Dissemination of the sustainable wastewater technology of constructed wetlands in Tanzania
ZEIN2011Z097

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Water-related Diseases of People using Municipal Wastewater: Risks, Exposure, Effects on Health and Control Approaches in Tanzania

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Water-related Diseases of People using Municipal Wastewater: Risks, Exposure, Control Approaches and Effects on Health in Tanzania
(VLIR3 Research Project)

AH Outwater, S Pamba, AB Outwater

Summary

October 2013

The amount of available freshwater in most low- and middle-income countries is not sufficient to meet increasing demand. Treated municipal wastewater often becomes a significant source of irrigation water.

Wastewater is valuable and its reuse has many potential benefits: flow is reliable even where water is scarce, nutrients increase agriculture production, and it can be used in many income-producing enterprises. Wastewater use also provides low cost reduction of a pollution hazard from direct release to the environment.

Wastewater use is a health risk to people and animals. Contaminants can include pathogenic microorganisms and industrial pollutants. Some pathogens cause harm in smallest numbers, and wastewater may spread diseases to sewage systems workers, farmers, their families, downstream communities and consumers of irrigated produce.

Common wastewater pathogens include helminths like roundworms, tapeworms, whipworms, hookworms and schistosomes. Perhaps half of Tanzanians have urinary or intestinal schistosomiasis; likewise, about half the population are infected with soil-transmitted helminths. Diseases caused by these worms are exacerbated by inaccessible health care and mediocre treatments.

Data includes operational parameters from the Iringa wastewater treatment plant, a field survey of effluent use, observations, and a helminth assessment of four wastewater treatment plants. Effluent from Arusha, Iringa and Moshi met WHO standards for agricultural use; in Morogoro, the effluent included hookworm eggs.

Many soil-transmitted helminth eggs settle into the sludge and are viable for years, making the sludge infectious. *Schistosoma* eggs hatch when they come into contact with water. The resulting miracidae must find snails, their obligatory host, within 48 hours. Without snails, the life cycle of the schistosome will end.

Prevention, where actions are taken to prevent the occurrence of disease, is the most equitable way to deal with disease threats. Environmental modifications are generally more sustainable than treatment, and have longer-term impact. Environmental modifications that prevent disease include sewage treatment systems like waste stabilization ponds and constructed wetlands.

Recommendations for wastewater reuse are divided into five categories: planning, design, construction, implementation, and monitoring.

During planning, disease prevalence of humans and other animals must be evaluated. High background disease levels show that risk management procedures should be improved. Multisectoralism is crucial: the health sector and the engineering sector must work together. For effective disease control, engineering designs must consider the biological aspects of pathogens and their diseases; likewise, disease control will not be effective if health workers depend on drugs and health education without the preventive aspects inherent to well-engineered sewage treatment systems. Educational campaigns should improve knowledge and actions over the long term.

Waste stabilization ponds should include fish to eat the mosquito larvae; constructed wetlands should generally be subsurface to decrease habitat for mosquito larvae.

To protect workers and their families from wastewater pathogens, staff should wear clothing that can be cleaned in boiling water and rubber boots to protect their feet, and treatment plants should have a place to shower and disinfect after work.

Agricultural practices and crops can be changed to reduce pathogen transmission from wastewater irrigation; sludge can be stored or composted to reduce ova content before land application.

Regular monitoring should be site specific. Data on local disease incidence and prevalence should be collected periodically. Pond monitoring should include periodic checks for snails that are *Schistosoma* hosts. Influent should be tested for total petroleum hydrocarbons, heavy metals, pharmaceutics, and other pollutants; effluent should be monitored for coliforms and helminth eggs.

We need continued research to reduce the disease-carrying potential of wastewater while utilizing its fertilizer value, and on the role of natural systems like mangrove forests and marshes in cleaning sewage-laden streams and rivers.

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ABBREVIATIONS AND ACRONYMS

CW	Constructed Wetland
FSCW	Free Surface Constructed Wetlands
IRUWASA	Iringa Urban Water Supply & Sanitation Authority
MDG	Millennium Development Goals
MKUKUTA	Mkakati wa Kukuza Uchumi na Kupunguza Umaskini Tanzania (National Strategy for Growth and Reduction of Poverty)
MPN	most probably number
SCI	Schistosomiasis Control Initiative
WHO	World Health Organization
WSP&CW	Wastewater Stabilization Ponds & Constructed Wetlands

CHAPTER ONE

1.1 Introduction / Background

The amount of available freshwater in most low- and middle-income countries is not sufficient to meet the increasing demand.

Taking into account that 80% of water consumption leads to wastewater generation (Qadir et al., 2010; Meneses et al., 2010), treated municipal wastewater can be a significant source of irrigation water. In addition, urban expansion and increasing population and industrial use has led to remarkable production of wastewater and growing water scarcity for agricultural use.

The use of industrial or municipal wastewater in agriculture and aquaculture is a common practice in many parts of the world (Blumenthal et al., 2000; Ensink et al., 2002; WHO, 2006). The reuse of wastewater in these regions has grown rapidly and has become a recommended practice (Agrafioti and Diamadopoulos, 2012).

Wastewater is valuable and its reuse has many potential benefits. It is often a reliable supply of water to farmers for crop production, even in places of water scarcity (Lubello et al., 2004; Oron et al., 1999; Pedrero et al., 2010). A major objective of wastewater reuse is effective utilization of its nutrients, thereby reducing the need for artificial fertilizers, increasing crops' yields and returns from farming (Lubello et al., 2004; Oron et al., 1999). In addition, wastewater provides sources of income through its uses in other enterprises such as aquaculture or construction. Irrigating with wastewater diminishes a pollution hazard from direct release to environment. It can reduce the volume of wastewater being discharged to the environment (Pedrero et al., 2010) and it is a low cost method for sanitary disposal of municipal wastewater (IMWI, 2001).

Despite its many benefits, wastewater harbors potential dangers. Long-term wastewater use can have negative impacts on soil resources – buildup of salts and heavy metals in the soils, which may reduce the productive capacity of the soil in the long run (IWMI, 2001). The most serious danger of wastewater use is the risks to people. Wastewater may contain contaminants, like heavy metals and industrial pollutants. Most commonly, wastewater harbors dangerous levels of pathogenic microorganisms such as bacteria, viruses, parasitic worms and protozoa that can lead to disease. Some of these pathogens can cause harm in smallest numbers (Blumenthal et al. 2000). The reuse of domestic wastewater for agriculture and aquaculture increases exposure of sewage treatment system workers farmers, their families, neighboring communities and even consumers of agricultural produce to infectious diseases.

The World Health Organization (WHO) has estimated that 24% of the global disease burden, and 23% of all deaths can be attributed to environmental factors (Prüss-Üstün and Corvalán, 2006); among children 0–14 years of age, the proportion of deaths attributed to environment factors is as high as 36%. There are more than 4 million environmentally caused deaths among children every year, mostly in low- and middle-income countries.

How much disease can be prevented with modification of the environment?

The definition of "modifiable" environmental risk factors include those reasonably amenable to management or change (Prüss-Üstün and Corvalán, 2006). Examples of modifiable waterborne environmental factors include:

- