PREVALENCE AND GEOGRAPHICAL DISTRIBUTION OF SINGLE AND MULTIPLE SPECIES OF HELMINTH INFESTATIONS IN PRIMARY SCHOOL CHILDREN IN KISUMU MUNICIPALITY

BY

KIROREI KIPROTICH JOSIAH

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF PUBLIC HEALTH IN EPIDEMIOLOGY AND POPULATION HEALTH

SCHOOL OF PUBLIC HEALTH AND COMMUNITY DEVELOPMENT

MASENO UNIVERSITY

ABSTRACT

Helminth infestations is one of the neglected tropical diseases that affects over 90 million school aged children in Africa. It is a major public health problem especially in communities with poor sanitation and hygiene practices. In Kenya, approximately 8,661,333 primary school children are at risk of helminths. The degree of morbidity is related to the intensity and the number of species harboured. Control is neccesary because children are at higher risk of infection and may suffer from nutritional deficiencies, cognitive and physical development impairement as well as other serious illnesses. To achieve this, updated epidemiologic data is neccesary to guide policy makers and mass drug administrators. This was a cross-sectional study that aimed to determine the prevalence, intensities of infestation, pattern, relationships and geographical distribution of single and multiple species of helminths in primary school children aged 5-12 years old in Kisumu Municipality. Three stool samples were collected from 1300 pupils selected from 12 schools and analyzed for parasites using Kato-Katz technique. Primary schools were mapped using geographical information system data generated by hand-held geographical global positioning system units. Prevalence and intensities maps were generated using ArcView geographical information system software. Overall, 40.69% (529) of the pupils were infected by at least a species of helminths. The prevalence of single helminths infections for, *Ancylostoma duodenale*, *Ascaris lumbricoides*, *Trichuris trichiura* and *Schistosoma mansoni* was 2.15% (28), 3% (39), 12.08% (157) and 32.77% (426) respectively. The prevalence of dual co-infections was 7.54% (98), triple helminths co-infestations 0.1% (10) and quadruple co-infestations 0.08% (1). Light intensity was common in all the helminths. Most helminths were more prevalent in 9-12 years age group than in 5-8 years age group, *Ascaris lumbricoides* P =0.0159 (95% CI = 1.391-24.285,), *Trichuris trichuria* P = 0.0002 (95% CI = 1.599-4.541) and *S. mansoni* P = 0.0001(95% CI = 2.461-4.888) and not significant in *Ancylostoma duodenale* P = 0.0592 (95% CI = 0.947-17.059). Male pupils were more infested than female pupils with *Ancylostoma duodenale* (OR 2.83, 95% CI = 1.07-5.04, P = 0.03), *Ascaris lumbricoides* (OR 2.57, 95% CI =1.28 – 5.13, P = 0.01), *Trichuris trichiura* (1.43, 95% CI =1.02 – 5.31, P = 0.03) and *Schistosoma mansoni* (OR 1.40, 95 % CI = 1.40-1.78, P = 0.01), Chi-square test was used. Mapping showed presence of *Schistosoma mansoni* and *Trichuris trichuria* in all the school and the more proximate a school was to the Lake Victoria the more the number of helminths types present. In conclusion helminths are a public health problem in Kisumu municipality. *Schistosoma mansoni* and *Trichuris trichiura* were present in all the schools. The trend of *Ancylostoma duodenale* being the most prevalent soil transmitted helminth as shown in earlier studies changed to *Trichuris trichiura.* This could have been attributed by persistent use of albendazole which has less efficacy to *Trichuris trichiura,* thus alternative use of albendazole and mebendazole should be embraced in mass drug administration. The more proximate the school was to Lake Victoria the more the number of helminths present and all the schools at the periphery had only two helminths species of *Schistosoma mansoni* and *Trichuris trichiura*. These results provided current epidemiologic information to the Ministry of Health and stakeholders that could be used in targeted implementation of helminths control and eradication strategies.

CHAPTER 1: INTRODUCTION.

1.1. Background of the study

Helminths is a general term for parasitic worms. They are the most common infectious agents of humans in developing countries (Brooker *et al.*, 2010). Approximately 1 billion people in developing regions of Central and South America, China, South Asia and sub-Saharan Africa are infected with one or more helminths (De silva *et al.*, 2003; Hotez *et al.*, 2008). The high prevalence rates of these infections in developing countries is strongly associated with poverty, poor living conditions and hygiene, impoverished health services and warm climate (Montresor *et al.*, 1998; Albonico *et al.*, 1999; Jia *et al.*, 2012). Although helminths continue to blight lives and threaten the health of many people, especially children in impoverished tropical settings (WHO, 2002a ; Hotez *et al.*, 2008), they have traditionally been ranked low on international and the national health agendas (MOPHS, 2011). Kisumu municipality in Kenya is one of areas in sub-Saharan Africa with low economic status, poor environmental hygiene and warm climate that favor exposure and risk of infection with helminths. Approximately 74,000 primary school children in Kisumu municipality are at risk of helminths infection (Brooker, 2008; MOPHS, 2011). However, data on the prevalence of single and multiple species of helminths in primary school children in scarce and the magnitude of the problem thus remains unclear.

Helminths are classified into two major phyla; nematodes (roundworms) and platyheminths (flatworms) (Crook and Zumia, 2014). Four major species of intestinal nematodes also known as geohelminths or Soil-Transmitted Helminths (STHs), cause widespread disease in humans: round worms *(Ascaris lumbricoides)*, whipworm *(Trichuris trichiura)* and the hookworms *(Ancylostoma duodenale* and *Necator americanus)* (Brooker, 2006). The STHs are spread by faecal contamination of soil, food and water (Crook and Zumia 2014). The platyheminths include the tapeworms (also known as cestodes) and trematodes (flukes) , with infection caused by *Schistosoma mansoni* being one of the most common throughout the tropics and subtropics (Bethony *et al.*, 2006; Drake and Bundy, 2008 and Odiere *et al.*, 2011). School-aged children tend to have a high infection rate and greatest numbers of these intestinal worms and schistosomes (Handzel *et al.*, 2003; Holland, 2009). For each species of helminth the associated degree of morbidity is related to the intensity of infection (Pullan *et al.*, 2008). These parasitic infections may result in stunted growth due to impaired nutrient utilization, diminished physical fitness, impaired memory and cognition (Stephenson *et al.*, 1993; Simion and Macgregor 1999; Bethony *et al.*, 2006) with consequent poor educational performance. The is very little data on intensities of helminth infestations in Kenya for the period 1980-2010 as highlighted by the Ministry of Health (MOPHS, 2011). Moreover, the intensities of helminth infection in primary school children in Kisumu municipality have not been described. .

An increasing number of studies of helminth epidemiology have shown that it is common for individuals to be infected with more than one species of helminths (King *et al.*, 2007). A study in Tanzania that investigated the relationship between multiple species infections and intensity of infection of each species demonstrated that children infected with two or more species of helminths generally carry heavier infections of each species than children carrying single species infections (Brooker, 2007)). Other studies have indicated that there is heterogeneity in worm burden among different individuals infected with the same helminth, with a small proportion of hosts in endemic communities being rapidly, frequently, and/or heavily infected (Lwambo *et al.*, 1999; Yared *et al.*, 2009). Some of the major factors suggested to contribute to the heterogeneity and predisposition to helminth infection include genetics, household clustering and age (Noma *et al.*, 2008; Woodhall *et al.*, 2013). There is currently limited study that has investigated the pattern and relationships of single and multiple species of helminths in primary school children in Kisumu municipality.

Geographical and host overlap exit for schistosomes and the STHs (Holland, 2009). The epidemiological distribution of schistosomiasis and STHs has clearly been mapped in Latin America and the Caribbean countries, but remains unclear in sub-Saharan Africa (Brooker *et al.*, 2005). In Kenya, it has been partially mapped at national levels through surveys (MOPHS, 2011) but not much has been done at local levels including Kisumu municipality. Geographical information system (GIS) is applied to consider the spatial patterns of helminths in order to improve efficiency of available interventions (Oliver, 2005; Brooker, 2007). It is necessary to update the mapping for prevalence and intensity of infection of STHs in order to make better evidence-based decisions regarding deworming activities. The data available for preschool going children and school going children are insufficient to know the real situation of STHs prevalence and intensity of infection within Kisumu municipalities (PAHO, 2011; Odiere *et al.*, 2011).

1.2. Problem Statement

Helminths are responsible for extensive morbidity and mortality globally, and especially in SSA which Kenya is part of (Anderson and May, 1991; Handzel *et al.*, 2003; Holland, 2009). It affects more than 400 million school-age children across the globe (Jukes, Drake and Bundy, 2008) and over 90 million school aged children in Africa (Tcheum *et al.*,2012).

Kenya is a high risk country for intestinal helminth infection with an estimated five million (56.8%) of school children in Kenya being affected. The Lake Victoria region, which Kisumu municipality is part of, is a highly endemic area for the STH's and *S. mansoni* (Pullan *et al.*, 2011), but lacks updated data on prevalence and intensities.

There is limited research done on prevalence and intensities as integrated and as dependable variables before. Evidence on this needed in order to show that they are related and failure to address intensities as related prevention and control would be still a big task.

No available data on risks, patterns and relationships of the helminths based on gender, age categories and helminths combinations as well as their geographical distribution within Kisumu municipality. Failure to do this partners and government would continue to provide interventions blindly and depending on general prevalence leads to wastage of drugs, time, manpower, financial resources. Knowing the patterns of helminths will assist in choice of drug regiment and alternation thus avoiding resistance to some drugs by the helminthes. Such data are required by researchers, policy makers, the municipality, county government, ministry of health, ministry of education the government, non-governmental organizations, WHO and other health partners so as to improve prevention and control interventions.

Minimal studies on helminths within Kisumu municipality have not embraced the use of geographical information system in mapping out the distribution of helminths with various variable like intensities, helminths type, prevalence, age and gender risks per specific schools where this study focused. This is important because it puts the data into simplest form that is visual and easy for everyone to understand top from experts to lay people at the community level.

Adopted intervention of mass drug deworming through schools, without information on helminths prevalence, intensities, patterns and mapping, this efforts would be in vain.

1.3. Objectives of the study.

1.3.1. General objective.

To describe the prevalence, intensities, patterns, relationships and mapping out single and multiple species of helminths infestations in primary school children in Kisumu municipality.

1.3.2. Specific objectives.

Specific objectives of this study included:

1. To determine the prevalence of single and multiple species of helminths in primary school children in Kisumu municipality.
2. To describe the intensities of helminths infestations in primary schools children in Kisumu municipality.
3. To establish the pattern and relationships of single and multiple species of helminths in primary school children in Kisumu municipality.
4. To map geographical distribution of single and multiple species of helminths within Kisumu municipality.

1.4. Research questions

Research questions in this study were:

1. What is the prevalence of the single and multiple species of helminths in primary school children in Kisumu municipality?
2. What are the intensities of helminths in primary school children in Kisumu municipality?
3. How is the pattern of single and multiple species of helminths in primary school children in Kisumu municipality?
4. How is single and multiple species of helminths distributed geographically within Kisumu municipality?

1.5. Justification of the study

The Kenyan government is rolling out school deworming programs. Control and eradication efforts are necessary because helminths are known causes of morbidities such as nutritional deficiency (Simeon and McGregor, 1990), impaired physical development and learning disabilities (Nokes and Bundy, 1994; Bundy & de silvia, 1998). Regular treatment of those infested can decrease worm burden and reduce the risk of serious complications later in life (Stepheson *et al.,* 1993). To be able do this there is need to look at the issue of helminths in holistic manner. Whenever prevalence is determined, intensities, patterns and distribution maps of helminths should be generated (Utzinger and de Savigny 2006). This would provide a comprehensive guidance in preventive and control strategies.

However, in Kenya, Ministry of Health reporting tools i.e. MOH 705A and B summary does not provide monthly, quarterly and yearly information about helminths and the available information on epidemiology of helminths in Kenya was last updated between the years of 2000-2003 (MOPHS, 2011). Maps available for the country are also scanty and out-of-date thus need for new up-to-date maps that are specific and not generalized in nature (MOPHS, 2011).

Hence, this study may help in updating the existing prevalence, intensities and mapping of helminths. Reliable and up-to-date maps on helminths are helpful in improving the targeted coverage and cost effectiveness of school based and community based deworming (Figueirodo *et al.,* 2012).

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

This section has been organized into the background of helminths, helminths burden, classification, life cycles, diagnosis, prevention, control, prevalence, intensities, geographical distribution, spatial distribution and use of geographical information system in mapping.

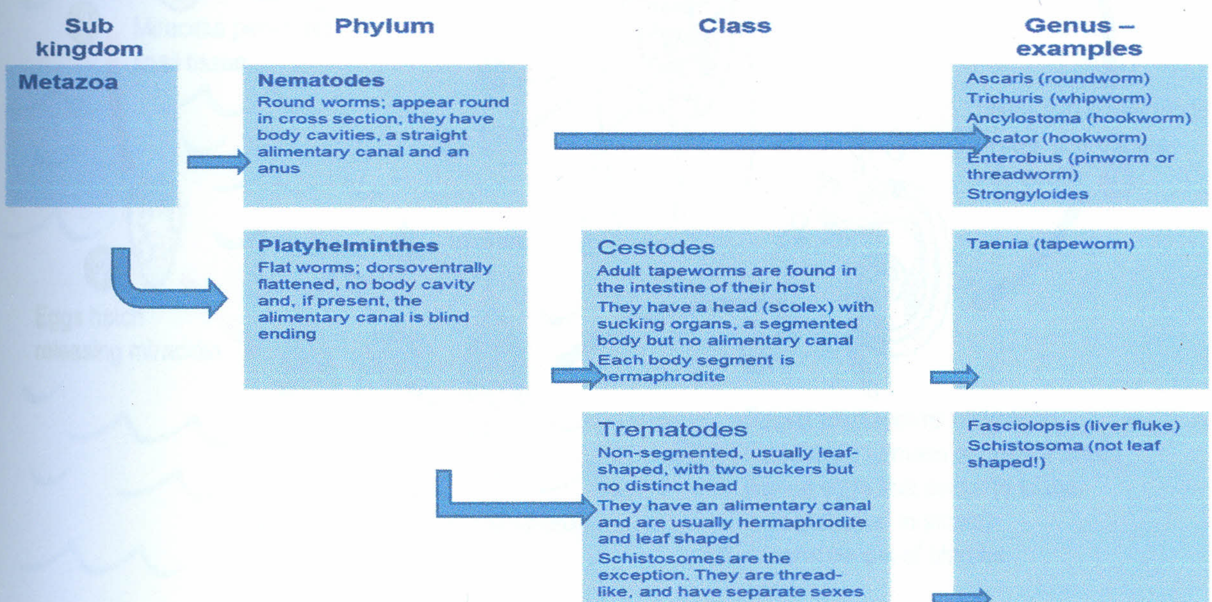
2.2. Helminths transmission and burden

Geohelminths, also known as soil-transmitted helminths (STH's) are soil-transmitted parasitic nematodes with a life cycle that involves no intermediate hosts or vectors and includes; *Ascaris lumbricoides, Trichuris trichiura* and *Ancylostoma duodenale*. They occur all over the world and transmitted to humans through soils, food and water contaminated with eggs of geohelminths (Savioli *et al.*, 2002; WHO, 2002b; de Silva *et al.*, 2003).

Helminths cause significant morbidity worldwide, with 39 million disability adjusted life years (DALYs) lost each year (Hotez *et al.*, 2008; Liese *et al.*, 2010). *Ascaris lumbricoides, Trichuris trichiura, Ancylostoma duodenale* and *Schistosoma mansoni* have global burden of 10.5 million, 17.6 million, 6.4 million and 4.5 million DALYs respectively. There has been growing global attention on control of the NTD's in the last few years, with several countries in sub-Saharan Africa implementing national control programs (Stothard *et al.*, 2009). Controlling helminths should mainly focus on children because prevalence and intensity peaks with school age children (Albonico *et al.*, 2008). *Ancylostoma duodenale* infestation even at low intensities, *T. trichiura* and schistosomes infestations at moderate to heavy intensities causes anemia, while co- infection of helminths exacerbate the state anemia (Robertson *et al.*, 1992; Brooker *et al.*, 1999; Stephenson *et al.*, 2000). Soil transmitted helminths and schistosomes compromises children growth through reduced food intake due to mal-absorption and reduced appetite (Crompton and Neisheim, 2002) thus stunting growth (Stephenson *et al.*, 2000: Stoltzfus *et al.*, 1997 and Stoltzfus *et al.*, 2004). *Ascaris lumbricoides* and *Trichuris trichiura* are associated with low serum vitamin A (retinol) (Stephensen *et al.*, 2001) thus xerothalmia. Soil transmitted helminths brings about cognitive problems, intestinal obstruction and rectal prolapse (Kwalsivig, 2002).

Kenya did launched its five year multi-plan covering 2011- 2015, focusing on control and prevention of NTDs and without epidemiological data it would be difficult in planning and implementing the program. The base line of this plan is to establish the epidemiology, the challenges, and stepping up control efforts of all NTD's (MOPHS 2011)

2.3. Classification of helminths



(Crook and Zumia, 2014)

Figure 2.3.1. Classification of helminths.

Helminths belongs to a broader sub-kingdom called metazoan further it subdivides to: nematodes (*Ascaris lumbricoides*, *Ancylostoma duodenale*, and *Trichuris trichuira*), Platyhelminths (*Schistosoma mansoni*) (Crook and Zumia, 2014)

2.4. Life cycles of helminths

2.4.1. Life cycle of *Schistosoma mansoni*

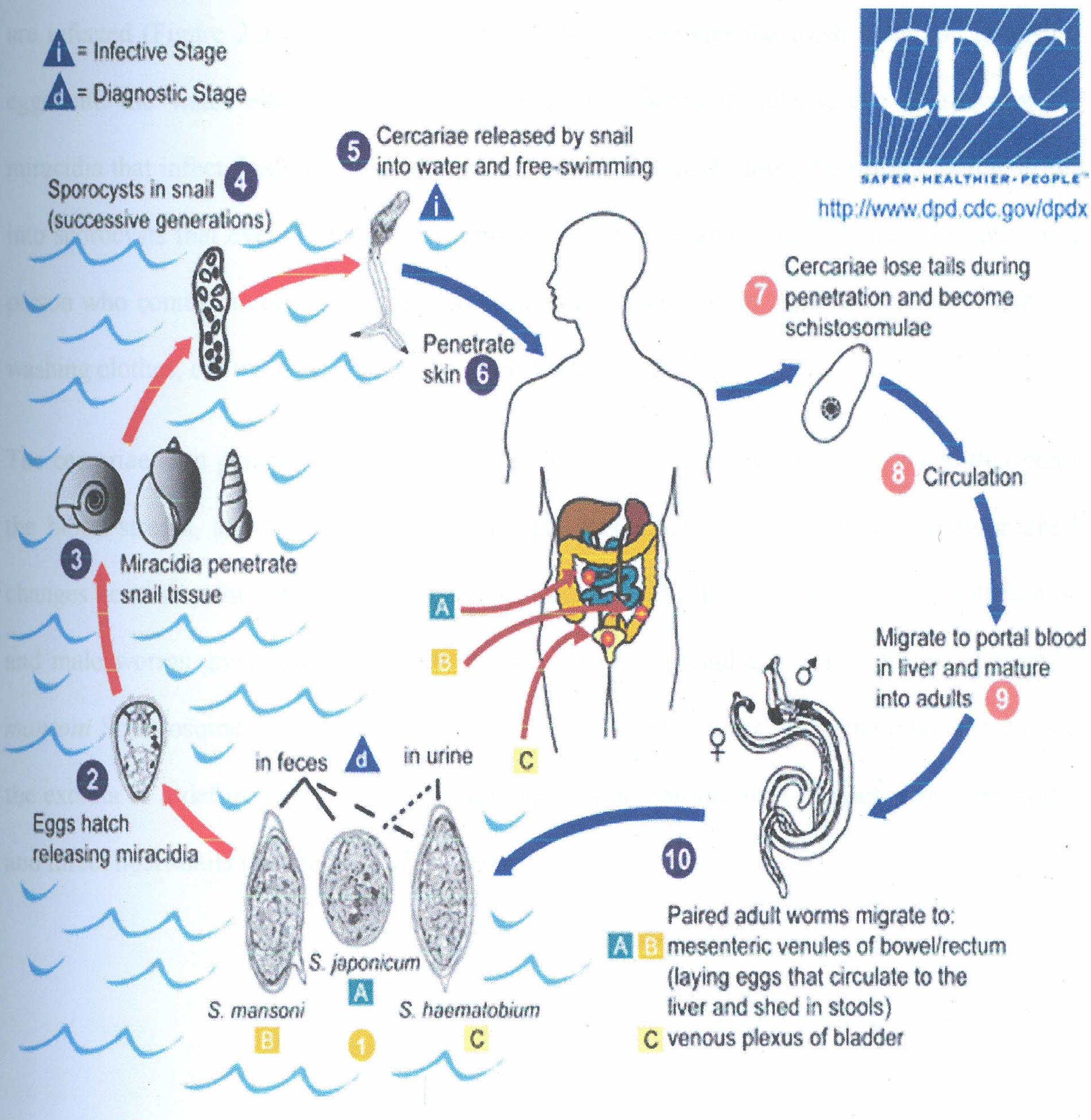


Figure 2.4.1.1. Life cycle of *Schistosoma mansoni.*

(Adopted from CDC; http://www.dpd.cdc.gov/dpdx/html/Ascariasis.htm; accessed on 10th April 2014).

