (2001) have been used.

pathogens could survive the harsh local environmental conditions i.e. high temperature and humidity (refer to table 1.1).

- In most cases, there would be incidences of cross contaminations or additional contamination during harvest and marketing. This is brought about by unhygienic nature of harvesting, packaging and transportation as well as sales of the produce.
- Even though in most cases irrigation is carried out until the day of harvest, preventive measures such various form of washings including routine inspections of street food vendors by the public health department of the AMA and good personal hygiene among others could also lead to significant pathogen die-off or reduction before consumption.

Table 5. 5: Summary of pathogen reduction due to some activities

| **Activity/Protection measure** | **Plausible reduction in exposure to pathogens (log units)** | **Reference/Source** |
|---|---|---|
| Irrigation with shallow reservoirs/ withholding pond | 0.5 per day[4] | Draft WHO Guidelines, 2005 |
| Irrigation with partially treated wastewater | 0.5 - 1 | Draft WHO Guidelines, 2005, Obuobie et al., 2003 |
| Pathogen die-off on the surface of crops after the last irrigation | 0.5 – 2 per day | WHO Guidelines, 2006, Obuobie et al., 2003 |
| Washing of produce with clean water | 1 | WHO Guidelines, 2006, Amoah, 2004 |
| Disinfection of produce (using salt solution) | 2 | Amoah, 2004 |
| Disinfection of produce (using one part vinegar on two parts water) | 5 | WHO Guidelines, 2006 |
| Cooking of produce (but in this case, washing with warm water) | 5 – 6 (<5) | Draft WHO Guidelines, 2005 |
| Kids protected from wastewater storage sites (including buffers) | 1 – 2 | Draft WHO Guidelines, 2005 |
| 65% of the vegetables are from outside Accra | 1 – 2 | IWMI, |
| Irrigation with pipe-borne water | ($10^1$MPN/100ml detected) | Obuobie et al., 2003 |

(modified from WHO, 2006,)

The summary of the findings in table 5.5 was informed by the following:

a) Wastewater irrigation farmer: Although majority of the farmers use wastewater flowing through drain cum streams, it has been established by IWMI that pipe borne

[4] Based on virus inactivation, enteric bacteria probably inactivated at a similar rate. Protozoa will be inactivated if withholding periods involved desiccation. Based on Haas et al (1999), Asano et al (1992), Tanaka et al (1998), Mara and Horan (2003), Petterson et al (2001) and advice from food technologists and air quality experts

water and dug-out reservoirs are in use at the Dzorwulu/Plant Pool site. Furthermore, at La farm site some farmers use pipe borne while very few use water from a treatment pond.

b) On the issue of kids playing at various wastewater storage sites, it was observed that kids help mostly in weeding and other errands and not irrigation.

c) Harvest of vegetables (lettuce as a case study): Market women are seen washing vegetable produce with tap water although most of the times with wastewater from the drains.

d) Sale of vegetables (market women): Just like above, washings were done although in most cases using the same water repeatedly therefore high probability of recontamination.

e) Street food vending: Vegetables were mostly processed and washed with warmed water and salt or vinegar. Routine inspections are also carried out by health department of AMA (refer to Annex 5). From the few interviews carried out, personal hygiene is also seen as a way of attracting more customers.

f) Consumption of raw vegetables: Same as for street vending but with more emphasis on hygiene. Furthermore about 65% of the vegetable (lettuce) consumed in Accra are brought from outside the city often irrigated with relatively less polluted wastewater.

In the case of Helminthes it is assumed that due to the prevailing irrigation method, more than 70% would be retained in the irrigation water even after with-holding (brought about by re-suspension of the helminthes). Furthermore, Amoah, 2004 reported that more than half are removed from the vegetables depending on the washing method used before consumption. The outcome of the estimation of infection risk after taking the above confounding factors are also presented in section 6.6.1 followed by some discussions on the outcome.

**5. Sensitivity Analysis**

Due to variability and uncertainty of the estimated parameters used in the models used, a method of sensitivity analysis was further used in this research. An extensive review undertaken by Frey and Patil (2002) highlighted the following roles for sensitivity analysis as an invaluable tool for risk assessment. Sensitivity analysis may be used to:

- Identify the most significant exposure or risk factors and aid in developing priorities for risk mitigation
- Identify important uncertainties for the purpose of prioritizing additional data collection or research
- Verify and validate models
- Provide insight into the robustness of model results when making decisions.

## 5.5 Adaptation of the Hazard Analysis & Critical Control Points System (HACCP)

Performing quantitative microbial risk assessment on all possible exposure points and subsequent ranking based on the severity of hazardous exposures for pathogens is part of first step in applying Hazard Analysis & Critical Control Points system (Westrell et al.,

2004**).** The focus would be placed on controlling infection risk potential by exposure points to wastewater in order to reduce if not eliminate the hazard through risk management approach being adopted by WHO and other water guideline setting agencies. Table 5.6 summarizes the approach used for this research based on the possible ranking schemes elucidated in section 4.5 of this report.

Table 5. 6: Likelihood & consequences* weighing factors used for the various exposures

| **Definition** | **Weighing** |
|---|---|
| 6 times per week (street food vending) | 4.29 |
| 3 times per week (vegetable consumption) | 2.14 |
| 2 times per week (sale of vegetable) | 1.43 |
| 3 times per week for 8 months in a year (farm irrigation) | 1.43 |
| 0.25 times per week (kids playing at wastewater storage sites) | 0.18 |
| 0.2 times per week (Vegetable harvesting) | 0.14 |
| Potentially harmful to 280,000 consumers | 3 |
| Potentially harmful to 5,000 street food vendors | 0.054 |
| Potentially harmful to 704 vegetable farmers | 0.0075 |
| Potentially harmful to 421 vegetable sellers | 0.0045 |
| Potentially harmful to 337 kids playing at wastewater storage sites | 0.0036 |
| Potentially harmful to 40 vegetable harvesters | 0.00043 |

* here taken as the scale of effect

Since all pathogens considered are presumed to be present in all the exposure routes, it is assumed that the consequence of severity would mainly depend on the number of affected persons via each route, the amount consumed and the duration of exposures. Overall, the severity of consequence of the exposure with the highest impact is considered as moderate i.e. potentially harmful to the exposed individuals (refer to table 4.7); this is due to the relatively minute ratio of the number of affected persons compared to the population of the whole of Accra Metropolitan Assembly. The weight factor for the highest severity, which is that of the consumers of raw vegetable, is thus taken as 3. The weighing for the rest of the exposed groups is therefore extrapolated/ deduced based on the number of the affected persons (e.g. that of the street food vendors would be 5000/280,000*3 and so on). It is however, worth mentioning that an additional consideration may be given to the vulnerable ones such as the kids playing around the wastewater storage sites. The weighing factor for the likelihood of exposures is determined by the occurrences of each exposure routes per week. From table 4.7, using a weight of 5 for the likelihood of an event occurring every day (i.e. seven times a week), then street food vending that occurs 6 times in a week would have a weight factor of 4.29 (i.e. 6/7*5). Other exposure routes are thus obtained. The risk scores for each of the exposure routes are presented in table 6.22 of section 6.6.1.

# 6 Results and Discussion

## 6.1 Urban Wastewater Irrigation Farms in Accra

In Accra, about 680 ha are under maize, 47 ha under vegetables and 251 ha under mixed cereal-vegetable systems. Irrigated urban vegetable production takes place on more than seven larger sites (Obuobie et al., 2005). IWMI (unpublished) estimated on average about 100 ha under vegetable irrigation in the dry season. Some of the sites have been in use for more than 50 years (Anyane, 1963). About 50-70 additional hectares are distributed over 80,000 tiny backyards (often just a few plantain and chicken) involving nearly 60% of Accra's houses (IWMI and RUAF, unpubl.). This figure is much higher than the one of Maxwell and Armar-Klemesu (1999) who surveyed mostly low-income and high-density suburbs. However, it is worth emphasizing that the scope and focus of this research is mainly on vegetable (specifically lettuce as a case study) farm sites within Accra. Obuobie et al., 2005 reported that in Accra, there are about 800-1000 vegetable farmers of whom 60% produce exotic and 40% indigenous local or traditional vegetables. Some of the modern or exotic crops cultivated are lettuce, cabbage, spring onions, and cauliflower while the more traditional crops are tomatoes, okra, garden eggs (aubergine) and hot pepper. Plot sizes under cultivation in the city range between 0.01-0.02 ha per farmer, and max. 2.0 ha in peri-urban areas. The plot sizes of most of these sites have diminished over time because of land loss to estate development and widening of drains. This has led to reduced land reservations along the drains which used to be cultivated. An additional problem faced by farmers in relation to their farm size is tenure insecurity and low soil fertility. The location of some of the irrigated (open-space) vegetable farming sites in the city is shown in Figure 6.1.

### 6.1.1 Major Urban Vegetable Farm sites

Some major urban vegetable farm sites including their respective sizes, approximate number of farmers and their sources of irrigation water is presented in table 6.1.

Table 6. 1: Summary of selected urban vegetable farm sites in Accra

| Vegetable farm site | Farm size (ha) | Number of farmers | Source of irrigation water |
|---|---|---|---|
| **Marine drive** | 3.6 | 98 | wastewater drain |
| **Dzorwulu/Plant Pool** | 15 | 62 | drains, dug-outs, pipe-borne water |
| **La** | 100 | 400 | drains, partially treated wastewater, pipe-borne water |
| **Korle-bu** | 10 | 80 | drains |

Source: IWMI, Accra – Ghana

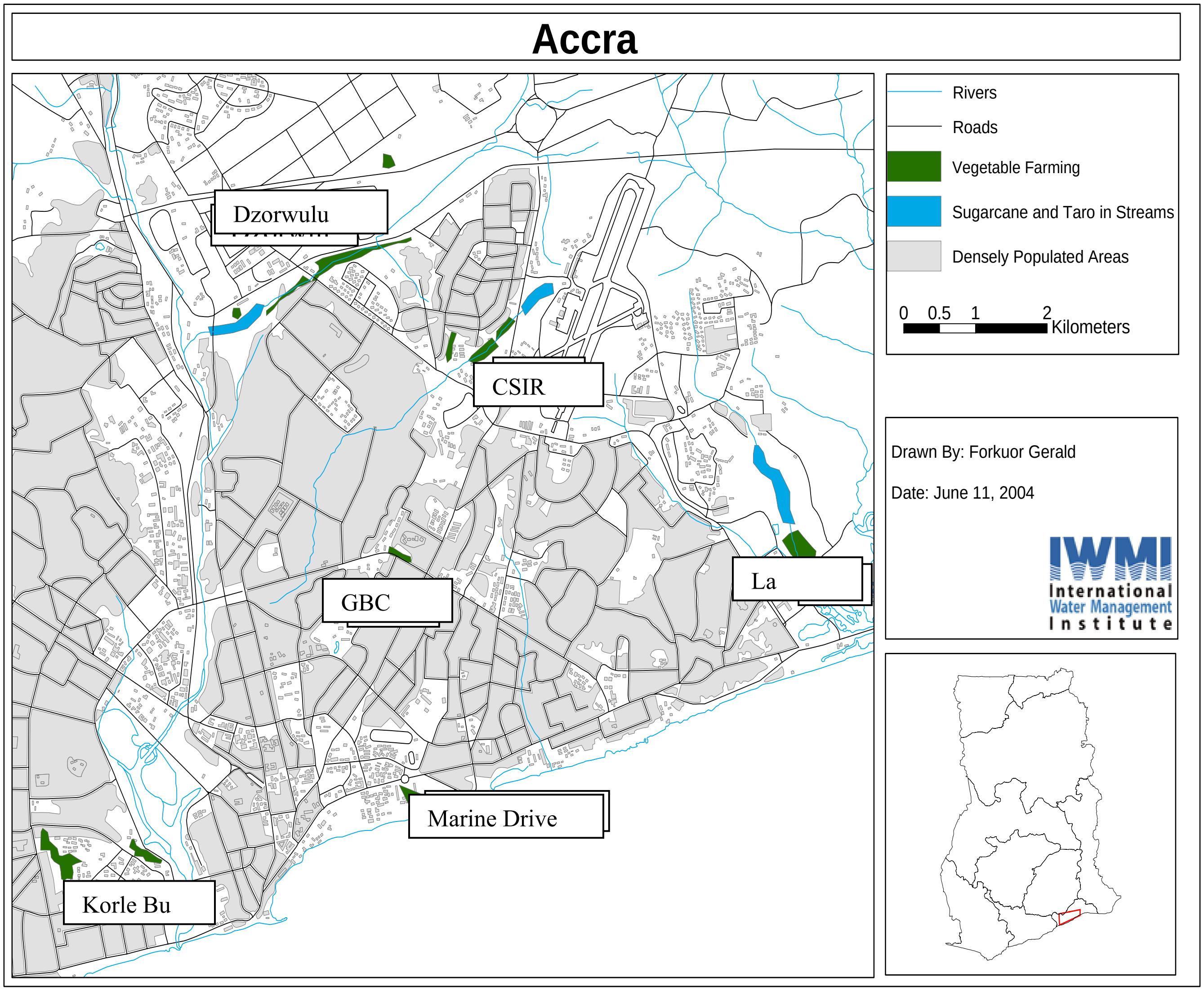


Figure 6. 1: Vegetable producing sites in central Accra (IWMI, unpubl)

Other sites with smaller farm sizes and lower number of farmers are located around the CSIR and IWMI offices as well as the one close to the GBC. Figure 6.1 shows the location of vegetable producing sites in central Accra. The listed farm sites are unevenly distributed within Accra Metropolitan Area. Dzorwulu/Plant Pool, CSIR and GBC sites located in Ayawaso Sub-metro, Marine drive site is in Osu Clottey Sub-metro, La farm site is in Kpeshi Sub-metro while Korle-bu is located in the Ablekuma Sub-metro.

## 6.2 Irrigation Practices of the Study Area

### 6.2.1 Sources of Irrigation Water

The main source of irrigation water in the city is urban drains. The contents of these drains vary from raw wastewater as in Korle-Bu to diluted wastewater (mostly with run-offs) as in Marine Drive, although this changes with seasons. In Dzorwulu, a polluted stream (Onyasia) is used in combination with pipe-borne water. Other than using a big drain that runs through Accra's La area, a few farmers there also use partially 'treated' wastewater' from the maturation pond of the stabilization pond treatment system belonging to the Burma military camp. Other farmers in La use piped water. Considering the overall urban vegetable farm size in Accra, it could be deduced from a study by Agodzo et al. (2003) that about 783,000m$^3$ of wastewater is used for irrigation per year.

### 6.2.2 Irrigation Methods and Technologies Used

Obuobie at al., (2006) reported that watering cans, buckets, motorized pumps with hosepipe, surface irrigation methods are being used in within urban Accra. Some of the farm sites were visited to observe some of these practices (refer to figures 6.2, 6.3, 6.4 and 6.5). Table 6.2 gives brief descriptions of some of the methods/practices.

Table 6. 2: Brief description of irrigation practices in the study area

| **Irrigation method** | **Brief description** |
|---|---|
| Watering cans | This is the most common irrigation method used in all the sites visited. With a capacity of 15 litres of water each, farmers use the cans to fetch from a water source, mostly shallow dug wells, streams or dugouts, to the fields for irrigation. |
| Bucket method | Like in the case of watering can method, bowls and buckets are used to fetch water, usually from a stream/river or dugout to the fields for irrigation. Here, the fetched water is either applied directly or put in a drum to be applied later. This practice mostly involves women and children. |
| Motorized pumps | Motor pump is placed temporarily near a water source; usually the bank of stream cum drain and water is pumped through a hosepipe for direct irrigation or to be stored in dug-outs to be fetched with cans/buckets. |
| Surface irrigation | Furrow irrigation method is being practiced at La farming site with a comparatively wider open space and a topography that allows for furrow irrigation. This is normally carried out via an open weir and diversion channel created for irrigation downstream. Sometimes farmers divert water into dugouts from where they can fetch with a watering can. |
| Sprinkler irrigation | This method was only observed in Dzorwulu where the sprinkler system is connected to a pipe borne water source. Low cost materials were used, like bamboos as sprinkler risers etc. The system is the portable type and farmers in this site combine it with the watering can method. |

Source: modified from Obuobie at al., (2006)

Figure 6. 2: Getting ready for irrigation with watering cans

Figure 6. 3: Irrigation with motorized pump

Figure 6. 4: Furrow irrigation in La

Figure 6. 5: The use of bucket for irrigation (source: IWMI)

## 6.3 Microbial Quality of Water for Vegetable Irrigation

Table 6. 3: Range of total and faecal coliform bacteria in irrigation water

| **Irrigation water source** | **Irrigation water (MPN/100ml)** | |
|---|---|---|
| | Total coliforms | Faecal coliforms |
| Drain | $2 * 10^4 – 2 * 10^9$ | $4 * 10^2 – 9 * 10^6 (6 * 10^4)$* |
| Stream | $4 * 10^4 – 2 * 10^8$ | $9 * 10^2 – 2 * 10^7 (1.3 * 10^5)$* |
| Piped water | 0 – 3 | 0 |

*Geometric Mean Source: Amoah, 2004

With the exception of piped water, the microbial quality of irrigation water at some selected sites in urban Accra, which are shown in table 6.3, is unsuitable for vegetable irrigation. This is due to the fact that in most cases, the WHO's recommended level for unrestricted irrigation of 1000 per 100ml was exceeded. Furthermore, there were no significant differences between faecal coliform populations from drains and streams in Accra (Amoah, 2004). Amoah (2004), also reported a value range of between 2 – 25 helminthes per 4g dry weight of soil during a field trial in Accra.
From a technical report by Gbireh (1999), which is subsequently modified by Obuobie et., al (2006), a summary of sources and quality of irrigation water on selected urban farming sites in Accra is presented in table 6.4.

Table 6. 4: Water quality on selected urban farming sites in Accra

| **Location** | **Sources and quality of irrigation water** |
|---|---|
| Marine Drive | Faecal coliforms (FC) up to $10^{6-7}$/ 100 ml; Electrical conductivity (EC): 0.7-1.1 ds/m; irrigation with watering cans from drains |
| Dzorwulu | 1. River Onyasia with contributions of wastewater from neighbouring settlements (FC up to $10^{5-6}$/ 100 ml); irrigation with watering cans<br>2. Piped water; irrigation with drag hoses or watering cans (FC< $10^1$/100 ml) |
| Korle Bu | Drain water from hospital staff houses and shallow wells (FC up to $10^8$/100 ml); irrigation with watering cans |
| La | Wastewater from the Burma Camp barracks, partially treated (FC still up to $10^6$ per 100 ml); Irrigation of okra, maize and other tall crops by furrows; irrigation of vegetables by watering cans around the last treatment pond |

Source: Gbireh (1999), updated and modified by Obuobie et al., (2006)

Obuobie et al., (2006) also observed that shallow wells (dugouts close to streams) in general had better water quality than the streams, but showed in many cases relatively high coliform levels of $10^6$/100 ml. These were brought about by run-offs into the wells as well as the extensive use of (fresh) poultry manure in vegetable farming.

## 6.4 Types of Vegetables Being Cultivated in Urban Accra

From the more than fifteen types of vegetables being cultivated in the study area, many often "exotic" (non-traditional) vegetables, such as lettuce, spring onions, and cabbage, are consumed raw. Obuobie et al., 2006 further reported that in peri-urban areas of Accra, more traditional diet vegetables like ayoyos (*Corchorus sp*) and alefi (*Amaranths)* or less

perishable (fruity) vegetables like garden eggs and tomatoes, which are often cooked before consumption, are grown.

