EVALUATING THE OCCURRENCE OF *SCHISTOSOMA HAEMATOBIUM* AND GEOHELMINTHES INFECTION IN RESIDENTS OF TWO VILLAGES IN MSAMBWENI DISTRICT OF COAST PROVINCE, KENYA.

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DECLARATION

I declare that this is my original work and has not been submitted for the award of degree in any other University or for any other award.

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DEDICATION

This thesis is dedicated to my family and friends;
The ones that have stood with me all the way and those I have lost along the way.

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ABBREVIATIONS AND ACRONYMS

EPG : Eggs per Gram of Faeces

CDC : Centre for Disease Control

DALYs: Disability-Adjusted Life Years

LF : Lymphatic Filariasis

MDGs : Millennium Development Goals

NGOs : Non Governmental Organizations

NTDs : Neglected Tropical Diseases

RFC : Relative Centrifugal Force

STH : Soil Transmitted Helminthes

WHO : World Health Organization

ABSTRACT

The presence of multiple concurrent infections, or polyparasitism, is quite common in schistosomiasis endemic areas. Msambweni District in the Coast Province of Kenya is highly endemic for *Schistosoma haematobium*. Previous studies showed an overall prevalence of schistosomiasis in Msambweni District at 40% to 60%. This is a prevalence way above the national prevalence of approximately 23%. There has been continued support by various agencies, including the government and non-governmental organizations (NGO's) in providing treatment and control of the disease in the area. However, the long term impact of these programs in the reduction of the overall prevalence of the disease has not been fully evaluated. This survey of 1232 people aged 5-78 years in two villages in Vingujini Sub-Location Msambweni District of Coast Province, Kenya was conducted to determine prevalence of *Schistosoma haematobium* and soil transmitted helminthes infections. Urine and stool samples were collected and examined for eggs of *Schistosoma haematobium* and intestinal helminthes. Haematuria was determined using urine dip strips. Hemoglobin levels were determined to establish the relationship between the intensity of hookworm disease and anemia. The overall occurrence of parasitic infections were, 43.99% for *Schistosoma haematobium*, 29.63% for hookworm disease, 0.49% for ascariasis and 24.59% for trichuriasis (N=1232). Only 32.71% were free from any of the parasitic infections screened. Age was related to infection with schistosomiasis ($f=95.17$, $p>0.01$), hookworm disease ($f=11.51$, $p= 0.010$) and trichuriasis ($f=26.46$, $p>0.01$). Infection with Schistosomiasis was highly correlated with *Trichuris* infection ($r=0.96$, $p=0.006$). Intensities of Schistosomiasis and hookworm were highly related to age ($p<0.01$). High intensities of *Schistosoma haematobium* were associated with haematuria ($f=639.99$, $p<0.01$). Intensity with hookworm was correlated to anemia ($r=-0.091$, $p<0.01$). Individuals with heavy and light infections were more likely to suffer from anemia than individuals with low intensities or the non-infected ($f=5.5$, $p<0.01$). The results of this study have shown that the problem of urinary schistosomiasis and soil transmitted helminthes persists despite the control programs and enhancement of these control programs is required.

CHAPTER ONE: INTRODUCTION

1.1 Background

Infection with soil transmitted helminthes, also known as geohelminthes and schistosomiasis is common in developing countries. It is also common to find individuals co-infected with schistosomiasis and soil transmitted helminthes. In areas where more than one species of *Schistosoma* occurs, some individuals may be infected with more than one species, for example *Schistosoma mansoni* and *Schistosoma haematobium* concurrent infections (Charles and Madeline, 2008).

Studies have often been based on examining specific parasite's role in causing morbidities such as anemia or under-nutrition (Engels and Savioli, 2006). Other researchers have focused on advanced pathogen specific disease outcomes such as site specific damages to tissues and organs as the only signs of infection attributable to morbidities, leaving the non-specific morbidities such as anemia and under-nutrition unacknowledged. However, lack of statistical significance does not necessarily mean absence of a clinically relevant effect.

Over the last decade, there has been convincing evidence to indicate the negative impact of parasitism, especially chronic parasitism on human growth and development (Stoltzfus *et al*., 1997), including cognitive development (Albonico *et al*., 1998), site specific morbidities, granulomatous reactions and fibrosis in specific organs due to repeated tissue inflammation (Van der Werf and de Vlas, 2001) and anemia (Stephenson *et al*., 1985b). Other effects include periportal liver fibrosis, portal hypertension with haematemesis and

splenomegally caused by *Schistosoma mansoni* and *S. japonicum* (Vennervald *et al.*, 2004).

There is also growth stunting and caloric under-nutrition as a result of hookworm infection, cystitis and urethritis with ulceration and haematuria caused by *Schistosoma haematobium* which can progress to bladder cancer in chronic situations (Van der Werf and de Vlas, 2001). Parasitic infections also lead to increased susceptibility to co-infection, fatigue, poor exercise tolerance and decreased work output (Brooker *et al*., 2004).

Some parasitic infections such as Ascariasis and Trichuriasis are known to cause the highest intensity infections in school children (Brooker *et al*., 2004). Hookworm infections however frequently occur in equally high intensities in both children and adult populations of both genders; and are an important health threat to adolescent girls, women of reproductive age and to outcomes in pregnancy who have a high blood demand as a result of menstruation and child birth (Adenusi and Ogunyomi, 2003).

1.2 Statement of the problem

In Msambweni area, surveys have established that the prevalence of *Schistosoma haematobium* in school age children ranges from 60% to 85% with an overall area prevalence of 40% to 50% (Muchiri *et al*., 1996). Control programs of parasites which are based on oral drug delivery have been developed and partially implemented as means to control morbidity within these affected populations (WHO, 2002). However questions remain about the long-term impact of the programs on schistosomiasis and geohelminthes transmission. Treatment of the most heavily infected segment of the population, i.e.

school age children, has been suggested as the best practical means of reducing contamination of local water by *Schistosoma* eggs (WHO, 2001). Although treatment has been shown to significantly reduce *Schistosoma haematobium* egg output by more than 90% among treated subjects over the short term (King *et al*., 1988), the actual impact of long-term, population-based treatment programs on year-to-year transmission of schistosomiasis has not been fully explored in this area. This calls for an evaluation to establish the impact of the current control measures on the prevalence of these diseases. This study investigated the occurrence of schistosomiasis and geohelminthes and the relationship between infection with hookworm disease and anemia in residents of 5 years and above in Bomani and Mwagundu villages in Vingujini sub-location of Msambweni district in the coast province of Kenya.

1.3 Justification

Evaluation of disease control methods is an important integral part for effective disease control. This project aimed at developing data on both single and concurrent infections with geohelminthes and schistosomiasis. It also captured the relationship between infection with hookworm disease and hemoglobin levels. This data can be utilized to determine the impact of control programs on the overall prevalence of schistosomiasis and geohelminthes in the area. The data obtained may also be used to assist in evidence-based decision-making, formulating strategies and providing technical decisions for formulating integrated, multi-disease based strategies for prevention, control and/or elimination; all based on evidence and with a clear vision towards fulfillment of the Millennium Development Goals (MDGs) and the development of neglected diseases agenda.

1.4 Research questions

i. What soil transmitted helminthes occur in people of ages five years up to 78 years in Bomani and Mwagundu villages of Msambweni location in Msambweni district at the Coast province of Kenya?

ii. What is the occurrence of urinary schistosomiasis in people of ages five years up to 78 years living in Bomani and Mwagundu villages?

iii. What is the occurrence of co-infections of *Schistosoma haematobium* and geohelminthes in people of ages five years up to 78 years in Bomani and Mwagundu villages?

iv. What is the relationship between infection with hookworm disease and levels of hemoglobin in people of ages five years up to 78 years in Bomani and Mwagundu villages?

1.5 Hypothesis

H_o- People aged five years and above in Bomani and Mwagundu villages in Vingujini sub-location of Msambweni location at the coast province of Kenya suffers neither urinary schistosomiasis nor soil transmitted infections.

1.6 Objectives of the study

1.6.1General objective

To determine the occurrence of urinary schistosomiasis and geohelminthes in residents of ages five years up to 78 years in Bomani and Mwagundu villages of Msambweni location in Msambweni district of the Coast province in Kenya.

1.6.2 Specific objectives

i. To determine the occurrence of geohelminthes and urinary schistosomiasis infections in people of ages five years up to 78 years in Bomani and Mwagundu villages of Msambweni location in Msambweni district of the Coast province in Kenya.

ii. To determine the occurrence of concurrent multiple helminthes infections in people of ages five years up to 78 years.

iii. To determine the relationship between hookworm disease and hemoglobin levels in people of ages five years up to 78 years.

iv. To determine the relationship between the intensity of urinary schistosomiasis and haematuria.

CHAPTER TWO: LITERATURE REVIEW

2.1 Helminthes infections in humans

The world health organization (WHO) classifies soil-transmitted helminthes (STH), schistosomiasis, lymphatic filariasis (LF), onchocerciasis and trachoma as neglected tropical diseases (NTDs). In 2002, WHO estimated that NTDs contributes to approximately 5% of the 457.7 million burden of disease according to the disability-adjusted life years (DALYs) due to infectious diseases (WHO Expert Committee, 2002). The impact of NTDs does not only stem from the approximately more than half a million deaths it causes annually, but largely from disability and morbidity, sometimes affecting a major proportion of the population in endemic areas (Hotez *et al*., 2006).

Subtle but often chronic NTDs manifestation may not be easily recognized because of lack of appropriate diagnostic tools leading to underestimation of the disease burden. Clinical manifestations are also easily overlooked and hence these diseases are often under-reported. A study by Hotez and others led to an increase in DALYs from 4.7 million, as estimated by WHO, to 39 million, or about 8% of the disease burden due to infectious diseases (Hotez *et al*., 2006)

The morbidities caused by soil transmitted helminthes (STHs) and schistosomiasis are most commonly associated with heavy infections (Crompton, 1999; Montressor *et al*., 2002). The four most common soil transmitted helminthes in the world are *Ascaris lumbricoides*, *Trichuris trichiura*, and the hookworm diseases caused by *Necator americanus* and *Ancylostoma duodenale* (de Silva *et al*., 2003). Global infection rates with these diseases are estimated at 1.221 billion people for *A. lumbricoides*, 795 million

for *T. trichiura* and 740 million for hookworms (Hotez *et al*., 2005). Infections with *Strongyloides stercolaris* are also common, but detailed information on the prevalence of strongyloidiasis is lacking because of difficulties in diagnosing human infections.

2.2 Hookworm disease

Hookworm disease is caused by parasitic nematodes in the order Strongyloidae, family Ancylostomatidae. The two species that are responsible for the disease in humans are *Necator americanus* and *Ancylostoma duodenale*. The adult worm lives in the small intestine of its host (Stoll, 1962). *Necator americanus* predominates in the Americas, sub-Saharan Africa, Southeast Asia, China and Indonesia, while *Ancylostoma duodenale* is predominantly in the Middle East, northern Africa, India and southern Europe (Hotez *et al*., 2005).

Hookworm infection is generally considered to be asymptomatic; however, hookworm is an extremely dangerous infection because its damage is ‘silent and insidious’ (Stoll, 1962). Hookworm transmission occurs by skin contact with infective third-stage larvae (L3) that have the ability to penetrate through the skin, frequently entering the body through the hands, feet, arms, or legs. *A. duodenale* L3 also can be ingested. Hookworm Larvae invasion of the skin may give rise to intense, local itching, usually on the foot or lower leg, which are followed by lesions that appear like insect bites, and cause blisters that last for a week or more. A creeping eruption called cutaneous larva migrans occur when animal hookworm larvae the most common of which is *Ancylostoma braziliense*, penetrate human skin. People who have been exposed to very large numbers of larvae sometimes experience coughing, chest pain, wheezing and fever as the larvae begin to

break into the alveoli and travel up the trachea. Epigastric pain, indigestion, nausea, vomiting, constipation, and diarrhea that occur early or in later stages, are other signs of hookworm infection, although gastrointestinal symptoms tend to improve with time (John *et al.*, 2006).

Severe hookworm infections are characterized by anemia and protein deficiency (Bethony *et al*., 2006). The presence of between 40 and 160 adult hookworms in the human intestine results in blood loss sufficient to cause anemia and malnutrition. These result mainly from adult hookworms in the small intestine ingesting blood, rupturing erythrocytes and degrading hemoglobin in the host (Hotez *et al*., 2005). Long term blood loss can manifest itself through facial and peripheral edema; eosinophilia and pica which is caused by iron deficiency anemia in some hookworm infected patients (John *et al.*, 2006). Children who suffer from chronic hookworm infection can also suffer from growth retardation as well as intellectual and cognitive impairments which lead to reduced school performance and attendance, and adversely affect future productivity and wage-earning potential (Hotez *et al*., 2005).