Life cycle of human schistosomes involves snail intermediate hosts, *Biomphalariapfeifferi* as an intermediate host for *S. mansoni* (WHO, 2002b). Human infection occurs when the skin comes in contact with contaminated fresh water in which the intermediate host snail vectors are infected (Figure 2.3.1.1). Infected individuals contaminate the fresh water by releasing eggs into the water either by defecating. The eggs hatch to release the free-swimming miracidia that infect fresh-water snails by penetrating the snail's foot; the miracidia transform into sporocysts that eventually develop into free-living cercariae that penetrate the skin of a person who comes in contact with the contaminated water through activities such as fishing, washing clothes, car wash or swimming(Sturrock *et al.*, 2009).

The cercariae then penetrate the skin and transform into migrating schistosomulae that enter the blood stream, and then travel to the lungs where they undergo further developmental changes necessary for subsequent migration to the liver. In the liver the mature adult female and male worms grow, pair and mate to produce non-operculated eggs. Worm pairs of *S. mansoni* Schistosome transmission occurs when the parasite eggs reach the environment via the excreta of a definitive host, hatch into miracidia on coming into contact with fresh water and infect host snails (Sturrock *et al.*, 2009).

2.4.2. Life cycle of *Ancylostoma duodenale*

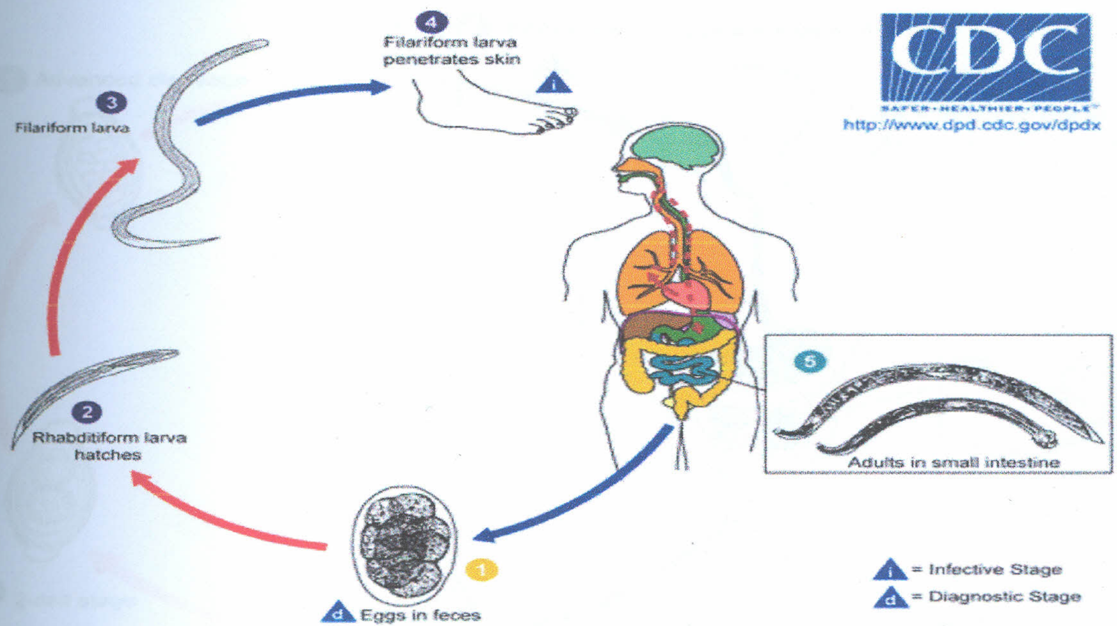


Figure 2.4.2.1. Life cycle for *Ancylostoma duodenale.* (Adopted from CDC; http://www.dpd.cdc.gov/dpdx/html/Ascariasis.htm; accessed on 10 th April 2014).

The life cycle of hookworms is shown in Figure 2.3.2.1. The female worm releases eggs in the intestines of the host. The eggs hatch within 24 to 48 hours and larvae moult twice in warm, shaded, moist, and well-aerated soil. The resultant 3rd stage larvae penetrate the skin of humans on contact with infested soil. The larvae access the blood circulation system via sub-cutaneous venules and lymphatic vessels. Humans can also be infected with *A. duodenale* through ingestion of the 3rd stage larvae. They are transported by blood to the right side of the heart and then to the pulmonary vasculature. They subsequently rupture the capillaries and access the parenchyma through which they ascend the respiratory tree to the trachea. From the trachea, they are coughed and swallowed thus entering gastrointestinal tract (Hotez *et al.*, 2004). In the intestines, the worms mature to adults in between 5 and 9 weeks. After mating, the female starts laying eggs which are voided together with faeces by the host. It is estimated that one *A. duodenale* female worm can lay up to up to 30,000 eggs whereas *N. americanus* can lay up to 10,000 eggs every day for up to 7 years (Bethony *et al.*, 2006).

2.4.3. Life cycle of *Trichuris trichiura*

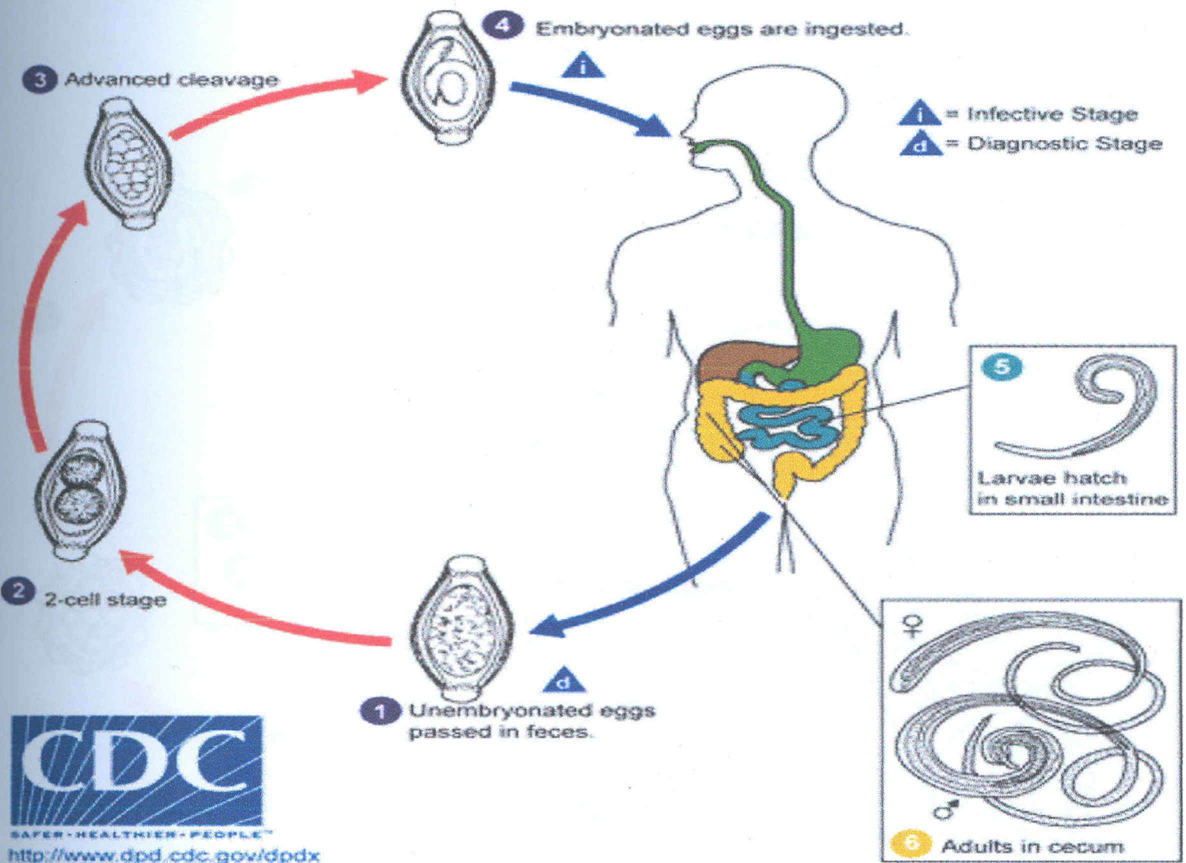


Figure 2.4.3.1. Life cycle of *Trichuris trichiura.*

(Adopted from CDC; http://www.dpd.cdc.gov/dpdx/html/Ascariasis.htm; accessed on 10th April 2014).

The life cycles of *T. trichiura* is described in Figure 2.3.3.2.1. After mating, the female worm lays between 3,000 and 5,000 unembryonated characteristically barrel-shaped eggs per day for about 2 years (Bethony *et al.*, 2006). These eggs are voided to the environment together with human faeces. Under ideal conditions such as shaded moist soil and warmth, the eggs are embryonated and become infective within three weeks. Humans are infected after ingesting embryonated eggs. The first-stage larvae hatch and burry themselves in the mucosa of the small intestine before moving to the caecum, where they grow and mature to adults. This cycle takes 30 to 90 days and the adult worms may live in the human host for several years (Stephenson *et al.*, 2000b; Bethony *et al.*, 2006).

2.4.4. Life cycle *Ascaris lumbricoides*

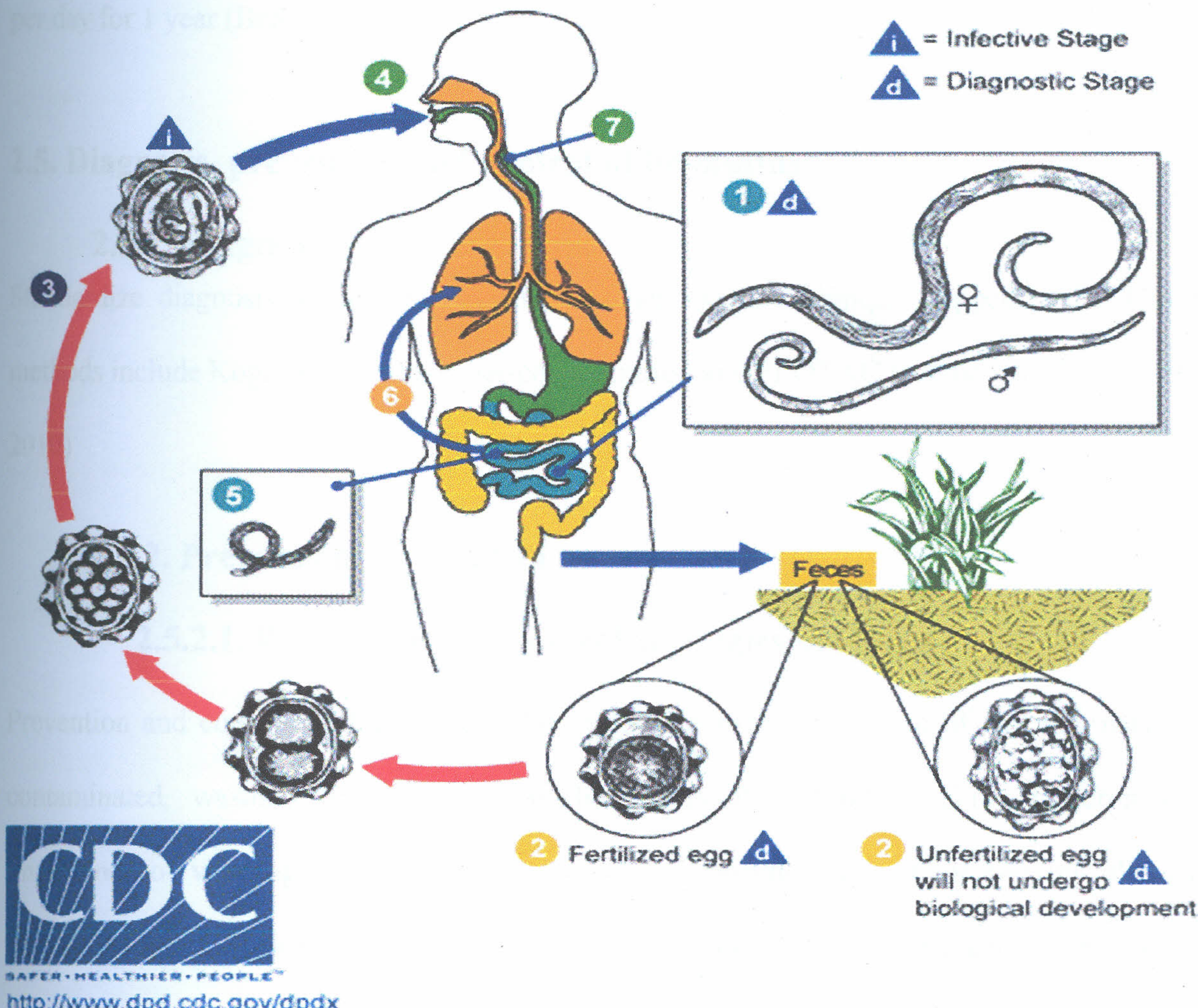


Figure 2.4.4.1. Life cycle of *Ascaris lumbricoides*

(Adopted from CDC; http://www.dpd.cdc.gov/dpdx/html/Ascariasis.htm; accessed on 10th April 2014).

The life cycle of *A. lumbricoides* is shown in Figure 2.3.4.1. Human infection with *A. lumbricoides* occurs when they ingest fully developed eggs. The eggs hatch in the intestine and the larvae penetrate the intestinal mucosa from where they access the blood circulation. They enter the liver and migrate through blood to the lungs. They subsequently break the lung capillaries into alveoli. They ascend the trachea and pass over the epiglottis where they are coughed and swallowed. They move down the oesophagus to return to the intestine where they mature into adult worms and, after mating, the female worm starts laying eggs

(Mahmoud, 1990, Markell *et al.*, 1992). One female worm can lay as many as 200,000 eggs per day for 1 year (Bethony *et al.*, 2006).

2.5. Diagnosis, prevention and control of helminths

2.5.1. Diagnosis

Standardize diagnosis method for helminths is kato-kartz technique (Appendix E). Other methods include Koga Agar plate, Ether-concentration and FLOTAC techniques (Glinz *et al.*, 2010)

2.5.2. Prevention and control

2.5.2.1. Prevention and control strategies of STHs

Prevention and control strategies for STHs include; avoiding ingestion of soil that may be contaminated, washing hands with soap before handling food, teaching children the importance of washing hands to prevent infection, washing, peeling, or cooking all raw vegetables and fruits before eating, proper disposal of human and animal waste and educating the children about the helminths.

2.5.2.2. Prevention and control strategies of *Schistosoma mansoni*

Prevention and control strategies include; avoid swimming or wading in freshwater with snails, drinking safe water, wearing foot ware i.e shoes and gumboots and use molluscicides to kill the snails.

2.6. Helminth Aspects

2.6.1. Prevalence of helminths.

Globally it is estimated that helminths affect more than one-third of the world population with the highest rates in school-age children (SAC). Worldwide, it is estimated that *T. trichiura* affects 795 million people, *A. Lumbricoides* 1.221 billion people, *Ancylostoma duodenale* and *Ancylostoma Necator* 740 million people and 200 million people with schistosomes (Hotez *et al.*, 2008). Robust number of helminths infestation occurs in America, China, East- Asia, and sub-Saharan Africa (Utzinger and Keiser, 2004; Olsen *et al.*, 2009). In Latin America and Caribbean, helminths are present in all countries with an estimate of 26.3 million school age going children infected. In 13 out of 14 countries in this region, many areas have an infection prevalence of 20 % (PAHO, 2009; Ault, 2007). The overall prevalence of intestinal parasitic infection in island in the Eastern Caribbean Sea was found to be 52.2%. The prevalence of specific parasites found were: *A. lumbricoids* (11.7%), *Ancylostoma duodenale* (11.6%), *S. stercoralis* (9.5%), *T. trichuria* (6.0%), *Taenia spp.* (0.2%) and *S. mansoni* at 0.2% which were more frequent in children aged 5-14 years. Most infections were single occurrences and most helminths infections were of light intensity (Rajini, 2010).

A recent study done in Sierra Leone on STHs found out that the overall *Ancylostoma duodenale* prevalence was moderate at 31.2%, but high in two villages; Bo (50.0%) and Tonkolili (56.7%). *Ancylostoma duodenale* intensity of infection was light with a mean egg per gram of 53. Prevalence and intensity of *Ascaris lumbricoids* (1.5%, 17.8 eggs per grams) and *Trichuris trichiura* (2.5%, 20.3 eggs per grams) was low with more boys infested than girls (Hodges *et al.*, 2011).

The prevalence and intensity of soil-transmitted helminthic infestations in Nigeria showed that 54.70% of the subjects were infected. The overall prevalence's by species were *Ascaris* *lumbricoides* (48.41%), *Ancylostoma duodenale* (29.76%), and *Trichuris trichiura* (17.39%). 12.88% were infected with two or more STHs. Males (60.81%) were generally more infected than females (43.30%), but this was only statistically significant among children aged between 5-7 years. The mean number eggs per grams was generally low with only 7.8, 7.6 and 1.7% of the subjects having high intensity of infestations with *Ascaris lumbricoids*, *Ancylostoma duodenale* and *Trichuris trichuria*, respectively. There was no relationship between intensity of infestation and wasting, but children with high intensity of infestations were more stunted than others (Egwunyenga and Athikuri, 2005).

A study conducted to determine *Ancylostoma duodenale* species distribution among school children in Ethiopia showed an overall intestinal parasitosis among the study participants at 70.9%, Ancylostoma duodenale 40.8%, A. *lumbricoids* 16% and *trichuris* 7.5% (Fekadu *et al.*, 2008).

Soil Transmitted Helminths in Kenya is widely distributed as shown by *Ancylostoma duodenale* infestations surveys done between 1980- 2008. Prevalence is very high in Western province with a median of 79.4%, with Nyanza and Coastal provinces estimated at 17.6% and 15.1% respectively. In Central and Eastern provinces, it is lower with median prevalence of 5.1% and 5.3% respectively. Rift valley province has the lowest prevalence of 1.3% (MOPHS, 2011). Helminths data urgently requires updating and should be done from local levels in order to enhance focal issues and high quality data and information.

Prevalence of *Ancylostoma duodenale* (42.5%), *A. lumbricoids* (22.3%) and *T. trichuria* (17.9%) was reported among school children from Western Kenya with prevalence being slightly higher in females (18.5%) than males (14.5%; $P = 0.06$) (Stephenson *et al.*, 1993). Findings from a study done by Brooker *et al.*, (2000) in Busia district, Kenya, showed that 91.6% of the children were infected helminths and *A. lumbricoids, T. trichuria, Ancylostoma* *duodenale* and *S. mansoni* at 41.9%, 55.2%, 77.5% and 22.0% respectively. No significant relationship between host age, sex and infection prevalence was observed for the other helminths species. This study done in western Kenya missed to capture essential issues that this study focused of intensities, patterns and mapping using GIS tools thus the gap.