Table 6. 5: Types of crops on selected urban farming sites in Accra

| Location | Crops |
|---|---|
| Marine drive | Lettuce, green pepper, spring onions, cucumber |
| Dzorwulu | Lettuce, cucumber, Cabbage, Cauliflower, onion, Chinese cabbage, spring onions, radish, spinach |
| Korle Bu | Lettuce, cabbage, spring onions, ayoyo, alefu, |
| La | Cabbage, lettuce, sweet pepper, okra, maize |

Source: Gbireh (1999), updated and modified

Figure 6. 6: Urban farming in Accra

### 6.4.1 Microbial Quality of Vegetables in the Study Area

Table 6. 6: Mean faecal coliform contamination levels of lettuce at different entry points along the production - consumption pathway of lettuce

| Irrigation water source | Statistics | Log faecal coliform levels (MPN* $100g^{-1}$) | | |
|---|---|---|---|---|
| | | Farm | Wholesale Market | Retail |
| Drain | Mean (range) | 4.25 (3.4 – 6.0) | 4.24 (3.0 – 6.8) | 4.48 (3.0 – 6.5) |
| Stream | Mean (range) | 4.22 (3.2 – 5.7) | 4.29 (3.1 – 5.9) | 4.37 (3.2 – 5.5) |
| Piped water | Mean (range) | 3.44 (2.9 – 4.7) | 3.46 (2.9 – 4.8) | 3.32 (2.8 – 4.5) |

*MPN=. Most Probable Number Source: Amoah et al., 2006b

Table 6.6 indicates that irrespective of the irrigation water source, the mean faecal coliform levels are still on the high side (exceeding ICSMF - recommended level of 1000 per 100g). An interesting result was that on-farm crop contamination also takes place under irrigation with piped water. Sources of contamination in these cases included the already contaminated soil (Faecal coliform levels of 10,000 $10g^{-1}$ in the upper 5 cm) and the frequent application of improperly composted (poultry) manure (Amoah et al., 2005; Drechsel et al., 2000). Furthermore, there were no significant differences in the average lettuce contamination levels at different entry points (i.e. farm, wholesale market and

retail outlet). Also the analysis of individual samples followed from farm to retail on the various sampling dates confirmed that the contamination of lettuce with pathogenic microorganisms does not significantly increase through post-harvest handling and marketing (Amoah et al., 2006b).

***Helminth eggs***

Table 6. 7: Mean Helminth egg contamination levels of lettuce at different entry points along the production/ consumption pathway

| | **Mean* helminth egg per 100g wet weight** | | |
|---|---|---|---|
| ***Irrigation water source*** | ***Farm*** | ***Market*** | ***Retail*** |
| Drain | 6 | 6 | 5 |
| Stream | 4 | 3 | 4 |
| Piped water | 3 | 2 | 3 |

* Mean number represent the mean of all the different types of helminthes and values were rounded to the nearest whole number. Source: Amoah, 2004

Table 6.7 shows helminth populations from the vegetables analyzed. According to Amoah, 2004, the eggs identified include *Ascaris lumbricoides*, *Trichostrongylus*, *Schistosoma haematobium* and *Trichuris trichiura*. *Strongyloides stercoralis* larvae were observed but not included in the counts. *S. stercoralis* had a high occurrence and was observed in all samples. *A. lumbricoides* was the most predominant among all the other organisms and was observed in 85% of the contaminated vegetables. This could be attributed to the high level of persistence of *A. lumbricoides*, hence high survival time. The presence of helminths, particularly *A. lumbricoides*, on the vegetables could pose a serious problem because of their high infective dose and low host immunity. For a better assessment of the potential threat it is required to determine egg viability.

## 6.5 Market Locations

De Lardemelle (1996) identified about 47 market sites in Accra, most of which are day markets. Most of the recent markets have developed spontaneously within each sub-metro, near rail stations or in new residential areas as shown in figure 6.7.

Five are identified as night markets while other markets operate on specific weekdays; for example, the Mamprobi Market takes place on Tuesdays. Eight markets are specialized in the marketing of food out of which four to five are predominantly wholesale; they include:

- the Yam market at Fadama;
- the Makola market (tomatoes and some vegetables);
- the Kaneshie market (maize and cassava);
- the Mamprobi market (maize and smoked fish). and
- the Agbogbloshie market (vegetables and other food crops) = market number 2 on the map in figure 6.7. It plays a very important role in vegetable distribution and marketing in Accra.

Table 6.8 gives an estimation of the number of lettuce dealers within Accra, based on the information gathered on the markets by IWMI (modified from De Lardemelle, 1996) at the time of survey.

Table 6. 8: Estimated number of vegetable dealers and markets

| Item | Estimated Number |
|---|---|
| Central markets | 7 - 8 |
| Neighborhood markets | 43 |
| Wholesalers | 40 |
| Permanent retailers (excluding *Independent Vegetable Sellers)* | 400 |
| Mobile retailers | 21 |

Source: Obuobie et al. (2006), modified

Agbogbloshie market was identified as the main lettuce distributed point in Accra (Obuobie et al 2006). Vegetables are bought from here and distributed to other smaller retail markets within Accra. According to IWMI, vegetable customers come from various parts of AMA as well as outside the metropolis.

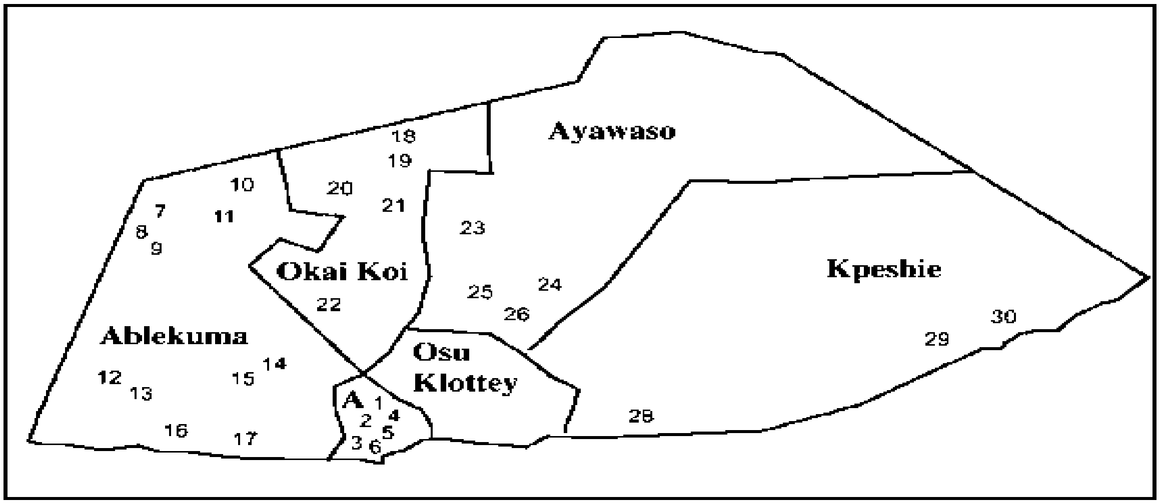


Figure 6. 7: Distribution of market sites in the AMA Sub-metros
(Source: adapted from Nyanteng, 1988)

**Legend:**

**Ashiedu Keteke** (A on map)
1. James Town Market
2. Agbogbloshie Market*
3. Kantanmanto Market
4. Adabraka Market
5. Ussher Town Market
6. Accra Central Market

**Ablekuma**
7. Odorkor Market
8. New Generation Market
9. Sabon Zongo Market
10. Kwashieman Market
11. Darkuman Market
12. Sukura Market
13. Malam Junction Market
14. Lartebiokorshie Market
15. Korle Gonno Market
16. Dansoman Market
17. Mamprobi Market

**Okai Koi**
18. Achimota Market
19. Ashiawo Market
20. Abeka Market
21. Kantanmanto Market
22. Kaneshie Market

**Ayawaso**
23. Alajo Market
24. Mamobi Market
25. Malata (New Town) Market
26. Nima Market

**Osu Klottey**
27. Christianborg Market

**Kpeshie**
28. La Market
29. Teshie Market
30. Nungua Market

* plays a very important role in vegetable distribution and marketing


Figure 6. 8: Various displays of vegetables at Agbogbloshie market

Figure 6. 9: Sanitary condition of Agbogbloshie market

### 6.5.1 Vegetable Distribution Pathway

The lettuce distribution pathway was chosen for this research, because IWMI had carried out detailed studies on this particular vegetable. The major distribution pathway is depicted in figure 6.10.

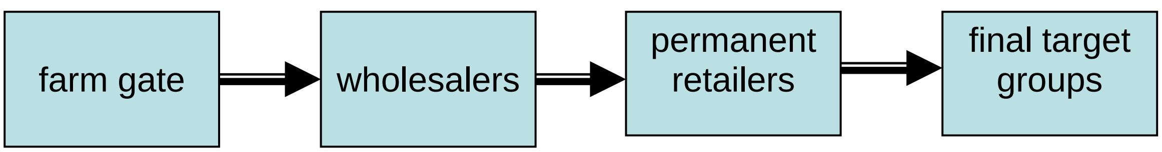


Figure 6. 2: Vegetable Distribution Pathway

### 6.5.2 Total Amount of Lettuce Traded in Accra

Table 6.9 and figure 6.11 show summaries of estimated quantity of lettuce produced and traded in Accra carried out by IWMI and Obuobie et al., 2006.

Table 6. 9: Summary of total amount of lettuce traded in Accra

| Lettuce Source | Estimated Quantity |
|---|---|
| Accra | 900 – 1000 tons per year |
| Other cities (Kumasi, Aburi and Koforidua in Ghana and Lome in Togo) | 300 tons per year |
| Urban farms (within and outside Accra) | 70% |

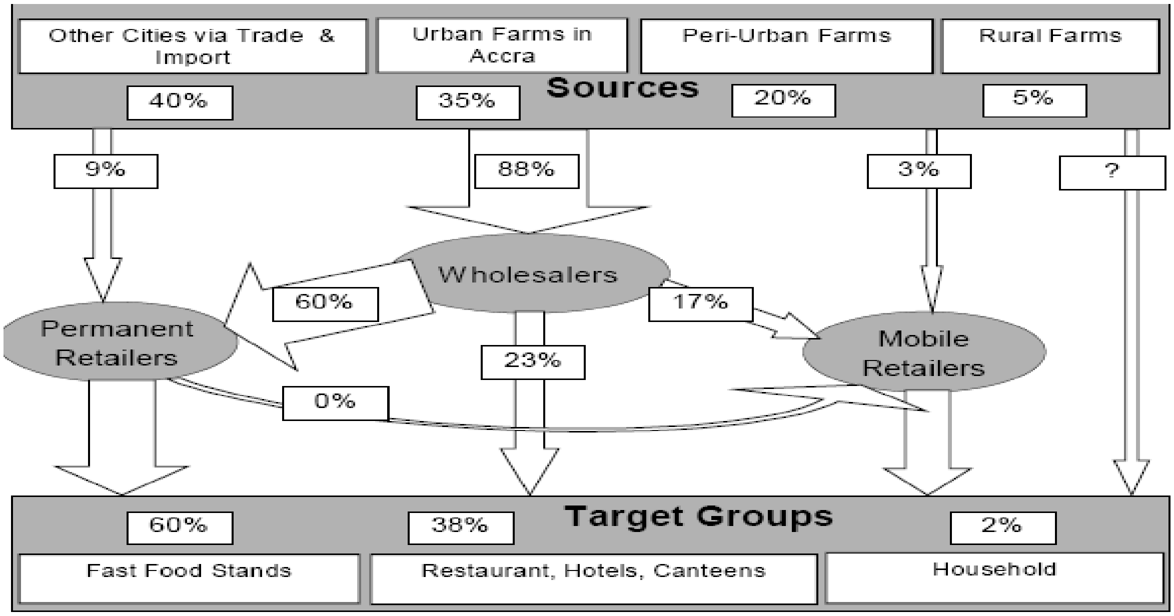


Figure 6. 3: Flow chart of lettuce distribution in Accra (Henseler et al., 2005).
Source: IWMI, Accra – Ghana

## 6.6 Microbial Risk Analysis

According to the information and data from secondary sources, the microbial qualities of the wastewater used for irrigation at the various sites within Accra are polluted; some more polluted than others (refer to tables 6.3 and 6.4). Even in a very few instances where pipe water is used for irrigation, the harvested vegetables were found to be contaminated with faecal coliforms (refer to table 6.6). This has been attributed to already contaminated soils from the use of animal manure as a source of soil nutrients. Within the limits of available data/information as well as the prevailing local conditions and practices, the results of the microbial risk analysis of wastewater irrigation in Accra are presented in the following sub-sections

### 6.6.1 Semi-Quantitative Microbial Risk Assessment

***1. Hazard Identification in the Study Area:*** The first step towards the semi-quantitative microbial risk analysis was the identification of various hazards (i.e. the range of pathogenic microorganisms) that may occur within Accra. This was carried out through literature search on studies done as well as the reported cases of especially water/food borne diseases in the study area. The results are presented in table 6.10.

Table 6. 10: Hazard identification in Accra Urban Agriculture

| **Hazards** | **Associated Illness** | **Reference** |
|---|---|---|
| ***Bacteria*** | | |
| *Campylobacter jejuni* | Gastroenteritis | Nakano et al., 1990, Sackey et al., 2001 |
| *Escherichia coli (Enteropathogenic)* | Gastroenteritis, haemolytic uremic syndrome | Nakano et al., 1990, Mensah et al, 2001, Mensah et al., 1999, Mensah et al., 1995, Sackey et al., 2001 |
| *Salmonella spp* | Gastroenteritis (typhoid), reactive arthritis | Mills-Robertson et al., 2003, Nakano et al., 1990, Mensah et al., 2000, Mensah et al., 1999, Sackey et al., 2001 |
| *Vibrio cholerae* | Cholera | Newman et al., 2004, Newman, 2001 |
| *Shigella spp* | Dysentery | Nakano et al., 1990, Mensah et al,1999, Mensah et al, 2001 Sackey et al., 2001 |
| *Staphylococcus aureus* | Skin, eye, ear infections, septicaema | Mensah et al., 2000, Agbodaze et al., 2005, Mensah et al., 1995 |
| ***Viruses*** | | |
| Rotavirus | Gastroenteritis (diarrhea), vomiting | Nakano et al., 1990 |
| Hepatitis A | Infectious hepatitis | Accra Metropolitan Health Service |
| ***Protozoa*** | | |
| *Giardia lamblia* | Giardiasis (affects gastro-intestinal tract), | Nakano et al., 1990 |
| *Entamoeba histolytica* | Amoebic dysentery | Nakano et al., 1990 |
| *Cryptosporidium parvum* | Gastroenteritis (profuse and watery diarrhea, weight loss; nausea; low grade fever) | Ayeh-Kumi, (unpublished results) |
| ***Helminthes*** | | |
| *Ascaris lumbricoides* | Ascariasis (roundworm infection) | Nakano et al., 1990, Amoah et al., 2005, Ayeh-Kumi, (unpublished results |
| *Taenia* sp | Tapeworm infection (beef measles) | Ayeh-Kumi, (unpublished results) |
| *Trichuris trichura* | Whipworm infection | Amoah et al., 2005 |

***2. Exposure Assessment:*** The outcome of carrying out exposure (dose) estimations for worst case scenario and then taking into consideration some preventive measures by some of the exposed victims coupled with other local confounding factors are presented in tables 6.11 and 6.12, respectively.

Table 6. 11: Dose estimations for worst case scenarios

| **Exposure** | **Dose per event (C* log reduction * N * q)** | | | |
|---|---|---|---|---|
| | ***Viruses* (MPN)*** | ***Bacteria* (MPN)*** | ***Protozoa* (MPN)*** | ***Helminthes* (eggs)*** |
| a) Wastewater Irrigation Farmers | | | | |
| 1. Marine drive | 5.5 (0.33) | 1.1 | 0.049 | 0.011 |
| 2. Dzorwulu | 0.55 ($3.3*10^{-2}$) | 0.11 | 0.0049 | 0.0011 |
| 3. La | 55 (3.3) | 11 | 0.49 | 0.11 |
| 4. Korle-bu | 550 (33) | 110 | 4.9 | 1.1 |
| 5. GBC site | 0.055 ($3.3*10^{-3}$) | 0.011 | 0.00049 | 0.00011 |
| 6.CSIR/IWMI site | 0.055 ($3.3*10^{-3}$) | 0.011 | 0.00049 | 0.00011 |
| b) Children playing at various wastewater storage sites | Same as farmers assumed | | | |
| c) Harvest of vegetables | Same as farmers assumed | | | |
| d) Sale of vegetables (market women) | 0.027 ($1.7*10^{-3}$) | 0.0055 | 0.00025 | $5.5*10^{-5}$ |
| e) Street food vending | 0.017 ($9.9*10^{-4}$) | 0.0033 | 0.00015 | $3.3*10^{-5}$ |
| f) Consumption of raw vegetables | 0.072 ($4.3*10^{-3}$) | 0.014 | 0.00064 | $1.4*10^{-4}$ |

* Viruses represented by *Rotavirus* and *Hepatitis A* (in bracket); Bacteria represented by *Salmonella*, Protozoa represented by *Cryptosporidium parvum;* Helminthes represented by *Ascaris lumbricoides.*

There were no available microbial water quality assessment for GBC and CSIR/IWMI sites, hence faecal coliform of $6 * 10^4$MPN/100 ml was assumed for both sites (refer to table 6.3). For the feacal coliform of the remaining sites, refer to table 6.4. The helminth contamination levels of vegetables in table 6.7 were used for *Ascaris lumbricoides*. In addition, refer to table 6.6 for the faecal coliform level of lettuce at different entry points for other estimations.

Children playing at various wastewater storage sites and those harvesting vegetables at the various farm sites are assumed to have similar doses of pathogens per single exposure as experienced by the farmers at the respective sites. The equation below was used for the calculations see Annex 6:

$$\text{Dose per event} = C * \text{log reduction} * N * q$$

Where C = Concentration of pathogens (based on microbial wastewater/lettuce quality, ratio pathogens/faecal coliform and number of pathogens,); q = Volume ingested per event (ml or g); N = Estimated number of viable pathogen; and log reduction due to pathogen die-off which could be as a result of availability of wastewater treatment system and fraction of those pathogens that might not survive the irrigation process