Hookworm prevalence and intensity can be higher among adult males than other members of the same population. This is because hookworm infection also tends to be occupational, for example, plantation workers, coal miners and other work groups maintain a high prevalence of infection among themselves by contaminating their work environment (Bethony *et al*., 2006). However, in most endemic areas, women are the most severely affected by anemia, mainly because they have much higher physiological needs for iron (menstruation and repeated pregnancy). In pregnant women, anemia as a result of hookworm disease results in outcomes that are adverse for both the mother and

her infant, including low birth weight, impaired milk production, and increased risk of death for both the mother and the child. (Hotez *et al*., 2005).

2.3 Ascariasis

Ascariasis is a human disease caused by a parasitic roundworm *Ascaris lumbricoides*. More than 1.221 billion people are infected with this worm, primarily in Africa and Asia (Hotez *et al*., 2005). Adult worms live in the lumen of the small intestine. A female may produce approximately 200,000 eggs per day, which are passed with the faeces. Unfertilized eggs may be ingested but are not infective. Fertile eggs embryonate and become infective after 18 days to several weeks, depending on the environmental conditions the optimum being moist, warm and shaded soil. After infective eggs are swallowed by humans, the larvae hatch and invade the intestinal mucosa, and are carried via the portal, then systemic circulation and/or lymphatics to the lungs. The larvae mature further in the lungs in 10 to 14 days, where they penetrate the alveolar walls, ascend the bronchial tree to the throat, from where they are swallowed. Upon reaching the small intestine, they develop into adult worms. Between 2 and 3 months are required from ingestion of the infective eggs to oviposition by the adult female. Adult worms can live between 1 to 2 years (figure 1) (Wu and Jones, 2000).

First appearance of eggs in stools is 60-70 days after initial infection with the larvae. In larval Ascariasis, symptoms occur 4-16 days after infection. The final symptoms are gastrointestinal discomfort and vomiting, fever, and observation of live worms in stools. Some patients may have pulmonary symptoms or neurological disorders during migration of the larvae. However there are generally few or no symptoms. A bolus of worms may

obstruct the intestine while migrating larvae may cause pneumonitis and eosinophilia (CDC, 2006).

Patients can remain asymptomatic for prolonged periods of time. As larval stages travel through the body, they may cause visceral damage, peritonitis and inflammation, enlargement of the liver and spleen, toxicity and pneumonia (Bethony *et al*., 2006). A heavy worm infestation may cause nutritional deficiency. Other complications, sometimes fatal, include obstruction of the bowel by a bolus of worms which is observed particularly in children and obstruction of the bile or pancreatic duct. For example, more than 796 *Ascaris lumbricoides* worms weighing 550 g were recovered at autopsy from a 2-year-old South African girl (Baird *et al*., 1986). The worms had caused torsion and gangrene of the ileum, which was interpreted as the cause of death.

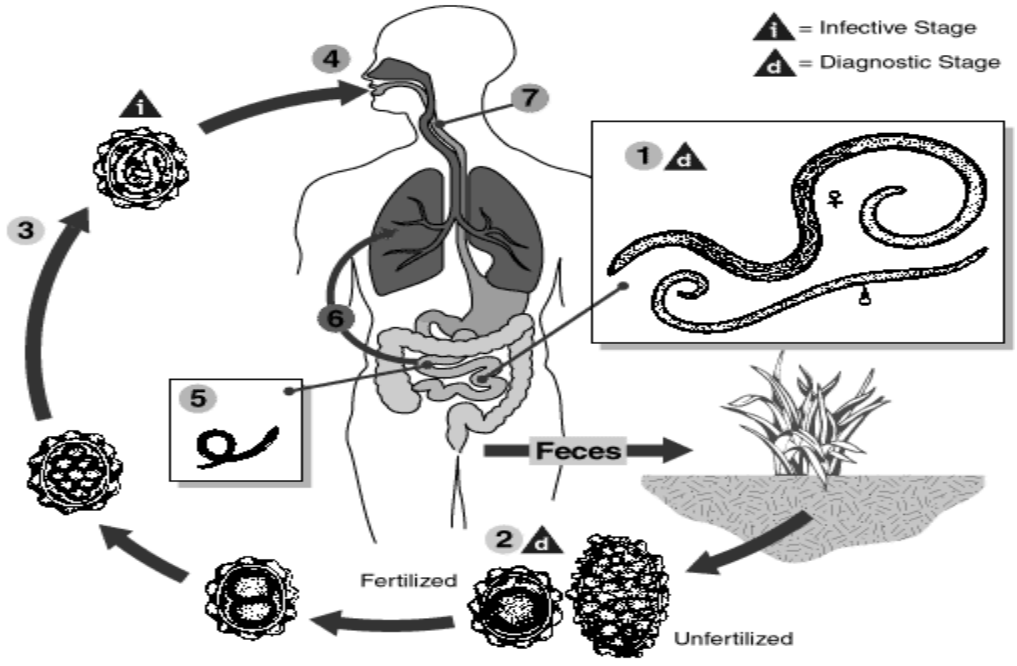

Figure 1. Life cycle of *Ascaris lumbricoides* (CDC, 2006).

Ascaris takes most of its nutrients from the partially digested host food in the intestine. There is limited evidence that it can also pierce the intestinal mucous membrane and feed on blood, but this is not its usual source of nutrition. As a result, *Ascaris* infection does not produce anemia associated with some other roundworm infections (Wu and Jones, 2000).

2.4 Schistosomiasis

The species of parasitic trematodes of the family Schistosomatidae associated with human infections are; *Schistosoma haematobium, S. intercalatum, S. japonicum, S. mansoni* and *S. mekongi* (Chitsulo, 2000). Urinary schistosomiasis, in which the bladder is affected, is caused by infection with *S. haematobium* which only occurs in Africa. Intestinal schistosomiasis results from infections with *S. mansoni*, which occurs in the Middle East, South America and Africa; and from infections with *S. japonicum*, which occurs in parts of China and the Philippines (Ross *et al*., 2002). Two other schistosome species are known to cause intestinal schistosomiasis in restricted geographical areas; for example, *S. intercalatum*, found in central Africa, and *S. mekongi* found in Cambodia and the Lao People's Democratic Republic. Schistosomiasis is estimated to affect 200 million people worldwide (de Silva *et al*., 2003), and is usually a chronic disease (Van Der Werf and De Vlas, 2001).

Many infections are sub clinically symptomatic, with mild anemia and malnutrition being common in endemic areas. Acute schistosomiasis also known as Katayama's fever may occur weeks after the initial infection, especially by *S. mansoni* and *S. japonicum*.

Manifestations include: abdominal pain, cough, diarrhea, eosinophilia which is characterized by extremely high eosinophil granulocyte count, fever, fatigue, hepatosplenomegaly –which is the enlargement of both the liver and the spleen (Van Der Werf and De Vlas, 2001). Occasionally central nervous system lesions occur: ectopic S. japonicum eggs in the brain may cause cerebral granulomatous disease. Granulomatous lesions around ectopic eggs in the spinal cord from *S. mansoni* and *S. haematobium* infections may result in a transverse myelitis with flaccid paraplegia (Hodder *et al*., 2000).

Continuing infection may cause granulomatous reactions and fibrosis in the affected organs. This may result in manifestations that include; colonic polyposis with bloody diarrhea mostly caused by *S. mansoni*, portal hypertension with hematemesis and splenomegaly in *S. mansoni* or *S. japonicum* infection. Infection with *Schistosoma haematobium* results in cystitis and urethritis, with haematuria. In some cases it can progress to bladder cancer. Other pathological effects include pulmonary hypertension in *S. mansoni* and *S. japonicum* infections, and more rarely glomerulonephritis as a result of *S. haematobium* infection (Ross *et al*., 2002). In sub-Saharan Africa where schistosomiasis constitutes an important public health problem, a survey in 2000 of disease-specific mortality reported that 70 million individuals out of 682 million had experienced haematuria and 32 million dysuria associated with *S. haematobium* infection. It was estimated that 18 million suffered bladder wall pathology and 10 million hydronephrosis. Infection with *S. mansoni* was estimated to cause diarrhea in 0.78 million individuals, blood in stool in 4.4 million and hepatomegaly in 8.5 million. Using the very limited data available, mortality rates due to non-functioning kidney (from *S.*

haematobium) and haematemesis (from *S. mansoni*) have been estimated at 150 000 and 130 000 per year, respectively (WHO, 2010).

Schistosoma haematobium and *S. mansoni* are endemic in Kenya. In 1938, Dowdswell reported that the prevalence of *S. haematobium* among children was 78 % around kavirondo gulf (Lake Victoria). In 1948 both *S. haematobium* and *S. mansoni* were reported in the Taveta region of coast province (Heisch, 1948). Since then, the disease prevalence has remained high. Treating children of school going age has been shown as the most cost-effective way of reducing prevalence of scistosomiasis (Partnership for Child Development, 1997; Bundy *et al.*, 2006; Brooker *et al.*, 2008). The World Health Assembly, in May 2001, resolved to regularly treat at least 75% of school-aged children and other high-risk groups by 2010 (WHO, 2002). In 1994, WHO suggested a control strategy for schistosomiasis that is based on the prevalence among 7- to 14- year-old school children. In areas where prevalence in this group is greater than 50%, treatment should be administered to the entire population. Where prevalence is between 20 and 50% in this age group, all children aged 5-19 years should be treated for schistosomiasis. Where prevalence is less than 20%, only children with a positive test should be treated (WHO, 1994). Light microscopy of repeated stool and/or urine examinations to detect and quantify distinctive schistosome eggs is the 'gold' standard of parasitological diagnosis (Bergquist *et al*., 2009).

Praziquantel (PZQ) is the drug of choice in the treatment of all forms of schistosomiasis. It is relatively cheap, non-toxic and easy to administer. It is also produced in a number of countries (Utzinger *et al*., 2003). The drug can also be used on pregnant women. Studies in Gezira, in South Sudan showed no significant difference in the rates of abortion and

preterm deliveries between pregnant women who had received PZQ compared with those who had not received it (Adam *et al*., 2004). Although the drug is cheap and readily available, it does not have residual effects and has to be taken repeatedly for every re-infection (Mutapi *et al.*, 1998; King *et al*., 1990)

2.5 Control of helminthes infections

Parasitic diseases, particularly helminthes infections can be effectively controlled. Failure to sustain control of parasites may be due to development of drug resistance or the failure to implement proven strategies as a result of decreased resources within the health system. Other limitations include decentralization of health management through health-sector reform and the lack of financial and human resources (Stephenson *et al*., 2000).

2.5.1 Anthelmintic drug treatment

Drug treatment in helminthes infections referred to as deworming, targets the reduction of morbidities by decreasing the worm burden. Repeated chemotherapy at regular intervals called periodic deworming in high risk groups can keep the levels of infection below those associated with morbidity and often results in improvement in child health and development (Albonico *et al*., 2004). Anthelminthic drug treatments often prevent the development of irreversible consequences of schistosomiasis that occur in adulthood as a result of childhood infections. Frequent and periodic deworming may reduce transmission over time; for example intensity peaks are reduced among school age children (Adams *et al*., 2004). The effectiveness of periodic deworming is however diminished by low efficacy of single dose mebendazole and albendazole for treatment of hookworm and Trichuriasis (Adams *et al*., 2004). High rates of post treatment re-

infection for STHs occur in areas of high endemicity and also diminished treatment efficacy occurs with repeated use of either single doze mebendazole or single doze albendazole for treatment of hookworm and Trichuriasis, possibly as a result of anthelminthic resistance (Albonico *et al*., 2004).

2.5.2 Improved sanitation

Improved sanitation can result in reduced soil and water contamination with parasitic organisms. Sanitation is the only intervention that has been known to eliminate STH infections. The success of sanitation in control of STH infections relies on the percentage of the population the measure will cover. This is limited by the high cost of implementing this strategy (Asaolu and Ofoezie, 2003). Provision of reliable clean water and connection to public sewer systems remains a pipe dream in most third world countries due to the costs involved. WHO estimates that more than 300 million Africans still lack access to safe drinking water. In addition, when used as the primary means of control, it can take years or even decades for sanitation to be effective since it does not result in treatment of active infections (Brooker *et al*., 2004).