In another study conducted to determine the prevalence of intestinal worm infections among primary school children within Nairobi municipality in Kenya, the four intestinal worms investigated constituted a total prevalence of 12.9%. *A. lumbricoides* 6.4% followed by *T. trichuria* 4.6%, Ancylostoma duodenale species 0.1% and *S. mansoni* at 0.4%. Differences in prevalence between males and females were observed only with respect to *T. trichuria* and *Ancylostoma duodenale* species. Fourteen to sixteen and 11-13 years of age groups had the highest total prevalence of 47% and 30.6% respectively (Mutuku *et al.*, 2008). A study done in Rarieda division within Kisumu showed that the mean STH's prevalence was 63%, *Ancylostoma duodenale* was 42%, *A. lumbricoides* 22.9% and *T. trichuria* was 17.9%. *A. lumbricoides* showed negative correlation to *S. mansoni* and showed multi-parasitism at 24%. 24% of children were infected with multiple helminths. The most common co-infections were *A. lumbricoids* and *Ancylostoma duodenale* at 9.9% followed by *T. trichuria* and *Ancylostoma duodenale* at 9.0% while 2.9 % were infested with the three helminths. *Ancylostoma duodenale* was the most common co-infection at 45% followed by *T.trichuria* at 19.3% then *A. lumbricoids* at 10.9% (Handzel *et al.*, 2003). This study improved to cover the gap from previous studies but not fully where it missed the intensities and mapping out of helminths as per specific species thus this study was done to breach the gap. Most of the studies done in western Kenya need to be update with current research studies.

2.6.2. Intensity of helminths

According to Raso *et al.* (2004), there is evidence that individuals with many helminths infestations have worse morbidities from helminths. Few heavily infested individuals are at higher risk of diseases and are prime source of environmental contamination (Mascarini-serra *et al.*, 2010). In Kisumu municipality few studies have focused and embraced intensities as important factor, it's through this that heavy infested individuals are noted and treated as per WHO guidelines as they are the main individuals who keep transmission at high levels. Thus this study comes to bridge the gap of intensities within the municipality. Helminths infestations of moderate and high intensity in gastrointestinal tract produce clinical manifestations and highest intensity of helminths infestations is common among children (Chan *et al.*, 1994). Morbidity from helminths infestations and rate of transmission are directly related to the number of worms harbored by the host, thus intensity of infection is the main epidemiological index used to describe helminths infestations (Anderson and May, 1991). Intensity of helminths infestations is measured by the number of eggs per gram of feces and normally done by Kato-Katz fecal smear technique (Katz *et al.*, 1972). WHO (2002b), has set a standard for measurement of intensity of helminths by species as light, moderate, or heavy according to thresholds based on number of eggs per gram(epg) of feces as shown below.

Table 2.6.2.1. Helminths intensities by egg per gram threshold.

	Intensity Threshold		
	Light	Moderate	Heavy
Ascaris lumbricoides	1 - 4999 epg	5.000 - 49,000 epg	≥ 50,000 epg
Acylostoma duodenale	1 - 1999 epg	2.000 - 3,999 epg	≥ 4,000 epg
Trichuris trichiura	1 - 999 epg	1.000 - 9,999 epg	≥ 10,000 epg
S. mansoni	1 - 99 epg	100- 499 epg	≥ 500 epg

(WHO, 2007)

2.6.3 Geographical distribution of helminths

The greatest burden of helminths occurs in sub-Saharan Africa (SSA) and this region has the most immediate need for reliable, up-to-date distribution maps (Brooker *et al.*, 2010). Until recently, only a handful of countries in SSA had conducted national surveys of worms, with information for most countries scattered across the literature and not catalogued (Brooker *et al.*, 2000).

National reporting on NTD's has been incomplete and unreliable because of weak disease surveillance systems, dedicated for reliable surveys to be undertaken (Brooker, 2010). In Kenya, MOH reporting tools i.e. MOH 705A and B summary does not provide monthly, quarterly and yearly information about helminths. Maps available for the country are also scanty and out-of-date thus need for new up-to-date maps that are specific and not more of generalized in nature (MOPHS, 2011). According to Noma *et al.*, (2002), the first attempt to develop evidence based maps of any NTD was for African Programme for Onchocerciasis Control (APOPC) which developed Rapid Epidemiological Maps of Onchocerciasis (REMO) approach. This approach proved successful. Helminths as one of NTD's need such mapping that stratifies areas of high endemicity and perform epidemiological studies that will provide up–to-date maps for successful helminths control.

Outside Shistosomiasis Control Initiative (SCI) supported countries, national surveys of helminths infestations are scarce and ad-hoc, with exception of some dedicated survey (Hopkins *et al.*, 2002; King *et al.*, 2009). Despite support from United States Agency for International Development (USAID), there remains a considerate mapping requirement to support global helminths control (Pullan *et al*, 2008). Also little has been appreciated that as control is successful in reducing the transmission of helminths, there will be even more increasing requirement to conduct mapping surveys for assessment whether to stop Mass Drug Administration (MDA) or switching to less frequent treatment (Sturrock *et al.*, 2009).

2.6.4. Spatial distribution of helminths

Knowledge of the spatial distribution of the helminths infestations is important not only for planning but also for scientific understanding of helminths transmission and epidemiology (Gyapong *et al.*, 2002; Hess *et al.*, 2002; Kirton, 2000). Once adequate knowledge is generated about distribution targeting specific areas as per generated maps would make prevention, control and treatment easy (Malone, 2005). This study focused on this gap and produced maps that would be of great assistance to all stakeholders. The value of a geographical perspective to infectious disease epidemiology and control has been long recognized, however the labor required to produce maps and keeping them to date has inhibited the development of this area and very little is currently known about the spatial distribution of infestations other than for malaria, trypanosomiasis and onchocerciasis (Brooker *et al.*, 2000; Yang *et al.*, 2005), but with current advance in GIS tools this will be overcome and this study was focused to reduce the gap of inadequate information on spatial distribution within the municipality. Appropriate targeting of chemotherapy requires information on regional geographical spatial distribution of helminths infestations prevalence's in an area; however, with its absence it provides greatest challenge for geographically targeted control efforts making an immediate need for accurate distribution maps (Savioli *et al.*, 1997).

2.7. Mapping of helminths

Recent advances in geographical information system (GIS) and mapping technologies have created new platforms thus new opportunities for public health experts to enhance planning, monitoring and management. GIS mapping enhances decision support at all levels; local, regional, and national. GIS aids in planning disease surveillance activities and reducing costs associated with clinical and public health interventions by predicting outcomes before financial commitments are made (Snow, Marsh and Le sueur, 1996). GIS also aids in prioritizing the allocation of resources, provides a common platform for multi-disease surveillance activities. Standardized geo-referencing of epidemiological data places disease surveillance data in context with information on demographics, the environment, administrative boundaries, hydrology, vegetation, climate, human activities and hosts. Mapping and spatial analysis reveal trends, dependencies, and interrelationships that would not be discerned in tabular format (Omumbo *et al.*, 1998).

GIS shows information on disease occurrence at a variety of levels from regions to individual cases. Mapping graphically portrays the distribution and pattern of disease and the intensity of a disease or vector. The dynamic link between databases and maps provided by GIS means that updates to data can be automatically reflected in maps (Tanser and Le suer, 2002).

Preventing disease is the ultimate objective of disease surveillance. This requires quality data analysis that can be used in developing control activity recommendations. GIS can map the locations of significant elements of this process such as occurrences of the disease, hosts, vectors, parasites, and occurrences of drug resistance in vectors and parasites in human populations, and the intensity of transmission by the vector populations (Omumbo *et al.*, 1998). Through synthesizing and continuously updating information on humans, vectors, and parasites and associating this information with environmental factors and control efforts, GIS can help make eradication efforts more focused and effective (Brooker, 2007).

In many countries, disease surveillance activities are focused on monitoring populations with a high incidence of disease, detecting outbreaks of diseases with the potential to cause epidemics, or measuring the success of eradication programs for endemic diseases. Existing disease surveillance systems rely heavily on routine reporting of diseases treated and health events by health care providers, also many public health epidemiological tools are only used once an outbreak has been reported (Snow, Marsh and Le sueur, 1996).

2.8. Flow chart showing the prevalence, intensities and risk of helminths

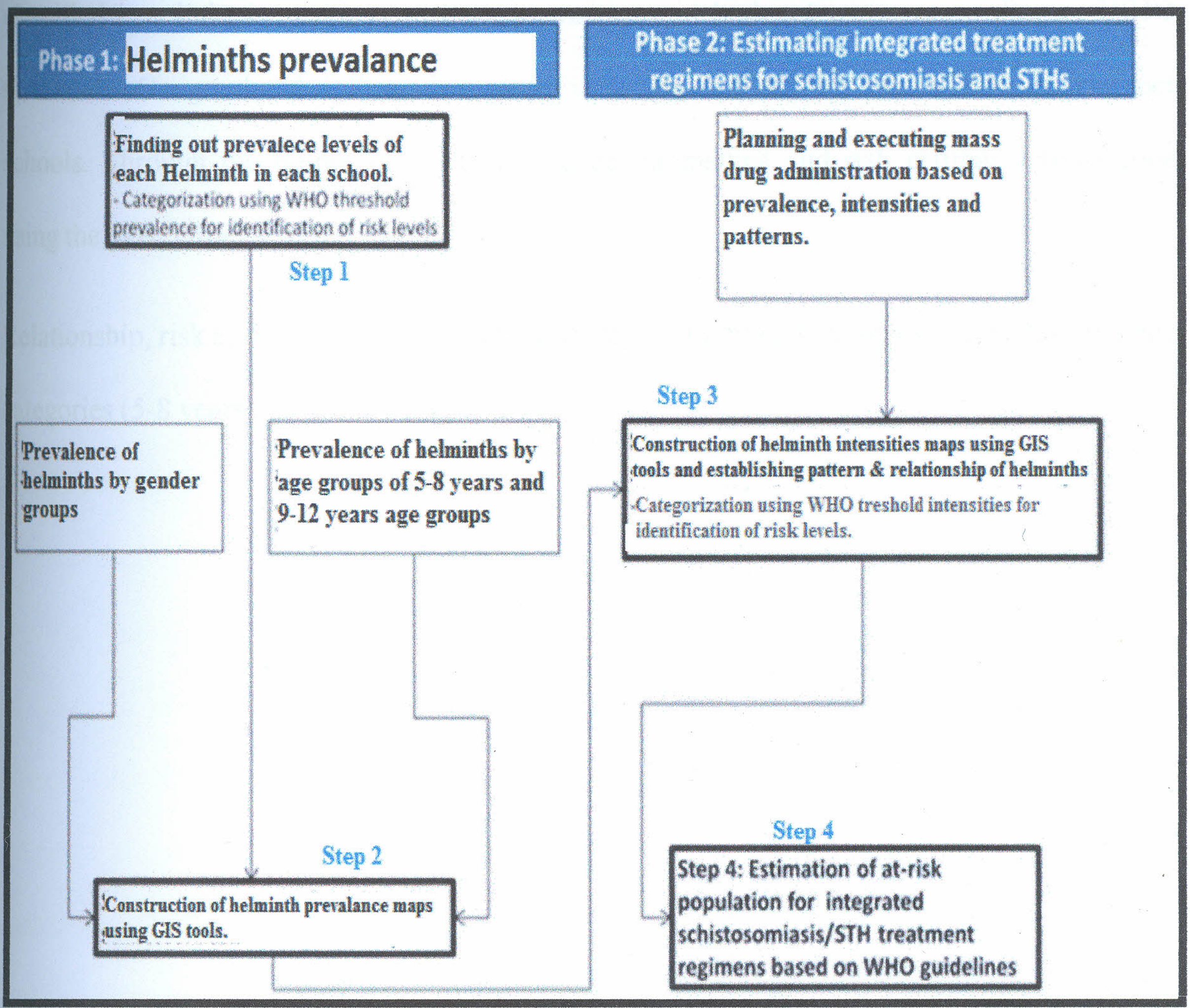


Figure 2.8. 1 A flow chart showing the prevalence, intensities, and risk estimation (Hodges *et al*,. 2012).

The flow chart above in figure 2.7 framework guided this study in focusing the helminths issues in integrated and broad manner. The first step was to find out the point prevalence's of each helminths, all possible helminths combinations in each school and as the overall percentage within the municipality. Furthermore prevalence in regard to gender and age categories was calculated. Data obtain from these prevalence were used to generate distribution maps within the municipality.

Intensities of helminths was the next important step, where various helminthes were classified into light intensities, medium intensities and high intensities according to WHO thresholds. Geographical information maps were generated from the intensities data per schools. Through the output of both prevalence, intensities and risk estimates were done using the WHO threshold.

Relationship, risk and pattern of helminths with regard to gender (females and males) and age categories (5-8 years and 9-12 years)

CHAPTER THREE: METHODOLOGY

3.1. Study site

This study was done within selected schools in Kisumu municipality. Kisumu is the 3rd largest city in Kenya, it is the headquarters of Kisumu County and a leading commercial, fishing, industrial, communication and administrative Centre in Western Kenya. It covers approximately 417 km^2 and harbors a population of 500,000 (census 2009). It lies at 0.2500° S, 34.9167° E by the coordinates, 1100m above the sea level with an average rainfall of 1245mm falling between march- June and October- November. Annual minimum and maximum mean temperatures are 17.3°c and 28.9°c respectively (UN Habitat, 2005).

High levels of skilled and unskilled unemployment exists within the municipality and 30% employment rate of which 52% of the working population are in informal activities with an average monthly wage of 3,000 – 4000 Kshs. Forty eight percent of the urban population live in absolute poverty with main source of income from; wage employment in industries, informal trade and public transportation popularly known as "*boda boda*". The city lacks adequate shelter and approximately 60% of urban resident live in peri-urban and informal settlements (UN Habitat, 2005).

Figure 3.1.1. Study site map

Table 3.1.Key for school names and coordinates

SCHOOL CODE	SCHOOL NAME	SCHOOL LONGITUDE	SCHOOL LATITUDE	SCHOOL ALTITUDE
KE158	DR. ROBERT OUKO	34.69802	-0.077998	
KE159	NGEGE	34.692635	-0.088255	1133
KE160	TIENG'RE	34.689934	-0.081067	1180
KE162	GONGO	34.607384	-0.141459	
KE164	USARI	34.665085	-0.10231	1138
KE165	ROTA	34.67319	-0.092514	1149
KE212	RAE KANYAIKA	34.79338	-0.117223	1112
KE213	BWANDA	34.785977	-0.134743	
KE214	NYALUNYA	34.80239	-0.117491	1154
KE221	ABOL	34.51065	-0.168614	1176
KE223	RODI PRI.	34.56953	-0.121911	
KE225	KOTETNI	34.714626	-0.07508	

3.2. Study design

The study adopted cross-sectional study design. This is where data was collected once and analyzed. This study design was used to determine point prevalence, point intensities, point patterns and point mapping of helminth infestation whose participants were drawn from 12 primary schools that were selected using random sampling technique within Kisumu municipality. This study design was chosen because it described situation and variables as they are without any manipulation, data is collected on individual characteristics and it provide a 'snapshot' of the outcome and the characteristics associated with it, at a specific point in time. (Kelvin, 2006).

3.3. Target population

The target population of this study were primary school children from Kisumu Municipality between the ages of 5-12 years. Total targeted population was 9,655 from 12 primary schools within the study area.

3.3.1. Inclusion criteria

The inclusion criteria included:

1. Being a registered pupil in a primary school within schools in Kisumu municipality.
2. Aged between of 5-12 years.
3. The pupil not dewormed within the last six months prior to stool collection.

3.3.2. Exclusion criteria

1. An eligible child whose parent or guardian decline to allow the child to participate in the study.
2. An eligible child who decline to ascent.

3.4. Sample size determination and sampling procedure

A sample size of 1300 pupils was determined using creative systems formula (Alonderince and Asta , 2013; www.surveysystems.com/*sscalc.htm retrieved on 27/6/2014*) was used to calculate the representative sample size for this study.

$$SS = \frac{Z^2 *(P)* (1-P)}{C^2}$$

Where by:

Z= Z value (1.96 for 95% confidence level)

P = Percentage picking a choice, expressed as decimal (0.5 used for sample size needed)

C = Confidence interval, expressed as decimal (0.04 +/- 4)

Hence $SS=\frac{1.96^2 *(0.5)*(1-0.5)}{(0.04)^2}$ thus 600* 2(Design effect) = 1200

(SS) was increased by 10% to compensate for person's not available and non-responses i.e. 1320 participants. The final sample size obtained was 1300 pupils which was far above the minimum sample size.

Multistage sampling procedure was used in this study. Four zones were selected from the six zones of municipality with regard to proximity to Lake Victoria. Twelve schools within the Kisumu east district, Kisumu west district and Township parts of municipality were proportionately selected. Systematic random sampling was used to select individual pupils to the study, every 7th child was selected where this was generated from total population of participating schools divided by total sample size sample size required.

Table 3.2 Proportionate table.

Zone	School Code	School Name	School Population	Sample Size
A	KE 212	Rae Kanyaika	1032	139
	KE 213	Bwanda	483	65
	KE 214	Nyalunya	877	118
B	KE 225	Kotetni	950	128
	KE 159	Ngege	787	106
	KE 158	Dr. Robert Ouko	847	114
	KE 160	Tieng're	973	131
C	KE 165	Rota	839	113
	KE 164	Usari	1099	148
	KE 162	Gongo	624	84
D	KE 221	Abol	929	125
	KE 223	Rodi	215	29
		TOTAL	9655	1300

3.5. Stool sample collection

During stool collection, children were briefly educated about helminths. Stool containers were distributed to the study participants and instructed to provide a stool sample, which was collected between 8:30 am and 12 pm. The stool samples were well labeled with barcodes that matched with pupil identity then it was transported to KEMRI/CDC lab in Kisumu for analysis in lockable cooler boxes. The same procedure was repeated for three consecutive days and on fourth day missed cases due to absenteeism

3.6. Parasitological screening and intensities classification

Parasitological screening was based on three stools per child. Each stool sample was analyzed in duplicate by different independent lab technicians using Kato-Katz fecal technique of 41.7 mg template (Montresor *et al.*, 1998; WHO, 1994) for identification of helminths eggs following their morphology (*A. Lumbricoides, T. trichiura, Ancylostoma duodenale* and *S. mansoni*) (Tanowitz *et al.*, 1993). They were classified according to intensities and morphological type. Concentration of eggs was expressed as egg per gram (epg) of feces. Intensities of each helminths was classified according to World Health Organization thresholds (WHO, 2007) For *Ancylostoma duodenale*, all slides were read within 24 hours after collection to avoid degeneration on Ancylostoma duodenale eggs.

3.7. Geographical distribution of helminths

Geographical distribution of helminths in schools was done by prevalence, intensities and by helminths combinations in all primary schools participating in the study were mapped using hand-held differential geographical global positioning system (GPS) units (Trimble Navigation Ltd, California, USA) with estimated accuracy of +/- 1 meter. Data was downloaded into GPS database (GPS pathfinder office 2.8 Trimble Navigation Ltd, California, USA) and analyzed using ArcView version 9.2 software (Environmental Systems Research Institute, Inc., Redlands CA).

Prevalence of Soil-transmitted helminths was calculated for each school then classified into three categories of zero prevalence schools (0%), low risk schools (1-9%), moderate risk schools (10 – 24%) and high risk schools (≥25%). *S. mansoni* prevalence was also calculated per school and classified into four categories of zero prevalence schools (0%), low risk schools (1-9%), moderate risk schools (10-49%) and high risk schools (≥50%) (WHO, 2007).

Mean intensities of each helminth was grouped according to WHO standards for light, moderate and heavy intensities per schools. For *Ascaris lumbricoids* light intensities schools (1- 4,999 epg), moderate intensities schools (5,000- 49,999 epg) and heavy intensities schools (≥ 50,000 epg), *Trichuris trichiura* light intensities schools (1- 999 epg), moderate intensities schools (1,000 -9,999 epg) and heavy intensities schools (≥ 10,000 epg), *Ancylostoma duodenale* light intensities schools (1- 1.999 epg), moderate intensities schools (2,000 – 3,999 epg) and high intensities schools (4,000 epg), S. mansoni light intensities schools (1- 99 epg), moderate intensities schools (100-499 epg) and high intensities schools ($\geq$500 epg)

Helminths combinations were first grouped into possible combinations and mapped as per the available combinations in the study schools.

3.8. Statistical analyses

Statistical analyses were performed using SAS statistical software, version 9.2, (SAS Institute Inc., Cary, NC, USA). Point prevalence (P) was defined as the percentage of infected individuals (NP) among the total number of individuals examined (N) (P= (NP/N) X 100 at that point of data collection. Prevalence was grouped in various categories of single helminths, multiple helminthes and overall helminthes. Z score test was used to test for the proportions and determine the significance difference. Both one proportion Z test and two proportion test was used.