Table 6. 12: Dose estimations after considering other confounding factors

| **Exposure** | **Dose per event (C* log reduction * N * q)** | | | |
|---|---|---|---|---|
| | *Viruses(MPN)** | *Bacteria(MPN)** | *Protozoa(MPN)** | *Helminthes(eggs)** |
| a1) Marine drive farm site (on-site preventive measures not observed apart from occasional with-holding of wastewater) | 1.74 (0.104) (1 day ww) | 0.35 | $1.6*10^{-2}$ | $3.5*10^{-3}$ |
| | $5.5*10^{-}1(3.3*10^{-2})$ (2 days ww) | 0.11 | $4.9*10^{-3}$ | $1.1*10^{-3}$ |
| | $1.7*10^{-1}$ $(1.0*10^{-2})$ (3 days ww) | 0.035 | $1.6*10^{-3}$ | $3.5*10^{-4}$ |
| a2) Dzorwulu farm site (the use of withholding dug-outs and pipe borne water) | $5.5*10^{-5}$ $(3.3*10^{-6})$ (tap water) | $1.1*10^{-5}$ | $4.9*10^{-7}$ | $1.1*10^{-7}$ |
| | $1.7*10^{-5}$ $(1.0*10^{-6})$ (1 day t/w) | $3.5*10^{-6}$ | $1.6*10^{-7}$ | $3.5*10^{-8}$ |
| | $1.7*10^{-1}$ $(1.0*10^{-2})$ (for 1 day ww) | $3.5*10^{-2}$ | $1.6*10^{-3}$ | $3.5*10^{-4}$ |
| | $5.5*10^{-2}$ $(3.3*10^{-3})$ (for 2 days ww) | $1.1*10^{-2}$ | $4.9*10^{-4}$ | $1.1*10^{-4}$ |
| | $1.7*10^{-2}$ $(1.0*10^{-3})$ (for 3 days ww) | $3.5*10^{-3}$ | $1.6*10^{-4}$ | $1.1*10^{-5}$ |
| a3) La farm site (the use of partially treated wastewater & pipe borne water | $5.5*10^{-5}$ $(3.3*10^{-6})$ (tap water) | $1.1*10^{-5}$ | $4.9*10^{-7}$ | $1.1*10^{-7}$ |
| | 17.39 (1.04) (0.5 log reduction) | 3.5 | $1.6*10^{-1}$ | $3.5*10^{-2}$ |
| | 5.5 (0.33) (1 log reduction) | 1.1 | $4.9*10^{-2}$ | $1.1*10^{-2}$ |
| a4) Korle-bu farm site (the use of dug-out wells) | 173.9 (10.44) (for 1 day ww) | 34.8 | 1.6 | 0.35 |
| | 55 (3.3) (for 2 days ww) | 11 | 0.49 | 0.11 |
| | 17.39 (1.04) (for 3 days ww) | 3.5 | $1.6*10^{-1}$ | 0.035 |
| a5) GBC farm site (occasional with-holding of wastewater) | $1.7*10^{-2}$ $(1.0*10^{-3})$ (for 1 day ww) | $3.5*10^{-3}$ | $1.6*10^{-4}$ | $3.5*10^{-5}$ |
| | $5.5*10^{-3}$ $(3.3*10^{-4})$ (for 2 days ww) | $1.1*10^{-3}$ | $4.9*10^{-5}$ | $1.1*10^{-5}$ |
| | $1.7*10^{-3}$ $(1.0*10^{-4})$ (for 3 days ww) | $3.5*10^{-4}$ | $1.6*10^{-5}$ | $3.5*10^{-6}$ |
| a6)CSIR/IWMI farm site (occasional with-holding of wastewater) | $1.7*10^{-2}$ $(1.0*10^{-3})$ (for 1 day ww) | $3.5*10^{-3}$ | $1.6*10^{-4}$ | $3.5*10^{-5}$ |
| | $5.5*10^{-3}$ $(3.3*10^{-4})$ (for 2 days ww) | $1.1*10-^{3}$ | $4.9*10^{-5}$ | $1.1*10^{-5}$ |
| | $1.7*10^{-3}$ $(1.0*10^{-4})$ (for 3 days ww) | $3.5*10^{-4}$ | $1.6*10^{-5}$ | $3.5*10^{-6}$ |

| Exposure | Dose per event (C* log reduction * N * q) | | | |
|---|---|---|---|---|
| | *Viruses(MPN)** | *Bacteria(MPN)** | *Protozoa(MPN)** | *Helminthes(eggs)** |
| b) kids playing at wastewater storage sites (log reduction due to protected sites) | Most polluted site 55 (3.3) (1 log reduction) | 11 | $4.9*10^{-1}$ | 0.11 |
| | Most polluted site 5.5 (0.33) (2 log reduction) | 1.1 | $4.9*10^{-2}$ | 0.011 |
| | Least polluted site $5.5*10^{-3}$ ($3.3*10^{-4}$) (1 log reduction) | $1.1*10^{-3}$ | $4.9*10^{-5}$ | $1.1*10^{-5}$ |
| | Least polluted site $5.5*10^{-4}$ ($3.3*10^{-5}$) (2 log reduction) | $1.1*10^{-4}$ | $4.9*10^{-6}$ | $1.1*10^{-6}$ |
| c) Harvest of vegetables (cessation of irrigation before harvest) | Most polluted site 173.9 (10.44) (0.5 log reduction) | 34.8 | $4.9*10^{-1}$ (1 log) | 1.1 (no change) |
| | Most polluted site 55 (3.3) (1 log reduction) | 11 | $1.6*10^{-1}$ (1.5 log) | 0.35 (0.5 log red) |
| | Lest polluted site $1.7*10^{-2}$ ($1.0*10^{-3}$) (0.5 log reduction) | $3.5*10^{-3}$ | $4.9*10^{-5}$ (1 log) | $1.1*10^{-4}$ (no change) |
| | Least polluted site $5.5 * 10^{-3}$ ($3.3*10^{-4}$) (1 log reduction) | $1.1*10^{-3}$ | $1.6*10^{-5}$ (1.5 log) | $3.5*10^{-5}$ (0.5 log red) |
| d) Sale of vegetables (market women) – pathogen die-off and washing with water) | $2.8*10^{-4}$ ($1.7*10^{-5}$) | $5.5*10^{-5}$ | $2.5*10^{-6}$ | $5.5*10^{-7}$ |
| e) Street food vending (pathogen die-off and various types of washings) | $1.7*10^{-4}$ ($9.9*10^{-6}$) (with clean water) | $3.3*10^{-5}$ | $1.5*10^{-6}$ | $3.3*10^{-7}$ |
| | $1.7*10^{-5}$ ($9.9*10^{-7}$) (with weak solution) | $3.3*10^{-6}$ | $1.5*10^{-7}$ | $3.3*10^{-8}$ |
| | $1.7*10^{-8}$ ($9.9*10^{-10}$) with vinegar solution | $3.3*10^{-9}$ | $1.5*10^{-10}$ | $3.3*10^{-11}$ |
| f) Consumption of raw vegetables (pathogen die-off and various types of washings) | $7.2*10^{-4}$ ($3.3*10^{-4}$) (with clean water) | $1.4*10^{-4}$ | $6.4*10^{-6}$ | $1.4*10^{-6}$ |
| | $7.2*10^{-5}$ ($3.3*10^{-5}$) (with warm water) | $1.4*10^{-5}$ | $6.4*10^{-7}$ | $1.4*10^{-7}$ |
| | $7.2*10^{-8}$ ($3.3*10^{-8}$) with vinegar solution | $1.4*10^{-8}$ | $6.4*10^{-10}$ | $1.4*10^{-10}$ |

* Viruses represented by *Rotavirus* and *Hepatitis A* (in bracket); Bacteria represented by *Salmonella*, protozoa represented by *Cryptosporidium parvum;* Helminthes represented by *Ascaris lumbricoides*

Some comments on table 6.12

The following should be noted for the confounding factors/site specific activities (refer to table 5.5 for the corresponding log reductions):

- 1 day ww: with-holding wastewater for one day
- 2 days ww: with-holding wastewater for two days etc.
- 1 day tw: with-holding tap water for one day etc.
- log reductions for children playing at various wastewater storage sites: based on kids protection mechanisms. Also, estimations were done for the most polluted and least polluted sites respectively.
- log reductions during harvests: estimation based on pathogen die-off after cessation of irrigation (refer to tables 4.4 and 5.5. Also, like that of the exposed children, estimations were done for the most polluted and least polluted sites respectively.
- Refer to tables 5.5 and 6.6 for the case of vegetable sellers.
- Street food vendors and vegetable consumers: Various preventive measures/ hygienic practices are considered (refer to table 5.5).

***3. Variability and Uncertainty:*** For a one time exposure, the main determinant of the outcome of infection risk after applying the various mathematical models for each pathogen is the dose ingested at any point in time. The estimated values for each component of the dose (exposure) model will spatially and temporally vary based on some influences (biophysically or anthropogenically). In addition, the nature and extent of this variability are not certain. It is therefore appropriate to consider accounting for variability and uncertainty in the exposure modelling. For this research, deterministic mathematical (as against stochastic) approach is used to describe variable values and propagate uncertainty in exposure assessment (Petterson and Ashbolt, 2004). In the chosen approach, a single "best guess" value as against the worst case scenarios assumed for each variable in the model are used for variability or uncertainty propagation. Sensitivity analysis is used as a tool for this purpose.

Two methods proposed by Petterson and Ashbolt (2004), for measures of sensitivity are:
*1. Characterisation of the main determinants of risk*: For selection of the most relevant determinants of risk, a step characteristic ($SC_K$) can be used. The step characteristic indicates the log reduction or increase in the number of organisms relative to the previous step in the model and is given by:

$$SC_K = Log\ (N_K/N_{K-1})$$

Where $N_k$ is the number of organisms at step $k$

*2. Worst case sensitivity*: Using a similar measure, the factor sensitivity ($FS_K$) shows the relevance of variations of a factor for each process step.

$$FS_K = Log\ (N_K Extreme/N_K Average)$$

A high FS value means high sensitivity to variations and shows that changes to the assumptions/conditions at that process step has profound effects on the model outputs. From the exposure (dose) formula used, i.e.:

Dose per event (Exposure) = C* log reduction * N * q

At each exposure point (i.e. from irrigation to consumption) in the model a best estimate of the model parameters and an extreme estimate were selected. A summary of parameters used in this research is included in table 6.13:

Table 6. 13: Model parameters used for undertaking sensitivity analysis

| **Model Component** | **"Best" Estimate*** | **"Extreme" Estimate*** |
|---|---|---|
| FC concentration (C) in wastewater | $6 * 10^1$MPN/100ml | $6 * 10^8$ MPN/100ml |
| FC viable numbers (N) | 0.055 | 0.55 |
| FC log reduction (die-off or inactivation) | $10^{-5}$ | $10^{-0.5}$ |
| Consumption per event (q) | 12g | 100g |

* "Best" & "Extreme" Estimates: $6 * 10^1$ & $6 * 10^8$ FC concentrations are the values used for the least and most polluted farm sites (Obuobie et al, 2006). 0.055 & 0.55 are number of units pathogen used by Mara et al, 2007. $10^{-5}$ & $10^{-0.5}$ are pathogen die-off on the surface of crops after the last irrigation through to washing with vinegar by WHO, 2006. 12g of lettuce consumption is by IWMI, Accra while 100g is used as a default from Petterson, 2002.

The step characteristic and factor sensitivity were calculated for each component of the process. The results are included in the table 6.14.

Table 6. 14: Results of Step Characteristic and Factor Sensitivity

| **Process Step** | Step Characteristic | Factor Sensitivity |
|---|---|---|
| *Occurrence of FC* | | 7 |
| *Attachment by viable FC numbers* | -3 | 1 |
| *FC Inactivation or log reduction* | -3.7 | 4.5 |
| *Consumption* | | 0.9 |

According to Ashbolt and Petterson (2004), the step characteristic indicated the importance of each component to the calculated exposure. They further stated that the value of the step characteristic shows the magnitude of reduction in faecal coliform numbers at each stage in the model. For the lettuce model used in this research, viable faecal coliform attachment resulted in a 3 log reduction in faecal coliform numbers, whereas faecal coliform inactivation/log reduction led to a 3.7 log reduction (i.e. approximately 4 log reduction). The influence of faecal coliform inactivation/log reduction was therefore much more important for reducing risk, and had a greater influence on the calculated exposure. The factor sensitivity may be used to evaluate the

sensitivity of the model to variation within each component of the model. The highest factor sensitivity was for virus occurrence (factor sensitivity = 7). This indicated that the estimation of exposure was very sensitive to changes in the initial faecal coliform concentration (and ultimately pathogen concentration, which in this case depends on the ratio of faecal coliform to each pathogen used). The uncertainty associated with faecal coliform numbers is very high ($6 * 10^1$MPN/100ml compared with $6 * 10^8$ MPN/100ml). The lettuce model was also sensitive to variation in the value of the inactivation/log reduction parameters (factor sensitivity = 4.5). Hence, the uncertainty associated with parameter estimation has significant implications for calculating risk. The uncertainty associated with the estimation of the attachment by viable number (factor sensitivity = 1) and the quantity consumed (factor sensitivity = 0.9) were also worth considering but less significant compared to the concentration of faecal coliform.

***4. Dose-Response Assessment:*** Microsoft excel was used to calculate both the single and yearly infection risks at the different exposure routes. The dose –response relationships for different pathogens in tables 5.4 & annex X and the estimated doses (exposures) for worst case scenarios as well as other confounding factors/practices at the various exposure points (see tables 6.11 and 6.12) were used for this purpose. The estimated results are discussed and presented in the following figures and tables:

***Infection risks per single exposure for worst case scenarios***: From figure 6.12 (see Annex 7) for worst case scenarios, it could be observed that the risk of infection per single exposure of Korle-bu farmers is the highest. This also affects the vegetable harvesters and children playing on this particular farm site. This could be attributed to the fact that the site has the most polluted wastewater (see table 6.4). In the same vain, GBC and CSIR/IWMI sites with relatively better water qualities (earlier assumed) have the least risk of infection. Even with similar contamination levels of faecal coliforms on raw lettuce, higher infection risk of raw vegetable consumers was observed compared to vegetable sellers and street food vendors; this could be attributed to the higher amount of raw lettuce taken by consumers. The difference of infection risk between *Rotavirus* and *Hepatitis A* (both being viruses) could be attributed to the different ratios of each pathogen to the faecal coliforms (see table 5.3) and different mathematical models used.

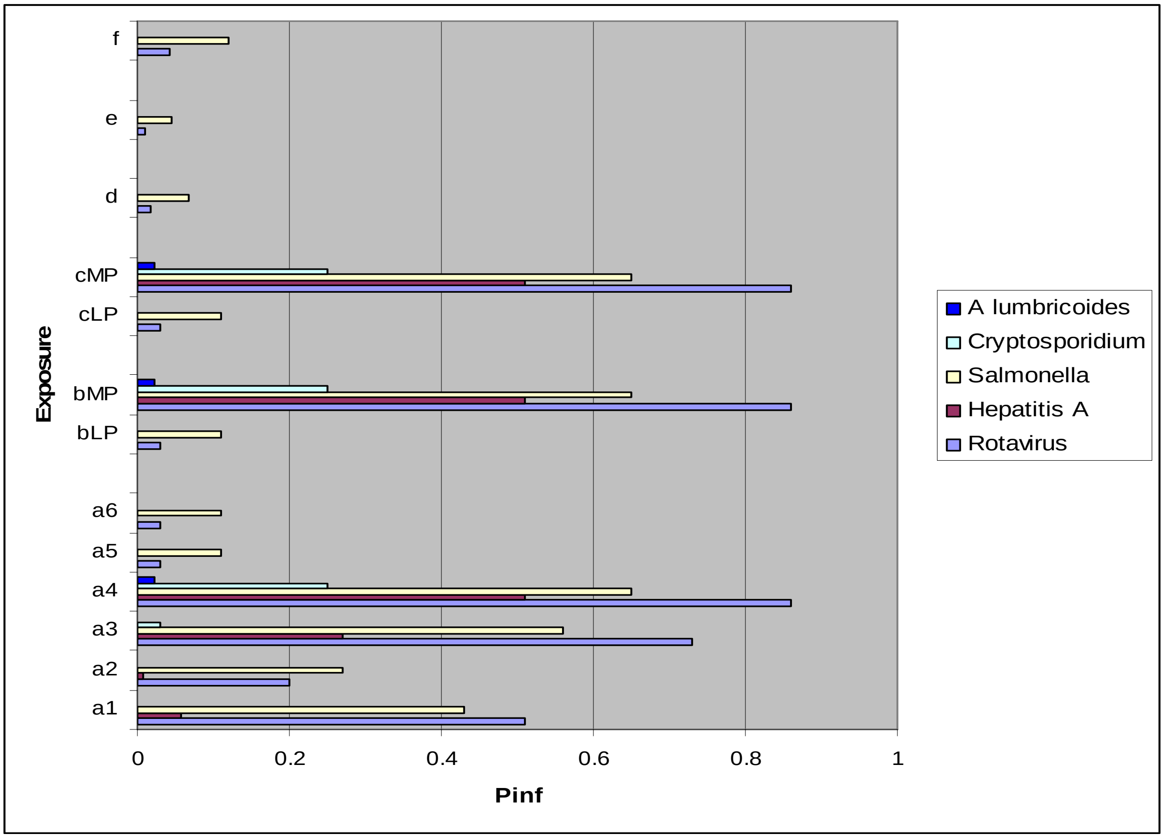


Figure 6. 4: Estimated risk of infection per single exposure for worst case scenarios

LP = least polluted site and MP = Most polluted site
a = various farm sites (i.e. 1 = Marine drive, 2 = Dzorwulu, 3 = La, 4 = Korle-bu, 5 = GBC site and 6 = CSIR/IWMI site); b = Children playing at various wastewater storage sites; c = Harvest of lettuce; d = Sale of lettuce; e = Street food vending; f = Consumption of raw lettuce

***Yearly infection risks resulting from frequency of exposure for worst case scenarios***: Figure 6.13 shows that the yearly infection risks taking into account the frequency of exposure per single individual are much higher than the single exposures in figure 6.12. This could be attributed to continuous exposures to the various hazards (pathogens), the more number of exposures in a year, the higher the infection risk. Apart from the less polluted sites (i.e. sites 5 & 6), the yearly infection risks are almost 1 for *Rotavirus*, *Hepatitis A* and *Salmonella* cases; these may be due to low infective doses of these pathogens compared to that of *Cryptosporidium* and *Ascaris lumbricoides*. The same can be said of the exposed children and lettuce harvesters (b & c) at the various sites.

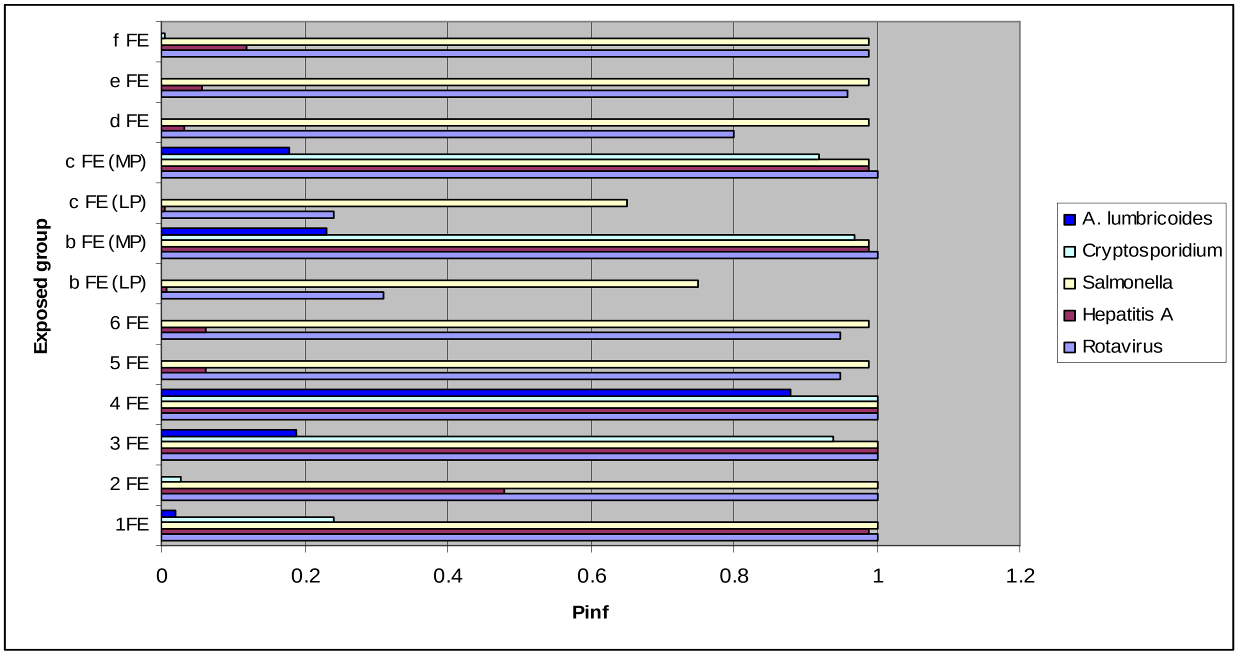


Figure 6. 5: Estimated risk of infection per year resulting from frequency of exposure for worst case scenarios

FE = considering only frequency of exposure; LP = least polluted site; MP = most polluted site 1 = Marine drive; 2 = Dzorwulu site; 3 = La site; 4 = Korle-bu; 5 = GBC site; 6 = CSIR/IWMI site; b = exposed children; c = lettuce harvesters, d = lettuce sellers; e = street food vendors; f = lettuce consumers

The steady increase of infection risks for lettuce sellers, street food vendors and consumers (d, e & f) are as a result of differences in consumption levels estimated and respective frequency of exposures.

After considering the estimated number of exposed persons at each exposure routes, the outcome of figure 13 is reflected on the estimated number of infected persons in table 6.15.