2.5.3 Health education

Health education targets encouraging healthy behavior to reduce transmission and re-infection; for example, communities may be educated on the importance of using latrines and hygienic behavior like proper disposal of fecal material and household water treatment, to reduce contamination of soil and water which prevents re-infection with soil transmitted helminthes (Montressor *et al*., 2002). The aim of health education is to develop a sense of responsibility for health conditions by individuals, as members of

families, and as communities. Assessment of habits and attitudes of the people that relate to spread and frequency of the disease will provide information of specific means to make the necessary changes in behavior required to control infectious diseases.

2.5.4 Other control measures

In specific epidemiological conditions, environmental or chemical control of snails can be useful tools for reducing the transmission of schistosomiasis. Controlling populations of snail hosts through the use of molluscicides at one time was considered the only effective way to preventing large-scale infection in communities living near aquatic habitats. With the advent of safe drugs, such as praziquantel, this strategy has declined in popularity, though it still plays a crucial role in controlling the spread of the disease.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study area

Vingujini sub-location is situated in the Msambweni District of Coast Province, approximately 50 km south of the city of Mombasa, along the Indian Ocean. The area has a monsoon-type of climate, with the period from January to March being hot and dry. There are two rainy season's with heavy rains in April to June and short rains in October to November. The total annual rainfall ranges between 1000 to 1600 mm. The mean monthly temperature varies from a high of 26.7°C (August) and minimum of 23.5°C (July). Relative humidity is about 95 % due to close proximity to the sea (McClanahan, 1988).

The area is on the coastal plain; an area sometimes referred to as the 'coral rag'. This is a narrow strip of corals, sand and alluvial deposits extending 3-20 km from seashore. It lies 0-30 meters above sea level. Vingujini Sub-Location comprises of seven villages; Vingujini, Bomani, Mwaembe, Mwagundu, Sawasawa, Tumbe and Kisimachande. Mwaembe, Mwagundu, Sawasawa, Tumbe and Kisimachande villages border the ocean line. Bomani and Vingujini are located further inland (Ministry of Agriculture, 2008). Bomani village is traversed by the Mombasa Lungalunga road and in some areas it has characteristics of a modern slum, with overcrowding and poor drainage facilities. The economic activities in Bomani are mostly trading and farming. Mwagundu village has typical rural characteristics where the households are spread apart. The predominant economic activities in this village are farming and small scale fishing. In both villages, rainfall causes seasonal flooding which provides necessary conditions for breeding of

snail vectors. Residents use this source of water for laundry and children play and swim in, exposing them to *Schistosoma haematobium* infection.

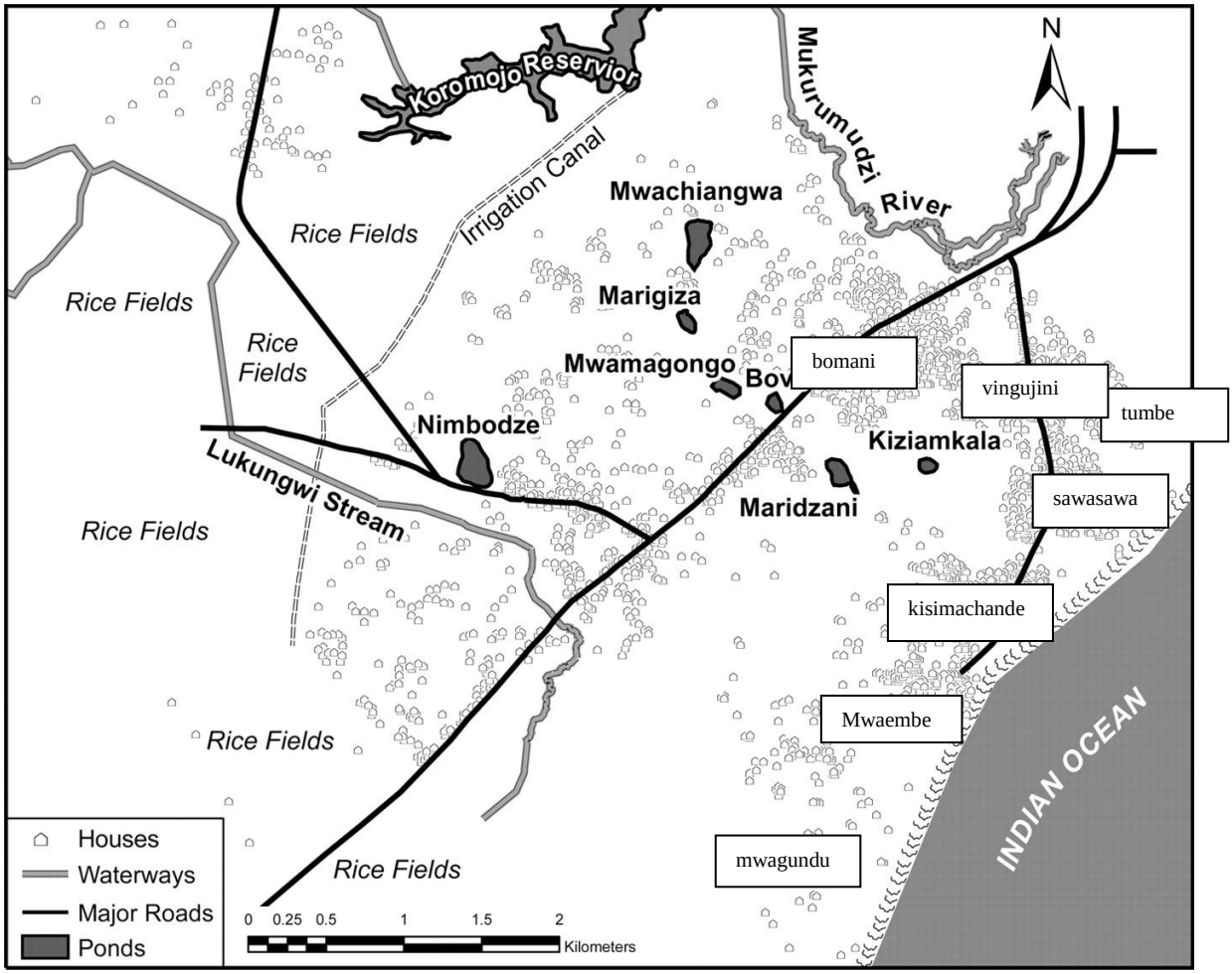

Figure 2. Water masses in Msambweni division where Mwagundu and Bomani are located (Clennon *et al.*, 2006).

3.2 Study design

This was a cross sectional study that was aimed at capturing whole human populations above five years in Bomani and Mwagundu villages located in Vingujini Sub Location of Msambweni district. The two villages were purposively selected for this study. Mwagundu was selected because it lies along the beach line (0-5 km) while Bomani

village lies furthest from the beach line (12-20 km). The estimated population of Vingujini sublocation is 12,662 (Kenya National Bureau of Statistics, 2009).

Prior to the study, all houses in the study area were visited and given a code. All house hold members were given a registration number related to their position in household for example, 01 for household head, 02 for spouse of household head and 03 for other members of the household. This coded registration was used for labeling all samples collected during the study.

3.3 Study population

A prior demographic survey showed population above 5 years in Mwagundu village was 689. This consisted of 342 (49.64%) female and 347 (50.36%) male. The population in Bomani above 5 years was 1,399; 727 (51.97%) were female while 672 (48.03%) were males. The main economic activities in the area are agriculture and fishing.

3.4 Data collection

Information meetings were held with community members prior to the study. The people were informed that collection of samples would be done in primary schools convenient to the villages. The stool and urine samples collected were transported to Msambweni district hospital clinical laboratory for examination. Urine samples were examined for eggs of *Schistosoma haematobium*. Hematuria was determined using urine dip strips. Stool samples were examined microscopically for intestinal helminthes. Blood samples were collected to determine hemoglobin levels in order to establish the relationship between hookworm disease and anemia.

3.5 Collection of samples

All the individuals who had been registered during the demographic study were invited on specific days for sampling. It was expected that the whole population of residents above 5 years in each of the two villages would be sampled according to WHO recommendations for areas where prevalence with schistosomiasis is above 50%.

One hundred people were invited per day for a period of 21 days. Each individual provided a fecal and urine sample. The sample containers were labeled with the respondents' number codes that had been assigned during the time of the demographic survey. Blood samples for determining hemoglobin status were collected at primary schools located in the two villages using capillary blood collection tubes.

3.5.1 Collection of fecal samples

Approximately ten grams of fresh fecal specimens were provided by the study subjects in clean clearly labeled plastic sealable sample containers. The individuals were advised to provide the first stool of the day. Collected fecal specimens were transported in cool boxes to the Msambweni district hospital clinical laboratory. All the samples were analyzed for parasites within two hours of collection.

3.5.2 Collection of urine samples

About 30 ml of urine was collected from each individual in clean receptacles. The urine samples were collected between 10.00 am and 2.00 pm, to coincide with the period when excretion of *S. haematobium* eggs is highest (Fleck and Moody, 1988).

3.6 Determining of hematuria status

The hematuria status of each sample was observed by gross examination and also using reagent strips (medi-test combi®). The reagent strips were dipped into urine inside a test tube. Microhematuria were evaluated according to the manufacturers' instructions and recorded.

3.7 Preparation and examination of urine filters

Polycarbonate membrane filters (Whatman/GE™) of 13 mm diameter and 12 µm pore size were used for filtration of *Schistosoma haematobium* eggs from urine. The filters were carefully placed on the filter support of the filter holder using blunt-ended forceps. The filter holder was then re-assembled and attached to the end of a 10 ml luer syringe. The plunger was then removed from the syringe after which the syringe was filled with well-mixed urine sample to the 10 ml mark, and the plunger was then replaced. Holding the syringe over a beaker, the urine was slowly passed through the filter. The filter holder was unscrewed and placed on specially designed racks labeled with the study subjects demographic codes and transported to Msambweni district hospital clinical laboratory to be examined microscopically.

The filters were removed at the laboratory from filter holders using a blunt-ended forceps and transferred to a microscope slide, face upwards. Using a teat dropper, a drop of lugols iodine was added, and then the slide was covered with a cover glass and examined microscopically using 10x magnification with the condenser iris closed sufficiently to give good contrast. The entire filter was systematically examined for eggs of *Schistosoma haematobium*. The number of eggs in the preparation was counted and reported per 10ml

of urine. 1-50 eggs per 10ml of urine were considered as light infection, 51-200 eggs per 10ml of urine as moderate infection and above 200 eggs per 10ml of urine as heavy infection.

3.8 Examination of stool samples for geohelminthes

Stool samples collected were examined microscopically. Kato katz technique was used to quantify hookworm eggs.

3.8.1 Microscopic examination of feacal specimens

Saline and iodine slide preparations were made for fresh faecal samples. A drop of saline was placed on one half of a microscope slide and a drop of iodine on the other half. With an applicator stick, a portion of faeces approximately the size of a match head was picked and mixed with the saline drop on the slide. Similarly another portion of the same size was mixed with the drop of iodine. A cover slip was placed separately on each preparation. These were examined microscopically at a magnification of 10x and 100x for motile geohelminthes such as the larvae of *Stercolaris spiralis* and helminthes eggs and cysts.

3.8.2 Quantification of hookworm eggs

Kato katz technique was used to quantify the intensity of hookworm infection. A plastic template with a hole (accommodating 41.7mg of formed faeces) was placed at the centre of a microscope slide. Approximately 10g of freshly collected faeces was placed on the surface of a glazed tile. An 80 mm plastic screen was pressed on top of the faecal material using a gloved hand. The upper surface of the screen was then scraped with a

flat spatula to collect the filtered faeces. The collected filtered faeces in the screen were added in the hole of the template so that it became completely filled. The template was then removed carefully so that the cylinder of faeces was left on the slide. The faecal material was then covered with a cellophane strip that had been pre-soaked in glycerol-malachite green solution. The microscope slide was then inverted and pressed on a smooth tile to spread the faecal material evenly. The slide was carefully removed by gently sliding it sideways to avoid separating the cellophane strip. The slide was placed with the cellophane upwards. The smear was examined in a systematic manner for hookworm eggs and the number reported. This number was then multiplied by 24 as per the manufacturer's instructions to give number of eggs per gram of faeces (epg). Intensity was estimated as proposed by WHO where 1-1999epg were considered as light infections, 2000-3999epg as moderate and more than 4000epg were considered to be heavy infections.