Intensities was analyzed using the prevalence rates after classification of the infested children into three categories of low intensities, medium and high intensities for each helminths. Variables of age and gender were also used. Graphs were generated to represent the data for intensities. Mean intensities per schools was done by averaging the intensities per schools and mapped.

Risk, Patterns and relationships was done using Chi-square test where estimates of likely hood of gender and age categories affect infestations of helminthes. Odds ratio, confidence interval at 95% and P value ($P < 0.05$).

Geographical distribution data was extracted from the prevalence and intensities per schools. The data was mapped using ArcView software 9.2 version into a visible map that represented different helminths in different schools.

3.9. Ethical considerations

The proposed study was reviewed and approved by Maseno University School of Graduate Studies and ethical approval was sought from KEMRI ethical committee (KEMRI/RES/7/3/1). Informed consent was obtained from the parent(s) or guardians whom were contacted through their children. Informed consent was written in both Luo and English version and assent was sought from the participants. Anonymity of children who provided stool samples was ensured by using coded unique barcodes for identification of children, stool samples, glass slides and screening results booklets. Stool samples were stored in lockable cooler boxes and were transported to the laboratory between 2-3 pm of each day of sample collection, were they were stored in lockable fridge at temperature below 10°C. Processing started immediately and results for *Ancylostoma deudonale* generated within 4 hours after storage in the fridge. Once slides had been prepared, they were be stored in lockable slide boxes where they would be quantified by independent laboratory technicians and the rest of the samples were discarded in KEMRI incinerator. Infected pupils were treated by trained neglected tropical diseases department staff and trained school health teachers for respective helminths with anti-helminthic after seeking permission from their parents or guardians.

CHAPTER 4: RESULTS.

4.1. Demographic Characteristics of the Study participants

A total of 1300 pupils were recruited into the study to determine the epidemiology of helminths and influence of age and gender on infection status among primary school children in Kisumu municipality. The total number of participants investigated was divided into two age groups, 5-8 years age group whom where pupils freshly admitted to class one excluding those who repeated the class and 9-12 years age group where pupils that were in class 3-7. This grouping was to bring out influencing factor of exposure and morbidity in regard to age. The proportions of the age groups were determined by the enrollment rate of pupils in each age group. Up to 22.77 % (296) were aged 5-8 years, while a much higher proportion of 77.23% (1004) were aged 9-12 years old. There was no significant difference in numbers by gender and age categories. The demographics of these children are summarized in Table 4.1. Of the 1300 children enrolled into the study, 676 (52%) were female and 624 (48%) male. Among the 5-8 years age category, 147 (11.31%) were female and 149 (11.46%) male. Of the 1004 children in the 9-12 years category, 529 (40.69%) were female and 475 (36.54%) male.

Table 4.1. Distribution of the study participants by age and gender

	Female	Male	Total
5-8 Years	147(11.31%)	149(11.46%)	296(22.77%)
9-12 Years	529(40.69%)	475(36.54%)	1004(77.23%)
Total	676(52%)	624(48%)	1300(100%)

4.2. Prevalence of single and multiple species of helminths

4.2.1. Prevalence of single helminths

Table. 4.2. Prevalence of helminths and Z test by gender and age groups.

	Female (n=676)	Male (n=624)	*Z* value of between gender groups	CI Level 95%	5-8 years age group (n=296)	9-12 years age group (n=1004)	*Z* value of between age groups	CI level 95%	Overall percentages (n=1300)
Helminths types.	% (n)	% (n)			% (n)	% (n)			
Ancylostoma duodenale	1.33% (9)	3.04% (19)	**-14.5527**	-0.33 - -0.25	0.68% (2)	2.59% (26)	**3.4407**	0.0181 – 0.0661	2.15%
Ascaris lumbricoides	1.78% (12)	4.33% (27)	**-2.691**	-0.01 – 0.04	0.68% (2)	3.69% (37)	**2.2932**	0.0045 - 0.0577	3%
Trichuris trichiura	10.36% (70)	13.94% (87)	-0.3389	0.0277 – 0.393	5.74% (17)	13.94% (140)	**-3.8053**	-0.0398 – 0.1242	12.08%
S. mansoni	29.59% (200)	36.22% (226)	**-2.5444**	-0.0152 – 0.1174	15.2 (45)	37.95% (381)	**-7.3283**	-0.1667 - - 0.2883	32.77%
At least an helminths	36.24%(245)	45.51%(284)	**-3.3991**	-0.0392 - -0.1462	19.93%(59)	46.81%(470)	**-8.273**	-0.2051 - - 0.3325	40.69%

Table 4.2. Summarizes the prevalence of helminths by gender and age groups. Statistical test used was chi-square test. Up to 40.69% (529) of the pupils were infested by at least an helminths, *Ancylostoma duodenale* was the lowest at 2.15% (28) followed by *A. lumbricoides* at 3% (39) then *T. trichiura* at 12.08%(157) and S. *mansoni* was most prevalent at 32.77%(426). For all the helminths, male pupils had significantly higher

prevalence levels than females, proportions were significantly different except for *T. trichiura*; while those aged between 9-12 years had higher prevalence levels than those aged 5-8 years. For gender groups Z score test showed that was significant difference in all helminths with regard to proportions. In regard to WHO the overall prevalence shown would categorize Kisumu municipality as a low risk area for STHs and a moderate risk area for S. mansoni thus it would implicate that MDA should be done once bi-annually which is partially misleading thus prevalence alone without intensities is not a perfect way to guide controlling helminths.

4.3. Prevalence of two helminths combinations

Table 4.3. Prevalence of dual helminths co-infections by gender and age group

	Female	Male	Z values between gender	CI level (95%)	5-8 years age group	9-12 years age group	P values between age groups	CI level (95%)	Overall %
	n=38	n=60			n=7	n=91			n=1300
Dual helminths infections	% (n)	% (n)			% (n)	% (n)			
HW & AS	0.08% (1)	0.08% (1)	0	-0.01 - - 0.12	0.00% (0)	0.20% (2)	-	-	0.15%
SCH &AS	0.30% (4)	0.60% (8)	-0.21	-0.03 – 0.03	0.00% (0)	0.90% (12)	-	-	0.92%
SCH & HW	0.20% (3)	0.40% (5)	-0.17	-0.03 - 0.21	0.00% (0)	0.60% (8)	-	-	0.62%
SCH & TT	2.00% (26)	3.00% (39)	-0.30	-0.07 – 0.05	0.40% (5)	4.60% (60)	-0.53	-0.20-0.11	5.00%
TT & AS	0.00% (0)	0.40% (5)	-	-	0.10% (1)	0.30% (4)	-0.10	-0.04-0.04	0.38%
TT & HW	0.30% (4)	0.20% (2)	0.10	-0.02 - - 0.02	0.10% (1)	0.40% (5)	-0.12	-0.05-0.44	0.38%

Key: **HW**- *Ancylostoma duodenale*, **AS**- *Ascaris lumbricoides*, **TT**- *Trichuris trichiura* and **SCH**- *Schistosoma mansoni.*

Dual infections were grouped into the six possible co-infection combinations including: HW & AS, SCH & AS, SCH & HW, SCH & TT, TT & AS and TT & HW. The most prevalent dual infection was SCH & TT at 5% (65) and the least common was HW & AS at 0.15% (2). There were no females that had TT & AS dual infections. 5-8 year olds did not have any HW & AS, SCH & AS, SCH & HW; this age group had more percentage prevalence of SCH & TT, TT & AS and TT & HW than the older age group. There was no significance difference between genders of pupils and age groups of pupils. All *P* values were <0.005

4.2.3. Prevalence of multiple helminths combinations

Table 4.4. Prevalence of multiple helminths co-infections by gender and age groups.

	Female (n=676)	Male (n=624)	Z test	CI at 95 %	9-12 years age group (n=1004)	Z Test	CI at 95 %	Overall % (n=1300)
Multiple Helminths infections								
SCH, HW & AS	0.00% (0)	0.16% (1)	-	-	0.01% (1)	**1584.1**	-0.003 - 0.0007	0.08%
SCH, TT &AS	0.44% (3)	0.32% (2)	0.35	-0.01 – 0.01	0.50% (5)	**222.4**	0.0006 – 0.01	0.38%
SCH, TT & HW	0.30% (1)	0.48% (3)	-0.52	-0.01 – 0.01	0.40% (4)	**249.0**	0.0001-0.002	0.31%
SCH,TT, HW & AS	0.00% (0)	0.16% (1)	-	-	0.01% (1)	**1584.1**	-0.0025 - 0.0007	0.08%

Key: HW- *Ancylostoma duodenale*, AS- *Ascaris lumbricoides*, TT- *Trichuris trichiura* and SCH- *Schistosoma mansoni.*

Table 4.4. Summarizes the prevalence's of triple helminths co-infections by gender and age groups. Overall, only 10 (0.1%) of the 9-12 year olds had triple infections. There were no triple infections in the 5-8 years age group. Among the 9-12 year olds, only one child had SCH, HW & AS infection (0.01%), five (0.50 %) had SCH, TT &AS and only 4 (0.40 %) had SCH, TT & HW. Only one male pupil aged 11 years old had all the four helminths infections. There was no significance difference in gender but there was significance difference with regard to age categories were it was based on one proportion Z test.

4.3. Infection intensities of Helminths

4.3.1. Helminths intensities categorized by age

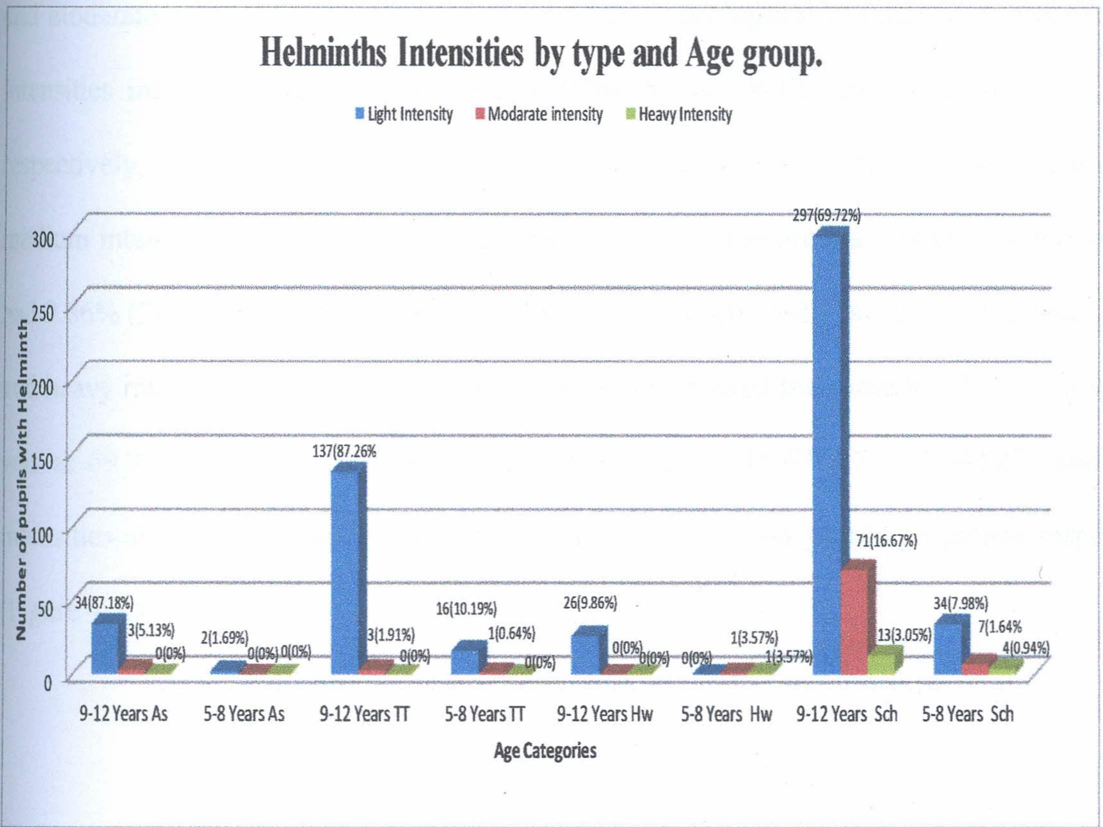


Figure 4.1. Graph showing helminths intensities by type and age groups.

In all age groups light intensities on each helminths was the most common. For *A. lumbricoides* 5- 8 years group had only light intensities at 1.69% (2) and none for moderate and heavy intensities. In 9-12 years age group light intensities infestation was at 84.18% (34), and moderate intensities at 5.13 % (3). *T. trichuria* had highest number of pupils with light intensities infestations at 87.26%(137), 10.19%(16) for 9-12 years and 5-8 years groups respectively, 9-12 years age group was at 1.91%(3) and 0.64%(1) for 5-8 years age group for medium intensities and none for high intensities to both age groups. *Ancylostoma duodenale* had 9.86% (26) for light intensities in 9-12 years age group. 5-8 years age group had medium and heavy intensities each at 3.57 % (1). *S. mansoni* showed the same trend , light intensities was at 69.72%(297), 7.98%(34), medium intensities at 16,67%(71), 1.64%(7) and heavy intensities at 3.05%(13) and 0.94%(4) for 9-12 years and 5-8 years age groups respectively (Figure 4.1.).

4.3.2. Helminths intensities categorized by gender

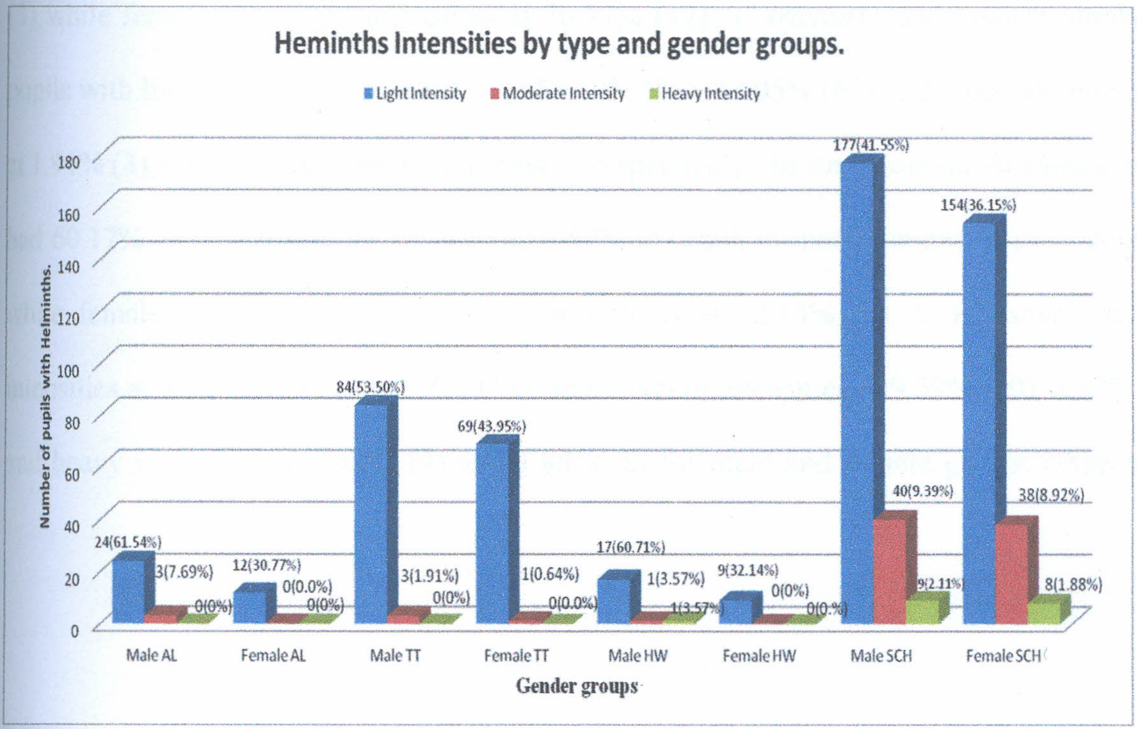


Figure 4.2. Graph showing helminths intensities by type and gender groups.

In all gender groups light intensities on each helminths was the most common Figure 4.2. For *A. lumbricoids* males had light intensities at 61.54 % (24) and moderate intensities at 7.69 % (3) while females had light intensities at 30.77% (12). *T. trichuria* had highest number of pupils with light intensities infestations at 53.50% (84), 43.95% (69) and moderate intensities at 1.91% (3), 0.64% (1) for males and females respectively. In *Ancylostoma duodenale* males had 60.17% (17), for light intensities and 3.57% (1) each in moderate and heavy intensities while female had only light intensities infestations at 32.14% (9). *S. mansoni* had light intensities at 41.55% (177), 36.15% (154), and medium intensities at 9.39% (40), 8.92% (38) and heavy intensities at 2.11% (9) and 1.88% (8) for male and female groups respectively

4.4. Pattern and Relationships of Helminths

4.4.1. Risk and pattern of getting infected by gender and age

Table 4.5. The risk and pattern of helminths infection in relation to age and gender

Helminthes	Odds Ratio (OR)	Confidence Interval (CI) at 95 %	*P* Value
***Ascaris lumbricoides* Effect**			
Age Category - 9 -12 Years Versus 5 - 8 years	5.812	1.391-24.285	**0.0159**
Gender Category- Male Versus Female	2.572	1.2829-5.131	**0.0074**
***Trichuris trichiura* Effect**			
Age Category - 9 -12 Years Versus 5 - 8 years	2.695	1.599-4.541	**0.0002**
Gender Category- Male Versus Female	1.432	1.022-2.007	**0.0371**
***Ancylostoma duodenale* Effect**			
Age Category - 9 -12 Years Versus 5 - 8 years	4.02	0.947-17.059	0.0592
Gender Category- Male Versus Female	2.83	1.067-5.307	**0.0341**
***Schistosoma mansoni* Effect**			
Age Category - 9 -12 Years Versus 5 - 8 years	3.468	2.461-4.888	**<0.0001**
Gender Category- Male Versus Female	1.402	1.402-1.778	**0.0053**

The risk pattern of helminths infestations in regard to gender was higher male pupils than female pupils. A male child was 2.572 times (OR = 2.57, p = 0.01, CI = 1.28 -5.13) more likely to be infested with A. *lumbricoides* than a female child. A male child was 1.432 times (OR = 1.43, p = 0.04, CI = 1.02 -2.01) more likely to be infested with T. *trichiura* than a female child. A female child was 2.83 times (OR = 2.83, p = 0.03, CI = 1.07 -5.31) less likely to be infested with *A. duodenale* than male child. A female child was 1.40 times (OR = 1.40, p = 0.01, CI = 1.40-1.78) less likely to be infested with *S. mansoni* than male child. All p values were significant (Table 4.5).

Age category proved to be a risk factor for helminths infestation. A child on 9 – 12 years age category was 5.812 times (OR = 5.81, p = 0.02, CI = 1.39-24.28) more likely to be infested with A. *lumbricoides* than a child in 5 – 8 years category. A child on 9 – 12 years age category was 2.695 times (OR = 2.70, p = <0.0002, CI = 1.60-4.54) more likely to be infested with T. *trichiura* than a child in 5 – 8 years category. A child in age category of 5 – 8 years was 4.02 times (OR = 4.02, p = 0.06, CI = 0.94-17.06) less likely to be infested with *A. duodenale* than a child in 9 -12 years age category. A child in age category of 5 – 8 years was 4.02 times (OR = 3.47, p = <0.0001, CI = 2.461-4.88) less likely to be infested with *S. mansoni* than a child in 9 -12 years age category. All p values were significant except in *A. duodenale* (Table 4.5).