Table 6. 15: Estimated risk of infection per year resulting from frequency of exposure and number of affected persons for worst case scenarios

| ***Exposure*** | ***Rotavirus*** | ***Hepatitis A*** | ***Salmonella*** | ***Cryptosporidium*** | ***A. lumbricoides*** |
|---|---|---|---|---|---|
| 1+ NEP | 98 | 97.02 | 98 | 23.52 | 2.06 |
| 2+ NEP | 62 | 29.76 | 62 | 1.74 | 0.13 |
| 3+ NEP | 400 | 400 | 400 | 376 | 76 |
| 4+ NEP | 80 | 80 | 80 | 80 | 70.4 |
| 5+ NEP | 24.7 | 1.64 | 25.74 | 0.07 | 0.0055 |
| 6 + NEP | 36.1 | 2.39 | 37.62 | 0.11 | 0.0079 |
| b + NEP (LP) | 104.47 | 2.73 | 252.75 | 0.117 | 0.0088 |
| b + NEP (MP) | 337 | 333.63 | 333.63 | 326.89 | 77.51 |
| c + NEP (LP) | 9.6 | 0.24 | 26 | 0.01 | 0.00079 |
| c + NEP (MP) | 40 | 39.6 | 39.6 | 37 | 7.2 |
| d + NEP | 336.8 | 13.89 | 416.79 | 0.59 | 0.046 |
| e + NEP | 4800 | 280 | 4950 | 12.5 | 0.94 |
| f + NEP | 277200 | 33600 | 277200 | 1540 | 112 |

NEP = considering number of exposed persons with frequency of exposure; LP = least polluted site; MP = most polluted site1 = Marine drive; 2 = Dzorwulu site; 3 = La site; 4 = Korle-bu; 5 = GBC site; 6 = CSIR/IWMI site; b = exposed children; c = lettuce harvesters; d = lettuce sellers; e = street food vendors; f = lettuce consumers

Pathogens with low infective doses (i.e. those with higher viable organisms in the dose-response models) tend to have higher estimated infection risks in a year. As expected, the most polluted sites (MP) had higher infections than the less polluted sites (LP). Furthermore, high daily lettuce consumers (f) with thrice exposure time per week resulted in higher yearly infection risks across all the pathogens. Cryptosporidium and A. lumbricoides with high infective dose lead to lower risks of infection.

***Infection risks per single exposure after considering other confounding factors:*** For a better appreciation of figures 6.14, 6.15 and 6.16, see Annex 7. The figures show different infection risks per single exposure after considering what could be termed as preventive measures by some exposed groups. In figure 6.14, the use of tap water for irrigation at the Dzowulu & La farm sites (a2 & a3) for instance gives nearly zero risk of infection while with-holding wastewater for more than one day before irrigation also results to reduced infection risks. These are in contrast to the worst case scenarios where it is assumed that irrigation is carried out without with-holding periods or any form of partial treatment.

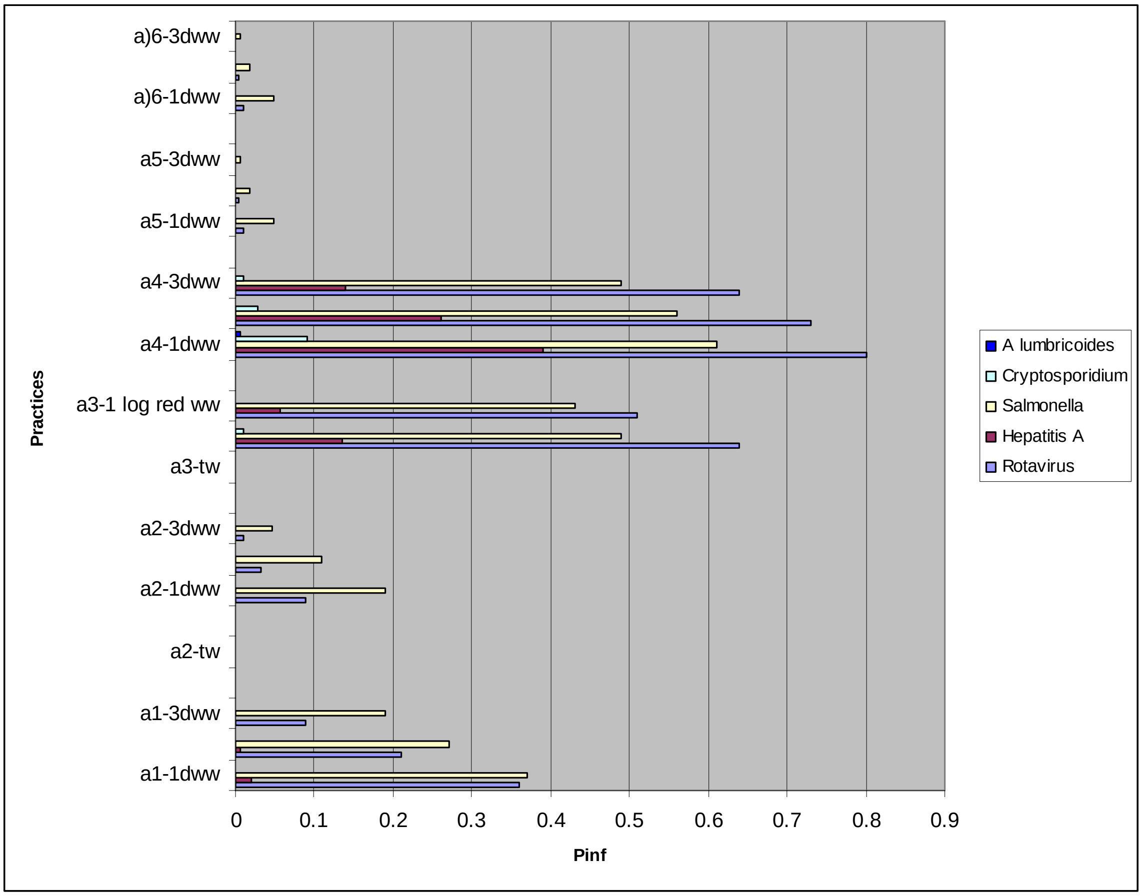


Figure 6.6: Estimated risk of infection per single exposure after considering other confounding factors for exposed farmers

a1-1dww = with-holding wastewater for one day at Marine drive farm site; a1-3dww = with-holding wastewater for three days at Marine drive farm site; a2-tw = the use of tap water for irrigation at Dzorwulu farm site; a2-1dww = with-holding wastewater for two days at at Dzorwulu farm site; a2-3dww = with-holding wastewater for three days at at Dzorwulu farm site; a3-tw = the use of tap water for irrigation at La farm site; a3-1 log red ww = the use of partially treated wastewater with 1 log reduction at La farm site; a4-1dww = with-holding wastewater for one day at Korle-bu farm site; a4- 3dww = with-holding wastewater for three days at Korle-bu farm site; a5-1dww = with-holding wastewater for one day at GBC farm site; a5-3dww = with-holding wastewater for three days at GBC farm site; a6-1dww = with-holding wastewater for one day at CSIR/IWMI farm site; a6-3dww = with-holding wastewater for three days at CSIR/IWMI farm site.

In figure 6.15, protecting children from getting in contact with wastewater through restriction and provision of buffer zones reduced the infection risks as compared to the worst case scenarios where nothing is done to that effect. Similarly, according to the WHO guidelines (2006), cessation of irrigation before harvesting leads to between 0.5–2 log reduction per day (see table 5.5) of faecal coliform which consequently reduced the risk of infection during harvest.

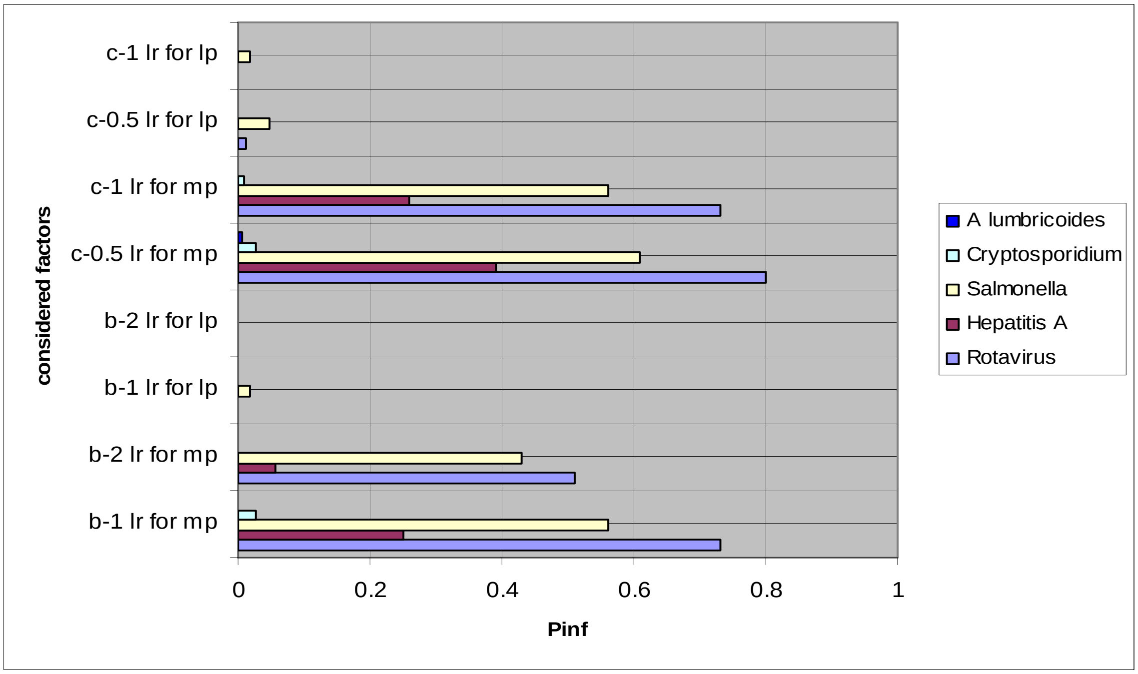


Figure 6. 7: Estimated risk of infection per single exposure after considering other confounding factors for exposed children & harvesters

b-1 lr for mp = considering 1 log reduction as a result of protection or restricting children from getting in contact with wastewater storage for most polluted sites; b-2 lr for mp = considering 2 log reduction as a result of protection or restricting children from getting in contact with wastewater storage for most polluted sites; b-1 lr for lp = considering 1 log reduction as a result of protection or restricting children from getting in contact with wastewater storage for least polluted sites; b-2 lr for lp = considering 2 log reduction as a result of protection or restricting children from getting in contact with wastewater storage for least polluted sites; c-0.5 lr for mp = considering 0.5 log reduction as a result of cessation of irrigation before harvest for most polluted sites; c-1 lr for mp = considering 1 log reduction as a result of cessation of irrigation before harvest for most polluted sites; c-0.5 lr for lp = considering 0.5 log reduction as a result of cessation of irrigation before harvest for least polluted sites; c-1 lr for lp = considering 1 log reduction as a result of cessation of irrigation before harvest for least polluted sites.

Various forms of washing of lettuce resulted in a variety of reduced cases of infection risk (figure 6.16); vinegar gave the least infection risk this is followed by the use of weak disinfectant solution. The consumers have the highest risk because they consume more grams of lettuce per exposure compared to the sellers and vendors.

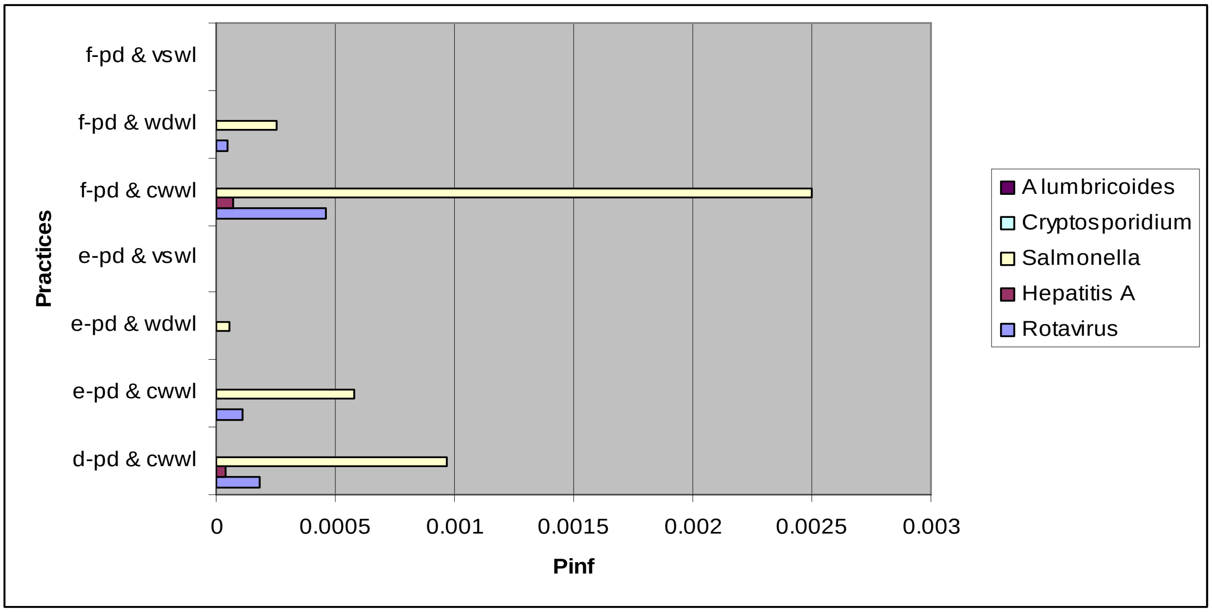


Figure 6. 8: Estimated risk of infection per single exposure after considering other confounding factors for exposed sellers, vendors and consumers

d-pd & cwwl = considering pathogen die-off and clean water washing of lettuce by sellers; e-pd & cwwl = considering pathogen die-off and clean water washing of lettuce by vendors; e-pd & wdwl = considering pathogen die-off and weak disinfectant washing of lettuce by vendors; e-pd & vswl = considering pathogen die-off and vinegar solution washing of lettuce by vendors; f-pd & cwwl = considering pathogen die-off and clean water washing of lettuce by consumers; f-pd & wdwl = considering pathogen die-off and weak disinfectant washing of lettuce by consumers; f-pd & vswl = considering pathogen die-off and vinegar solution washing of lettuce by consumers.

***Yearly infection risks after considering some practices/confounding factors***: As anticipated, the use of tap water for irrigation leads to insignificant values of infection risk for all categories of pathogens. Figure 6.17 shows comparatively high infection risks even with about three day's with-holding period of wastewater; this was because the log reduction of pathogen during these periods were still not good enough to bring about a significant decrease in infection risk. The same can be attributed to the use of partially treated wastewater at the La farm (i.e. site 3), with highest log reduction of 1 (see table 6.4). However, apart from the most polluted site (i.e. Korle-bu or site 4) when wastewater with-holding is done for more days, a relatively reduced infection risks are observed for all pathogens. However, some pathogens such as *Ascaris lumbricoides* could be resuspended due to the irrigation methods used such as the use of watering can, bucket and pumping and thus re-contaminate the irrigation water.

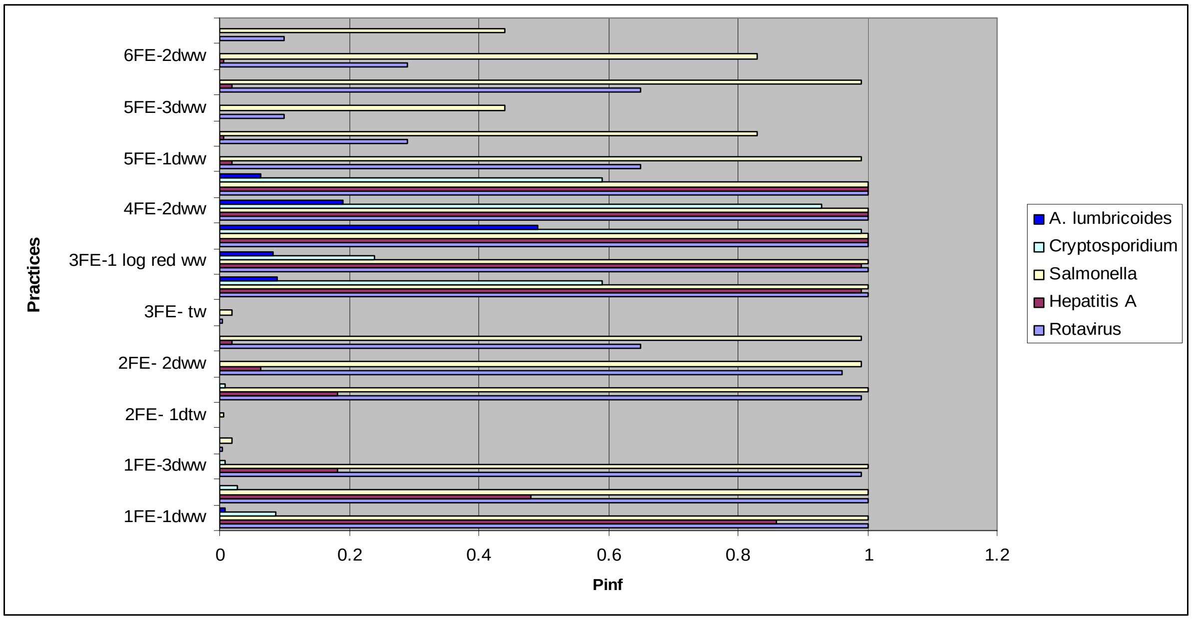


Figure 6. 9: Estimated yearly risk of infection after considering some practices at the farm sites (see Annex 7)

Table 6. 16: Estimated yearly risk of infection resulting from frequency of exposure and number of affected persons after considering some practices at the farm sites

| *Exposure* | *Rotavirus* | *Hepatitis A* | *Salmonella* | *Cryptosporidium* | *A. lumbricoides* |
|---|---|---|---|---|---|
| 1+ NEP1dww | 98 | 84.28 | 98 | 8.46 | 0.93 |
| 1+ NEP2dww | 98 | 47.04 | 98 | 2.7 | 0.21 |
| 1+ NEP3dww | 97.02 | 17.93 | 98 | 0.88 | 0.07 |
| 2+NEP tw | 0.2 | 0.004 | 1.12 | 0.0002 | 0.000012 |
| 2+NEP 1dtw | 0.07 | 0.0013 | 0.37 | 0.000056 | 0.000006 |
| 2+NEP 1dww | 61.38 | 11.35 | 62 | 0.56 | 0.041 |
| 2+NEP 2dww | 59.52 | 3.9 | 61.38 | 0.17 | 0.013 |
| 2+NEP 3dww | 40.56 | 1.24 | 61.38 | 0.056 | 0.0013 |
| 3+NEP tw | 1.36 | 0.026 | 7.2 | 0.001 | 0.00008 |
| 3+NEP0.5 logredww | 400 | 396 | 400 | 238.4 | 35.2 |
| 3+NEP 1 log red ww | 400 | 396 | 400 | 96 | 32.8 |
| 4+ NEP1dww | 80 | 80 | 80 | 79.2 | 39.2 |
| 4+ NEP2dww | 80 | 80 | 80 | 74.4 | 15.2 |
| 4+ NEP3dww | 80 | 80 | 80 | 47.68 | 5.12 |
| 5+ NEP1dww | 16.9 | 0.49 | 25.74 | 0.023 | 0.002 |
| 5+ NEP2dww | 7.54 | 0.17 | 21.58 | 0.008 | 0.001 |
| 5+ NEP3dww | 2.6 | 0.051 | 11.44 | 0.0023 | 0.0003 |
| 6+ NEP1dww | 24.7 | 0.76 | 37.62 | 0.03 | 0.0027 |
| 6+ NEP2dww | 11.02 | 0.25 | 31.54 | 0.01 | 0.0008 |
| 6+ NAP3dww | 3.8 | 0.08 | 16.72 | 0.0034 | 0.00027 |

FE = frequency of exposures (per exposed individual); +NEP = with number of exposed people 1 = Marine drive site; 2 = Dzorwulu/Plant Pool site; 3 = La site; 4 = Korle-bu site; 5 = GBC site; 6 = CSIR and IWMI offices site; tw = considering irrigation with pipe borne water; 1dww = considering irrigation with wastewater with-held for one day; 2dww = considering irrigation with wastewater with-held for two days; 3dww = considering irrigation with wastewater with-held for three days; 0.5 log red ww = considering 0.5 log reduction after partial treatment of wastewater (specifically at the La site i.e. site 3); 1 log red ww = considering 1 log reduction after partial treatment of wastewater(specifically at the La site i.e. site 3)

After considering the estimated number of exposed persons for each exposure route, the estimated numbers of infections shown in table 6.16 are obtained. The various practices and factors such as the use of pipe borne water, partial treatment and with-holding of wastewater lead to lower infection risks compared to the worst case scenarios considered in table 6.15. Pathogens such as *Rotavirus, Hepatitis A* and *Salmonella* with low infective doses (i.e. those with higher viable organisms in the dose-response models) tend to have higher estimated infection risks in a year.

Depending on the farm site and level of pollution, exposed children and lettuce harvesters tend to have comparable yearly infection risks due to the similar dose estimations (i.e. through accidental ingestion). The differences are however due to different frequencies of exposures, log reduction considered as well as the number of the exposed persons in each case (see figure 6.18 and table 6.17).