3.9 Determination of hemoglobin levels

Hemoglobin levels were determined for each participant using a HemoCue® haemoglobinometer. Capillary blood samples were collected by finger prick in the middle finger of left hand, after cleaning and massaging the finger to facilitate blood flow. A standard cuvette (10mm) was filled with blood from the finger-prick. The test was performed as stated by the manufacturer. After calibration of the HemoCue® haemoglobinometer machine, hemoglobin values were read and recorded to one decimal point. The HemoCue® photometer was checked on a daily basis using the control cuvette and a standard of known concentration.

3.10 Data analysis

Data obtained from this study was recorded and analyzed using computer statistical software; spreadsheets Microsoft excel (2007) and minitab14. Data on the number of people infected with schistosomiasis and geohelminthes was pooled in five age groups of 5-15, 16-25, 26-40, 41-60 and >60. Mean infections were determined for schistosomiasis, geohelminthes infections and for co-infections with Schistosoma and geohelminthes. Data transformations were done to normalize it. Analysis of Variance, ANOVA (general linear model and one way) were done on weighted means to determine differences in the mean infections between the villages, sex and age groups. ANOVA was also carried out to determine differences in hemoglobin levels in individuals with different infection intensities of hookworm disease and also for the relationship between hematuria and intensity with *Schistosoma haematobium*. Group comparisons were done using the tukey test at 95% confidence interval. Correlation was examined between infection with *Schistosoma haematobium* and soil transmitted helminthes using Pearson coefficients.

3.11 Permission

Permission to carry out the study was obtained from the School of Pure and Applied Sciences, Kenyatta University and the Ministry of Health, Msambweni district hospital.

3.12 Ethical consideration

All work was done according to the guidelines for human experimentation in clinical research as stipulated by the Ministry of Health of Kenya. Ethical clearance was obtained from KEMRI before the commencement of the study. All subjects included in the study

were required to give oral informed consent and a signed written consent was given by household heads and all adult participants. For respondents below the age of 12 years, consent was sought from their parents or legal guardians before inclusion in the study.

3.13 Exclusion criteria

Children below 5 years were excluded from this study. This is because the incidence of schistosomiasis is rare in this group since they do not normally actively participate in activities that expose them to infection (Chitsulo *et al*., 2000).

3.14 Confidentiality

The information obtained from subjects was treated confidentially and was used only for the purposes of the current research study.

CHAPTER FOUR: RESULTS

4.1 Prevalence of parasitic infections

Fifty nine per cent (1,232) of the total 2,088 legible subjects turned out for screening. Out of these, 495 subjects were from Mwagundu village. This accounts for 72.37% of the target population (689 people aged 5 years or more) in this village. Of the 495 people sampled, 258 (52.12%) were female and 237 (47.88%) male. A total of 737 subjects from Bomani village were involved in the study. This accounts for 37.81% of the target population (1,399 people aged 5 years or more). Out of this population, 409 (55.50%) were female and 328 (44.50%) male.

The overall occurrence of parasitic infections were, 43.99% for *Schistosoma haematobium*, 29.63% for hookworm disease, 0.49% for ascariasis and 24.59% for trichuriasis (N=1,232). Only 32.71% were free from any of the parasitic infections screened. The occurrence of urinary Schistosomiasis and soil transmitted helminthes in the two villages are represented in table 2.

Table 1. Percentage occurrence of urinary schistosomiasis and soil transmitted helminthes in Mwagundu and Bomani.

Village	Disease	Male	Female	Population
Mwagundu	Schistosomiasis	43.04 ±6.45	46.51 ±6.43	44.85 ±6.15
	Hookworm disease	29.96 ± 4.43	25.68 ±5.09	27.68 ±4.10
	Ascariasis	1.22 ±0.13	-	0.68 ±0.06
	Trichuriasis	24.89 ±3.45	18.60 ±3.59	21.62 ±2.98*
Bomani	Schistosomiasis	44.82 ±7.01	42.30 ±6.58	43.42 ±6.23
	Hookworm disease	33.54 ±4.66	28.85 ±4.35	30.94 ±3.31
	Ascariasis	-	1.22 ±0.75	0.68 ±0.41
	Trichuriasis	29.27 ±3.63	24.45 ±3.25	26.59 ±3.18*

* Shows there is a significant difference in the occurrence of trichuriasis between Mwagundu and Bomani (ANOVA table in appendix 3, f=4.9, df=1, p=0.045).

There was no significant difference in occurrence of infection with urinary schistosomiasis between the two villages. Similarly, the occurrence of hookworm and ascariasis did not show any significant difference. However infection with trichuriasis was slightly correlated to village, where infection with this disease was slightly higher in Bomani than Mwagundu.

4.2 Co-infection with urinary schistosomiasis and soil transmitted helminthes

Of the 542 individuals infected with *S. haematobium*, 152 (28.04%) were co-infected with hookworm disease, 3 (0.55%) with ascariasis and 168 (31%) with trichuriasis. 257 people were co-infected with *S. haematobium* and at least one soil transmitted helminth. This represents 47.42% (n=542) of all *S. haematobium* infected individuals, and 20.86% (N=1,232) of the population. Table 4 shows the percentage occurrence of soil transmitted

infection in *Schistosoma haematobium* infected individuals. Infection with *S. haematobium* was highly correlated with trichuriasis infection (r=0.96, p=0.006).

Table 2. Percentage occurrence of soil transmitted infection in *Schistosoma haematobium* infected individuals.

Disease	Male	Female	Population
Hookworm disease	31.33 % ±3.24	25.26 % ±2.22	28.04 % ±2.68
Ascariasis	0.40 % ±0.08	0.68 % ±0.08	0.55 % ±0.07
Trichuriasis	35.34 % ±4.39	27.30 % ±4.86	31.00 % ±4.60

There was no significant difference in the infection with soil transmitted helminthes in *Schistosoma haematobium* infected individuals between the two villages.

4.3 Occurrence of parasitic infection in different age groups and sex

The results show that there was a significant relationship between age and infection with *S. haematobium* (f=95.17, p>0.01), hookworm (f=11.51, p= 0.01) and trichuriasis (f=26.46, p>0.01). Individuals of age group 5-25 had significantly higher *S. haematobium* infections than other ages. The lowest infections with *S. haematobium* were in age group 41-60 years (11.11%) and those above 60 years (11.26%). Infection with hookworm disease was highest in older people of age groups 41-60 (42.11%) and people above 60 years (43.66%). Prevalence with this disease was lowest in age group 16-25 years (22.17%) and age group 5-15 years (25.23%). Prevalence data did not reveal significant differences in infection between different age groups for ascariasis. Prevalence of this disease was 0.74 % for age group 5-15 years and 1.17% for age group 41-60 years. The age group with the highest prevalence of trichuriasis was 5-15 years (38.31%). The lowest infection with this disease was with the age group 26-40 (10.18%).

Figure 3 gives a summary of percentage prevalence of parasitic diseases in different age groups.

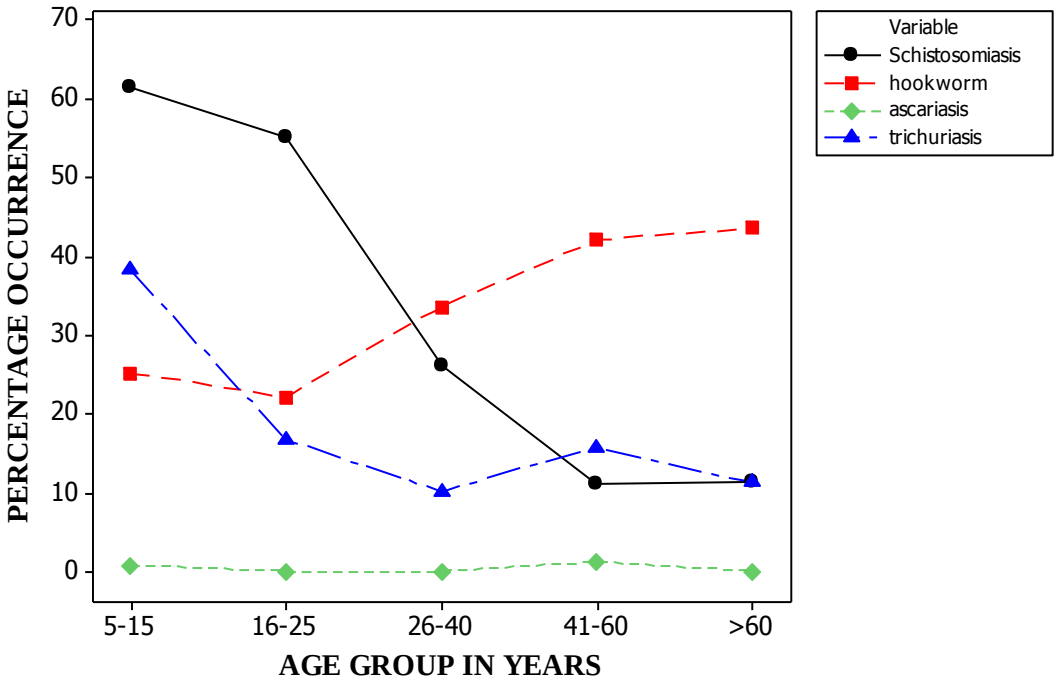

Figure 3. Percentage prevalence of parasitic diseases in different age groups.

Table 3. Percentage prevalence of parasitic diseases by age.

Age group	*S. haematobium* (±10.7)	Hookworm (±4.32)	Ascariasis (±0.243)	Trichuriasis (±5.12)
5-15	61.51^{a}	25.23^{a}	0.74^{a}	38.31^{a}
16-25	55.20^{a}	22.17^{a}	-	16.74^{b}
26-40	26.11^{b}	$33.63^{a,b}$	-	10.18^{b}
41-60	11.11^{b}	$42.11^{c,b}$	1.17^{a}	15.79^{b}
>60	11.26^{b}	$43.66^{c,b}$	-	11.28^{b}

Table 5 gives a summary of percentage prevalence of parasitic diseases in different age groups. Values with different letters in superscript indicate significant differences (ANOVA, df=4, $P< 0.05$) within each group.

Table 6 shows the weighted percentages for each age group and for the sexes. This table reveals that individuals of age group 5-15 years account for 27.11% of the 43.99% *S. haematobium* occurrence in the area. Those of age groups 41-60 and >60 account for only 1.54% and 0.65% of this respectively. Infection with trichuriasis was significantly higher in age group 5-15 years, accounting for 16.88% of the 24.59% occurrence of the disease. For hookworm disease, age group 5-15 accounted for 11.12% of the 29.63%, while the lowest contribution was by age group >60, who contributed 2.52%. There was no significant difference in occurrence of infection between the sexes for all diseases screened.

Table 4. Percentage occurrence *S. haematobium* and geohelminthes infections by age in males and females.

Age	Schistosomiasis			Hookworm			Ascariasis			Trichuriasis		
group	P* ±4.9	F* ±2.5	M* ±2.4	P* ±1.5	F* ±0.5	M* ±1.0	P* ±0.1	F* ±0.5	M* ±0.1	P* ±0.1	F* ±1.4	M* ±1.6
5-15	27.11	14.12	12.99	11.12	4.38	6.73	0.34	0.24	0.08	16.88	8.03	8.85
16-25	9.90	5.19	4.71	3.98	2.11	1.87				3.00	1.38	1.62
26-40	4.78	3.25	1.54	6.17	3.33	2.84				1.87	0.81	1.06
41-60	1.54	0.89	0.65	5.84	3.49	2.35	0.16	0.16		2.19	1.38	0.81
>60	0.65	0.32	0.33	2.52	1.62	0.89				0.65	0.41	0.24
Total	43.99	23.77	20.22	29.63	14.93	14.68	0.49	0.4	0.08	24.59	12.01	12.58

Results are in weighted percentages for; P-population, F- females, M-males indicating proportion that each group contributes to the total percentage occurrence.

4.4 Intensity of helminthes infection in different age groups and sex

The intensity of urinary schistosomiasis and hookworm disease were estimated as eggs/10 ml of urine for *Schistosoma haematobium* and eggs per gram (epg) of faeces for hookworm. Intensity of urinary schistosomiasis was highly related to age (f=29.39, p=0.00) and sex (f=6.13, p=0.013). Males had significantly higher intensities of urinary schistosomiasis (mean of 113.5±10.9 eggs per 10ml of urine) than females (mean of 69.9±7.55 eggs per 10ml of urine). The overall populations mean *Schistosoma* eggs shed was 89.95±6.48 eggs per 10 ml of urine. Individuals of age 5-15 years shed the highest number of eggs (160.7 ±12.5 eggs/10 ml of urine). The individuals of age group 41-60 years shed the lowest number of *S. haematobium* eggs (2.94±1.54) (Table 5, Figure 5).