4.5. Geographic distribution of helminths per schools

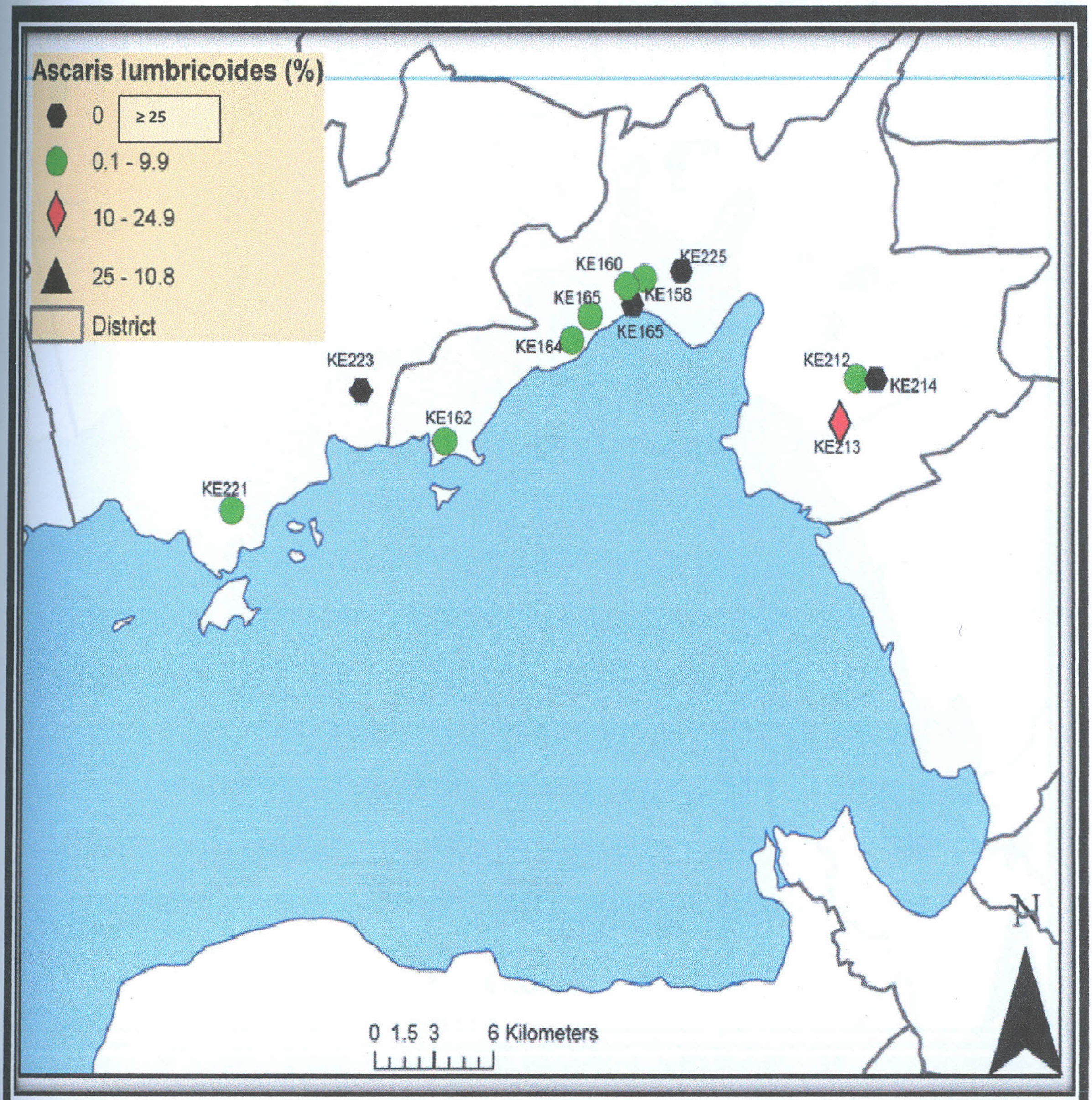


Figure 4.5.1. Prevalence of *Ascaris lumbricoides* per schools

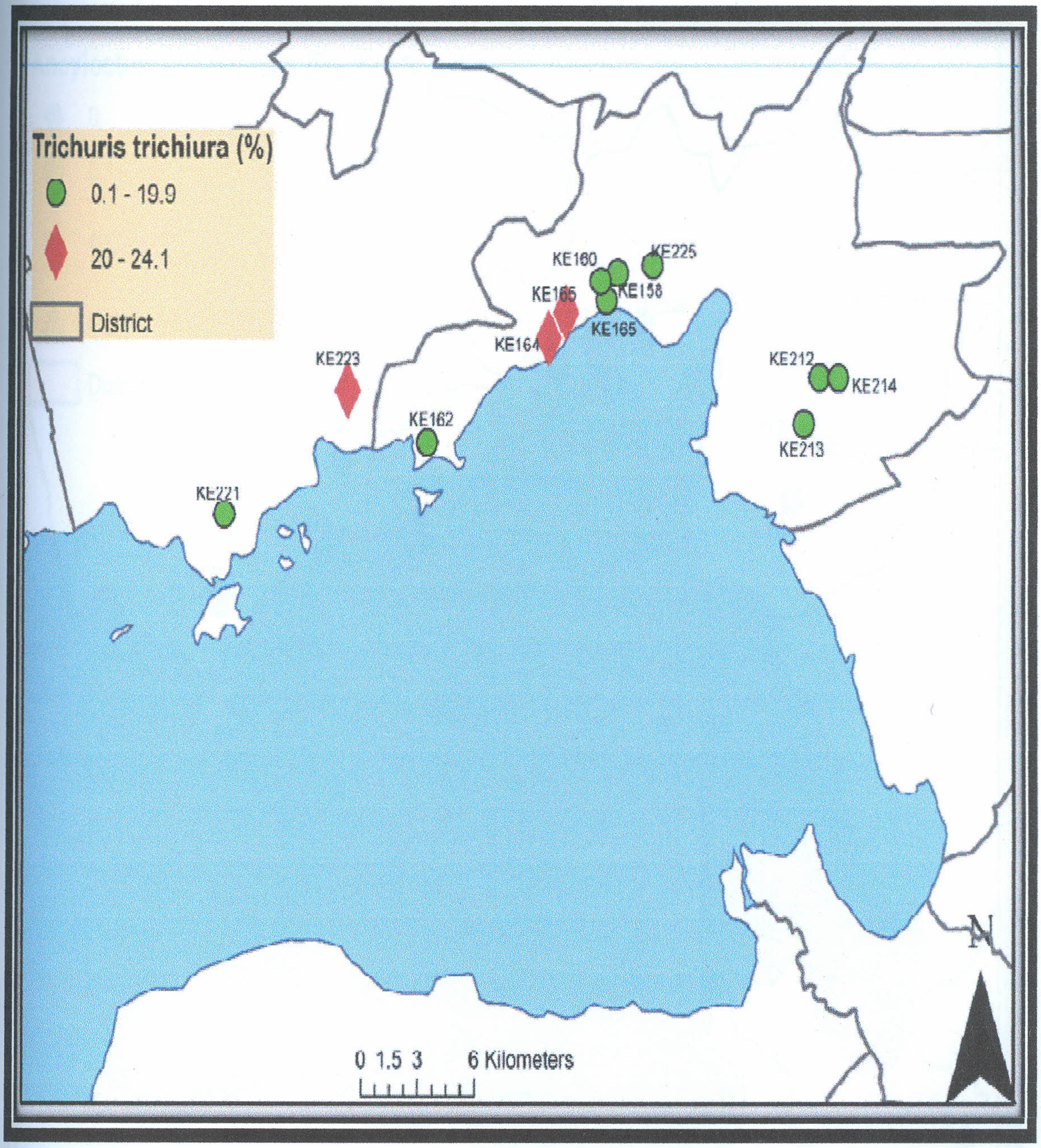


Figure 4.5.2. Prevalence of *Trichuris trichiura* per schools

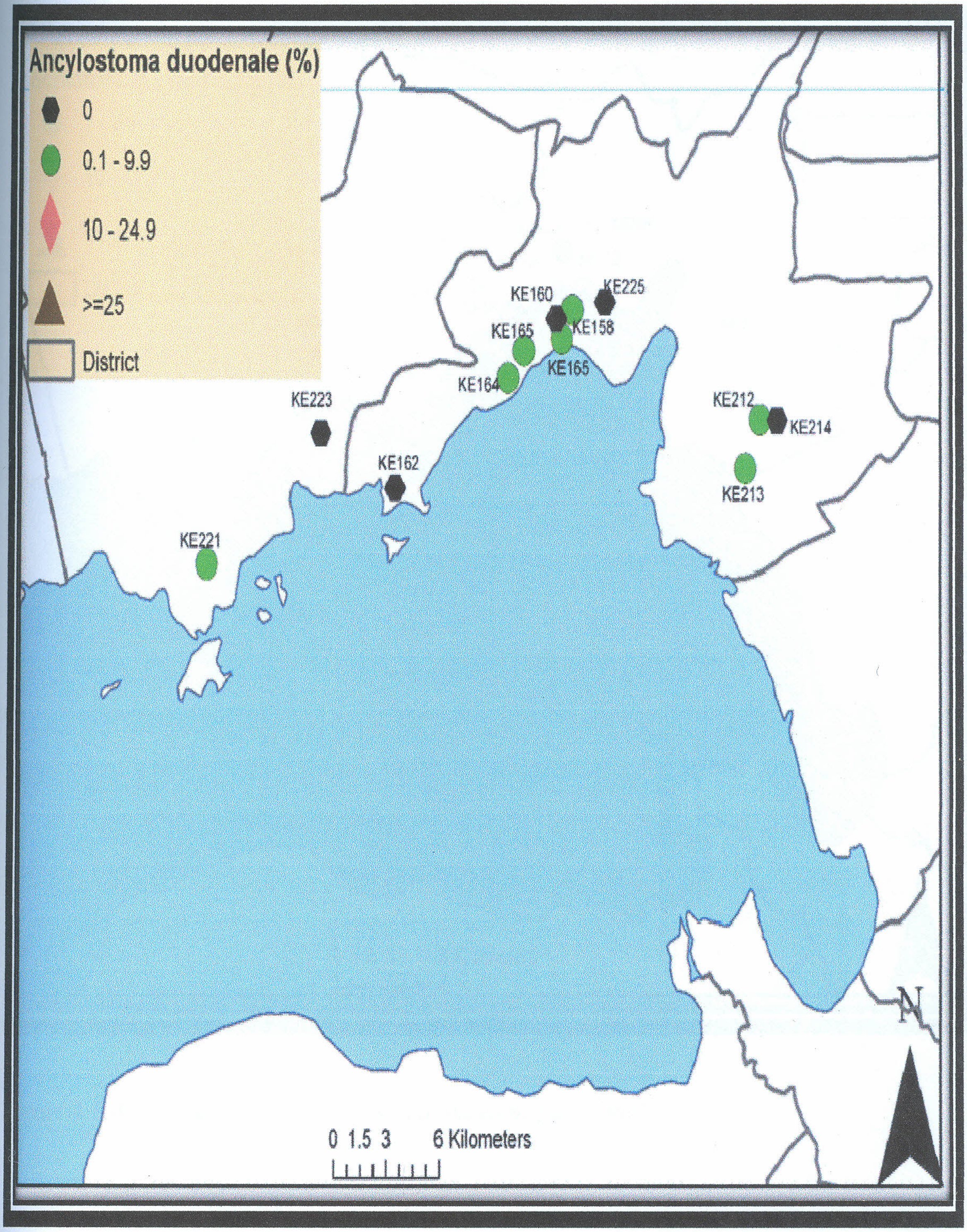


Figure 4.5.3. Prevalence of *Ancylostoma duodenale* per school

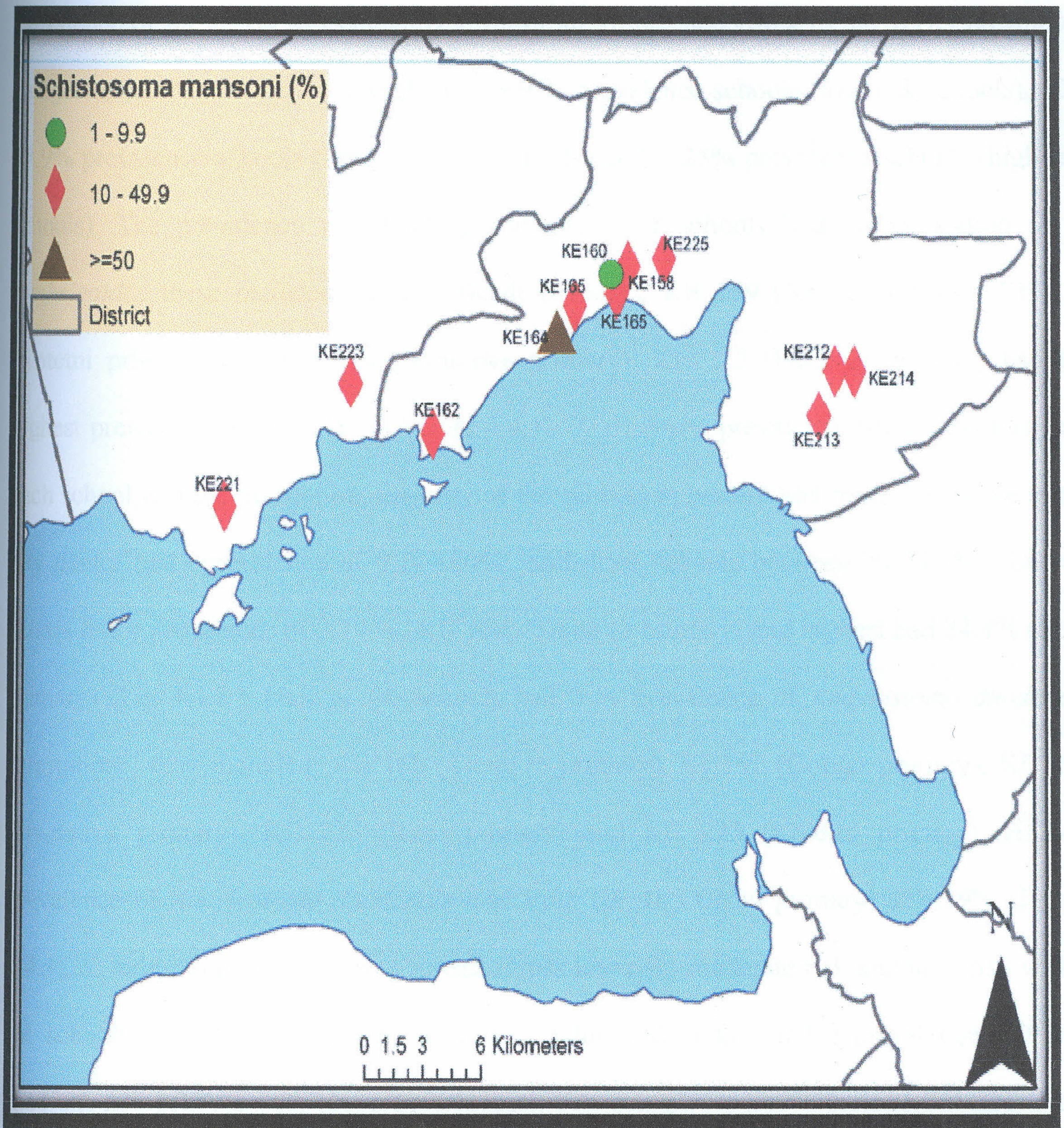


Figure 4.5.4. Prevalence of *Schistosoma mansoni* per school.

Prevalence of the STHs was categorized into four groups according to the WHO prevalence categories of 0% prevalence schools, 0.1 -9.9 % prevalence schools (low risk schools), 10 – 24.9% prevalence schools (Moderate risk-schools) and ≥ 25% prevalence schools (high risk schools). The prevalence was point prevalence. Four schools had no infestation of *A. lumbricoides* these included KE 223 (Rodi primary), KE 159 (Ngege primary), KE 225 (Kotetni primary) and KE 214 (Nyalunya primary). KE 213 (Bwanda primary) had the highest prevalence at 10.77% (7) Figure 4.4.1. *T. trichiura* prevalence showed that at least each school had the infestation, majority of the schools in eastern and more proximate to the city center had prevalence of 0.1- <20% and three schools between 20-24.1%. Lowest school had a prevalence of 2.29 % (KE 160 - Tieng're primary) and highest had 24.1% (Rodi primary) (Fig 4.4.2.). Half of the schools had 0 % prevalence of *Ancylostoma duodenale* infestations, they included: KE 160 (Tieng're primary), KE162 (Gongo primary), KE 214 (Nyalunya primary), KE 223 (Rodi primary) and KE 225 (Kotetni primary). Highest prevalence of *Ancylostoma duodenale* was from KE 165 (Rota primary) at 6.19% (Figure 4.4.3). *S. mansoni* prevalence was spread across low risk, moderate risk and high risk within the schools. KE 160 (Tieng're primary) was a low risk school at the prevalence of 9.9%, medium risk schools with prevalence ranging between 10 - ≥49.9% include KE 221 (Abol primary), KE 223 (Rodi primary), KE 162 (Gongo primary), KE 165 (Rota primary), KE 159 (Ngenge primary), KE 225 (Kotetni primary), KE 212 (Rae kanyaika primary), KE 214 (Nyalunya primary) and KE 213 (Bwanda primary). KE 164 (Usari primary) was a high risk school at the prevalence of 50%.

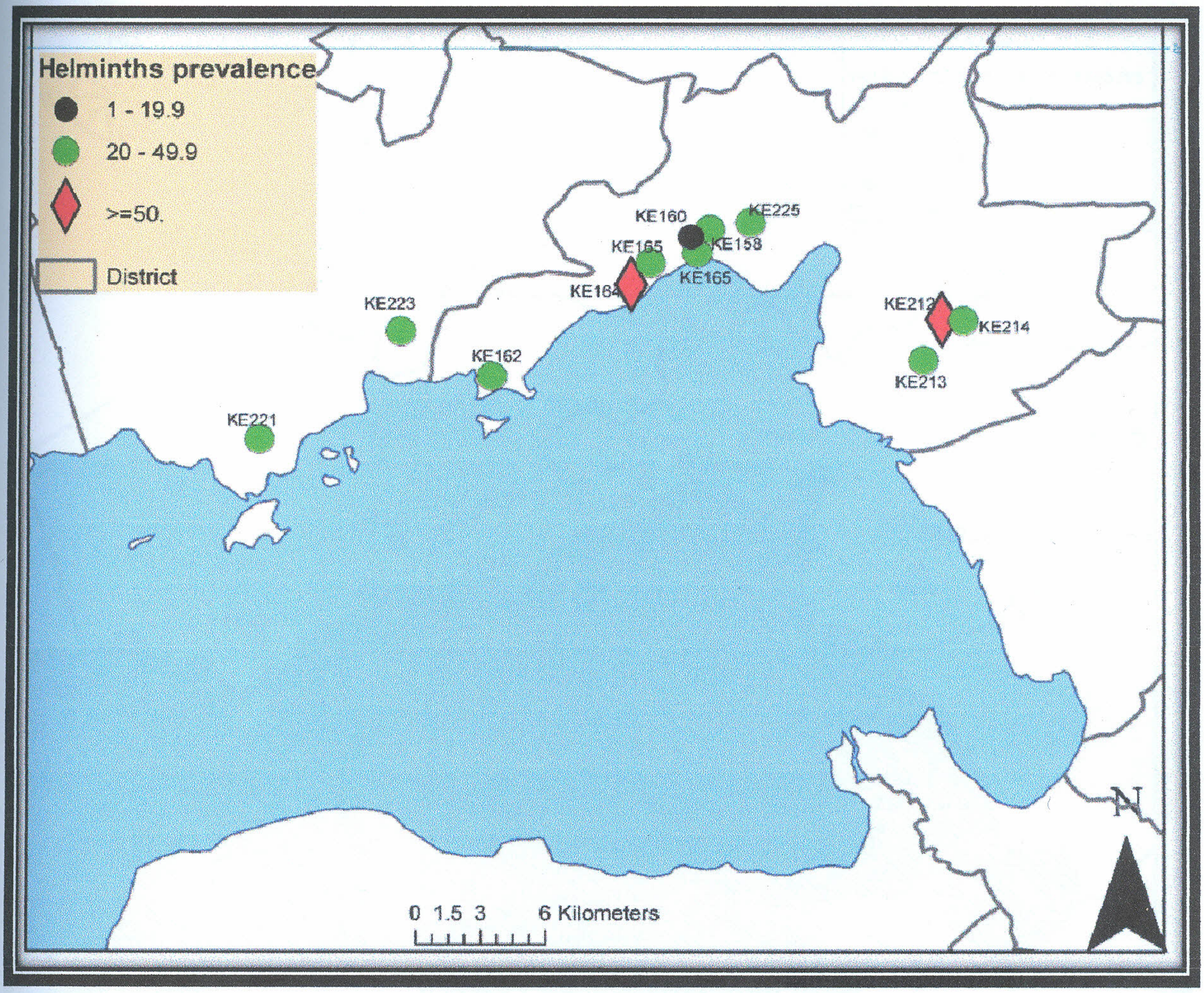


Figure 4.5.5. Prevalence of Helminths per school.