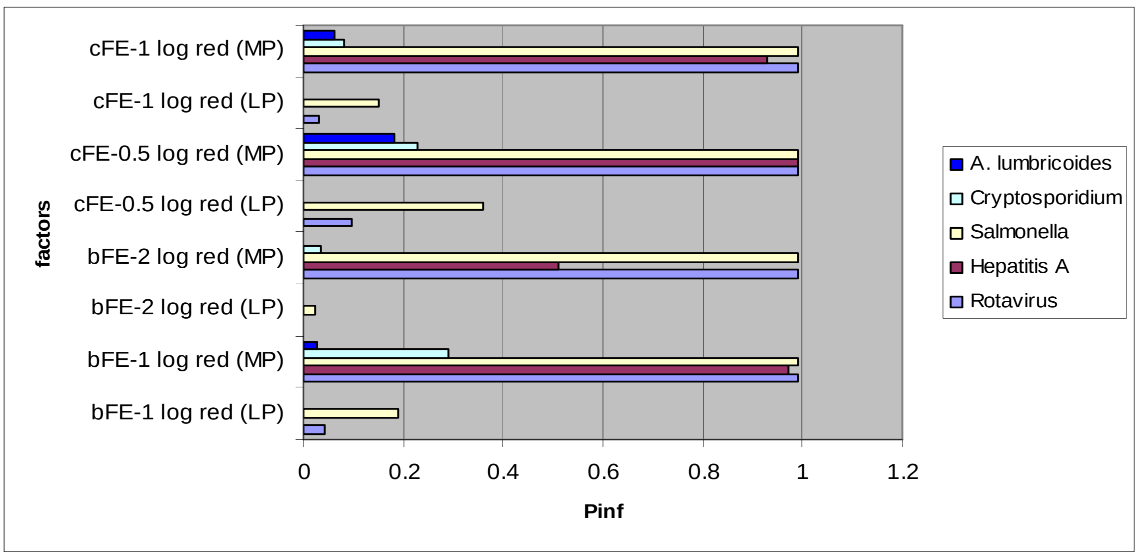


Figure 6. 10: Estimated yearly risk of infection for exposed children and lettuce harvesters after considering some practices

FE = frequency of exposures (per exposed individual); MP = most polluted site; LP = least polluted site; b-1 log red = considering 1 log reduction by protecting children from wastewater storage area; b-2 log red = considering 2 log reduction by protecting children from wastewater storage area; c- 0.5 log red = considering 0.5 log reduction as a result of pathogen die-off after cessation of irrigation before harvest; c- 1 log red = considering 1 log reduction as a result of pathogen die-off after cessation of irrigation before harvest

Table 6. 17: Estimated yearly risk of infection resulting from frequency of exposure and number of affected persons for exposed children and lettuce harvesters after considering some practices

| *Exposure* | *Rotavirus* | *Hepatitis A* | *Salmonella* | *Cryptosporidium* | *A. lumbricoides* |
|---|---|---|---|---|---|
| b+NEP1 log red (LP) | 13.82 | 0.27 | 64.03 | 0.012 | 0.0009 |
| b+NEP1 log red (MP) | 333.63 | 326.89 | 333.63 | 97.73 | 8.76 |
| b+NEP 2 log red (LP) | 1.42 | 0.03 | 7.75 | 0.0012 | 0.0001 |
| b+NEP 2 log red (MP) | 333.63 | 171.87 | 333.63 | 11.46 | 0.88 |
| c+NEP 0.5 log red (LP) | 3.8 | 0.08 | 14.4 | 0.001 | 0.00076 |
| c+NEP 0.5 log red (MP) | 39.6 | 39.6 | 39.6 | 9.2 | 7.2 |
| c+NEP 1 log red (LP) | 1.24 | 0.02 | 6 | 0.00034 | 0.00025 |
| c+NEP 1 log red (MP) | 39.6 | 37.2 | 39.6 | 3.28 | 2.4 |

+NEP = with number of exposed persons; LP = lest polluted site; MP = most polluted site; b 1log red = considering 1 log reduction of pathogen by protecting children from wastewater reservoir; b 2log red = considering 2 log reduction of pathogen by protecting children; c 0.5log red = considering 0.5 log reduction as a result of pathogen die-off after cessation of irrigation before harvesting; c 1log red = considering 1 log reduction as a result of pathogen die-off after cessation of irrigation before harvesting

Pathogens with low infective doses such as *Rotavirus, Salmonella* and *Hapatitis A* gave high infection risks compared to *Cryptosporidium* and *A. lumbricoides* with higher infective dose although the latter have more persistence. The differences in infection risks of *Rotavirus* and *Hapatitis A* even though both pathogens are viruses are due to the differences in each pathogen ratio to faecal coliform and dose-response mathematical relationship used.

For exposed lettuce sellers, street food vendors and raw lettuce consumers, washing lettuce with vinegar and weak disinfectants solutions leads to reduced infection risks. However, during discussions with some of the exposed groups, washing with pipe borne water, warm water or week disinfectant solutions including salt solution are practiced in most cases. Notwithstanding the estimated infection risks, with about 65% of the consumed lettuce brought from outside Accra, which is being irrigated with relatively better wastewater quality as well as routine inspection by the health department of the AMA (refer to Annex 5), a lower risk of infection could be encountered in reality.

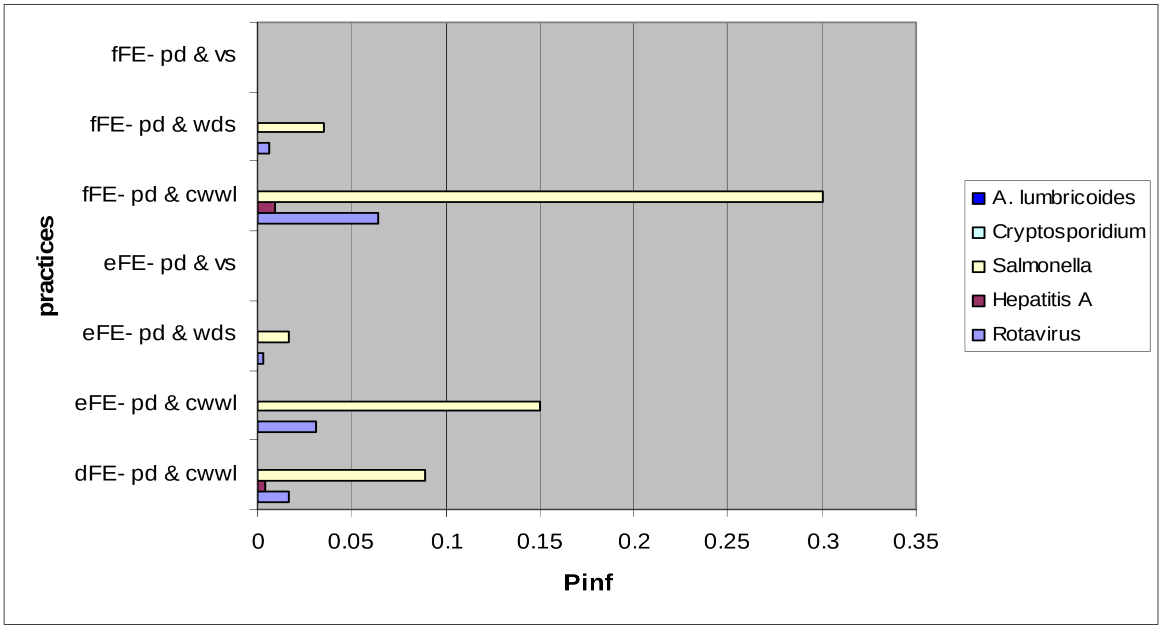


Figure 6. 19: Estimated yearly risk of infection for exposed sellers, vendors and consumers after considering some practices

FE = frequency of exposures (per exposed individual)
d-pd & cwwl = considering pathogen die-off and clean water washing of lettuce by sellers; e-pd & cwwl = considering pathogen die-off and clean water washing of lettuce by vendors; e-pd & wds = considering pathogen die-off and washing of lettuce with weak disinfectant solution by vendors; e-pd & vs = considering pathogen die-off and washing of lettuce with vinegar solution by vendors; f-pd & cwwl = considering pathogen die-off and clean water washing of lettuce by consumers; f-pd & wds = considering pathogen die-off and washing of lettuce with weak disinfectant solution by consumers; f-pd & vs = considering pathogen die-off and washing of lettuce with vinegar solution by consumers;

Table 6. 18: Estimated yearly risk of infection resulting from frequency of exposure and number of affected persons for exposed sellers, vendors and consumers after considering some practices

| *Exposure* | *Rotavirus* | *Hepatitis A* | *Salmonella* | *Cryptosporidium* | *A. lumbricoides* |
|---|---|---|---|---|---|
| d+NEP* pd & cwwl | 7.21 | 1.6 | 37.47 | 0.005 | 0.00042 |
| e+NEP* pd & cwwl | 155 | 2.9 | 769.5 | 0.13 | 0.0095 |
| e+NEP* pd & wds | 15.5 | 0.29 | 85 | 0.03 | 0.00095 |
| e+NEP* pd & vs | 0.0155 | 0.00029 | 0.085 | 0.00003 | 0.000001 |
| f+NEP* pd & cwwl | 17,920 | 2,716 | 84,000 | 15 | 1.13 |
| f+NEP* pd & wds | 1,848 | 281.96 | 9,800 | 1.53 | 0.110 |
| f+NEP* pd & vs | 1.848 | 0.28 | 10.08 | 0.0014 | 0.00011 |

* +NEP = with number of exposed persons, others are same as in figure 6.19

***Estimation of risks of illness***

One time and yearly risk of illnesses are further estimated from the calculated infection risks (considering only frequency of exposure by a single individual for one time risk and number of exposed persons for overall estimated annual risks). The results obtained from the worst and best scenario cases of each pathogen via the various exposures are used for this task. Since not every person infected by the ingestion of pathogens becomes ill, an independent estimate is made of $P_D$ (the probability of contracting a disease or becoming ill).

$P_D = P_{D:I} \times P_I$ (Fattal et al., 2004).
$P_D$ = the risk of an infected person becoming ill
$P_{D:I}$ = the probability of an infected person developing clinical disease
$P_I$ = estimated risk of infection

$P_{D:I}$ for each pathogen, which is the ratio illness to infection is given by:
*Rotavirus* = 0.5 (Fattal eta al., 2004 and WHO guidelines), also to be used for *Hepatitis A*
*Salmonella* (*Campylobacter*) = 0.3 (WHO guidelines, 2006)
*Cryptosporidium* = 0.7 (WHO guidelines, 2006), also to be used for *Ascaris lumbricoides*

Table 6. 19: Estimated risk of illness for exposed farmers

| | **Estimated one time risk/ person** | | **Overall estimated annual risk** | |
|---|---|---|---|---|
| Pathogen | $P_I$ | $P_D$ | $P_I$ | *Estimated cases* |
| *Rotavirus* | worst case = 0.86<br>best case = $3.4*10^{-5}$ | 0.43<br>$1.7*10^{-5}$ | worst case = 700<br>best case = 185 | 350<br>93 |
| *Hepatitis A* | worst case = 0.51<br>best case = $6.8*10^{-7}$ | 0.3<br>$3.4*10^{-7}$ | worst case = 611<br>best case = 98 | 306<br>49 |
| *Salmonella* | worst case = 0.65<br>best case = $1.9*10^{-4}$ | 0.19<br>$5.7*10^{-5}$ | worst case = 703<br>best case = 214 | 211<br>64 |
| *Cryptosporidium parvum* | worst case = $2.5*10^{-1}$<br>best case = $2.9*10^{-8}$ | 0.18<br>$2.0*10^{-8}$ | worst case = 481<br>best case = 49 | 337<br>34 |
| *Ascaris lumbricoides* | worst case = $2.2*10^{-2}$<br>best case = $2.2*10^{-9}$ | $1.5*10^{-2}$<br>$1.5*10^{-9}$ | worst case = 149<br>best case = 5.2 | 104<br>4 |

Table 6. 20: Estimated risk of illness for exposed children

| | **Estimated one time risk/ person** | | **Overall estimated annual risk** | |
|---|---|---|---|---|
| Pathogen | $P_I$ | $P_D$ | $P_I$ | *Estimated cases* |
| *Rotavirus* | worst case = 0.86<br>best case = $3.5*10^{-4}$ | 0.43<br>$1.8*10^{-4}$ | worst case = 337<br>best case = 1.42 | 169<br>0.7 |
| *Hepatitis A* | worst case = 0.51<br>best case = $6.8*10^{-6}$ | 0.26<br>$3.4*10^{-6}$ | worst case = 334<br>best case = 0.03 | 167<br>0.02 |
| *Salmonella* | worst case = 0.65<br>best case = $1.9*10^{-3}$ | 0.19<br>$5.7*10^{-4}$ | worst case = 334<br>best case = 7.75 | 100<br>2 |
| *Cryptosporidium parvum* | worst case = $2.5*10^{-1}$<br>best case = $2.9*10^{-7}$ | 0.18<br>$2.0*10^{-7}$ | worst case = 327<br>best case = 0.001 | 229<br>0.0007 |
| *Ascaris lumbricoides* | worst case = $2.2*10^{-2}$<br>best case = $2.2*10^{-8}$ | $1.5*10^{-2}$<br>$1.5*10^{-8}$ | worst case = 77.5<br>best case = 0.0001 | 54<br>0.00007 |

Table 6. 21: Estimated risk of illness for exposed vegetable harvesters

| | **Estimated one time risk/ person** | | **Overall estimated annual risk** | |
|---|---|---|---|---|
| Pathogen | $P_I$ | $P_D$ | $P_I$ | *Estimated cases* |
| *Rotavirus* | worst case = 0.86<br>best case = 3.5*10$^{-3}$ | 0.43<br>1.8*10$^{-3}$ | worst case = 40<br>best case = 1.24 | 20<br>0.6 |
| *Hepatitis A* | worst case = 0.51<br>best case = 6.8*10$^{-5}$ | 0.26<br>3.4*10$^{-5}$ | worst case = 39.6<br>best case = 0.02 | 19.8<br>0.01 |
| *Salmonella* | worst case = 0.65<br>best case = 0.018 | 0.19<br>5.4*10$^{-3}$ | worst case = 39.6<br>best case = 6 | 12<br>1.8 |
| *Cryptosporidium parvum* | worst case = 2.5*10$^{-1}$<br>best case = 9.4*10$^{-7}$ | 0.18<br>6.6*10$^{-7}$ | worst case = 37<br>best case = 0.00034 | 26<br>2.4*10$^{-4}$ |
| *Ascaris lumbricoides* | worst case = 2.2*10$^{-2}$<br>best case = 6.9*10$^{-7}$ | 1.5*10$^{-2}$<br>4.8*10$^{-7}$ | worst case = 7.2<br>best case = 0.0003 | 5<br>2.1*10$^{-4}$ |

Table 6. 22: Estimated risk of illness for exposed vegetable sellers

| | **Estimated one time risk/ person** | | **Overall estimated annual risk** | |
|---|---|---|---|---|
| Pathogen | $P_I$ | $P_D$ | $P_I$ | *Estimated cases* |
| *Rotavirus* | worst case = 0.017<br>best case = 1.8*10$^{-4}$ | 8.5*10$^{-3}$<br>9.0*10$^{-5}$ | worst case = 336.8<br>best case = 7.2 | 130.5<br>8.42 |
| *Hepatitis A* | worst case = 3.5*10$^{-4}$<br>best case = 4.0*10$^{-5}$ | 1.8*10$^{-4}$<br>2.0*10$^{-5}$ | worst case = 13.89<br>best case = 1.6 | 6.9<br>0.8 |
| *Salmonella* | worst case = 6.7*10$^{-2}$<br>best case = 9.7*10$^{-4}$ | 2.0*10$^{-2}$<br>2.9*10$^{-4}$ | worst case = 416.79<br>best case = 37.47 | 125<br>11.24 |
| *Cryptosporidium parvum* | worst case = 1.5*10$^{-5}$<br>best case = 1.5*10$^{-7}$ | 1.1*10$^{-5}$<br>1.1*10$^{-7}$ | worst case = 0.59<br>best case = 0.005 | 0.41<br>3.5*10$^{-3}$ |
| *Ascaris lumbricoides* | worst case = 1.1*10$^{-6}$<br>best case = 1.1*10$^{-8}$ | 7.7*10$^{-7}$<br>7.7*10$^{-9}$ | worst case = 0.046<br>best case = 0.00042 | 0.03<br>2.9*10$^{-4}$ |

Table 6. 23: Estimated risk of illness for exposed street food vendors

| | **Estimated one time risk/ person** | | **Overall estimated annual risk** | |
|---|---|---|---|---|
| Pathogen | $P_I$ | $P_D$ | $P_I$ | *Estimated cases* |
| *Rotavirus* | worst case = 0.011<br>best case = 1.1*10$^{-5}$ | 5.5*10$^{-3}$<br>5.5*10$^{-6}$ | worst case = 4800<br>best case = 15.5 | 2400<br>7.7 |
| *Hepatitis A* | worst case = 2.0*10$^{-4}$<br>best case = 2.0*10$^{-7}$ | 1.0*10$^{-4}$<br>1.0*10$^{-7}$ | worst case = 280<br>best case = 0.29 | 140<br>0.15 |
| *Salmonella* | worst case = 4.6*10$^{-2}$<br>best case = 5.9*10$^{-5}$ | 1.4*10$^{-2}$<br>1.8*10$^{-5}$ | worst case = 4950<br>best case = 85 | 1485<br>25.5 |
| *Cryptosporidium parvum* | worst case = 8.8*10$^{-6}$<br>best case = 8.9*10$^{-9}$ | 6.2*10$^{-6}$<br>6.2*10$^{-9}$ | worst case = 12.5<br>best case = 0.03 | 8.8<br>0.02 |
| *Ascaris lumbricoides* | worst case = 6.5*10$^{-7}$<br>best case = 6.5*10$^{-10}$ | 4.6*10$^{-7}$<br>4.6*10$^{-10}$ | worst case = 0.94<br>best case = 0.0009 | 0.7<br>6.3*10$^{-4}$ |

Table 6. 24: Estimated risk of illness for exposed vegetable consumers

| | **Estimated one time risk/ person** | | **Overall estimated annual risk** | |
|---|---|---|---|---|
| Pathogen | $P_I$ | $P_D$ | $P_I$ | *Estimated cases* |
| *Rotavirus* | worst case = 0.042<br>best case = $4.6*10^{-5}$ | 0.02<br>$2.3*10^{-5}$ | worst case = 277,200<br>best case = 1,848 | 138,600<br>924 |
| *Hepatitis A* | worst case = $8.9*10^{-4}$<br>best case = $7.0*10^{-6}$ | $4.5*10^{-4}$<br>$3.5*10^{-6}$ | worst case = 33,600<br>best case = 281.96 | 16,800<br>141 |
| *Salmonella* | worst case = 0.12<br>best case = $2.5*10^{-4}$ | 0.04<br>$7.5*10^{-5}$ | worst case = 277,200<br>best case = 9,800 | 83,160<br>2,940 |
| *Cryptosporidium parvum* | worst case = $3.8*10^{-5}$<br>best case = $3.8*10^{-8}$ | $2.7*10^{-5}$<br>$2.7*10^{-8}$ | worst case = 1,540<br>best case = 1.53 | 1,078<br>1.1 |
| *Ascaris lumbricoides* | worst case = $2.8*10^{-6}$<br>best case = $2.8*10^{-9}$ | $1.9*10^{-6}$<br>$1.9*10^{-9}$ | worst case = 112<br>best case = 0.11 | 78<br>0.08 |

Table 6. 25: Total estimated risk of illness for each pathogen considered

| | **Estimated one time risk/ person** | **Overall estimated annual risk** |
|---|---|---|
| Pathogen | $P_D$ | *Estimated cases* |
| *Rotavirus* | worst case = 1.32<br>best case = 0.0021 | worst case = 141,669<br>best case = 1,035 |
| *Hepatitis A* | worst case = 1.1<br>best case = $9.5*10^{-5}$ | worst case = 17,439<br>best case = 191 |
| *Salmonella* | worst case = 0.65<br>best case = $6.4*10^{-3}$ | worst case = 85,093<br>best case = 3,044 |
| *Cryptosporidium parvum* | worst case = 0.61<br>best case = $1.0*10^{-6}$ | worst case = 1,679<br>best case = 35 |
| *Ascaris lumbricoides* | worst case = 0.05<br>best case = $5.1*10^{-7}$ | worst case = 324<br>best case = 66 |

Table 6. 26: Yearly average reported cases of some diseases in AMA

| Year | Tyhpoid | Cholera | Diarrhoea | Infectious Hepatits | Intestinal Worms | Skin Diseases & Ulcers |
|---|---|---|---|---|---|---|
| 2002* | 2350 | 760 | 26741 | 213 | 6759 | 30861 |
| 2003* | 1620 | 20 | 24439 | 167 | 4255 | 32999 |
| 2005* | 2037 | 1084 | 32765 | 169 | 3870 | 36535 |
| | | | | | | |
| **Average** | **2,002** | **621** | **27,982** | **183** | **4,961** | **33,465** |
| **With Under-reporting** | **3,463** | **1,074** | **48,409** | **317** | **8,583** | **57,894** |

*Source: Accra Metropolitan Health Service

As shown in table 6.25, an overall estimated annual risk of illness for rotavirus, which is known to cause Diarrhoea disease is 141,669 considering worst case scenarios. A lower annual illness risk value of 1,035 is obtained when the various practices in form of preventive measures are considered. The later estimated risk of illness is more reasonable considering the reported annual average cases of 27,982 even with estimated under-

reporting of 73%, i.e. making up to 48,409 cases at the Accra Metropolitan Health Service (see section 1.3.4.1 of this report). Furthermore, *Cryptosporidium parvum* with worst illness risks of 1,679 and best illness risks of 35 is also known to cause profuse and watery diarrhoea. Combining these two pathogenic causes of diarrhoea, a total of 143,348 and 1,070 risks of illness are obtained for worst and best scenario cases respectively. Therefore, realistic estimated diarrhoea cases of 1,070 could be considered considering the annual average reported cases (even with the under-reported estimated cases).