The number of hookworm eggs shed consistently increased with an increase in age (f=7.32, p=0.00). The highest group shed a mean 855±345 eggs per gram of faeces for age >60 years. The group that shed the lowest number of eggs was age 16-25 years with an average of 176.0±52.0 eggs per gram of faeces (Figure 4). Males shed significantly higher amounts of eggs than females (f=4.81, p=0.028).

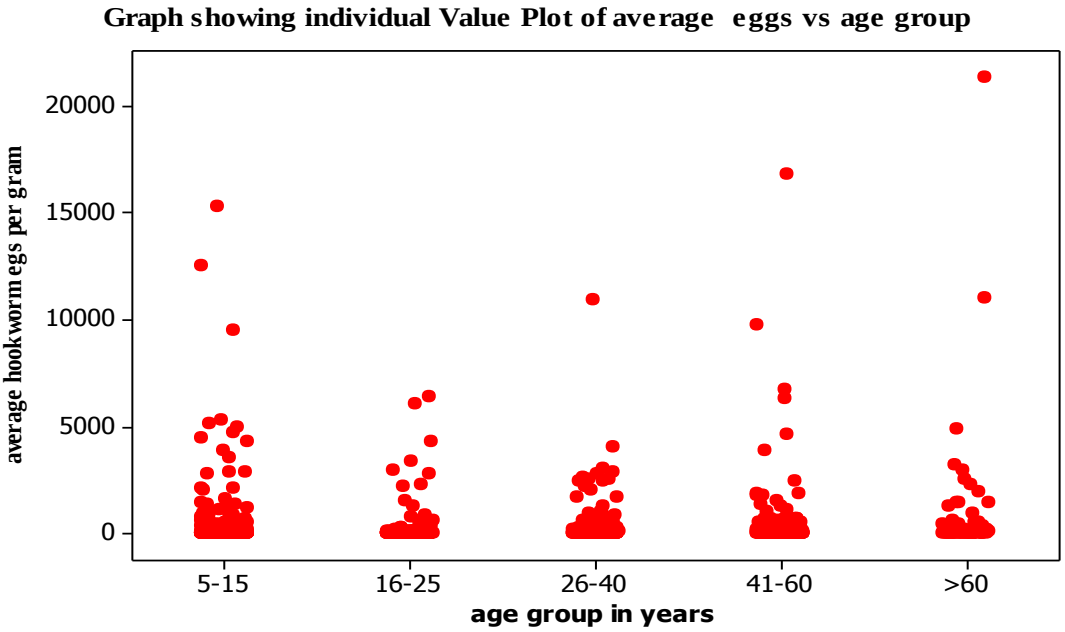

Figure 4. Scatter plots showing average hookworm eggs shed versus age.

Figure 4 shows the relationship between age and the number of hookworm eggs shed.

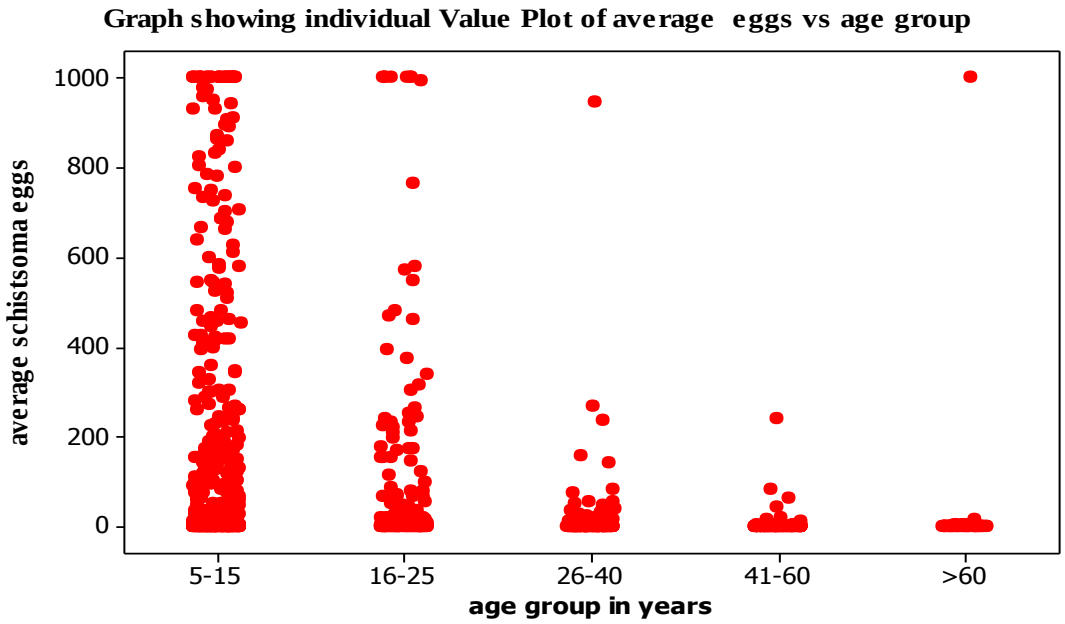

Figure 5. Scatter plots showing average Schistosoma eggs shed versus age.

Figure 5 shows the relationship between age and the number of *S. haematobium* eggs shed.

Table 5. Mean eggs shed expressed as eggs per 10 ml of urine for Schistosoma haematobium and eggs per gram of faeces for hookworm in different age groups.

Age group	Urinary schistosomiasis (eggs/10 ml urine)	Hookworm (eggs/gram of faeces)
5-15	160.70 ±12.5[a]	222.3±47.9 [a]
16-25	88.00±14.3[b]	176.0±52.0 [a]
26-40	11.40±4.59[c]	263.3±62.7 [a]
41-60	2.94±1.54[c]	454.0±130[a,b]
>60	14.40±14.1[b,c]	855±345 [b]

Values with different letters in superscript indicate significant difference at 95% confidence interval (ANOVA table at appendix 4, df=4, $p< 0.05$).

In urinary schistosomiasis, individuals shedding 1-50 eggs per 10ml of urine were considered as having light infection, those shedding 51-200 eggs per 10ml of urine as moderate infection while those shedding above 200 eggs per 10ml of urine as having heavy infection. The individuals with the highest intensity of the disease shedding more than 200 eggs per 10 ml of urine comprised 12.66% of the population. This portion of the population however accounted for 86.2% of all the eggs shed in the population. 22.4% of the population had light infections of *Schistosoma haematobium* (less than 50 eggs per 10 ml of urine). This group accounted for only 2.9% of the total eggs shed (Table 9).

In hookworm disease, 7.31% (n=90) of the population had heavy infections shedding >4000 eggs per gram of faeces. This relatively small proportion of the population however accounted for 82.82% of all the hookworm eggs shed in the population. The group shedding 2000-3999 eggs per gram of faeces shed 8.68% of the eggs shed in the population, while those with light infections shedding 1-1999 eggs per gram of faeces shed 8.5% of all the eggs shed (table 9).

Table 6. Proportion of eggs shed by individuals with different intensities of Urinary schistosomiasis and hookworm disease.

Disease	Eggs shed	Proportion of the sample	Proportion of eggs
Urinary schistosomiasis	Heavy >200	12.66% (n=156)	86.2%
	Moderate 51-200	8.84% (n=109)	10.9.%
	Light 1-50	22.40% (n=276)	2.9%
	None	56.09% (n=691)	0.0%
Hookworm	Heavy >4000	7.31% (n=90)	82.82%
	Moderate 2000-3999	3.65% (n=45)	8.68%
	Light 1-1999	62.1% (n=765)	8.5%
	None	62.1% (n=765)	0.0%

n= Number of individuals with the particular intensity of infection. Most eggs are shed by the most heavily infected groups for both *S. haematobium* and hookworm infections.

4.5 *Schistosoma haematobium* and hematuria

Individuals with Urinary schistosomiasis who had higher intensities of the disease (measured as eggs per 10 ml of urine) had a significantly higher incidence of hematuria (f=639.99, p=0.00). Of the 541 *S. haematobium* positive individuals, 73 showed hematuria. Out of these, 78.08% of all hematuria occurred in individuals with heavy infections (shedding more than 200 eggs per 10 ml of urine), although this groups makes up only 28.8% of the *S. haematobium* positive group. The group which had moderate infection, shedding 51-200 eggs per 10 ml of urine constituted 20.1% of all *S. haematobium* positive individuals. This group contributed 12.4% of all hematuria cases in the sample. More than half of the *S. haematobium* infected individuals (51%) had a light infection, shedding 1-50 eggs per ml of urine. This group contributed only 6% of all hematuria cases in the sample (Table 10).

Table 7. Hematuria in groups with different *Schistosoma* intensity.

Intensity	Proportion of sample	Proportion of hematuria
Heavy >200	28.8% (n=156)	78.0%
Moderate 51-200	20.1% (n=109)	12.4%
Light 1-50	51.0% (n=276)	9.6%

n= Number of individuals with the particular intensity of infection. Hematuria was significantly higher in heavily infected individuals than in moderate and light infections (ANOVA table at appendix 5, df=1, p=0.000)

4.6 Hookworm infection and haemoglobin level

A HemoCue© haemoglobinometer was used to determine the hemoglobin levels. Hemoglobin levels below 11.0g/dl (110g/l) were considered as anemic. (Dallman and Reeves, 1984). From the results, 26.61% of the population had a hemoglobin level of below 11.0g/dl.

Table 8. Hemoglobin levels in different intensities of hookworm disease.

Hookworm eggs shed	Anaemic individuals (Hb>11 g/dl)	Mean Hb
Heavy >4000	37.50%	11.081 ± 0.226^{a}
Moderate 2000-3999	30.36%	11.872 ± 0.109^{a}
Light 1-1999	27.74%	12.036 ± 0.311^{b}
None	25.74%	12.108 ± 0.076^{b}

Values with different letters in superscript indicate significant difference (df=3, p f=5.5, p<0.01). Individuals with heavy and moderate infections had significantly lower haemoglobin levels than those with light and no infection.

The mean hemoglobin level was 11.98±0.06g/dl (range, 7.6-17.4g/dl). Mean hemoglobin level in females was 11.44±0.07 g/dl and 12.59±0.09 g/dl in males. The mean hemoglobin level in hookworm positive individuals was 11.89g/dl.±0.1. There was a

significant correlation between increasing hookworm egg counts and decreasing hemoglobin levels ($r=-0.091$, $p<0.01$) (Table 12).

CHAPTER FIVE: DISCUSION

5.1 Occurrence of parasitic infections

Of the four diseases studied, urinary schistosomiasis had the highest prevalence for both villages (44.85% ±6.15 in Mwagundu and 43.42% ±6.23 in Bomani; overall prevalence of 43.99%). This is a prevalence way above the national prevalence of approximately 23%. It is however a significantly lower prevalence compared to the prevalence of 50-70% reported in previous years in this area (King *et al.*, 1988, 1990; Muchiri, 1996). This decrease can be attributed to the regular annual oral therapy since 1984 which has had a marked impact on the prevalence and intensity of *Schistosoma haematobium* (King *et al.*, 1988, 1990, 1991; Muchiri, 1996; Satayathum *et al.*, 2006).

This study has revealed that many people infected with urinary schistosomiasis are also infected with other helminthes (47.42%). Individuals who were infected with *Schistosoma haematobium* were more likely to be infected with hookworm disease and trichuriasis than those that were not infected with the disease ($r=0.96$, $p=0.006$). Previous studies on the effect of multiple concurrent helminth infections have revealed that the degree of mobidity is also related to the number of different species harbored (Booth *et al.*, 1998; Buck *et al.*, 1978). Studies done in Tanzania also revealed that children with two or more species of helminthes generally carry heavier infections of each species than children carrying single species infections (Buck *et al.*, 1978). Biological interactions have been established among several helminthes species with respect to anemia in children (Ezeamama *et al.*, 2008) and infection with urinary schistosomiasis and soil

transmitted helminthes are both associated with increased risk of anemia (Olds *et al.*, 1999; Friedman *et al.*, 2005).

Ascariasis is the most common soil transmitted helminth in the world (WHO, 1981). This study observed a relatively low *infection* levels with ascariasis in Msambweni (0.68% ±0.06 in Mwagundu and 0.68% ±0.41 in Bomani compared to the global picture of this disease (26% global prevalence). This may be attributed to the soil type in this area, which is mainly sandy. *Ascaris* eggs develop best in less permeable clay soils, with survival ability increasing with the soil depth (Crompton, 1989a). Clay soils are believed to prevent egg dispersal by water while sandy soils have poor water retention properties (Mizgajska, 1993).