Tieng're primary school (KE 160) had prevalence below 20% it was the only school that fall at low risk in overall helminths infestations. Nine schools had prevalence of between 20% - ≤ 49.9%, these are moderate risk schools they included; KE 221(Abol primary), KE 223(Rodi primary), KE 162(Gongo primary), KE 165 (Rota primary), KE 159 (Ngenge primary), KE 158 (Dr.Robert Ouko primary), KE 225 (Kotetni primary), KE 213 (Bwanda primary) and KE 214 (Nyalunya primary). Two schools had prevalence of ≥ 50% thus a high risk schools with helminths, they were KE 164 (Usari primary) and KE 212 (Rae Kanyaika primary).

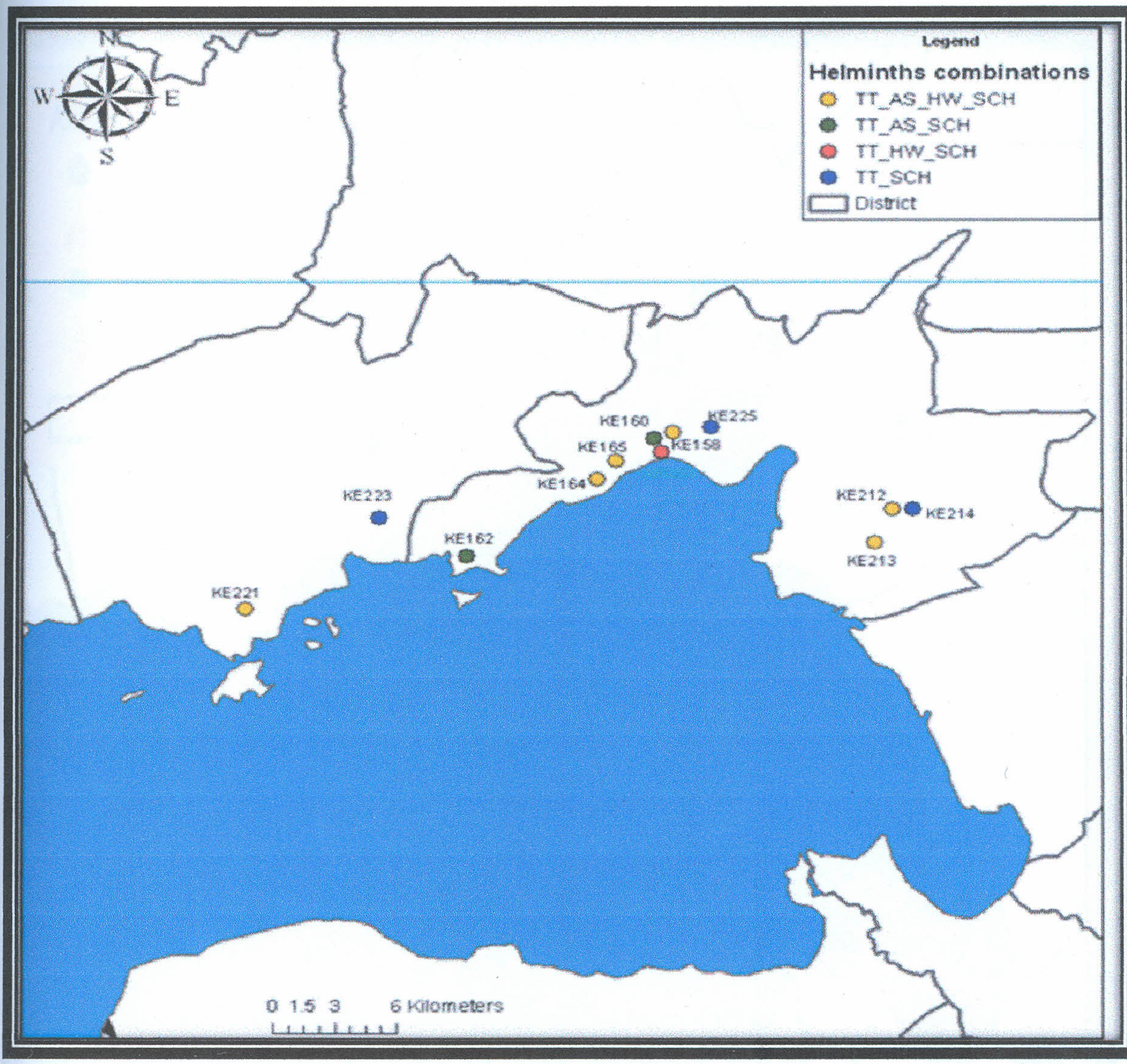


Figure 4.5.6. Prevalence of type helminths present per school.

Half of the schools 50% (6) had all four helminths (TT, AS, HW and SCH) infecting its pupils (KE221, KE164, KE 165, KE 158, KE 212, and KE 213), two schools had TT, AS and SCH (KE 162 and KE 160), one school had TT, HW and SCH helminths (KE 159) and three schools had TT and SCH helminths (KE 223, KE 225 and KE 214). *T. trichiura* and *S. mansoni* were helminths that were found in all the school. Many schools that had all helminths were more proximate to the lake and those with two helminths (TT and SCH) were the furthest schools from the lake.

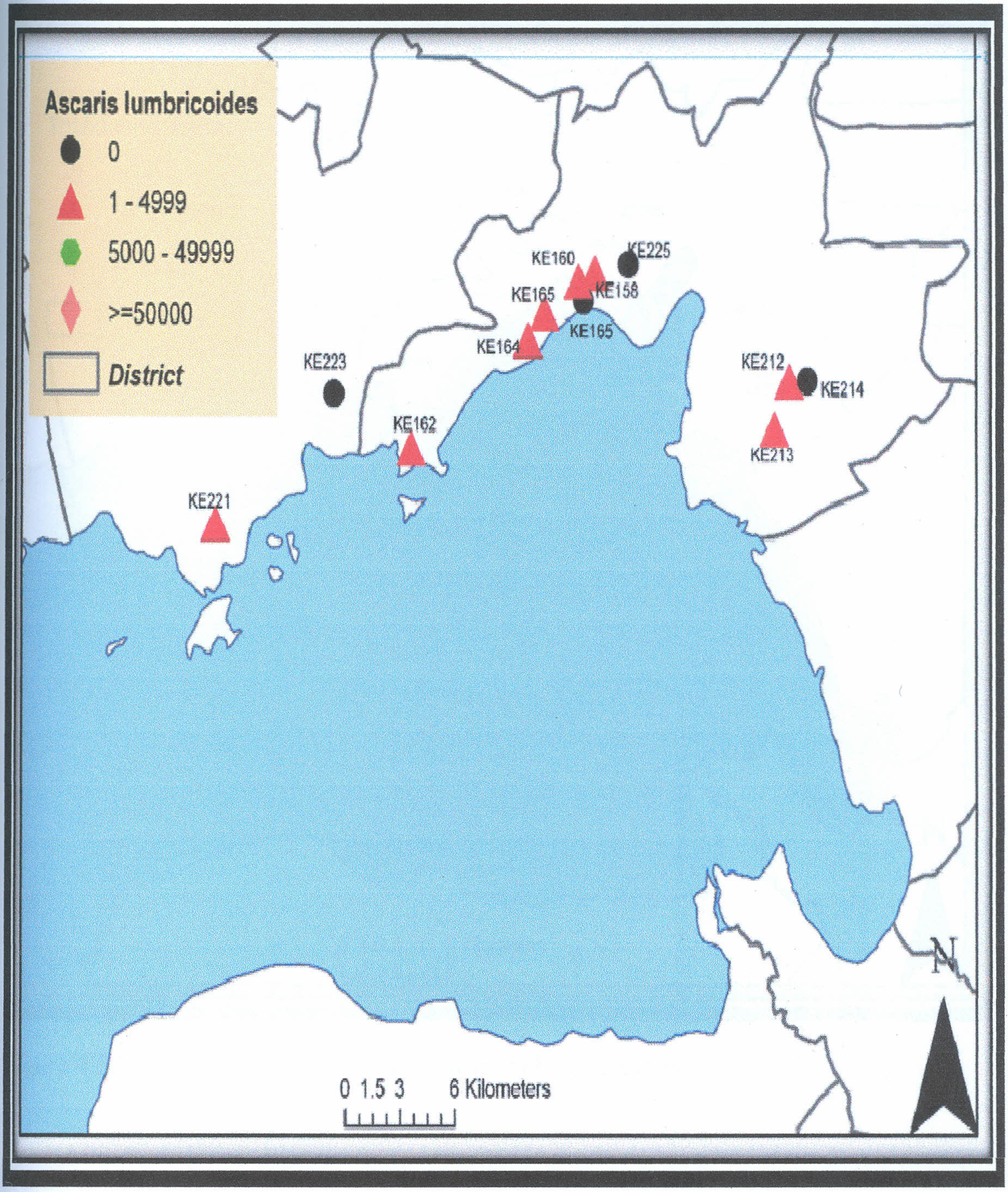


Figure 4.5.7. Distribution of *Ascaris lumbricoides* by intensities per school

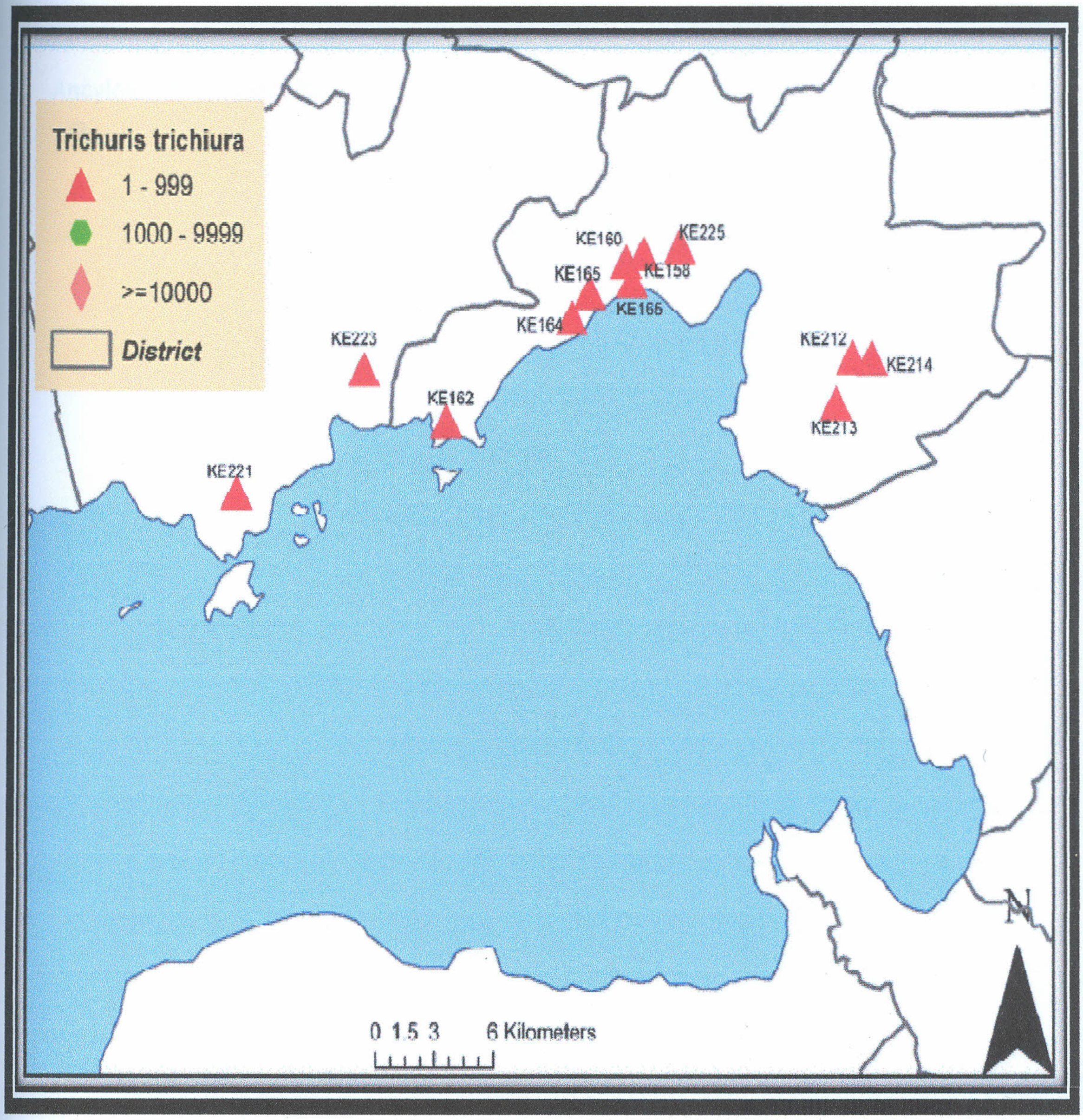


Figure 4.5.8. Distribution of *Trichuris trichiura* by intensities per school

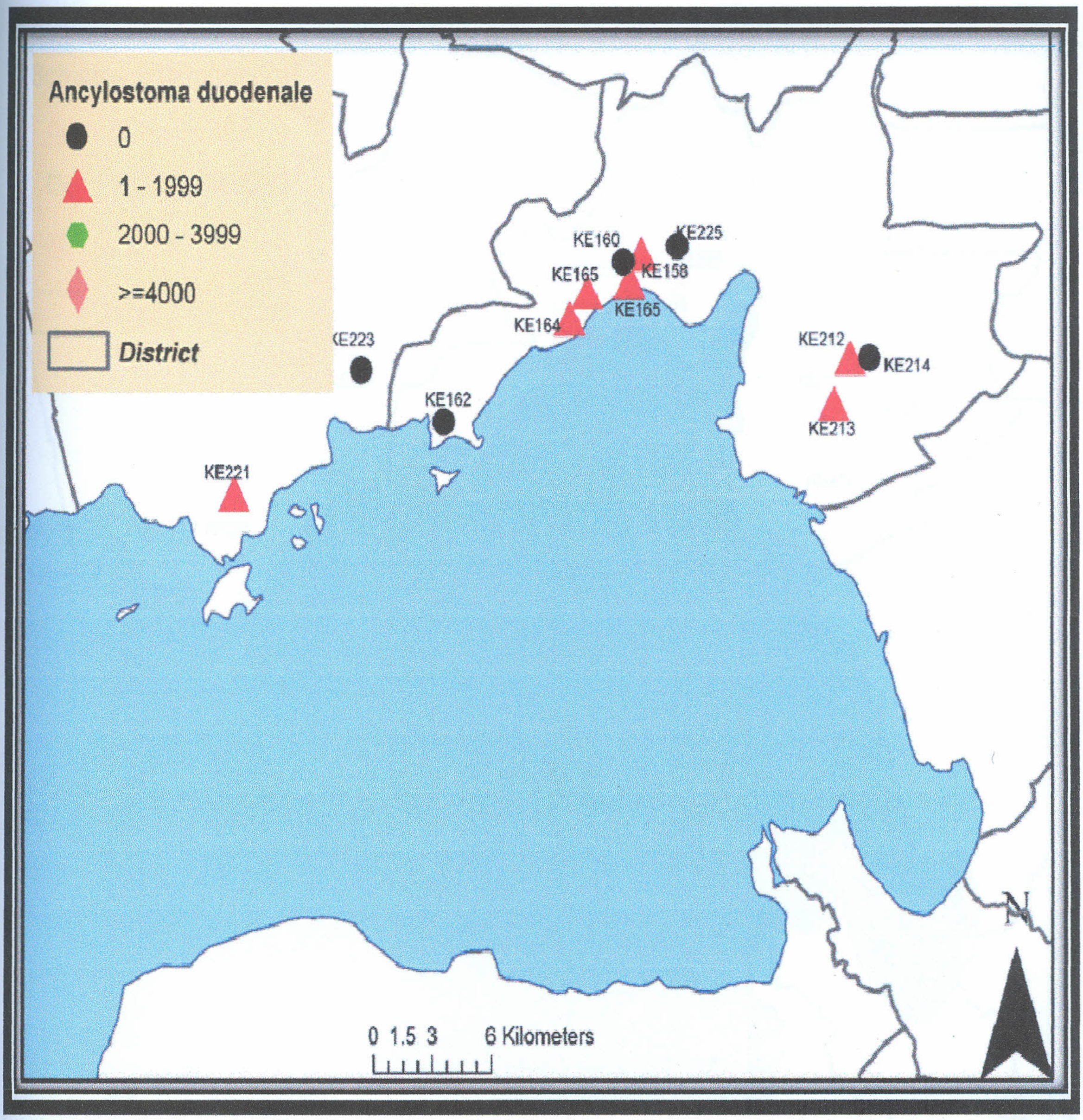


Figure 4.5.9. Distribution of *Ancylostoma duodenale* by intensities per school

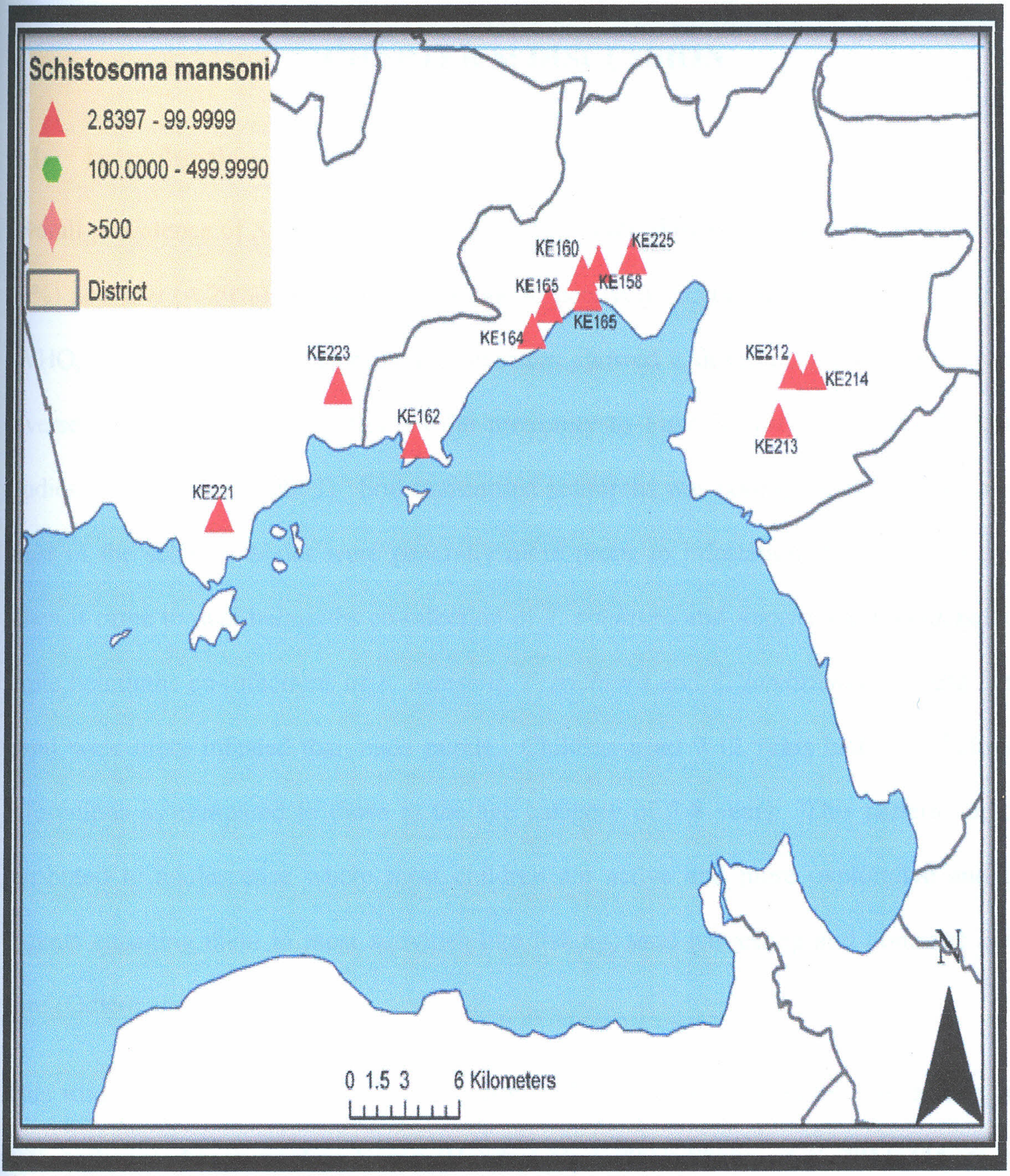


Figure 4.5.10. Distribution of *Schistosoma mansoni* by intensities per school.