In the case of *Hepatitis A,* which is known to cause Infectious hepatitis, an overall estimated annual risk of illness is 17,439 considering worst case scenarios. A lower annual illness risk value of 191 is obtained when the various practices in form of preventive measures are considered. With an annual average of 183 reported cases (making up to 322 cases after considering estimated under-reporting of 73%), annual illness risks of 191 could be a realistic outcome.

*Salmonella typhi* known to cause Typhoid has an overall estimated annual risk of illness of 85,093 considering worst case scenarios. Again, a lower annual illness risk value of 3,044 is obtained when the various practices in form of preventive measures are considered. With an annual average of 2,002 reported cases (making up to 3,463 cases after considering estimated under-reporting of 73%), annual illness risks of 3,044 could be a likely outcome.

For *Ascaris lumbricoides*, which causes Intestinal Worms, an overall estimated annual risk of illness of 324 considering worst case scenarios while a lower annual illness risk value of 66 is obtained when the various practices in form of preventive measures are considered. With an annual average of 4,961 reported cases (making up to 8,583 cases after considering estimated under-reporting of 73%); it should be noted that this figure could be as a result of combination of other worms and helminthes aside *Ascaris lumbricoides*. In any case, annual illness risks of 66 could be a likely outcome due to the numerous preventive measures usually practiced.

In estimating infection risks and subsequently illness risks, it is worth noting that each exposure route was independently assessed. However, if all the exposure routes are considered as a chain of event i.e. from vegetable farms through to consumption with all the various preventive measures at each route, then it could be deduced that barring cases of recontamination infection/illness would be progressively reduced at each step of the chain of exposure routes.

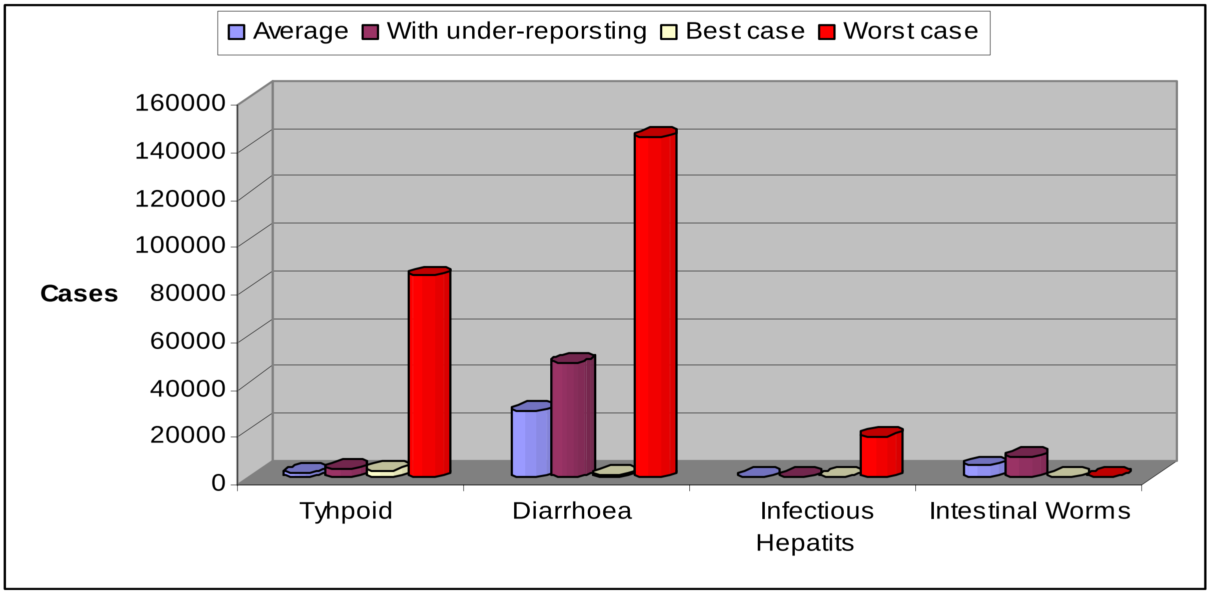


Figure 6. 11: Comparison of Average Reported Diseases and Estimated Amount

The differences between the estimated risks of illness and the reported cases depicted in figure 6.21 could be due to several reasons amongst which are:

i. The estimated risks of illnesses may have either been over or under estimated.

ii. The estimated percentage of underreported cases of diseases can not be considered a true reflection of what happens on the ground. The estimated risks of illness could be termed as potential health risk because it's mostly based on the number of pathogens in the wastewater and estimated quantity ingested while the actual health risk also depends on other factors such as the host immunity for pathogen circulating in the environment. While some respondents did not complain of specific ailments due to their contacts with wastewater or consumption of lettuce, symptoms mostly complain about at some farm sites, markets and street food consumers include gastrointestinal symptoms, fatigue and headache. Some farmers also complained of skin irritations. Most of the respondents resort to self medications rather than visiting hospital.

iii. Most reported cases of water/food borne diseases could be as a result of other exposure routes and not wastewater irrigation of vegetables (lettuce) in Accra Metropolitan Area.

The estimated cases of illnesses (in this case, the best case scenarios) as a result of wastewater irrigation are therefore considered as contributing to the general disease incidences in the study area.

## 5. *Qualitative Microbial Risk Assessment*

From the outcome of table 5.6, the risk scores for the various exposure/ hazard scenarios were obtained using:

likelihood * severity of consequences (scale of effect)

Table 6. 27: Risk Scores for the various exposure types in Accra (qualitative results)

| Exposure/Hazard Scenario | Likelihood | Severity of Consequence | Estimated Risk Score |
|---|---|---|---|
| Irrigation with untreated wastewater (farmers) | 1.43 | 0.0075 | $1.07*10^{-2}$ |
| Exposed wastewater storage sites (mostly kids) | 0.18 | 0.0036 | $6.48*10^{-4}$ |
| Harvesting of contaminated vegetables | 0.14 | 0.00043 | $6.02*10^{-5}$ |
| Sale of contaminated vegetables (mostly trading women) | 1.43 | 0.0045 | $6.44*10^{-3}$ |
| Street food vending | 4.29 | 0.054 | 0.23 |
| Consumption of raw vegetables | 2.14 | 3 | 6.42 |

Basically, using a qualitative risk assessment, the results of the estimated risk score of each exposure shown in the above table indicates that the consumers of raw lettuce could be at the highest risk of infection/illness. This is followed by street food vendors, farmers at various sites, vegetable sellers, children playing around wastewater storage sites and finally harvesters of vegetable.

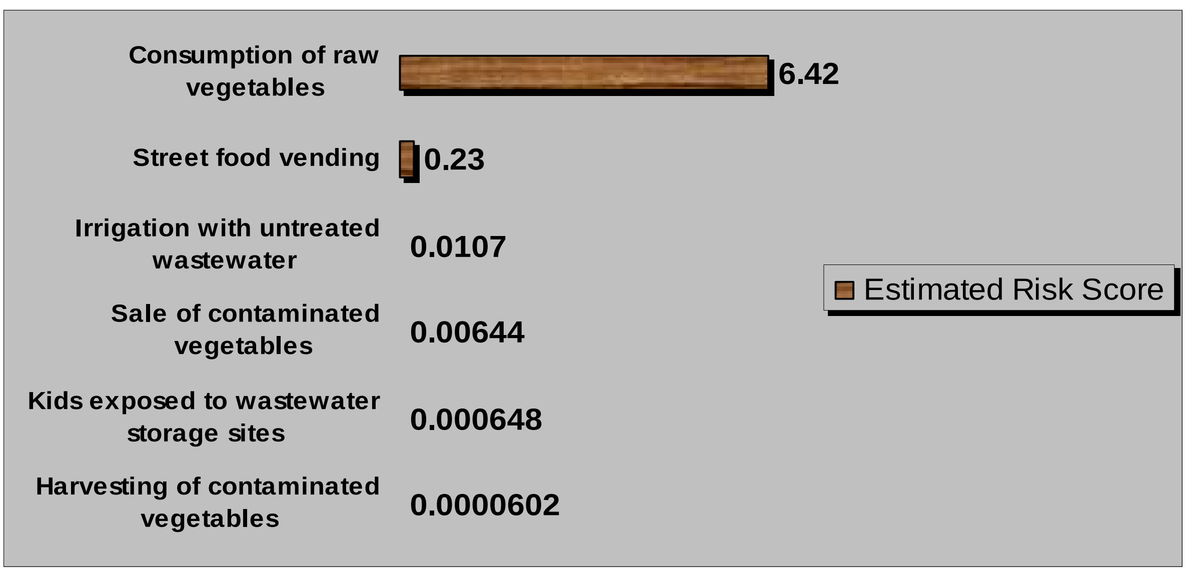


Figure 6. 12: Estimated Risk Ranking

Within the context of available data and information and margins of error that might have occurred during various estimations made, the consumers of lettuce are at higher risk of pathogenic infection than any of the exposed groups. The outcome could be attributed to the relatively higher amount of lettuce consumption leading to the ingestion of high pathogen level coupled with the frequency of consumption (exposure) per week. Although food vendors are exposed to the hazards more frequently than the consumers in a week, the estimated consumption levels are lower. This is because they do not consume the lettuce as often as they sell even though accidental ingestion of pathogen may occur during processing and sale of vegetables. Ordinarily, one might expect farmers to be at almost the same risk with the consumers, but the situation is such that it's very difficult to estimate the level of ingestion by this group. The farmers indicated during the discussion with some of them, that they mostly consume the indigenous vegetables, which involves cooking before consumption. They revealed that they prefer eating lettuce and other related salads with rice or "wache" (a local dish, rice mixed with beans); as such, they buy from the street food vendors. A default accidental ingestion via direct contact with wastewater prescribed by the WHO is therefore used. The outcome of discussions held with some vegetable sellers (often market women) was that just like the farmers, they usually consume cooked local vegetables. Accidental ingestion could occur during contact with contaminated lettuce especially as same quantity of water is re-use for washing of lettuce hence high risk of re-contamination.

Being the most vulnerable of the exposed groups, children playing around the wastewater storage sites are at a high risk of pathogenic infection. However, with a limited frequency of exposure (mostly once per month according to the farmers interviewed) coupled with accidental ingestion of 1ml as suggested by WHO's guidelines, a relatively lower estimated risk score was derived. It is worth emphasizing that children are mostly seen playing along polluted drainages and drain-cum-streams within and at the outskirts of the city, this research is limited to the kids on the various farm sites. According to the interviewed farmers, apart from their children who are in most cases not involved in irrigation, they do not allow loitering of children on their farms because they could mess up with the farm produce. Finally, lettuce harvesters (mostly wholesalers) only come in contact with the contaminated lettuce or even contaminated water and soil on the farms during harvesting, which is about nine times in a year. Therefore a low frequency of exposure is used in this instance; furthermore, a reduced ingestion volume is assumed because processes such as evapo-transpiration among others would have taken place before harvest.

The discussion of above analysis was done without considering the actual viability or otherwise of each pathogen involved due to its complex nature. In addition, the various preventive measures and other confounding factors applied in the semi-quantitative analysis were not taken into consideration in the qualitative analysis. It is worth emphasizing that the inclusion of the aforementioned with other considerations might give more insight to the discussion of the final outcome.

## 5. *Some Proposed Cost effective Measures to Reduce Infection Risks*

For realistic cost-effective measures in reducing infection risks or hazards due to wastewater irrigation in Accra to be made, a comprehensive cost-benefit analysis is required which is beyond the scope of this research. However, some interventions (measures) to curb or manage the hazards/risks based on available information and outcome of the microbial risk analysis of this research are proposed. These are not limited to the following:

i. First of all the high cost of treating wastewater to the WHO guideline level of 1000 FC/100ml has generally been acknowledged especially in a developing country like Ghana. Achieving low levels of infection/illness risks through more advanced wastewater treatment technologies increases costs substantially. Furthermore pipe borne water is too expensive to be used as a source of irrigation. In this regard, the realistic and cost-effective measure is the retention/with-holding of the wastewater at each farm site for couple of days before irrigation. Parts of the outcome of this research have demonstrated the fact that this particular measure reduces the risk of infection and subsequent illness thereof.

ii. Considering the methods of irrigation used, protective clothing by farmers could significantly reduce risks of infection to farmers. Fencing of wastewater storage sites would go a long way in protecting children from infection, although risks of infection are still possible through open drainages.

iii. In carrying out sensitivity analysis, the influence of faecal coliform inactivation/log reduction was shown to be much more important for reducing risk because it had a greater influence on the estimated exposure. Hence apart from the above preventive measure through wastewater, vegetables to be eaten raw should be harvested after some days of last irrigation to allow for pathogen die-off. Various forms of vegetable washings (i.e. with clean water, salt and other mild disinfecting solutions) by sellers, street vendors and final consumers and other forms of hygiene should be encouraged.

iv. The risk scores of the various exposure routes by qualitative microbial risk assessment provide alternative method for managing potential infection risks. Thus in order to curb yearly infection risks, relevant authorities and managers should pay more attention to raw lettuce consumers, street food vendors and farmers since these routes had high scores. In order words, more resources should be committed to these routes.

v. As part of the food, water and drug safety programme, the routine inspection of food vendors shown in Annex 5 by the Health Department of the Accra Metropolitan Assembly indicates that only about 46% of notices served due to nuisance complied with notice directives. Compliance should strictly be enforced by the authorities while sanctioning non-compliant individuals.

vi. For successful execution of afore mentioned preventive measures, public enlightenments (in form of education and media publication; see Annex 8) is one of the most vital routes. The IWMI office in Accra should be credited for their efforts in this regards. For instance in November 2003, Metro-TV, a private TV station in Ghana broadcasted several times a related interview with IWMI staff on appropriate risk-reducing measures. However, more such efforts are needed from other related organizations/agencies for effective results to be achieved.

Notwithstanding the above proposed preventive measures, it is advisable to consider the risk of water/food borne (especially gastrointestinal) illness in Accra Metropolitan Area (AMA) in the context of total risk from all possible exposures (i.e. drinking water, recreational water contact, and other contaminated foods apart from the vegetable considered). This facilitates making risk-management decisions that address the greatest risks. For instance, the impact of these preventive measures on the considered disease burden would not be felt if the number of cases of water/food borne diseases attributed to the use of wastewater irrigation in AMA is reduced by half when about 90% of the cases are transmitted through other routes.

However, in order to achieve the greatest impact on health, guidelines should be implemented with such other health promoting measures as: health education, hygiene promotion, provision of adequate drinking water and sanitation, etc. Successful implementation of these proposed cost-effective measures and others would lead to reduction in infection/illness risks hence maximising the health benefits thereof.

# 7 Link to the Millennium Development Goals (MDGs)

By a target date of 2015, eight Millennium Development Goals (MDGs) range from halving extreme poverty to halting the spread of HIV/AIDS and providing universal primary education were to be achieved. These form a blueprint agreed to by all the world's countries and all the world's leading development institutions; these form part of efforts to meet the needs of the world's poorest.

Implementation of the various cost-effective interventions would hopefully help in achieving the Millennium Development goals; specifically the following goals and targets:

***Goal 7***: Ensure environmental sustainability

*Target 9*: Integrate the principles of sustainable development into country policies and programmes; reverse loss of environmental resources
*Target 11*: Achieve significant improvement in lives of at least 100 million slum dwellers, by 2020

***Goal 6***: Combat HIV/AIDS, malaria and other diseases

*Target 8*: Halt and begin to reverse the incidence of malaria and other major diseases (UN Millennium, 2005).

The re-use of urban wastewater after considering safety measures not only help in conservation of water by prevention of pollution of rivers, canals and other surface water but also enhances nutrients recycling thereby reducing the need for investing in chemical fertilizer. This is in line with ensuring environmental sustainability especially in achieving target 9 of the MDGs. Urban vegetable farmers within Accra metropolis are mostly slum dwellers from low income class. Adequate policies towards supporting all relevant stakeholders through implementing appropriate intervention/measures lead to economic empowerment resulting in improvement in their lives. This would help in achieving target 11. Furthermore, in achieving target 8 of goal 6, incidences of water/food borne diseases would be reduced. This is in view of the fact that adhering to the various proposed measures would lead to the reduction in levels of pathogens in the wastewater as well as the vegetables barring any incidences of either re-contamination or infection through other exposure routes.

# 8 Conclusions and Recommendations

## 8.1 Conclusions

i. Aside few backyard gardens and other smaller farms scattered around, six major urban vegetable farms with varying sizes were identified in Accra Metropolitan Area. Raw wastewater from open drains and drain-cum-streams and in few cases, partially treated wastewater and pipe borne water are used for irrigation.
ii. High risks of viral infections were obtained for all considered exposure routes compared to other pathogenic infections. Few farmers using pipe borne water (La and Dzorwulu farm sites) have the lowest risk of infections while the ones using drain/drain-cum-streams at all the farm sites have the highest risk of infections.
iii. The microbial risk assessment carried out indicated that consumers of raw lettuce are at the highest risk of infection/illness. This is followed by street food vendors, farmers at various sites, vegetable sellers, children playing around wastewater storage sites and finally harvesters of vegetable.
iv. About 65% of the lettuce traded in Accra, which are irrigated with relatively better wastewater in terms of microbial quality comes from outside the city.
v. Street food vendors and consumers of raw vegetable such as lettuce are scattered within all parts of the metropolis but are mostly located in the middle and low income class areas.
vi. There was no direct correlation between the reported cases on water/food borne disease and the estimated cases as a result of wastewater irrigation. Hence the infection/illness risks estimated are said to contribute to the general endemic levels in the metropolis.
vii. Some basic preventive measures such as the use of personal protective clothing by farmers, fencing of wastewater storage sites, wastewater retention for couple of days before irrigation and various forms of washing lettuce would help in curbing the risk of pathogenic infections and subsequently risk of water/food borne diseases.
viii. In order to protect the public from contaminated vegetables, authorities in Accra banned the use polluted water for irrigation. However, enforcement would not only affect the livelihoods of urban farmers and vegetables traders but would also reduce the continuous supply of traditional and non-traditional vegetables in the city. It is therefore a very contentious and complex situation.