Occurrence of hookworm disease and trichuriasis were 29.63% and 24.59% respectively. Severe hookworm infections are characterized by anemia and protein deficiency (Bethony *et al*., 2006). Children who suffer from chronic hookworm infection can also suffer from growth retardation as well as intellectual and cognitive impairments which lead to poor school performance and attendance, and adversely affect future productivity and wage-earning potential (Hotez *et al*., 2005). Deworming pregnant women especially is of particular importance in improving outcomes of pregnancies and in reducing child mortality by improving child birth weight. Regular deworming helps reduce malnutrition and improves motor and language development in young children. It also has a positive effect on nutritional status, physical fitness, growth, and language development in school–age children; and improves maternal hemoglobin levels as well as birth weight and child survival (Albonico *et al*., 2004; Hotez *et al*., 2005).

Only one tablet of mebendazole or albendazole per individual is required for treatment of soil transmitted helminthes (Adams *et al*., 2004). The drugs can be administered by persons without medical training. Until new approaches become available, whether a hookworm vaccine or improved sanitation infrastructures, antihelminthic therapy for school–age children remains the most practical way to control helminth infections in the developing world.

5.2 Occurrence and intensity of parasitic infection in different age groups and sex

The results obtained shows that age is a highly significant factor in infections with *Schistosoma haematobium*, hookworm disease and trichuriasis. Infection with Urinary schistosomiasis was highly related to age ($f=95.17$, $p>0.01$). Individuals of age group 5-25 had significantly higher schistosome infections than other ages. A study done in Blantyre, Malawi in 2006 revealed that people in this age group were more likely to come into contact with an open water source through swimming, playing and other activities than other age groups, thereby exposing themselves to schistosome infection (Atupele *et al.,* 2009). Infection with *S. haematobium* and trichuriasis diseases was significantly lower in individuals of age group >60. However highest infection with hookworm disease was seen among older age groups (43.66% in the age group >60 years and 42.11 in the age group 41-60 years). While heavy hookworm burdens still occur among children in some tropical areas (Stephenson *et al.*, 1989; Labiano-Abello *et al.*, 1999), in most of the world studied to date the peak prevalence and infection intensities for hookworm occurs in individuals in middle age, or even over the age of 50 years (Gandhi *et al.*, 2001; Bethony *et al.*, 2002). In this study, infection with this disease was lowest among individuals of age group 16-25 years (22.17%). Better hygiene practices and frequency in

use of shoes are attributed with low incidence of the disease. Studies conducted in 2005-2007 in a rural community in central Thailand revealed that villagers exposed to soil by walking barefoot were 4.2 times at a greater risk of hookworm infection (Vittaya *et al.*, 2011). This is attributed to the fact that acquiring a hookworm infection is directly related to exposure to soil where filariform larvae, the infective stage, live in and penetrate the skin. Trichuriasis infections were highest among individuals of age 5-15 years. This is consistent with previous cross sectional surveys carried out in areas where ascariasis and trichuriasis is endemic. Such studies revealed three patterns as follows; firstly, the prevalence with these diseases rises rapidly once infancy has passed and tends to remain high. Secondly, intensity rises rapidly and peaks during childhood (among 5–15 year-olds) before declining steadily. Thirdly, the frequency distribution of numbers of worms per host is overdispersed, where only a small fraction of the population harbors most worms (Crompton, 2001).

A common measurement of helminthes infection is the estimate of intensity of infection. In urinary schistosomiasis and soil transmitted infections, intensity is a continuous, quantitative variable expressed as eggs/10 ml of urine in *Schistosoma haematobium* and eggs per gram of faeces for soil transmitted helminthes and intestinal Schistosomiasis. Quantitative measurements of intensity, though more difficult to obtain, are more sensitive to change, especially repeated measurements on a cohort than prevalence measures. Although fundamentally different measurements, prevalence and intensity are related: prevalence rises with increasing intensity to an upper limit of 100% but intensity has no theoretical upper limit. It is accepted (WHO, 1998) that rising intensity is accompanied by an increased risk of developing morbidity and disease for example,

pathology of the urogenital tract; hepatomegaly and hepatosplenomegaly in Schistosomiasis. Egg counts are conventionally transformed to log(x+1) to include zero counts and normalize their distribution for statistical analysis. Egg counts give a reflection of the number of worms present at a specific time. They also show significant changes when, for example, children acquire increasing worm loads due to cumulative exposure over time, or worm numbers drop after successful treatment.

In this study, the individual *Schistosoma haematobium* and hookworm egg counts are distributed asymmetrically; 86.18% of all *Schistosoma* eggs are passed by 12.66% of the subjects and the rest passing few or no eggs. Individuals of age group 5-15 and 16-25 passed significantly higher levels of schistosoma eggs in urine as compared to the other age groups. In hookworm infection, older individuals shed significantly higher amounts of eggs in faeces, the highest being those >60 years of age who shed an average 855±345 eggs per gram of faeces. The nutritional and health status of older individuals in developing countries is often poor (Tucker, 2001), which makes them vulnerable to morbidities as a result of chronic and high intensity of infection. The incidence of increased intensity and prevalence has been observed in China and other places (Bethony, 2002). The group with the least intensity was age group 16-25 years who shed an average of 176.0±52.0 eggs per gram of faeces. In this study, individuals of 5-15 years had the highest prevalence of trichuriasis (38.31%) followed by those of 16-25 (16.74%). Previous studies revealed that the prevalence and intensity of trichuriasis peak at 10-20 years and then starts to decline (Kabatereine *et al.,* 2004). Studies on infection with *Ascaris* after peak intensity has been reached at about 5–10 years of age, clearly demonstrate the difference between the prevalence and age intensity profiles. Such

studies have revealed a marked decline in intensity after this period and it remains at low levels throughout adulthood, whereas prevalence rates remain high (Kabatereine *et al.*, 2004).

Intensity of *Schistosoma haematobium* infection was sex related (f=6.13, p=0.013), while infection with hookworm disease showed no significant difference in the sexes (f=3.29, p=0.07) which is however closer to a significant level than for analysis done using prevalence data alone (f=1.24, p=0.284). In the previous analyses of published data intensity of infection with hookworm and *Schistosoma haematobium* was significantly higher overall in males than females. Previous Meta-analysis studies to investigate whether there is a consistent host sex bias in infection with helminth infections among non-human hosts indicated a tendency for infection prevalence to be higher in males in many types of host-parasite associations, particularly for nematode infections in birds and mammals. By contrast, intensity of infection showed no clear sex bias except for nematodes parasitizing mammals, differences in infection intensity being significantly male-biased (Poulin**,** 1996). Explanation for this bias is largely lacking, with some research pointing to the differences in the activities that the members of different gender are involved in, while other studies suggesting that the difference is in the physiology particularly the effect of the male hormones on suppression of immunity (Hotez *et al*., 2003).

5.3 Occurrence of trichuriasis in the two villages

In the present study, prevalence of trichuriasis was significantly higher in Bomani village compared to Mwagundu (p=0.045). This may be attributed to the fact that Bomani has

characteristics related to an unplanned urban slum of overcrowding, poor drainage systems, inadequate sanitation facilities like toilets thereby facilitating faecal-oral transmission. Mwagundu village on the other side represents a rural setting with households largely separated. This is consistent to previous studies which have demonstrated a high prevalence of these infections in children of slums, shanty towns and squatter settlements (Crompton and Savioli, 1993).

5.4 Schistosoma haematobium and hematuria

It is clear from this study that individuals who shed higher levels of schistosoma eggs are more likely to have hematuria. Degree of mobidity as a result of infection with helminthes has been shown to be related to the intensity of the infection (Stoltzfus *et al.*, 1996; Ramdath *et al.*, 1995). The group which had moderate infection, shedding 51-200 eggs per 10 ml of urine contributed 12.4% of all hematuria cases in the sample. More than half of the *schistosoma* infected individuals (51%) had a light infection (1-50 eggs per ml of urine). This group contributed only 6% of all hematuria cases in the sample. Individuals with heavy infections (shedding more than 200 eggs per 10 ml of urine) accounted for 78.08% of all hematuria, despite the fact that this groups makes up only 28.8% of the schistosoma positive group. Previous studies have associated human *S. haematobium* infection with high risk for urinary tract injury, which is manifested as hematuria, proteinuria and pathologies of the ureters and bladder (Eni *et al.*, 2008). A study conducted in rural Nigeria revealed ten pathological conditions in the bladder; wall thickness, abnormal shape, irregular bladder wall, masses, pseudopolyps, significant residual volume, echogenic particles, calcifications, hydroureter and hydronephrosis. The individuals with heavy infections had the most prevalent pathological conditions.

(Nmorsi *et al.,* 2007).The loss in blood has been associated with iron deficiency anaemia (Stephenson *et al*., 1985), carcinoma of bladder squamous cells (Eni *et al.,* 2008) and exercise intolerance in children (Stephenson *et al*., 1985).

5.5 Hookworm disease intensity and anaemia

This study has revealed that the prevalence of soil transmitted infection; particularly hookworm disease is high in this population. The study also reveals that intensity of infection is an important measure of these diseases. For example, higher intensity with hookworm infection was found to be associated with low levels of hemoglobin; 37.50% of those with >4000 eggs per gram of faeces had hemoglobin levels of less than 11 g/dl of blood, while only 27.74% of those with light infections (less than 1999 eggs per gram of faeces) had such low hemoglobin levels. Those with heavy infection had mean hemoglobin of 11.13±0.54 g/dl; those with moderate infection had a mean hemoglobin level of 11.90±0.12 g/dl, while those with light infections had a mean of 11.99±0.30 g/dl. Such association between heavy and low/ moderate infection and anemia had been revealed in previous studies. In a study carried out in Iquitos, Peru by Renee and others (2005), it was revealed that this relationship is strengthened when there was coinfection with moderate and heavy Trichuriasis.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

1. Infection with *Schistosoma haematobium* is high in Msambweni. This is evidenced by the occurrence of 43.99% compared to the national infection levels of 23%. Infection with Urinary schistosomiasis was highly correlated to age ($f=95.17$, $p>0.01$). Individuals of age group 5-25 had significantly higher schistosome infections than other ages.

2. The soil transmitted helminthes found were hookworm, Ascariasis, and Trichuriasis. Hookworm disease had the highest occurrence of 29.63% while ascariasis had the lowest occurrence of 0.49% in Msambweni. The occurrence of Trichuriasis was 26.59%.

3. There was co-infection with *Schistosoma haematobium* with soil transmitted helminthes. The highest co-infection was with hookworm disease at 28.04% while co-infection with Ascariasis was the lowest at 0.55%. Co-infection with trichuriasis was at 31%. Of all *Schistosoma* infected individuals, 47.42% were co-infected with Schistosoma and at least one soil transmitted helminth. Infection with Urinary schistosomiasis was highly correlated with *Trichuris* infection ($r=0.96$, $p=0.006$).

4. Individuals with Urinary schistosomiasis who had higher intensities of the disease (measured as eggs per 10 ml of urine) had a significantly higher incidence of hematuria. 78.08% of all hematuria occurred in individuals with heavy infection of the disease. Individuals with hookworm disease were more likely to have lower

hemoglobin levels than those who were not infected ($f=5.5$, $p<0.01$). This is evident from the differences in hemoglobin levels between the infected individuals which was 11.89g/dl.±0.1 while that of non-infected individuals was 12.0g/dl±0.07. Individuals who had higher intensity of hookworm disease (measured as number of eggs per gram of faeces) had significantly lower hemoglobin levels than those with low intensity of the disease. The hemoglobin levels in the individuals with different intensity of the disease are; 11.13 g/dl for heavy infection, 11.9 g/dl for moderate and 11.99 g/dl for light infection.

5. Assuming that intensity of infection reflects the number of worms harbored by an individual; the distribution of number of worms in this area is overdispersed where most worms are harbored by a few individuals. This is evidenced by examining the distribution of the number of eggs shed in these diseases, for example 12.66% of the population accounted for 86.2% of the *Schistosoma* eggs shed, while 7.31% of the population shed 82.82% of all hookworm eggs shed.

6.2 Recommendations

1. The long term effect of the control programs already in place need to be evaluated regularly to determine their effect on the overall effect on transmission. There is need for urgent large scale screen and treat program for both schistosomiasis and soil transmitted helminthes in Msambweni as a result of the high prevalence of *Schistosoma haematobium,* hookworm disease and trichuriasis. WHO recommends screening of whole populations and treating the positive cases in areas where infection is between 40-50% and at least 75% of school-aged children

in the high-burden regions should be regularly treated with praziquantel by the year 2010 for schistosomiasis and where prevalence is above 20 for soil transmitted helminthes (WHO, 2001).