Mean intensities of helminths in all the schools (Figures 4.4.6, 4.4.7, 4.4.8) fall under low intensities categories respectively as per WHO classification thresholds in Table 2.6.2.1. Each shape in the map represented a range of egg mean average.

CHAPTER 5: DISCUSSION

5.1. Introduction

Overall prevalence of *S. mansoni* and STHs in this study showed that they are moderate (10-49%) and low (< 20%) endemic infestations respectively, according to WHO classification (WHO, 2006). School prevalence of *S. mansoni* showed a differential prevalence rates of inverse proportionality in relation to the proximity to Lake Victoria as shown by earlier studies (Handzel *et al.*, 2003). Soil transmitted helminths was homogeneously distributed in most of the schools. Males were generally more prone to infestations than females except when it came to dual helminths co-infection of *T. trichiura* and *Ancylostoma duodenale* and triple helminths co-infections of *S. mansoni*, *T. trichiura* and *A. lumbricoides* where female pupil were more infested than male pupils. Children aged 9-12 years had more helminths infestations as compared to those in the age category of 5-8 years. This pattern could be attributed to adolescence where most children are active and more explorative and their parents engaging them in most activities like fishing, sand harvesting and domestic animal care (Odiere *et al*,. 2012).

This study showed a significant decrease of overall prevalence of helminths when compared with earlier studies in western Kenya (Handzel *et al,* 2003; Shane, *et al,* 2011; Odiere *et al,* 2012. The reduction could be associated with the role out of the National school deworming programme done once a year by former Ministry of Public Health and Sanitation Kenya (MOPHS, 2011). Trends on STH's varied from the earlier studies in that *T. trichiura* became the most prevalent at 12.08%, unlike before where *Ancylostoma duodenale* was dominant (Brooker *et al.* 2010; Odiere *et*, *al.*, 2012). This could have been attributed to mass drug treatment with Albendazole in both schools and at the community levels. Albendazole drug has been found to have low efficacy of ≤27% on *T. trichiura* thus high levels of it (Albonico *et al.*, 2003; Keiser and Utzinger, 2010; Keiser and Utzinger, 2008; Olsen *et al.*, 2009 and Soukhathammavong *et al.*, 2012). This low efficacy is resolved by frequent deworming and alternative use of albendazole and melbendazole drugs during National school deworming programmes. All helminths showed high number of light intensities with only *S. mansoni* having heavy intensities in both genders.

5.2. Prevalence of single and multiples species of helminths

Overall prevalence of *S. mansoni* in this study was 32.77% which was significantly lower than a study done in Tanzania (Mazigo *et al*, 2010) but similar with studies done in Uganda at 34.6% (Sandley, *et al*, 2010). Earlier studies done in western Kenya had shown a prevalence rate ranging between 16.3 % and 38.8% (Handzel, *et al*, 2003; Shane, *et.al*, 2011). The observed differences in Kenya may be attributed to MDA age range differences in each study, the season which study took place, environmental factors and the locality of the study (Booth *et al.*, 2004; Odiere *et al.*, 2012 ; Brooker *et al*,. 2010.). Male pupils were more infested with *S. mansoni* and STH's than female pupils and those of age between 9-12 years were also significantly infested than those aged between 5-8 years. Several factors may have contributed to this age and gender preference of *S. mansoni*: male pupils at this age are more active, explorative and they are group that parents delegate activities that are risk factors for helminths like looking after cattle and sand harvesting. This exhibited pattern is in agreement with those of earlier studies (Fulford, *et al.*, 1998; Uneke, *et al.*, 2007; Tchuem *et al.*, 2012; Odiere *et al.*, 2012).

In contrast with earlier studies that shows *Ancylostoma duodenale* as the common STH along the Lake Victoria region (Handzel *et al.*, 2003; Odiere *et al.*, 2012), this study found out that *T. trichiura* was the predominant STH's. This is in agreement with a study done in Cameroon where *T. trichiura* prevalence was higher followed by *A. lumbricoides* and *Ancylostoma duodenale* respectively (Tcheum *et al.*, 2012). This switch in dominance from *Ancylostoma duodenale* to *T. trichuria* could be attributed to single dose Albendazole drug in MDA which has been going on in this region (MOPHS, 2011). Albendazole has poor efficacy on *T. trichiura* with low cure rate and egg reduction rate (Albonico *et al.*, 2003; Steinmann *et al.*, 2011).

Dual infections prevalence between helminths in this study was lower than in previous studies (Albonico, *et al.*, 1997; Brooker, *et al.*, 2000). This study further classified possible dual co-infections combinations which where HW and AL, TT and AL, TT and HW, SCH and AL, SCH and HW and SCH and TT. Male had higher helminths infestations than female except in TT and HW combinations where female gender helminths infestation was twice higher than male gender. Thus some helminths combinations thrive well with gender this could be brought by different hormones between male and female at adolescent age. Pupils between 9-12 years had all dual co-infection combinations higher than those between 5-8 years old except SCH and TT, TT and AL and TT and HW. The most common dual co-infection helminths combination was SCH and TT and commonest STH dual co-infection combination was TT & HW which contradicts the previous studies that showed AS and TT as the common one (Booth and Bundy, 1992; Odiere *et al.*, 2011, 2012). This could be explained by use of albendazole and melbendazole in MDA, where these two drugs have high cure rates of above 90% and almost complete egg reduction on *A. lumbricoides* thus change in trend of commonest STH dual combination from AS and TT to TT and HW (Utzinger,2008; Keiser and Utzinger, 2010; Keiser and Soukhathammavong *et al*,. 2012)

Triple and Quadruple infections of helminths were at a lower percentages, the most common triple co-infection combination was SCH, TT and AL and quadruple infection combination was only one male pupil with 11 years. Majority of the studies have not reported on these combinations. Knowing infection pattern is very important in that it allows identification of areas of high transmission of multiple helminths species thus prioritization of integrated treatment and management (Magalhaes *et al*., 2011a).

S. Mansoni was the most prevalent helminths and present in all the schools surveyed. This could be due to the presence of water body of Lake Victoria which is the source of many human activities to the local residence and harbors snails that are the host of schistosomes. The landscape of this area could have also played a role in that it is flat area and water tend to stagnate providing breeding grounds of the same. *T.trichiura* was also the commonest soil transmitted helminths because of use of albendazole drug as a single dose and the drug has low efficacy on the helminths, thus co-infection of *S. mansoni* and *T. trichiura* is the most prevalent one.

5.3. Intensities of helminths

S. mansoni and STHs infestations were of light intensities in pattern in both male and female pupils as well as between the age groups. Moderate and high intensities were scanty in this study population. This was in agreement with earlier studies in Cameroon where moderate and heavy intensities were rare (Tcheum *et al*., 2012). Mean eggs per grams per schools on both *S. mansoni* and STH, s showed that all school had light intensities according to WHO classification. This is likely to be attributed to SCORE project deworming initiative and National deworming programme initiated in 2009. This shows the effectiveness of MDA in fighting helminths.

Light, moderate and heavy intensities of *S. mansoni* were present in all genders and age groups and were higher in percentages in all the soil-transmitted helminths. This could be due to abundant distribution of schistosomes snails; *B. sudanica*, *B. pfeifferi* and *B. globosus* along Lake Victoria shores and inland sites (Opisa *et al.*, 2011). These snails shed cercaria thus high prevalence of *S. mansoni* (Odiere *et al.*, 2011) reflecting also to presence of all intensities categories in the study samples. Lake Victoria is the main source of transmission of *S. mansoni* (Handzel *et al.*, 2003) thus increasing the risk of infections especially more to active age group of 9-12 years (Figure 4.1 and 4.2).

5.4. Risk and pattern of infection with helminths in regard to age and gender groups

Gender and age groups showed association with having helminths. Male gender and being between the ages of 9-12 showed a strong association with *S. mansoni* and STH's. *S. mansoni* is male biased among children as previously shown (Carnargo-nerves *et al.*, 1998; Lima *et al.*, 1998; Gueirra & Abad, 2013). Pupils aged 9-12 years have more risk of having each category of worms compared to children aged 5-8 years. This is because of explorative and active nature of the latter group. Males also showed high infectivity rate to all the worms compared to female pupils. Females are more resistant to parasitic infections (Zuk & McKleen, 1996). With the aim of assisting in planning, implementation of MDA, and reaching target towards elimination of helminths, mapping is very crucial (Magalhaes *et al.*, 2011b). These maps showed clearly that co-infections are frequent. Soil transmitted helminths distribution had spatial heterogeneity pattern except for *T. trichiura* that was distributed in wholly pattern in all schools though majority of the schools had low prevalence levels. Soil transmitted helminths prevalence in the maps per schools showed that the pupils were low and moderate risk groups according to WHO prevalence classification system thus the schools would be recommended for a single deworming in a year (WHO, 2006). *S. mansoni* was distributed in all schools with majority of the schools being moderate risk population, and this could be attributed to MDA of SCORE project and national schooling deworming programme. A new unexpected result on distribution of *T. trichiura* and *S. mansoni* on schools that had both helminths showed that they were located far from the lake and those schools that had all the helminths were located proximately to the lake and those with three worms had no notable pattern. This brings out that water body and mashed areas is a risk factor for having more helminths.

Patterns of dual infections increased with age, it was highest in pupils within 9-12 years, and this contradicted with a study done in Zanzibar by Knopp *et al.*, 2010 that showed polyparasitism as highest in the ages of 5-11 years. Multiple co- infections was only demonstrated in 9-12 years pupils, this can be explained by the active and explorative nature of this age group of children (Brooker et al., 2009; Koroma et al., 2010). They get more exposed to the environmental risk factors than those of 5-8 years age group thus higher risks than the later. Female pupils missed co- infections of TT and AS, SCH, HW and AS and SCH, TT ,HW and AS an observation that has been attributed to the sex biased patterns that occurs with infestations and infections, and they rarely affect males and females equally despite even demographic ratios (Guierra-Silvera *et.al*,. 2013) Females are more resistant to parasitic infections (Zuk & McKleen, 1996). Physiological hypothesis of interaction between sex hormones, immunity system and chromosomes differences is also likely to play a role (Brabin & Brabin, 1992; Zuk & Mcklean, 1996; Klein, 2004; Fish, 2008 and Ober *et.al*,. 2008). Behavioral hypothesis also explains the sex-biased different infections rates. Behavior differences may render one group more exposed to the risk factors thus the pattern where male pupils are more infested with both dual and multiple helminths infestations (Brabin & Brabin, 1992; Tolhurst *et al*,. 2002; Krieger, 2003 and WHO, 2007).

5.5. Geographical distribution of helminths

Integrated control of helminths requires careful planning (Brooker *et al*, 2009: Koroma *et.al.*, 2010) therefore it was essential to map the distribution of each helminths by prevalence, intensities, type(s) available in each school in order to determine the disease specific preventive chemotherapy and transmission control strategy within Kisumu municipality.

Schools surveyed within the municipality showed presence of *S. mansoni* and *T. trichiura in* all schools. Schools with prevalence of <10% are low risk group, moderate risk groups have prevalence of between 10-≤49.9% and high risk groups with prevalence of ≥50 % (WHO, 2002). With this risk classification WHO recommends mass treatment administration with praziquantel for shistosomes and Albendazole or Mebendazole for STHs where prevalence exceeds 10%. Moderate risk schools to get mass drug administration once every two years and high risk schools to get it once every year (WHO, 2006a). The absence of *A. lumbricoids* and *Ancylostoma duodenale* in several schools and all the other schools being low risk groups, perhaps reflects the effectiveness of the 2009 national pilot mass drug administration and SCORE project deworming exercises. Mapping brought out clearly that the more the school was proximate to the Lake Victoria the more the number of helminth types that were present in its pupils. This is attributed to the human activities around the lake, presence of water as a mode of transporting agent and fecal disposal to the areas around the lake by open sewage, thus more deworming should focus on the schools that are near to the lake in Kisumu municipality.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSIONS

1. Prevalence of single helminths within Kisumu Municipality was 32.77%, 12.08%, 3% and 2.5% for *S. mansoni, Trichuris trichiura, Ascaris lumbricoides* and *Ancylostoma duodenale*. Multiple helminth prevalence were less than 5% and majority of combinations below 1%.
2. Light intensities were the most common in all age groups and gender. It was highest in male pupils and those aged between 9-12 years old. *Schistosoma mansoni* and *Trichuris trichiura* helminths had light, moderate and heavy intensities within the pupils while *Ancylostoma duodenale* and *Ascaris lumbricoides* had light and moderate intensities.
3. The risk of having an infection in relation to age and gender showed that pupils aged between 9-12 years old and male pupils across all age groups were more infested by helminths compared to female counterparts.
4. Geographical mapping showed that schools proximate to Lake Victoria had more number of helminths types and the furthest schools from the Lake Victoria the fewer number of helminths types infesting the pupils.

6.1. RECOMMENDATIONS

1. Prevalence and distribution of helminths from this study has implications on planning, organizing and executing mass treatment programmes according to WHO criteria as per prevalence categories. Thus deworming of individual infested in schools less than 10%, mass deworming once in two years for schools with ≥10%-≤49% and yearly for schools with ≥50% with albendazole for STHs and Prazintaquel for schistosomes. Light intensities was common and this could be attributed to previous mass drug administration, thus similar intervention should be promoted and encouraged in order to reduce morbidities brought by heavy infestation of worms. Further studies and experiments are recommended to be done on pattern of helminths combination in regard to gender, to bring more insight on the relationships. It was noted that trend on STHs pattern had changed unlike in previous studies where *Ancylostoma duodenale* were dominant. *Ascaris lumbricoides* is the dominant STH thus mass drug deworming programmes should alternatively use albendazole and melbendazole drugs.
2. Mapping of helminths distribution using geographical information system has proved as an important tool for presenting accurate information on overall prevalence, schools prevalence, mean intensities per schools and helminth combinations thus could improve on proper planning and implementation of mass drug administration and control efforts on helminths. Mapping has brought accurate information by bringing in the real visual aspect of the distribution, has allowed classification on prevalence and distribution and now targeting is now easy and focus oriented.

REFERENCES.

Adams V, Lombard C, Dhansay M, Markus M. & Fincham E. (2005). Efficacy of albendazole against the whipworm *Trichuris trichiura*--a randomized, controlled trial. *South African Medical Journal*, (94). 12, 972-976.

Albonico M, Allen H, Chitsulo L, Engles D, Gabrielli A, & Savioli L. (2008). Soil-transmitted helminthiasis in pre-school-age children through preventive chemotheraphy. *PLoS Neglected Tropical Diseases*, *2*(3), e.126.

Albonico M, Crompton D, & Savioli L. (1999). Control strategies for human intestinal nematode infections. *Advanced Parasitology*, *42*, 277–341.

Albonico, M., Bickle, Q., Ramsan, M., Montresor, A., Savioli, L., & Taylor, M. (2003). Efficacy of mebendazole and levamisole alone or combination against intestinal nematode infections after repeated targeted mebendazole treatment in Zanzibar. *Bulletin World Health Organization. 81*, 343–352.

Albonico, M., Chwaya, H., Montresor, A., Stolfzfus, R., Tielsch, J., Alawi, K., & Savioli, L. (1997). Parasitic infections in Pemba Island school children. *East African Medical Journal*, *74*, 294–298.

Alonderince, R. and Asta K. (2013). Insights into Lutherian students Choice of University Program in Management and Economics. *Management*, *18*, 1–22.

Anderson RM, & May RM. (1991). Infectious Diseases of Humans: Dynamics and Control. New York: Oxford University Press.

Aulk K. (2007). Pan America Health Organization's regional strategic framework for addressing neglected diseases in neglected population in Latin America and the Carrebian. *Mem Institute of Oswaldo Cruz*, *102*, 99–107.

Bethony J, Brooker S, Albonico M, Geinget S, Loukas A, Diermert D, & Hotez P. (2006). Soil Transmitted Helminth Infections; Ascars, Trichuriasis and Hookworm. *Lancet, 367*, 1521–1532.

Booth, M., & Bundy, D. (1992). Comparative prevalence of *Ascaris lumbricoides*, *Trichuris trichiura* and hookworm infections and the prospects for control. *Parasitology, 105*, 151–157.

Booth, M., Vennervald, B., Butterworth, A., Kariuki, H., Kadzo, H., Ireri, E., Mwatha, G. (2004). Micro-geographical variation in exposure to *Schistosoma mansoni* and malaria and exacerbation of splenomegaly in Kenyan school-aged children. *BMC Infectious Diseases. 4*(13).

Borus. (1996). Medical Microbiology. (4th Edition.). Galveston: Galverston (TX) University of Texas.

Brabin, L., & Brabin, B. (1992). Parasitic infections in women and their consequences. *Advanced Parasitology, 31*, 1–81.

Brooker S, Hotez P, & Bundy D. (2010). The Global Atlas of Helminth Infection: Mapping the Way Forward in Neglected Tropical Disease Control. *PLoS Neglected Tropical Diseases, 4*(7), e779.

Brooker S, Pesu N, Waru P, Mosobo M, & Guyah H. (1999). The Epidemiology of Hookworms Infection and its contribution to anemia among pre- school children on Kenyan Coast. *Transactions of Royal Society of Tropical Medicine and Hygiene, 93*, 240–246.

Brooker S, Rowland H, Savioli L, & Bundy D. (2000). Towards an Atlas of Human Helminths Infection in sub-Saharan Africa: The use of Geographical Information System. *Parasitology Today, 16*, 303–306.

Brooker, S. (2007). Spatial epidemiology of human Schistomiasis in Afican; risk models, transmission dynamic and control. *Transactions of Royal Society of Tropical Medicine and Hygiene, 101*, 1–8.

Brooker, S., & Bundy, D. (2010). The Global Atlas of Helminth Infection: Mapping the Way Forward in Neglected Tropical Disease Control. *PLoS Neglected Tropical Diseases, 4*(7), e779.

Brooker, S., Clements, A., Hotez, P., Hay, S., Tatem, A., Bundy, D., & Snow, R. (2006). The co-distribution of plasmoduim falciparum and hookworms among African school children. *Malaria Journal, 99.*

Brooker, S., Kabatereine, N., Smith, J., Mupfasoni, D., & Mwanje, M. (2009). An updated atlas of human helminth infections: the example of East Africa. *International Journal of Health, 8*, 42.

Brooker, S., & Michael, E. (2000). The potential of geographical information systems and remote sensing in the epidemiology and control of human helminth infections. *Advanced Parasitology, 47*, 245–288.

Brooker, S., Miguel, E., Moulin, S., Louba, A., Bundy, D., & Kremer, M. (2000). Epidemiology of single and multiple species of helminth infections among school children in Busia District, Kenya. *East African Medical Journal, 77*, 157–161.

Brooker, S., & Utzinger, J. (2007). Integrated disease mapping in polyparasitic world. *Geospatial Health, 2*, 141–147.

Bundy D, & de silva N. (1998). Can we deworm this wormy World? *Britain Medical Bulletin, 54*, 421–432.

Camargo-Neves, V., Kanamura, H., Vellosa, S., Gargioni, C., & Dias, L. (1998). IgM antibodies to *Schistosoma mansoni* gut–associated antigens for the study of schistosomiasis transmission in Ribeira˜o Pires, Sa˜o Paulo. *Mem Institute of Oswaldo Cruz, Suppl 1*, 273–278.

Chan M, Medley G, Jemmision D, & Bundy D. (1994). The Evaluation of Potential Global Morbidity Attributable Intestinal Nematodes Infections. *Parasitology, 109*, 373– 387.

Cook, G., & Zumia, A. (2004). Manson's Tropical Diseases. (21st Edition.). China.

Crompton D, & Neisheim M. (2002). Nutritional impact of intestinal helminthiasis during the human life cycle. *Annals of Review Nutrition. 22*, 35–59.

de silva, Brooker N, Hotez P, Montresor A, Engles D, & Savioli L. (2003). Soil-transmitted helminthic infections: updating the global picture. *Disease Control Priorities, 12*, 38–45.

Egwunyenga O, & Athikuri D. (2005). Soil- transmitted helminthiasis among school age children in Ethiope East Local Government Area, Delta State, Nigeria. *African Journal of Biotechnology, 4*(9), 938–941.