## 8.2 Recommendations

i. The outcome of sensitivity analysis carried out indicated that estimation of exposure was very sensitive to changes in the initial faecal coliform concentration (and ultimately pathogen concentration, which in this case depends on the ratio of faecal coliform to each pathogen used). It is therefore prudent to carry out the microbial (or possibly pathogenic) analysis of the wastewater used at each farm

site in order to come out with more acceptable results. The same could be said of the log reductions of pathogens due to various practices as well as the estimated amount ingested at each exposure routes.

ii. For detailed research to be made, a particular farm site with various irrigation water types (i.e. raw wastewater, partially treated wastewater and pipe borne water) such as the one at La should be focused on. This would allow for detail stepwise approach study of the actual chain of events from irrigation at the farm site through to consumption. This will also address the issue of changes in the number of actual farmers and other dependants such as their children who help with the farming activities. Comprehensive interviews and questionnaires should be administered at all identified stages of exposure routes.

iii. Infection/ illness risks due to seasonal variations could be investigated; episodes of heavy rains causing floods and extreme dry condition (*Hamartan season*) would lead to changes in farming practices and some vital parameters used in the various estimations. Additionally, the effects of soil types/properties at various farm sites on retention of pathogens and transport to ground water should also be investigated.

iv. Cost-benefit analysis is required to evaluate the additional health benefit that might result from a further risk reduction to be gained by adhering to the proposed measures or any other intended measure in relation to the costs of implementing such measures.

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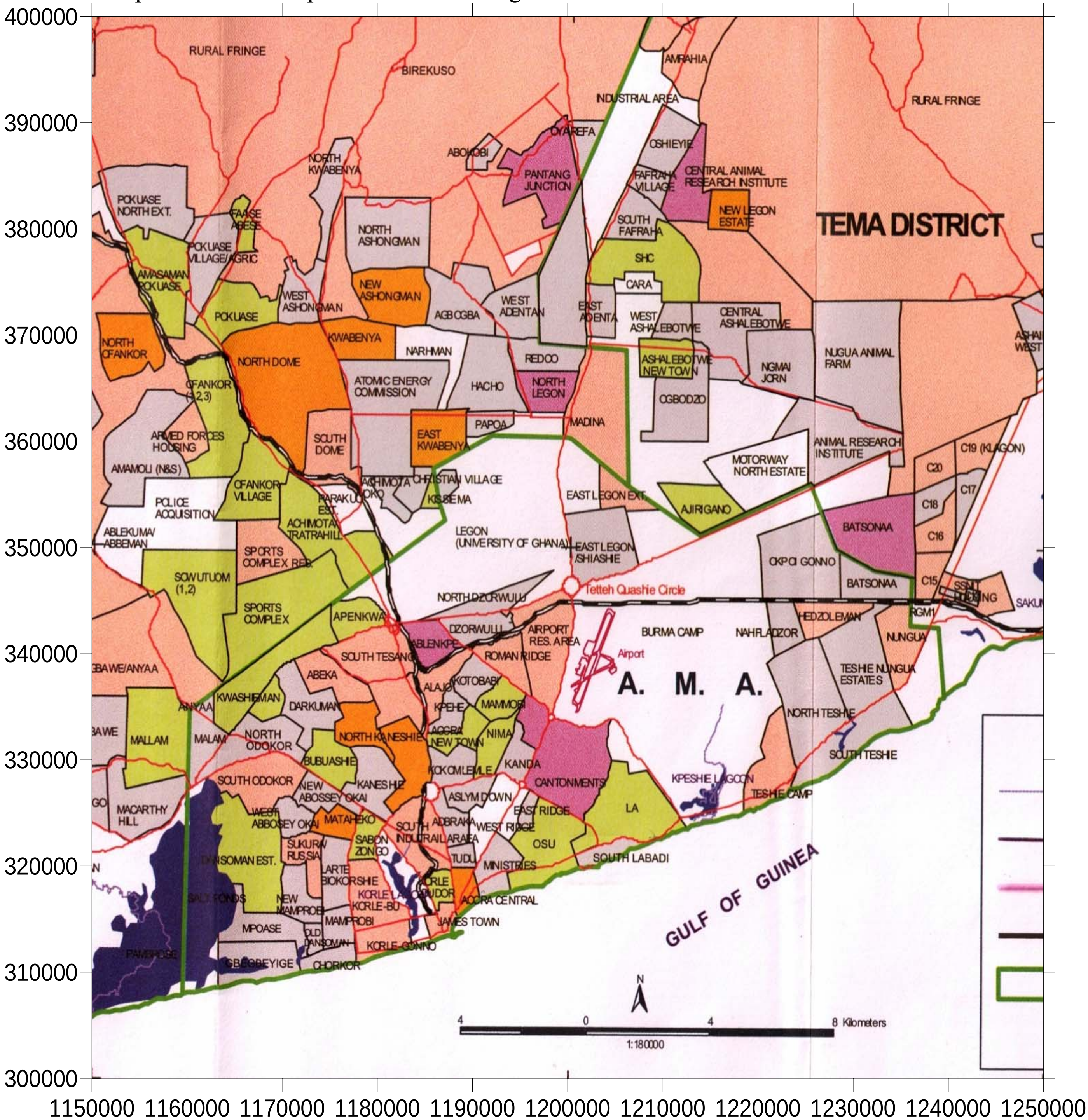
## Annexes

Annex 1: Map of Accra Metropolitan Area showing some residential areas




Source: modified from Songsore et al., 2005

Annex 2: Reported incidences of some communicable diseases in some health centers under AMA

| Year | Malaria | Tyhpoid | Cholera | Diarrhoea | Infectious Hepatits | Intestinal Worms | Skin Diseases & Ulcers |
|---|---|---|---|---|---|---|---|
| **Achimota** | | | | | | | |
| 2002 | 22468 | 0 | 242 | 2466 | 0 | 556 | 2137 |
| 2003 | 27045 | 10 | 0 | 2980 | 1 | 121 | 3098 |
| 2005 | 31820 | 0 | 141 | 2134 | 0 | 87 | 6747 |
| **RIDGE** | | | | | | | |
| 2002 | 12738 | 0 | 33 | 527 | 3 | 642 | 305 |
| 2003 | 1282 | 0 | 0 | 51 | 0 | 57 | 41 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **P.M.L** | | | | | | | |
| 2002 | 28390 | 45 | 64 | 4157 | 19 | 131 | 4311 |
| 2003 | 29925 | 73 | 3 | 4879 | 8 | 61 | 4322 |
| 2005 | 38108 | 288 | 54 | 6051 | 13 | 161 | 4944 |
| **POLICE** | | | | | | | |
| 2002 | 10019 | 52 | 0 | 983 | 6 | 108 | 859 |
| 2003 | 1703 | 9 | 0 | 158 | 0 | 33 | 210 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **MENTAL** | | | | | | | |
| 2002 | 47 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2003 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **ADABRAKA** | | | | | | | |
| 2002 | 13399 | 185 | 0 | 468 | 1 | 34 | 3794 |
| 2003 | 12543 | 310 | 0 | 475 | 13 | 14 | 2563 |
| 2005 | 16821 | 175 | 1 | 577 | 14 | 6 | 1833 |
| **KANESHIE** | | | | | | | |
| 2002 | 32491 | 14 | 14 | 2992 | 5 | 553 | 3770 |
| 2003 | 31795 | 126 | 2 | 2669 | 15 | 1194 | 3166 |
| 2005 | 30462 | 0 | 85 | 2833 | 0 | 538 | 4045 |
| **LA** | | | | | | | |
| 2002 | 32218 | 21 | 72 | 2823 | 4 | 1970 | 4578 |
| 2003 | 30758 | 7 | 0 | 3086 | 0 | 31 | 8843 |
| 2005 | 47247 | 25 | 1 | 6785 | 27 | 0 | 9712 |
| **MAMPROBI** | | | | | | | |
| 2002 | 26273 | 118 | 17 | 3291 | 72 | 707 | 2952 |
| 2003 | 23879 | 195 | 2 | 3843 | 73 | 830 | 3192 |
| 2005 | 35031 | 130 | 432 | 4157 | 57 | 1025 | 3451 |
| **MAAMOBI** | | | | | | | |
| 2002 | 15637 | 1 | 189 | 1947 | 5 | 717 | 2569 |
| 2003 | 19146 | 29 | 0 | 2157 | 6 | 676 | 2679 |
| 2005 | 31426 | 5 | 96 | 4074 | 1 | 750 | 3816 |
| **USSHER TOWN** | | | | | | | |
| 2002 | 14407 | 63 | 18 | 1177 | 32 | 550 | 960 |
| 2003 | 15821 | 94 | 2 | 1375 | 26 | 595 | 1228 |
| 2005 | 17844 | 140 | 76 | 2780 | 15 | 821 | 1325 |
| **KORLE GONO** | | | | | | | |
| 2002 | 9994 | 707 | 86 | 3514 | 43 | 27 | 274 |
| 2003 | 1982 | 172 | 4 | 749 | 13 | 13 | 128 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| CASTLE | | | | | | | |
| 2002 | 2480 | 93 | 0 | 251 | 0 | 89 | 156 |
| 2003 | 1079 | 12 | 0 | 150 | 0 | 5 | 76 |
| 2005 | 2046 | 33 | 17 | 184 | 0 | 49 | 59 |
| STADIUM | | | | | | | |
| 2002 | 5565 | 113 | 0 | 574 | 2 | 144 | 651 |
| 2003 | 4678 | 168 | 0 | 509 | 0 | 107 | 758 |
| 2005 | 5612 | 237 | 0 | 608 | 1 | 67 | 872 |
| TUC | | | | | | | |
| 2002 | 1587 | 0 | 0 | 109 | 0 | 29 | 45 |
| 2003 | 1177 | 1 | 0 | 92 | 0 | 6 | 28 |
| 2005 | 1073 | 0 | 2 | 47 | 0 | 0 | 11 |
| MAKOLA | | | | | | | |
| 2002 | 3841 | 701 | 0 | 4 | 0 | 4 | 226 |
| 2003 | 2604 | 109 | 0 | 22 | 0 | 11 | 152 |
| 2005 | 4527 | 396 | 0 | 213 | 0 | 24 | 321 |
| AIRPORT | | | | | | | |
| 2002 | 7498 | 145 | 0 | 19 | 0 | 300 | 333 |
| 2003 | 1975 | 37 | 0 | 3 | 0 | 52 | 52 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MALLAM ATTA | | | | | | | |
| 2002 | 3408 | 64 | 0 | 142 | 0 | 47 | 250 |
| 2003 | 3821 | 114 | 0 | 160 | 0 | 45 | 253 |
| 2005 | 4290 | 88 | 0 | 199 | 0 | 99 | 294 |
| PARLIAMENT | | | | | | | |
| 2002 | 850 | 1 | 0 | 130 | 0 | 0 | 379 |
| 2003 | 381 | 0 | 0 | 67 | 0 | 0 | 13 |
| 2005 | 888 | 0 | 0 | 114 | 6 | 0 | 33 |
| DANSOMAN | | | | | | | |
| 2002 | 12449 | 2 | 70 | 862 | 13 | 49 | 1849 |
| 2003 | 11476 | 2 | 2 | 855 | 10 | 269 | 1657 |
| 2005 | 17681 | 448 | 176 | 1781 | 22 | 63 | 2100 |
| JAMES CAMP | | | | | | | |
| 2002 | 3722 | 0 | 0 | 15 | 0 | 38 | 24 |
| 2003 | 4091 | 0 | 0 | 29 | 0 | 22 | 146 |
| 2005 | 8909 | 0 | 0 | 17 | 0 | 20 | 277 |
| NIMA 441 P.H.C | | | | | | | |
| 2002 | 936 | 0 | 0 | 12 | 0 | 0 | 83 |
| 2003 | 704 | 152 | 5 | 4 | 0 | 4 | 65 |
| 2005 | 920 | 72 | 0 | 2 | 0 | 38 | 58 |
| NIMA GOVCLINIC | | | | | | | |
| 2002 | 4835 | 0 | 0 | 206 | 8 | 58 | 223 |
| 2003 | 5080 | 0 | 0 | 99 | 2 | 108 | 288 |
| 2005 | 7560 | 0 | 3 | 172 | 13 | 122 | 246 |
| TRUST HOSPITAL | | | | | | | |
| 2002 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2003 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FIRE SERVICE CLINIC | | | | | | | |
| 2002 | 665 | 25 | 0 | 69 | 0 | 6 | 133 |
| 2003 | 161 | 0 | 0 | 27 | 0 | 1 | 41 |
| 2005 | 213 | 0 | 0 | 37 | 0 | 0 | 55 |
| LEGON HOSPITAL | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2002 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2003 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **37 MILITARY HOSPITAL** | | | | | | | |
| 2002 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2003 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Annex 3: List of contacted Institutions/ Individuals

- Ghana Health Service (Health Centres)
- Ghana Statistical Services
- Ghana Water Company Limited
- Environmental Protection Agency
- Accra Metropolitan Assembly (Waste Management & Public Health Departments)
- International Water Management Institute
- Water Research Institutes
- University of Ghana Legon
- Noguchi Memorial Institute for Medical Research
- Farm Owners and Workers
- Market Sellers and Buyers
- Workers at Wastewater Treatment Plants

Annex 4: Summary of best-fit dose response parameters (Reproduced from Haas and Eisenberg (2001)

| Organism | Exponential | Beta-Poisson | | Reference |
|---|---|---|---|---|
| | **k** | ***N50*** | **α** | |
| *Poliovirus I (Minor)* | 109.87 | | | Minor *et al.* 1981 |
| *Rotavirus* | | 6.17 | 0.2531 | Haas *et al.*1993 |
| *Hepatitis A virus (a)*<br>*Hepatitis A virus* | 1.8229 | <br>30 | <br>0.20 | Ward *et al.* 1986<br>WHO, 2001 |
| *Adenovirus 4* | 2.397 | | | Couch *et al.* 1966 |
| *Echovirus 12* | 78.3 | | | Akin 1981 |
| *Coxsackie (b)* | 69.1 | | | Couch *et al.* 1965 |
| | | | | Suptel, 1963 |
| *Salmonella* (c) | | 23,600 | 0.3126 | Haas *et al.* 1999 |
| *Salmonella typhosa* | | 3.6 106 | 0.1086 | Hornick *et al.* 1966 |
| *Shigella* (d) | | 1120 | 0.2100 | Haas *et al.* 1999 |
| *Escherichia coli* (e) | | 8.6 107 | 0.1778 | Haas *et al.* 1999 |
| *Campylobacter jejuni* | | 896 | 0.145 | Medema *et al.* 1996 |
| *Vibrio cholerae* | | 243 | 0.25 | Haas *et al.* 1996 |
| *Entamoeba coli* | | 341 | 0.1008 | Rendtorff 1954 |
| *Cryptosporidium parvum* | 238 | | | Haas *et al.* 1996 |
| | | | | Dupont *et al.* 1995 |
| *Giardia lamblia* | 50.23 | | | Rose *et al.* 1991 |

Source: Petterson and Ashbolt, 2002
(a) dose in grams of faeces (of excreting infected individuals)
(b) B4 and A21 strains pooled
(c) Multiple (non-typhoid) pathogenic strains (*S. pullorum* excluded)
(d) Flexnerii and dysenteriae pooled
(e) Nonenterohaemorrhagic strains (except 0111)

Annex 5: Routine inspection of food vendors

**FOOD WATER DRUG SAFETY PROGRAMME**

**Inspection of such hospitality premises**

| *Type of Hospitality or Food Premises* | *# enterprise* | *# Inspections* | *# with Nuisance* | *# Licensed* | *# Vendors/ Handlers* | *# Screened* | *# Notices Served* | *# Notices Complied with* |
|---|---|---|---|---|---|---|---|---|
| Prepared Food-Hotel | 298 | 261 | 43 | 182 | 707 | 574 | 33 | 7 |
| Prepared Food-Restaurant | 290 | 333 | 74 | 195 | 1216 | 975 | 89 | 58 |
| Prepared Food-Chop-Bar | 1112 | 1073 | 335 | 800 | 3070 | 2200 | 280 | 101 |
| Prepared Food-Bakeries | 273 | 207 | 72 | 135 | 641 | 474 | 52 | 20 |
| Packaged Food | 65 | 95 | 7 | 59 | 306 | 220 | 19 | 4 |
| Frozen Food | 155 | 135 | 45 | 66 | 391 | 281 | 40 | 5 |
| Drinking Bar | 1907 | 1337 | 546 | 960 | 1444 | 1056 | 330 | 88 |
| **Street Food** | **517** | **1370** | **750** | **340** | **1453** | **1054** | **138** | **63** |
| Fast Food | 168 | 309 | 102 | 119 | 457 | 312 | 80 | 19 |
| Water | 128 | 81 | 13 | 66 | 427 | 282 | 9 | 6 |
| Drugs | 293 | 83 | 26 | 129 | 105 | 31 | 0 | 0 |
| Total | 5206 | 5284 | 2013 | 3051 | 10217 | 7459 | 1070 | 371 |

Source: Health Department of Accra Metropolitan Assembly (2006)

Annex 6: Exposure/Dose Estimation Methodology

$$D = 10^m/(100*10^n)*V*N*10^{-D}$$

Where $10^m$ is the faecal coliform per 100 ml of wastewater ($10^m/100$ is the number per ml, and $10^m/(100*10^n)$ is the number of units of $10^n$ each pathogen per ml, $10^n$ is the ratio of each pathogen to faecal coliform); V is the volume of wastewater remaining on ingested g of lettuce after irrigation, ml; N is the number of viable pathogens per $10^n$; and $10^{-D}$ is the pathogen die-off between harvest and consumption of the lettuces. V is measured as 10.8 ml per 100g of lettuce and N of 0.1–1 (0.55 as mean) for rotavirus and Campylobacter (used for bacteria) and 0.01–0.1 (1.055 as mean) for Cryptosporidium oocysts (used for protozoa as well as helminthes in this research) (Mara et al., 2007). $10^{-D}$ is obtained from the WHO's default log reductions or pathogen die-off. This is depicted in the table shown below:

| **Exposure** | Con of pathogens (C) | Volume Ingested (V) | Pathogen Die-off ($10^{-D}$) | No of viable Pathogens (N) | Dose = $C*V*10^{-D}*N$ |
|---|---|---|---|---|---|
| a1). Marine drive site | | | | | |
| a2). Dzorwulu/Plant Pool site | | | | | |
| a3). La site | | | | | |
| a4). Korle-bu site | | | | | |
| a5). GBC site | | | | | |
| a6). CSIR and IWMI offices site | | | | | |
| b). Children playing at various wastewater storage sites | | | | | |
| c). Harvest of vegetables | | | | | |
| d). Sale of vegetables (market women) | | | | | |
| e). Street food vending | | | | | |
| f). Consumption of raw vegetables | | | | | |

After dose estimations for each exposure route, the risks of infection are then calculated using the various dose-response mathematical equations (i.e. for both single exposures and annual exposures respectively).