2. Further research should examine sufficient replicate samples to avoid misclassifying light infections as negative if egg counts are near the threshold of egg detection, especially after treatment.

3. Disease surveys should include a measure of intensity. Also, new reliable methods should be devised to assess intensity and severity of parasitic diseases especially for diseases that have proved difficult to quantify through the currently developed diagnostic methods. This is because prevalence data alone do not provide information on the numbers of worms harbored whereas intensity has a direct effect on morbidity.

4. This study has revealed that infection with shistosomiasis is correlated to infection with soil transmitted helminthes. Research on interactions between schistosomiasis and soil transmitted helminthes is scanty. Possible interactions between these parasites need to be investigated further.

6.3 Limitations of the study

One limitation of this study is that some of the study subjects may have been treated for urinary schistosomiasis and soil transmitted helminthes a short period before the study. This may have had an impact on the overall occurrence of these diseases. Obtaining such information from the subjects would have given largely unreliable information since most

rural populations do not seek information on the kinds of diseases they seek treatment from. Treated subjects may test negative even when they still harbor the worms as result of low number of eggs shed and low worm burdens resulting from chemotherapy.

REFERENCES

Adam, I.; Elwasila, E.T.; Homeida, M. (2004). Is praziquantel therapy safe during pregnancy? *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 98; 540–543.

Adenusi, A.A.; Ogunyomi, E.O.A. (2003). Relative prevalence of the hookworm species, *Necator americanus* and *Ancylostoma duodenale* in an urban community in Ogun state, Nigeria. *African Journal of Biotechnology*, 2(11); 470- 473.

Albonico, M.; Stoltzfus, R.J.; Savioli, L.; Tiesch, J.M.; Chjaway, H.M.; Ercole, E.; Cancrini, G. (1998.) Epidemiological evidence for a differential effect of hookworm species, *Ancylostoma duadenale* and *Nacator americanus*, on iron status of school children. *International Journal of Epidemiology*, 27; 530-537.

Albonico, M.; Engels, D.; Savioli, L. (2004). Monitoring drug efficacy and early detection of drug resistance in human soil-transmitted nematodes: a pressing public health agenda for helminth control. *International Journal of Parasitology*, 34;1205–1210.

Allen, A.V.H.; Ridley, D.S. (1970). Further observations on formal-ether concentration technique for faecal parasites. *Journal of Clinical Pathology*, 23; 545-546.

Asaolu, S.O.; Ofoezie, I.E. (2003). The role of health education and sanitation in the control of helminth infections. *Acta Tropica*, 86 ; 283-294.

Atupele, P.; Kapito, T.; Victor, M.; Steven, R.M.; Young, S.; Dan, B.; Cameron, B.; Sarah, R.(2009). Prevalence distribution and risk factors for *Schistosoma haematobium* infection among school children in Blantre, Malawi. *PLoS Neglected Tropical Diseases*, 3(1); 361.

Baird, J.K.; Mistrey, M.; Pimsler, M.; Connor, D. H. (1986). Fatal human ascariasis following secondary massive infection. *American Journal of Tropical Medicine and Hygiene*, 35(2); 214-218.

Beaver, P.C.; Jung, R.C.; Cup, E.W. (1984). Clinical parasitology, Trichuris trichiura. 9th ed. Lea & Febiger publishers, Philadelphia.

Bergquist, R.; Johansen, M.V.; Utzinger, J. (2009). Diagnostic dilemmas in helminthology: what tools to use and when? *Trends in Parasitology*, 25; 151–156.

Bethony, J.; Brooker, S.; Albonico, M.; Geiger,; Loukas,; Diemert,; Hotez. P.J. (2006). Soil transmitted helminth infections; ascariasis, trichuriasis and hookworm. *Lancet*, 367; 1521-1532.

Bethony, J.; Chen, J.Z.; Lin, S.X.; Xiao, S.H.; Zhan, B.; Li, S.W.; Xue, H.C.; Xing, F.Y.; Humphries, D.; Wang, Y.; Chen, G.; Foster, V.; Hawdon, J.M.; Hotez, P.J. (2002). Emerging patterns of hookworm infection: influence of aging on the intensity of Necator

infection in Hainan Province, People's Republic of China. *Clinical Infectious Diseases*, 35(11); 1336-44.

Birgitte, J.; Vennerveld, D.; David W. (2005). Working paper for the scientific working group meeting on schistosomiasis research, convened by the special programme for research and training in tropical disease. Geneva: WHO/ TDR.

Booth, M.; Bundy, D.A.P.; Albonico, M,; Chwaya, H.M.; Alawi, K.S.; Savioli, L. (1998a). Association among multiple geohelminth species infection in school children from Pemba Island. *Parasitology*, 116; 85-93.

Brooker, S.; Peshu, N.; Warn, P.A.; Mosobo, M.; Guyatt, H.L.; Marsh, K.; Snow, R.W. (1999). The epidemiology of hookworm infection and its contribution to anemia among pre-school children on the Kenyan coast. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 93; 240-246.

Brooker, S.; Kabatereine, N. B.; Fleming, F.; Devlin, N. (2008). Cost and cost effectiveness of nationwide school-based helminth control in Uganda: intra-country variation and effects of scaling-up. *Health Policy and Planning*. 23; 24–35.

Brooker, S.; Whawell, S.; Kabatereine, N.B.; Fenwick, A.; Anderson, R.M. (2004). Evaluating the epidemiological impact of national control programmes for helminthes. *Trends in Parasitology*. 11; 537-545.

Buck, A.A.; Anderson, R.I.; MacRae, A.A.; Fain, A. (1978). Epidemiology of poly-parasitism I. Combined effects on the state of health. *Tropenmedizin und Parasitologie*, 29; 253-268.

Bundy, D.A.; Farthing, M.J.G.; Keusch, G.T.; Wakelin, D. (1995). Epidemiology and transmission of intestinal helminthes in enteric infection, intestinal helminthes. 2nd ed. London: Chapman & Hall medicine publishers.

Bundy, D. A. P.; Shaeffer, S.; Jukes, M.; Beegle, K.; Gillespie, A.; Drake, L.; Seung-Hee Frances Lee,; Hoffman, A. M.; Jones, J.; Mitchell, A.; Wright, C.; Barcelona, D.; Camara, B.; Golmar, C.; Savioli, L.; Takeuchi, T.; Sembene, M. (2006). School based health and nutrition programs. In Disease Control Priorities in Developing Countries. (2nd ed.). NY, USA: The World Bank and Oxford University Press.

CDC. (2006). life cycle of *Ascaris lumbricoides http://www.dpd.cdc..gov/dpdx/HTML/ImageLibrary/Ascariasis_il.asp?body=AF/Ascariasis/body_Ascariasis_il11.htm* .

Charles, H. King, Madeline Dangerfield-Cha. (2008). The unacknowledged impact of chronic schistosomiasis.Center for Global Health and Diseases, Case Western Reserve University School of Medicine 10900 Euclid Avenue, Cleveland, Ohio 44106-7286, USA.

Chitsulo L. *et al.* (2000). The global status of schistosomiasis and its control. *Acta Tropica,* 77(1); 44-51.

Clennon, J. A.; Mungai, P. L.; Muchiri, E. M.; King, C. H.; Kitron, U. (2006). Spatial and temporal variations in local transmission of *Schistosoma haematobium* in Msambweni, Kenya. *American Journal of Tropical Medicine and Hygiene*, 75(6); 1034–1041.

Crompton, D. W. T. (2001). Advances in parasitology, vol. 48, p. 285-375. Academic Press, Boston, Mass.USA.

Crompton, D.W. (1999). How much helminthiasis is there in the world? *Journal of Parasitology,* 8; 397-403.

Crompton, D.W.T.; Savioli L. (1993) Intestinal parasitic infections and urbanization. *Bulletin of the World Health Organization,* 71; 1 –7.

Crompton, D.W.T,; Nesheim, M.C.; Pawlowski, Z.S. (1989). Biology of *Ascaris lumbricoides*. In: Ascariasis and its prevention and control. London: Taylor & Francis.

Dallman, P.R.; Reeves, J.D. (1984). Laboratory diagnosis of iron deficiency. In: Iron nutrition in infancy and childhood. Nestle Nutrition Workshop Series, Vol 4. New York: Raven Press.

de Silva, N.R.; Brooker, S.; Hotez, P.J.; Montresso, A.; Engeles, D.; Savioli, L. (2003). Soil transmitted helminth infection: updating the global picture. *Trends in Parasitology*. 19; 547-51.

Dowdeswell, R.M. (1938). Schistosomiasis in the Kavirondo District of Kenya colony. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 31(6); 78-94.

Engels, D.; Chitsulo, L.; Montresor, A.; Savioli, L. (2002). The global status of schistosomiasis and its control. *Acta Tropica,* 82; 139–146.

Engels. D.; Savioli, L. (2006). Reconsidering the underestimated burden caused by neglected tropical diseases. *Trends in Parasitology,* 22; 363–366.

Eni , U.; Na'aya, H.; Nggada, H.; Dogo, D. (2008). Carcinoma of the urinary bladder in Maiduguri: The Schictosomiasis connection. *The Internet Journal of Oncology*, 2(5). DOI:10.5580/459.

Ezeamama, A.; McGarvey, S.; Acosta, L.; Zierler, S.; Manalo, D.; Wu, H.; Kurtis, J.; Mor, V.; Olveda, R.; Friedman, J. (2008). The synergistic effect of concomitant schistosomiasis, hookworm and trichuris infections on children's anemia burden. *PLoS Neglected Tropical Diseases,* 2(6); 245.

Fleck, S.L.; Moody, A.H. (1988). Diagnostic techniques in Medical Parasitology. John Wright Publishers. London.

Friedman, J.; Kanzaria, H.;, McGarvey, S. (2005). Human schistosomiasis and anemia: the relationship and potential mechanisms. *Trends in Parasitology*, 21; 386-392.

Gandhi, N.S.; Chen, J.Z.; Koshnood, K.; Xing, F,Y,; Li, S,W,; Liu, Y,R,; Bin, Z.; Haechou, X.; Chong,-Jin T.; Wang, Yan; Wensen, W.; Dungxing, H.; Chong, C.; Shuhua, X.; Hawdon, J.M.; Hotez, P.J. (2001). Epidemiology of Necator americanus hookworm infections in Xiulongkan Village, Hainan Province, China: High prevalence and intensity among middle-aged and elderly residents. *Journal of Parasitology*, 87; 739-43.

Heisch R.B. (1948). A parasitological survey of Taveta. *East African Medical Journal*, 25(2); 78-94.

Hodder, S.L.; Mahmoud, A.A.F.; Sorenson, K.; Weinert, D.M.; Stein, R.L.; Ouma, J.H.; Koech, D.; King, C.H. (2000). Predisposition to urinary tract epithelial metaplasia in *Schistosoma haematobium* infection. *American Journal of Tropical Medicine and Hygiene*, 63; 133–138.

Hotez, P.; Bethony, J.; Bottazzi, M.E.; Brooker, S.; Buss, P. (2005). Hookworm; the great infection of mankind. *PLoS Neglected Tropical Diseases*, 2(3); 67.

Hotez, J. P.; de Silva, N.; Brooker, S.; Bethony, J. (2003). Soil transmitted helminth infections; the nature, causes and burden of the condition. DCPP working paper No. 3 (20); 18.

Hotez, P.; Ottesen, E.; Fenwick, A. *et al.* (2006).The neglected tropical diseases: the ancient afflictions of stigma and poverty and the prospects for their control and elimination. *Advances in Experimental Medicine and Biology*, 582; 23–33.

Hotez, P.J.; Molyneux, D.H.; Fenwick, A.; Molyneux, D. (2006). Incorporating a rapid-impact package for neglected tropical diseases with programs for HIV/AIDS, tuberculosis, and malaria. *PLoS Neglected Tropical Diseases*, 3; 102.

John, D.T.; William, A. Petri. (2006). Markell and Voge's Medical Parasitology. Sanders Publishers. Philadelphia, USA

Kabatereine, N.B.; Brooker, S.; Tukahebwa, E.M.; Kazibwe, F.; Onapa, A.W. (2004). Epidemiology and geography of *Schistosoma mansoni* in Uganda: Implications for planning control. *Tropical Medicine and International Health.* 9(3); 372–380.

Kaminsky, R.G. (1993). Evaluation of three methods for laboratory diagnosis of *Strongyloides stercolaris* infection. *Journal of Parasitology*, 79; 277-280.