Fekadu D, Beyne P, & Amha K. (2008). Hookworm species distribution among school children in Asendabo Town, Jimma Zone, South West Ethiopia. *Ethiopian Journal of Health Science, 18*(2), 53–56.

Figueirado J, Gamboa D, Pedro J, Langa A, Fancony C, Magahaes S, Nery S. (2012). Epidemiology of Malaria, Schistosomiasis, Geohelminths, Anemia and Malnutrition in the Context of a Demographic Surveillance System in Northern Angola. *PloS ONE, 7*(4), e33189.

Fish, E. (2008). The X-files in immunity: sex-based differences predispose immune responses. *Journal of Nature Rev Immunology., 8*, 737 – 744.

Fulford, A., Webster, M., Ouma, J., kimani, G., & Dunne, D. (1998). Puberty and age-related changes in susceptibility to schistosome infection. *Parasitology Today, 14*, 23–26.

Glinz, D., Silve, K., Knopp, S., Lohourignon, L., Yao, K., Steinmaun, P., Utzinger, J. (2010.). Comparing Diagnostic Accuracy of Kato-Katz, Kago Agar Plate, Ether Concentration and FLOTAC for Schistosoma mansoni and Soil- Transmitted Helminths. *PLoS Neglected Tropical Diseases*, *4*(7).

Guerra-Silveira, F., & Abad-Franch, F. (2013). Sex Bias in Infectious Disease Epidemiology: Patterns and Processes. *PLoS Neglected Tropical Diseases*, *8*(4), e62390.

Gyapong J, Kyelem D, Kleinschmidt I, Ahouandogbo F, Gaba J, Banahene G, Remme J. (2002). The use of spatial analysis in mapping the distribution of bancrofti and filariasis in four West African Countries. *Annals Tropical Medicine Parasitology, 96*, 695 705.

Handzel, T., Karanja, D., Addiss, D., Hightower, A., Rosen, D., Colley, D., Secor, W. (2003). Geographical distribution of schistosomiasis and soil- transmitted helminths in western Kenya: implications for anthelmintic mass treatment. *American Journal of Tropical Medicine Hygiene, 69*, 318–323.

Hay, S., & Snow, S. (2006). The malaria atlas project; developing the global maps of malaria risk. *PLoS Neglected Tropical Diseases*, *3*, e473.

Hess G, Rundolph S, & Arneberg P. (2001). Spatial aspect of disease dynamics, In Hudson P, Rizzoli A, Grrenfell B. Heeesterbeek j, Dobuson A . The ecology of wildlife diseases. *Oxford University Press, 102*, 102–118.

Hodges M, Dada N, Wamsley A, J, P., Nyorkor E, Sonnie M, ... Zang Y. (2011). Improved mapping strategy to better inform policy on control of Schistosomiasis and Soil-transmitted helminthiasis in Seira Leone. *Journal of Parasites and Vectors*, *4*, 97.

Hodges, M., Soares Maghaes RJ, Kiroma JB, M, S., Clements, A., & Zhang. (2012). Combined spatial prediction of schistosomiasis and Soil-Transmitted Helminthiasis in

Seira Leone: A tool for integrated Disease Control. *PLoS Neglected Tropical Diseases, 6*(6), e1694.

Holland C. (2009). Predisposition to ascaris: patterns, mechanisms and implications. *Parasitology, 136*, 1537–1547.

Hopkins D, Eigege A, Miri E, Gontor I, Ogah G, Umaru J, Richards F. (2002). Lymphatic filariasis elimination and schistomiasis control in combination with onchocerciasis control in Nigeria. *American Journal of Tropical Medicine Hygiene, 67*, 266–272.

Hotez, P. J., Brooker, S., Bethony, J. M., Bottazzi, M. E., Loukas, A. & Xiao, S. (2004). Hookworm infection. *New England Journal of Medicine*, (351) 8, 799-807.

Hotez P, Brindley P, Bethony J, King C, Pearce E, & Jacobson J. (2008). Helminth infections: the great neglected tropical diseases. *Journal of Clinical Investigation, 118*, 1131–1321.

Hotez, P. (2013). Forgotten people, forgotten diseases, the neglected tropical diseases and their impact on global health and development (2nd ed.). ASM Press.

Hotez, P., Molyneux, D., Frenwick, A., Kumaresan, J., & Sachs, S. (2007). Control of Neglected Tropical Diseases. *New England Journal Medicine, 357*, 1018–1027.

Jia T, Melville S, Utzinger J, King C, & Zhoux. (2012). Soil-transmitted Helminth Reinfection after Drug treatment: A systemic Review and Meta-Analysis. *PLoS Neglected Tropical Diseases, 6*(5), e1621.

Jukes, M., Drake, L., & Bundy, D. (2008). School health, nutrition and education for all: leveling the playing field. Wallingford UK: CAB Publisher.

Katz N, Chaves A, & Pellegrino J. (1972). A simple device for quantitative stool thick -smear technique in *schistosioma mansoni. Journal of the Institute Tropical Medicine Sao Paulo., 14*, 397–400.

Keiser, J., & Utzinger, J. (2008). Efficacy of current drugs against soil-transmitted helminth infections: systematic review and meta-analysis. *JAMA, 299*, 1937–1948.

Keiser, J., & Utzinger, J. (2010). The drugs we have and the drugs we need against major helminth infections. *Advanced Parasitology, 73*, 197–203.

Kevin, K. (2010). Study design III; Cross-sectional Studies. *Evidence Dentistry, 7*, 24–25.

King J, Eigege A, Richards F, Jip N, Umaru J, Deming M, Emerson PM. (2009). Integrating NTD mapping protocols: Can surveys for trachoma and urinary schistosomiasis be done simultaneously? *American Journal of Tropical Medicine Hygiene, 81*, 793–798.

Kitron U. (2000). Risk maps: transmission and burden of vector-borne diseases. *Parasitology Today, 16*, 324–325.

Klein, S. (2004). Hormonal and immunological mechanisms mediating sex differences in parasitic infections. *Parasitic Immunology, 26*, 247 – 264.

Knopp, S., Mohammed, K., Stothard, J., Khamis, I., Rollinson, D., Hanspeter, M., & Utzinger, J. (2010). Patterns and Risk Factors of Helminthiasis and Anemia in a Rural and a Peri-urban Community in Zanzibar, in the Context of Helminth Control Programs. *PLoS Neglected Tropical Diseases, 4*(5), e681.

Koroma, J., Peterson, J., Gbakima, A., Nylander, F., Sahr, F., Magalhaes, S., Hodges, M. (2010). Geographical Distribution of Intestinal Schistosomiasis and Soil-Transmitted Helminthiasis and Preventive Strategies in Sierra Leone. *PLoS Neglected Tropical Diseases, 4*(11), e891.

Kreiger, N. (2003). Genders, sexes, and health: what are the connections- and why does it matter? *International Journal of Epidemiology, 32*, 652 – 657.

Kwalsvig J. (2002). Intestinal Nematodes and Cognitive Development. Kluwer Academic Publishers.

Liese B, Rosenberg M, & Schratz A. (2010). *Programmes, partnerships, and governance for elimination and control of neglected tropical diseases. Lancet, 375*, 67–76.

Lima, V., Guercio, V., Rangel, O., Kanamura, H., & Dias, L. (1998). Immunofluorescence test on Schistosoma mansoni worm paraffin sections (IgM-IFT) for the study of schistosomiasis transmission in Campinas, Sa˜o Paulo, Brazil. *Mem Istitute of Oswaldo Cruz, Suppl. 1*, 283–287.

Lwambo, N., Siza, J., Brooker, S., Bundy, D., & Guyatt. (1999). Patterns of Concurrent hookworm infections and schistosomiasis in school children in Tanzania. *Transactions of Royal Society of Tropical Medicine and Hygiene, 93*, 497–503.

Magalhaes, R., Biritwum, N.-K., Gayapong, J., Brooker, S., Zhang, Y., Blair, L., Clements, A. (2011). Mapping Helminth Co-infection and Co- Intensity: Geostastistical prediction in Ghana. *PLoS Neglected Tropical Diseases, 5*(6), e1200.

Magalhaes, R., Clements, A., Patil, A., Gething, P., & Brooker, S. (2011). The application of model-based geostastictics in helminth epidemiology and control. *Advanced Parasitology*, *74*, 267–296.

Mahmoud, A. A. (1990). Intestinal nematodes. In: Mandell GI, Douglas RG, Bennet JE, editors. Principles and Practice of Infectious Diseases. Edinburg: Churchill Livingstone; 1990. p. 2137-2138.

Malone, J. (2005). Biology-based mapping of vector -borne parasites by GIS terms and remote sensing. *Parasitology*, *47*, 27–50.

Markell, E. K., Voge, M. & John, D. T. (1992). The intestinal nematodes. In: Ozmat S, editor'. Medical parasitology. Philadelphia: W.B. Saunders; 1992. p. 261-93.

Mascarini-Serra L, Telles C, Prado M, Mattos S, Strina A, Neuza M, & Mauricio B. (2010). Reductions in Prevalence and Incidence of Geohelminth Infections following a Citywide Sanitation Program in a Brazilian Urban Centre. *PLoS Neglected Tropical Diseases, 4*(2), e588.

Mazigo, H., Waihenya, R., Lwambo, N., Mnyone, L., Mahande, A., Seni, J., Mshana, S. (2010). Co-infections with *Plasmodiun faciparum, Schistosoma mansoni* and intestinal helminths among schoolchildren in endemic areas of northwestern Tanzania. *Parasitic Vectors, 3*, 44.

Montresor A, Crompton D, Bundy D, & Savioli L. (1998). Guidelines for the evaluation of soil transmitted helminthiasis and schistosomiasis at community level. Geneva. *World Health Organization, WHO/CTC/SIP/98.*

MOPHS. (2011). *National Multi-Year Strategic Plan of Action for Control of Neglected Tropical Diseases 2011-2015.* Government printer.

Mutuku A, Kinoti M, Wamae A, Ndong M, & Migori P. (2008). Prevalence of Intestinal Worm Infections among Primary School Children in Nairobi City, Kenya. *East African Journal of Public Health, 5*(2), 86–89.

Nokes C, & Bundy D. (1994). Does helminth infection affect mental processing and educational achievement? *Parasitology Today, 10*, 14–18.

Noma M, Nwoke B, Nutall I, Tambala P, Enyong P, Namasmo A, Sekateli A. (2008). Rapid epidemiology mapping of onchocerciasis (REMO): its application by the African Programme for Onchocerciasis Control (APOC). *Annals of Tropical Medicine Parasitology, 96*, S29–S39.

Ober, G., Loisel, D., & Gilad, Y. (2008). Sex-specific genetic architecture of human diseases. *Nature Rev Genetics, 9*, 911 – 922.

Odiere, M., Opisa, S., Odhiambo, G., Jura, W., Anyisi, J., Karanja, D., & Mwinzi, P. (2011). Geographic distribution of schistosomiasis and soil-transmitted helminths among school children in informal settlements in Kisumu city, western Kenya. *Parasitology, 138*(2), 1569–1577.

Odiere, M., Rawago, F., Ombok, M., Secor, W., Karanja, D., Mwinzi, P., Won, K. (2012). High prevalence of schistosomiasis in Mbita and its adjacent islands of Lake Victoria, western Kenya. *Parasitic Vectors, 5*, 278.

Oliver, A. (2005). Disability adjusted life years for decision making?

Olsen A, Lieshouth L, Martic H, Poldermemb T, Steimanne P, Stothardg R, Magnussena P. (1994). Strongyloidiasis the most neglected tropical disease. *Transactions of Royal Society of Tropical Medicine and Hygiene, 103*, 967–972.

Olsen, A., Nawanje, H., Nejsum, P., Roepstorff, A., & Thamsborg, S. (2009). Albendazole and mebendazole have low efficacy against Trichuris trichuria in school age children in Kabale District, Uganda. *Transactions of the Royal Society Tropical Medicine and Hygiene, 103*, 443–446.

Omumbo, J., Ouma, J., Rapuoda, B., Craig, M., Le Sueur, D., & Snow, R. (1998). Mapping Malaria transmissions intensity using geographical information systems (GIS); an example of Kenya. *American Health Journal, 92*(1), 7–21.

Opisa, S., Odiere, M., Jura, W., Karanja, D., & Mwinzi, P. (2011). Malacological survey and geographical distribution of vector snails for Schistosomiasis within informal settlements of Kisumu City, western Kenya. *Parasitic Vectors, 4*(226).

PAHO. (2009). Epidemiological profiles of neglected diseases and other infections related to poverty in Latin America and Caribbean. Washington DC: Pan American Health Organization.

Polllack S, Brooker S, Kuper H, Mariotti S, Mabey D, & Foster A. (2005). Mapping the global distribution of trachoma. *Bull World Health Organ, 84*, 913–919.

Pullan R, Bethony J, Geiger S, Cundilll B, Correa-Oliveira R, Quinnel J, & Brooker S. (2008). Human Helminth Co-Infection: Analysis of Spatial Patterns and Risk Factors in a Brazilian Community. *PLoS Neglected Tropical Diseases*, *2*(12), e352.

Pullan R, & Brooker S. (2012). The global limits and population at risk of soil-transmitted helminth infections in 2010. *Parasitic Vectors.*, *2*(4), e157.

Rajini K. (2010). Control of intestinal parasites among children in two communities of South Saint Lucia. *Journal of Rural and Tropical Public Health*, *9*, 95–100.

Raso G, A, L., Adjoua A, Tian-Bi N, Silue D, Matthys B, Utzinger J. (2004). Multiple parasite infections and their relationship to self-reported morbidity in a community of rural Cote d'Ivoire. *International Journal of Epidemiology*, *33*, 1092– 1102.

Robertson L, Crompton D, Sanjur D, & Nesheim M. (1992). Hemoglobin concentration and concomitant infections of hookworms and *Trichuris trichiura* in Panamian primary school children. *Transactions of Royal Society of Tropical Medicine and Hygiene*, *86*, 654–656.

Savioli L, Renganathan E, Montresor A, Davis A, & Behbehauni K. (1997). Control of Schistosomiasis- a global picture. *Parasitology Today*, *13*(11), 444–448.

Savioli L, Stansfield S, Bundy D, Mitchell A, Bhatia R, Engles D, ... Shein A. (2002). Schistosomiasis and soil-transmitted helminth infections: forging control efforts. *Transactions of the Royal Society Tropical Medicine and Hygiene*, *96*, 577–579.

Shane, H., Verani, J., Abudho, D., Montgomery, S., Blackstock, A., Mwinzi, P., Secor, W. (2011). Evaluation of Urine CCA Assays for Detection of *Schistosoma mansoni* Infection in Western Kenya. *PLoS Neglected Tropical Diseases*, *5*(1), e951.

Simeon D, & McGregor S. (1990). Nutritional deficiencies and children behavior and mental development. *Nutrition Research Reviews*, *3*(1), 1–24.

Snow, R., Marsh, K., & Le Sueur, D. (1996). The need for maps of transmission Intensity to guide malaria control in Africa. *Parasitology Today.*

Soukhathammavong, P., Sayasone, S., Phongluxa, K., Xayaseng, V., Utzinger, J., Vounatsou, P., Odermatt, P. (2013). Low Efficacy of Single-Dose Albendazole and Mebendazole against Hookworm and Effect on Concomitant Helminth Infection in Lao PDR. *PLoS Neglected Tropical Diseases*, *6*(1), e1417.

Standley, C., Andriko, M., Arinaitwe, M., Atuhaire, A., kazibwe, F., Frenwick, A., Stothard, J. (2010). Epidemiology and control of intestinal schistosomiasis on the Sesse Islands, Uganda: Integrating malacology and parasitology to tailor local treatment recommendations. *Parasitic Vectors, 3*(1), 64.

Stephensen C. (2001). Vitamin A, Infection and Immune function. *Annals Rev Nutrition, 21*, 167–192.

Stephenson L, Holland C, & Cooper. (2000). The Public Health Significance of *Trichuris trichiura. Parasitology, 121 supplementary*, S73–S95.

Stephenson L, Lathan M, Adams E, Kinoti S, & Pertet A. (1993). Physical fitness, growth, appetite of Kenyan School boys with hookworm, Trichuris trichuria and Ascaris lumbricoids infections are improved four months after single dose of albendazole. *Journal of Nutrition, 123*, 1036–1046.

Stephenson, L. S., Latham, M. C. & Ottesen, E. A. (2000b), Global malnutrition. *Parasitology*, 121 Suppl, S5-S22.

Stoltzufs R, Albonico M, Tielshch J, Chwaya H, & Savioli L. (1997). Linear growth retardation in Zanzibari school children. *Journal of Nutrition*, (127), 1099–1105.

Stoltzufs R, Chwaya M, Montresor A, Tielshch J, & Jape A. (2004). Low dose daily supplementation improve iron status and appetite but not anemia, whereas quarterly anthelminthic treatment improves growth, appetite and anemia, in Zanzibari pre-school children. *Journal of Nutrition*, *134*, 348–356.

Stothard J, Chitsulo L, Ktistensen T, & Utzinger J. (2009). Control of schistosomiasis in sub-Saharan Africa: progress made, new opportunities and remaining challenges. *Parasitology*, *136*, 1665–1675.

Sturrock H, Picon D, Sabasio A, Oguttu D, Robinson E, Lado M, Kolaczinski J. (2009). Integrated mapping of neglected tropical diseases: epidemiological findings and implications for integrated control for Northern Bahr-el-Ghazal State, Southern Sudan. *PLoS Neglected Tropical Diseases*, *3*, e537.

Tanowitz H, Weiss L, & Wittner M. (1993). Diagnosis and treatment of Intestinal helminths. Gastroentrology. *Gastroentrology*, *1*(4), 265–273.

Tanser, F., & Le Sueur, D. (2002). The Application of geographical information systems to important public health problems in Africa. *International Journal of Geographics*.

Tcheum, T., Tchuente, L.-A., Kamwa, R., Sumo, L., Ngassam, P., Dongmo, C., III. (2012). Mapping of Schistosomiasis and Soil-transmitted Helminthiasis in the Regions of Centre, East and West Cameroon. *PLoS Neglected Tropical Diseases*, *6*(3), e1553.

Tolhurst, R., Koning, K., Price, J., Kemp, J., & Theobald, S. (2002). The challenges of infectious disease: time take gender into account. *Journal of Health Manage*, *4*, 135–151.

UN Habitat. (2005). Situation analysis of informal settlements in Kisumu. Nairobi: United Nations Human Settlements programme.

Uneke, C., Eze, K. ., Onyibo, P. ., Azu, N. ., & Ali, E. (2007). Soil-Transmitted Helminth Infection in School Children in South-Eastern Nigeria: The public Health Implication. *The Internet Journal of Third World Medicine*, *4*(1).

Utzinger J, & Keiser J. (2004). Schistosomiasis and Soil transmitted helminthiasis: common drugs of treatment and control. *Expert Opin Pharmacorther*, *5*, 263–285.

WHO. (2006a). Preventive chemotheraphy in human helminthiasis: coordinated use of anthelminthic drugs in control intervention: A manual for health professionals and programme managers. Geneva: World Health Organization.

WHO. (2002a). Bench aids for the diagnosis of intestinal parasites. (Vol. 192). WHO Technical Report Series.

WHO. (2002b). Helminth control in school-age children; a guide for Managers of Control Programmes. Geneva.

WHO. (2006). Preventive Chemotherapy in human helminthiasis: coordinated use of anthelminthic drugs in control interventions. Geneva: World Health Organization.

WHO. (2007). Adressing Sex and Gender in Epidemic prone Infectious Diseases. *World Health Organization*, (iv), +40p.

www.surveysystem.com/sscalc.htm.

Woodhall, D., Wiegand, R., Wellman, M., Matey, E., Abudho, B., Diana, M., Secor, W. (2013). Use of geospatial modelling to predict schistosomiasis mansoni: prevalence in Nyanza province, in Kenya. *PloS ONE*, *8*(8), e71635.

Yamane T. (1967). Statistics, An Introductory Analysis (2nd ed.). New York: Harper & Row Publishers.

Yang, R., Vounatsou, P., Zhou, X., Utzinger, J., & Tanner, M. (2005). A review of GIS and remote sensing with application to the epidemiology and control of schistosomiasis in China. *Acta Tropical*, *96*, 117–119.

Zuk, M., & McKean, K. (1996). Sex Differences in parasitic infections: patterns and processes. *International Journal of Parasitology, 26*, 1009–1024.