# Annex 7: Estimated Infection Risks

| **Estimated risk of infection per single exposure ("single hit") for worst case scenario** | | | | | |
|---|---|---|---|---|---|
| *Exposure* | *Rotavirus* | *Hepatitis A* | *Salmonella* | *Cryptosporidium* | *A. lumbricoides* |
| a1 | 0.51 | 0.057 | 0.43 | 0.0029 | 0.00022 |
| a2 | 0.2 | 0.0067 | 0.27 | 0.00029 | 0.000022 |
| a3 | 0.73 | 0.27 | 0.56 | 0.029 | 0.0022 |
| a4 | 0.86 | 0.51 | 0.65 | 0.25 | 0.022 |
| a5 | 0.03 | 0.00068 | 0.11 | 0.000029 | 0.0000022 |
| a6 | 0.03 | 0.00068 | 0.11 | 0.000029 | 0.0000022 |
| | | | | | |
| bLP | 0.03 | 0.00068 | 0.11 | 0.000029 | 0.0000022 |
| bMP | 0.86 | 0.51 | 0.65 | 0.25 | 0.022 |
| | | | | | |
| cLP | 0.03 | 0.00068 | 0.11 | 0.000029 | 0.0000022 |
| cMP | 0.86 | 0.51 | 0.65 | 0.25 | 0.022 |
| | | | | | |
| d | 0.017 | 0.00035 | 0.067 | 0.000015 | 0.0000011 |
| | | | | | |
| e | 0.011 | 0.0002 | 0.046 | 0.0000088 | 0.00000065 |
| | | | | | |
| f | 0.042 | 0.00089 | 0.12 | 0.000038 | 0.0000028 |

*LP = least polluted site and *MP = Most polluted site

a) represents the various farm sites (1 - Marine drive, 2 – Dzorwulu, 3 – La, 4 - Korle-bu, 5 - GBC site and 6 - CSIR/IWMI site), b) represents Children playing at various wastewater storage sites, c) represents Harvest of lettuce, d) represents Sale of lettuce, e) represents Street food vending and f) represents Consumption of raw lettuce.

| **Estimated risk of infection per single exposure ("single hit") after considering other confounding factors** | | | | | |
|---|---|---|---|---|---|
| *Exposure* | *Rotavirus* | *Hepatitis A* | *Salmonella* | *Cryptosporidium* | *A. lumbricoides* |
| a1-1dww | 0.36 | 0.02 | 0.37 | 0.00094 | 0.000099 |
| a1-2dww | 0.21 | 0.0067 | 0.27 | 0.00029 | 0.000022 |
| a1-3dww | 0.088 | 0.0021 | 0.19 | 0.000094 | 0.0000069 |
| | | | | | |
| a2-tw | 0.000034 | 0.00000068 | 0.00019 | 0.000000029 | 2.2E-09 |
| a2-1dtw | 0.000011 | 0.00000021 | 0.000062 | 9.4E-09 | 6.9E-10 |
| a2-1dww | 0.088 | 0.0021 | 0.19 | 0.000094 | 0.0000069 |
| a2-2dww | 0.033 | 0.00068 | 0.11 | 0.000029 | 0.0000022 |
| a2-3dww | 0.011 | 0.00021 | 0.047 | 0.0000094 | 0.00000022 |
| | | | | | |
| a3-tw | 0.000034 | 0.00000068 | 0.00019 | 0.000000029 | 2.2E-09 |
| a3-0.5 log red ww | 0.64 | 0.136 | 0.49 | 0.0094 | 0.00096 |
| a3-1 log red ww | 0.51 | 0.057 | 0.43 | 0.0029 | 0.0009 |
| | | | | | |
| a4-1dww | 0.8 | 0.39 | 0.61 | 0.09 | 0.0069 |
| a4-2dww | 0.73 | 0.26 | 0.56 | 0.028 | 0.0022 |
| a4-3dww | 0.64 | 0.14 | 0.49 | 0.0094 | 0.00069 |
| | | | | | |
| a5-1dww | 0.011 | 0.00021 | 0.048 | 0.0000094 | 0.00000069 |
| a5-2dww | 0.0035 | 0.000068 | 0.018 | 0.0000029 | 0.00000022 |
| a5-3dww | 0.0011 | 0.000021 | 0.006 | 0.00000094 | 0.000000069 |
| | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| a)6-1dww | 0.011 | 0.00021 | 0.048 | 0.0000094 | 0.00000069 |
| a)6-2dww | 0.0035 | 0.000068 | 0.018 | 0.0000029 | 0.00000022 |
| a)6-3dww | 0.0011 | 0.000021 | 0.006 | 0.00000094 | 0.000000069 |
| | | | | | |
| b-1 lr for mp | 0.73 | 0.25 | 0.56 | 0.028 | 0.0022 |
| b-2 lr for mp | 0.51 | 0.057 | 0.43 | 0.0029 | 0.00022 |
| b-1 lr for lp | 0.0035 | 0.000068 | 0.018 | 0.0000029 | 0.00000022 |
| b-2 lr for lp | 0.00035 | 0.0000068 | 0.0019 | 0.00000029 | 0.000000022 |
| | | | | | |
| c-0.5 lr for mp | 0.8 | 0.39 | 0.61 | 0.028 | 0.022 |
| c-1 lr for mp | 0.73 | 0.26 | 0.56 | 0.0094 | 0.0069 |
| c-0.5 lr for lp | 0.011 | 0.00021 | 0.048 | 0.0000029 | 0.0000022 |
| c-1 lr for lp | 0.0035 | 0.000068 | 0.018 | 0.00000094 | 0.00000069 |
| | | | | | |
| d-pd & cwwl | 0.00018 | 0.00004 | 0.00097 | 0.00000015 | 0.000000011 |
| | | | | | |
| e-pd & cwwl | 0.00011 | 0.000002 | 0.00058 | 0.000000089 | 6.5E-09 |
| e-pd & wdwl | 0.000011 | 0.0000002 | 0.000059 | 8.9E-09 | 6.5E-10 |
| e-pd & vswl | 0.000000011 | 2E-10 | 0.000000059 | 8.9E-12 | 6.5E-13 |
| | | | | | |
| f-pd & cwwl | 0.00046 | 0.000068 | 0.0025 | 0.00000038 | 0.000000028 |
| f-pd & wdwl | 0.000046 | 0.000007 | 0.00025 | 0.000000038 | 2.8E-09 |
| f-pd & vswl | 0.000000046 | 7E-09 | 0.00000025 | 3.8E-11 | 2.8E-12 |

| **Estimated risk of infection per year resulting from frequency of exposure for worst case scenarios** | | | | | |
|---|---|---|---|---|---|
| *Exposure* | *Rotavirus* | *Hepatitis A* | *Salmonella* | *Cryptosporidium* | *A. lumbricoides* |
| 1FE | 1 | 0.99 | 1 | 0.24 | 0.021 |
| 2 FE | 1 | 0.48 | 1 | 0.028 | 0.0021 |
| 3 FE | 1 | 1 | 1 | 0.94 | 0.19 |
| 4 FE | 1 | 1 | 1 | 1 | 0.88 |
| 5 FE | 0.95 | 0.063 | 0.99 | 0.0028 | 0.00021 |
| 6 FE | 0.95 | 0.063 | 0.99 | 0.0028 | 0.00021 |
| | | | | | |
| b FE (LP) | 0.31 | 0.0081 | 0.75 | 0.00035 | 0.000026 |
| b FE (MP) | 1 | 0.99 | 0.99 | 0.97 | 0.23 |
| | | | | | |
| c FE (LP) | 0.24 | 0.0061 | 0.65 | 0.00026 | 0.000019 |
| c FE (MP) | 1 | 0.99 | 0.99 | 0.92 | 0.18 |
| | | | | | |
| d FE | 0.8 | 0.033 | 0.99 | 0.0014 | 0.00011 |
| | | | | | |
| e FE | 0.96 | 0.056 | 0.99 | 0.0025 | 0.00019 |
| | | | | | |
| f FE | 0.99 | 0.12 | 0.99 | 0.0055 | 0.0004 |
| | | | | | |
| 1+ NAP | 98 | 97.02 | 98 | 23.52 | 2.06 |
| 2+ NAP | 62 | 29.76 | 62 | 1.74 | 0.13 |
| 3+ NAP | 400 | 400 | 400 | 376 | 76 |
| 4+ NAP | 80 | 80 | 80 | 80 | 70.4 |
| 5+ NAP | 24.7 | 1.64 | 25.74 | 0.07 | 0.0055 |
| 6 + NAP | 36.1 | 2.39 | 37.62 | 0.11 | 0.0079 |
| | | | | | |
| b + NAP (LP) | 104.47 | 2.73 | 252.75 | 0.117 | 0.0088 |
| b + NAP (MP) | 337 | 333.63 | 333.63 | 326.89 | 77.51 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| c + NAP (LP) | 9.6 | 0.24 | 26 | 0.01 | 0.00079 |
| c + NAP (MP) | 40 | 39.6 | 39.6 | 37 | 7.2 |
| | | | | | |
| d + NAP | 336.8 | 13.89 | 416.79 | 0.59 | 0.046 |
| | | | | | |
| e + NAP | 4800 | 280 | 4950 | 12.5 | 0.94 |
| | | | | | |
| f + NAP | 277200 | 33600 | 277200 | 1540 | 112 |

| **Estimated risk of infection per year resulting from frequency of exposure after considering other confounding factors** | | | | | |
|---|---|---|---|---|---|
| *Exposure* | *Rotavirus* | *Hepatitis A* | *Salmonella* | *Cryptosporidium* | *A. lumbricoides* |
| 1FE-1dww | 1 | 0.86 | 1 | 0.086 | 0.0095 |
| 1FE-2dww | 1 | 0.48 | 1 | 0.027 | 0.0021 |
| 1FE-3dww | 0.99 | 0.183 | 1 | 0.009 | 0.0007 |
| | | | | | |
| 2FE- tw | 0.0033 | 0.000065 | 0.018 | 0.0000028 | 0.0000002 |
| 2FE- 1dtw | 0.0011 | 0.00002 | 0.0059 | 0.0000009 | 0.0000001 |
| 2FE- 1dww | 0.99 | 0.183 | 1 | 0.0089 | 0.00066 |
| 2FE- 2dww | 0.96 | 0.063 | 0.99 | 0.0028 | 0.00021 |
| 2FE- 3dww | 0.65 | 0.019 | 0.99 | 0.0009 | 0.0000211 |
| | | | | | |
| 3FE- tw | 0.0034 | 0.000065 | 0.018 | 0.0000028 | 0.0000002 |
| 3FE-0.5 log red ww | 1 | 0.99 | 1 | 0.59 | 0.088 |
| 3FE-1 log red ww | 1 | 0.99 | 1 | 0.24 | 0.082 |
| | | | | | |
| 4FE-1dww | 1 | 1 | 1 | 0.99 | 0.49 |
| 4FE-2dww | 1 | 1 | 1 | 0.93 | 0.19 |
| 4FE-3dww | 1 | 1 | 1 | 0.59 | 0.064 |
| | | | | | |
| 5FE-1dww | 0.65 | 0.019 | 0.99 | 0.0009 | 0.00007 |
| 5FE-2dww | 0.29 | 0.0065 | 0.83 | 0.0003 | 0.00002 |
| 5FE-3dww | 0.1 | 0.0021 | 0.44 | 0.00009 | 0.00001 |
| | | | | | |
| 6FE-1dww | 0.65 | 0.019 | 0.99 | 0.0009 | 0.00007 |
| 6FE-2dww | 0.29 | 0.0065 | 0.83 | 0.00028 | 0.00002 |
| 6FE-3dww | 0.1 | 0.002 | 0.44 | 0.00009 | 0.000007 |
| | | | | | |
| bFE-1 log red (LP) | 0.041 | 0.00082 | 0.19 | 0.000035 | 0.0000026 |
| bFE-1 log red (MP) | 0.99 | 0.97 | 0.99 | 0.29 | 0.026 |
| bFE-2 log red (LP) | 0.0042 | 0.000082 | 0.023 | 0.0000035 | 0.0000003 |
| bFE-2 log red (MP) | 0.99 | 0.51 | 0.99 | 0.034 | 0.0026 |
| | | | | | |
| cFE-0.5 log red (LP) | 0.095 | 0.0019 | 0.36 | 0.000026 | 0.000019 |
| cFE-0.5 log red (MP) | 0.99 | 0.99 | 0.99 | 0.23 | 0.18 |

| | | | | | |
|---|---|---|---|---|---|
| cFE-1 log red (LP) | 0.031 | 0.00061 | 0.15 | 0.0000085 | 0.0000062 |
| cFE-1 log red (MP) | 0.99 | 0.93 | 0.99 | 0.082 | 0.06 |
| | | | | | |
| dFE- pd & cwwl | 0.017 | 0.0038 | 0.089 | 0.000011 | 0.000001 |
| | | | | | |
| eFE- pd & cwwl | 0.031 | 0.00058 | 0.15 | 0.000026 | 0.0000019 |
| eFE- pd & wds | 0.0031 | 0.000058 | 0.017 | 0.0000026 | 0.00000019 |
| eFE- pd & vs | 0.0000031 | 5.8E-08 | 0.000017 | 2.6E-09 | 2E-10 |
| | | | | | |
| fFE- pd & cwwl | 0.064 | 0.0097 | 0.3 | 0.000055 | 0.000004 |
| fFE- pd & wds | 0.0066 | 0.001 | 0.035 | 0.0000055 | 0.0000004 |
| fFE- pd & vs | 0.0000066 | 1.008E-06 | 0.000036 | 0.000000005 | 4E-10 |
| | | | | | |
| 1+ NAP1dww | 98 | 84.28 | 98 | 8.46 | 0.93 |
| 1+ NAP2dww | 98 | 47.04 | 98 | 2.7 | 0.21 |
| 1+ NAP3dww | 97.02 | 17.93 | 98 | 0.88 | 0.07 |
| | | | | | |
| 2+NAP tw | 0.2 | 0.004 | 1.12 | 0.0002 | 0.000012 |
| 2+NAP 1dtw | 0.07 | 0.0013 | 0.37 | 0.000056 | 0.000006 |
| 2+NAP 1dww | 61.38 | 11.35 | 62 | 0.56 | 0.041 |
| 2+NAP 2dww | 59.52 | 3.9 | 61.38 | 0.17 | 0.013 |
| 2+NAP 3dww | 40.56 | 1.24 | 61.38 | 0.056 | 0.0013 |
| | | | | | |
| 3+NAP tw | 1.36 | 0.026 | 7.2 | 0.001 | 0.00008 |
| 3+NAP 0.5 log red ww | 400 | 396 | 400 | 238.4 | 35.2 |
| 3+NAP 1 log red ww | 400 | 396 | 400 | 96 | 32.8 |
| | | | | | |
| 4+ NAP1dww | 80 | 80 | 80 | 79.2 | 39.2 |
| 4+ NAP2dww | 80 | 80 | 80 | 74.4 | 15.2 |
| 4+ NAP3dww | 80 | 80 | 80 | 47.68 | 5.12 |
| | | | | | |
| 5+ NAP1dww | 16.9 | 0.49 | 25.74 | 0.023 | 0.002 |
| 5+ NAP2dww | 7.54 | 0.17 | 21.58 | 0.008 | 0.001 |
| 5+ NAP3dww | 2.6 | 0.051 | 11.44 | 0.0023 | 0.0003 |
| | | | | | |
| 6+ NAP1dww | 24.7 | 0.76 | 37.62 | 0.03 | 0.0027 |
| 6+ NAP2dww | 11.02 | 0.25 | 31.54 | 0.01 | 0.0008 |
| 6+ NAP3dww | 3.8 | 0.08 | 16.72 | 0.0034 | 0.00027 |
| | | | | | |
| b+NAP1 log red (LP) | 13.82 | 0.27 | 64.03 | 0.012 | 0.0009 |
| b+NAP1 log red (MP) | 333.63 | 326.89 | 333.63 | 97.73 | 8.76 |
| b+NAP 2 log red (LP) | 1.42 | 0.03 | 7.75 | 0.0012 | 0.0001 |
| b+NAP 2 log red (MP) | 333.63 | 171.87 | 333.63 | 11.46 | 0.88 |
| | | | | | |
| c+NAP 0.5 log red (LP) | 3.8 | 0.08 | 14.4 | 0.001 | 0.00076 |
| c+NAP 0.5 log | 39.6 | 39.6 | 39.6 | 9.2 | 7.2 |

| | | | | | |
|---|---|---|---|---|---|
| red (MP) | | | | | |
| c+NAP 1 log red (LP) | 1.24 | 0.02 | 6 | 0.00034 | 0.00025 |
| c+NAP 1 log red (MP) | 39.6 | 37.2 | 39.6 | 3.28 | 2.4 |
| | | | | | |
| d+NAP pd & cwwl | 7.21 | 1.6 | 37.47 | 0.005 | 0.00042 |
| | | | | | |
| e+NAP pd & cwwl | 155 | 2.9 | 769.5 | 0.13 | 0.0095 |
| e+NAP pd & wds | 15.5 | 0.29 | 85 | 0.03 | 0.00095 |
| e+NAP pd & vs | 0.0155 | 0.00029 | 0.085 | 0.00003 | 0.000001 |
| | | | | | |
| f+NAP pd & cwwl | 17,920 | 2,716 | 84,000 | 15 | 1.13 |
| f+NAP pd & ww | 1,848 | 281.96 | 9,800 | 1.53 | 0.110 |
| f+NAP pd & vs | 1.848 | 0.28 | 10.08 | 0.0014 | 0.00011 |

Annex 8: Media Publication

# Food vendors must obey the rules

Article: Esther Amofah

**FOOD safety is increasingly becoming an important public health issue since it is of great concern to everybody.**

This has become *necessary because* of the myriad of the diseases contracted from contaminated food sold by wayside food vendors.

It is public knowledge that a high proportion of the food that is served by these street vendors is prepared in a dirty environment and is not well cooked.

While driving along the streets of Accra, one can count a thousand and one food vendors by the wayside, and the environment in which these foods are prepared pose great danger to those who patronise them.

What has worsened the situation is the influx of the fried rice and chicken selling joints called "check check" dotted all over the place. One can hardly tell the source of the vegetables used in the preparation of the food.

Knowing about the water problem in the metropolis, one can easily imagine the source of the water the farmers use to water their vegetables. At some places in Accra, vegetable farmers openly use water running through the gutters to water the vegetables meant for human consumption.

What is alarming is that before the raw vegitables get to the neatest professional kitchen, some amount of contamination might have already taken place along the supply chain because of poor agricultural practices, residual chemicals deposited on harvested crops, poor handling, haulage, storage and unhygienic practices at the point of sale.

Such harm, if not corrected, can result in health consequences, leading to death in some cases.

Street food includes rice, waakye, kenkey, "check-check", beans and fried plantain, tuo zaafi and Hausa koko.

Schoolchildren whose parents are too busy looking for money and, therefore, cannot prepare nutritious and hygienic meals for them are given money to buy food from the wayside.

These children are forced to take their breakfast, lunch and sometimes dinner on the streets. These children pick all sorts of food borne diseases from what they eat.

*It is true that one should be mind*ful of what one eats. But people are compelled to patronise wayside food because of time and money. Wayside food is cheap and does not waste time to get, since food vendors are all over Accra.

People, who patronise street food have suffered from food borne diseases like diarrhoea, cholera, typhoid fever, food poisoning and worm infestation because of the poor handling of food, especially vegetables, right from the source.

From the food vendors' perspective, the variety, quality, method of preparation of food and services are meant to just satisfy the needs of the consumer and not to waste resources and run at a loss.

Street food vendors are known to contribute a significant amount of money to the economy.

Dr Paa-Nii Johnson, the Head of the Processing and Engineering Unit of the Food Research Institute, told the *Ghana News Agency* that the socio-economic survey of 334 vendors and a mini census indicated that street-vended foods made an important contribution to the economy of Accra.

The street foods sector employed more than 60,000 people, with an estimated annual turnover of about 100 million dollars and a profit of 24 million dollars, he said.

But Dr Johnson also stressed the health implications of street food. He said most vended foods like waakye, fufu and salads contained metals, pesticides, micro-organisms and mycotoxins that were harmful to the body and could cause behavioural problems and learning difficulties in children.

"I am not against the sale of food but my problem is the way it is handled," he said.

Some cautious Ghanaians have, for fear of contracting gastro-enteritis, cholera, dysentery and other food borne illnesses, vowed not to eat from food vendors when they go out. They prefer to remain hungry till they get home.

A visit by this writer to some famous markets in Accra like Agbogbloshie, Makola and Kaneshie revealed poor *sanitation and poor handling of* food.

Fresh vegetables were seen displayed on torn and dirty sacks and broken tables propped with stones, left at the mercy of the weather.

This practice causes leafy vegetables to wilt, fruits to shrivel, eggs to age and root crops and plantain to rot.

All these lead to deterioration in food quality and contamination with micro-organisms and worms. The same conditions affect fresh meat and fish distributed and sold to the public. May be the bye law of the Accra Metropolitan Assembly that all animals should be slaughtered at the Abattoir might help to save the situation.

Concerned about the situation, the Food and Drugs Board (FDB) organised a series of awareness programmes on food safety involving all stakeholders, including consumers.

Mr Kwamina Van Ess, the Deputy Executive Director of the FDB, said his outfit was collating information on the number of "check-check" operators so as to audit and inspect them to ensure that they obeyed the rules and regulations. Consumers should also be mindful of where they buy their food. They should look at the appearance of food sellers and check whether they have licences or medical certificate and if the surroundings were neat and very hygienic.

Mr Van Ess suggested that parents, especially, mothers should cook in the house to prevent situations where money is given to children to buy food from the wayside.

"This will really help to reduce the incidence of food poisoning and other illnesses associated with wayside food," he said.

Unfortunately, many infants do not survive under these circumstances. Those who do may suffer from stunted physical and mental development, never reaching their full functional potential in society.

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Source: IWMI's Library