Kenya National Bureau of Statistics. (2009). The Kenya national persons and housing population census. Nairobi.http/www.knbs.or.ke/finddata.php

King, C.H.; Lombardi, G.; Lombardi, C.; Greenblatt, R.; Hodder, S.; Kinyanjui, H,; Ouma, J.; Odhiambo, O.; Bryan, P.J.; Muruka, J.; Magak, P.; Weinert, D.; Mackay, W.; Ransohoff, D.; Houser, H.; Koech, D.; Siongok, T.K.; Mahmoud, A.A.F. (1988).

Chemotherapy-based control of schistosomiasis haematobia. I. Metrifonate versus praziquantel in control of intensity and prevalence of infection. *American Journal of Tropical Medicine and Hygiene,* 39; 295–305.

King, C.H,; Keating, C.E.; Muruka, J.F.; Ouma, J.H.; Houser, H.; Arap Siongok, T.K.; Mahmoud, A.A.F. (1988). Urinary tract morbidity in *Schistosoma haematobium*: associations with age and intensity of infection in an endemic area of coast province, Kenya. *American Journal of Tropical Medicine and Hygiene*, 39; 361-368.

King, C.H.; Lombardi, G.; Lombardi, C.; Greenblatt, R.; Hodder, S.; Kinyanjui, H,; Ouma, J.; Odiambo, O.; Bryan, P.J.; Muruka, J.; Magak, P.; Weinert, D.; Mackay, W.; Ransohoff, D.; Houser, H.; Koech, D.; Siongok, T.K.; Mahmoud, A.A.F. (1990). Chemotherapy-based control of schistosomiasis haematobia. II. Metrifonate versus praziquantel in control of infection associated morbidity. *American Journal of Tropical Medicine and Hygiene*, 42; 587-595.

King, C.H.; Muchiri, E.M,; Ouma, J.H.; Koech, D., (1991). Chemotherapy-based control of *Schistosoma haematobium*. IV. Impact of annual chemotherapy on prevalence and intensity of *Schistosoma haematobium* infection in an endemic area of Kenya. *American Journal of Tropical Medicine and Hygiene*, 45; 498-508.

Labiano-Abello, N.; Canese, J.; Velazquez, J.M;, Hawdon, J.M.; Wilson, M.L.; Hotez, P.J. (1999) Epidemiology of hookworm infection in Itagua, Paraguay: A cross sectional study. *Memorias do Instituto Oswaldo Cruz,* 94; 583-586.

McClanahan, T.R. (1988). Seasonality in East Africa's coastal waters. *Marine Ecology Progressive Series,* 44(2); 191-199.

Montresor, A.; Crompton, D.W.T.; Gyorkos, T.W.; Savioli, l. (2002). Helminth control in school age children: a guide for managers of control programmes. Geneva: World Health Organization.

Ministry of Agriculture. (2008). Annual report on district performance. G.O.K.Nairobi.

Mizgajska H. (1993). The distribution and survival of eggs of Ascaris suum in six different natural soil profiles. *Acta Parasitologia*, 38; 170 – 174.

Muchiri, E.M.; Ouma, J.H.; King, C.H. (1996). Dynamics and control of *Schistosoma haematobium* transmission in Kenya: An overview of the Msambweni Project. *Journal of Tropical Medicine and Hygiene,* 55; 127-134.

Mutapi, F.; Hagan, P.; Ndhlovu, P.D.; woolhouse, M.E.J. (1998). Changes in specific anti-egg antibody levels of infection following infection in children. *Parasite Immunology,* 20; 595-600.

Nmorsi, O.P.; Ukwandu, N.C.; Ogoinja, S.; Blackie, H.O.; Odoke, M.A. (2007). Urinary tract pathology in Schistosoma haematobium infected rural Nigerians. *Southeast Asian Journal of Tropical Medicine and Public Health,* 38(1); 32-37.

Olds, G.R.; King, C.; Hewlett, J. *et al.* (1999). Double-blind placebo-controlled study of concurrent administration of albendazole and praziquantel in schoolchildren with schistosomiasis and geohelminths. *Journal of Infectious Diseases,* 179; 996–1003.

Partnership for Child Development. (1997) This wormy world:Fifty years on. *Parasitology Today*, 13(11).

Poulin, R. (1996). Sexual inequalities in helminth infections: a cost of being a male? *The American Naturalist,* 147; 287–295.

Ramdath, D.D.; Simeon, D.T., Wong, M.S.; Grantham-McGregor, S.M. (1995). Iron status with varying intensities of Trichuris trichiura infection. *Parasitology*, 110; 347-351.

Renee, L.; Martin, C.;Eduardo, G.; Theresa, W.G. (2005). Relationship between intensity of soil-transmitted helminth infections and anemia during pregnancy. *American Journal of Tropical Medicine and Hygiene*, 73(4); 783–789.

Ross, A.G.; Bartley, P.B.; Sleigh, A.C.; Olds, G.R.; Li, Y.; Williams, G.M.; McManus D.P. (2002). Schistosomiasis. *New England Journal of Medicine*, 346; 1212-1220.

Satayathum S. A.; Muchiri E. M.; Ouma J. H.; Whalen, C.C.; King, C. H. Factors affecting infection or reinfection with *schistosoma haematobium* in coastal kenya: survival analysis during a nine-year, school-based treatment program (2006). *American Journal of Tropical Medicine and Hygiene*, 75(1); 83–92.

Savioli, S.; Hatz, C.; Dixon. H.; Kisumku. U.M.; Mott, K.E. (1990). Control of morbidity due to S*chistosoma haematobium* on Pemba Island: egg excretion and haematuria as indicators of infection. *American Journal of Tropical Medicine and Hygiene*, 43; 289-295.

Stephenson, L.S.; Latham, M.C.; Ottesen, E.A. (2000). Malnutrition and parasitic helminth infections. *Parasitology*, 121 (supplement); 523-28.

Stephenson, L.S.; Latham, M.C.; Kurz, K.M.; Kinoti ,S.N.; Brigham,H. (1989). Treatment with a single dose of albendazole improves growth of Kenyan schoolchildren with hookworm, Trichuris trichiura, and Ascaris lumbricoides infection. *American Journal of Tropical Medicine and Hygiene*, 41; 78-87.

Stephenson, L.S.; Latham, M.C.; Kurz, K.M.; Miller, D.; Kinoti, S.N.; Oduor, M.L. (1985a). Urinary iron loss and physical fitness of Kenyan children with urinary schistosomiasis. *American Journal of Tropical Medicine and Hygiene*, 34; 322-330.

Stephenson, L.S.; Latham, M.C.; Kurz, K.M.; Kinoti, S.N.; Oduor, M.L.; Crompton, D.W.T.(1985b). Relationships of schistosoma haematobium, hookworm and malarial infections and metrifonate treatment to hemoglobin level in Kenyan school children. *American Journal of Tropical Medicine and Hygiene*, 34; 519-528.

Stoltzfus, R.J.; Albonica, M.; Chwaya, H.M.; Savioli, l.; Tielsch, J.M.; Schulze, K.J.; Yip, R. (1996). Hemoquent determination of hookworm-related blood loss and its role in iron deficiency in African children. *American Journal of Tropical Medicine and Hygiene*, 110; 347-351.

Stoltzfus, R.J.; Dreyfuss, H.M.; Chwaya, H.M.; Albonico, M. (1997). Hookworm control as a strategy to control iron deficiency anaemia. *Nutrition Reviews*, 55; 223-232.

Stoll, N.R. (1962). On endemic hookworm, where do we stand today? *Experimental Parasitology*, 12; 241-252.

Tucker, K.L. (2001). Eat a variety of healthful foods: old advice with new support. *Nutrition Reviews*, 59; 156-158.

Utzinger, J.; Keiser, J.; Shuhua, X., Tanner, M.; Singer, B.H. (2003). Combination chemotherapy of schistosomiasis in laboratory studies and clinical trials. *Antimicrobial Agents and Chemotherapy*, 47(5); 1487-1495.

Van Der Werf, M.J.; De Vlas, S.J. (2001). Morbidity and infection with schistosomes and soil transmitted helminthes. *Acta Tropica*, 86; 1-3.

Vennervald, B.J.; Kenty, L.; Butterworth, A.E.; Kariuki, C.H.; Kadzo, H.; Ireri, E.; Amaganga, C.; Kimani, G.; Mwatha J.; Otedo, A.; Booth, M.; Ouma, J.H.; Dune, W. (2004). Detailed clinical and ultrasound examination of children and adolescents in a schistosoma mansoni endemic arera in Kenya: hepatosplenic disease in the absence of portal fibrosis. *Tropical medicine and international health*, 9; 461-470.

Vittaya, J.; Wongwarit, A.; Mathirut, M.; Rommanee, K.; Ram, R.; Rebecca, J.T; Phunlerd, P.; Tawee, N.; Paanjit, T.; Saovanee, L. (2011). Incidence and risk factors of hookworm infection in a rural community of central Thailand. *American Journal of Tropical Medicine and Hygiene*, 84(4); 594–598.

WHO (2002). Prevention and control of schistosomiasis and soil-transmitted helminthiasis: report of a WHO expert committee. WHO Technical Report Series No. 912; 1–57. Geneva: WHO.

World Health Organization (1994). The control of schistosomiasis. WHO Technical Report Series No. 830. Geneva: WHO.

WHO (1998). Report of the WHO Informal Consultation on schistosomiasis control. WHO/CDS/CPC/SIP/ 99(2). Geneva: WHO.

WHO (2001) Schistosomiasis and soil transmitted helminth infections. Fifty fourth World Health Assembly, resolution WHA54.19. www.http://who.int/gb/

WHO. (1981) Intestinal protozoan and helminthic infection. Report of WHO Scientific Group. WHO Technical Report Series no. 666. Geneva: WHO.

WHO. (2010) Partners for Parasite Control (PPC) www.who.int/wormcontrol.

WHO. (1993). The control of schistosomiasis; Second report of the WHO Expert Committee. Technical report series no. 830. Geneva:

Wu, M.L.; Jones, V.A. (2000). Ascaris lumbricoides. *Archives of Pathology & Laboratory Medicine*, 124(1); 174-5.

APPENDICES

Appendix 1. Demographic data for Bomani respondents and prevalence values for Schistosomiasis and geohelminthes.

sex	Age-group (yrs)	Number screened	Number with			
			Schistosoma haematobium	hookworm	*Ascaris lumbricoides*	trichuriasis
female	5-15	177	115	88	3	63
Male	5-15	166	96	34		71
female	16-25	66	38	30		12
Male	16-25	59	32	14		11
female	26-40	81	13	29	2	8
Male	26-40	50	11	20		7
female	41-60	52	5	25		13
Male	41-60	35	5	14		6
female	>60	33	2	16		4
Male	>60	18	3	6		1

Appendix 2. Demographic data for Mwagundu respondents and prevalence values for Schistosomiasis and geohelminthes

sex	Age-group (yrs)	Number screened	Number with			
			Schistosoma haematobium	hookworm	*Ascaris lumbricoides*	trichuriasis
female	5-15	92	59	20	1	36
Male	5-15	108	64	29		38
female	16-25	51	26	12		5
Male	16-25	45	26	7		9
female	26-40	58	27	12		2
Male	26-40	37	8	15		6
female	41-60	47	6	18		4
Male	41-60	37	3	15		4
female	>60	10	2	4		1
Male	>60	10	1	5		2

Appendix 3. Analysis of variance for helminthes infection for the two villages.

Disease	Source	DF	SS	MS	F	P
Schistosomiasis	Village	1	0.102	0.102	0.07	0.789
	Error	14	19.199	1.371		
Hookworm	Village	1	0.02046	0.02046	0.59	0.456
	Error	14	0.48812	0.03487		
Trichuriasis	Village	1	1.239	0.255	4.86	0.045*
	Error	14	3.567	0.255		

* Shows significant difference.

Appendix 4. Analysis of variance for eggs shed versus age-group and sex.

Disease	Source	DF	SS	MS	F	P
Urinary schistosomiasis	Age group	4	5813435	1380493	29.39	0.000*
	Sex	1	288018	288018	6.13	0.013*
	Error	1226	57584858	46970		
Hookworm	Age group	4	816243	204061	7.32	0.000*
	Sex	1	134166	134166	4.81	0.028*
	Error	1226	34190161	27888		

* Shows significant difference.

Appendix 5. Analysis of variance for average Schistosoma eggs versus hematuria.

Treatment	Source	DF	SS	MS	F	P
Schistosoma eggs	Hematuria	1	21796242	21796242	639.99	0.000
	Error	1230	41890068	34057		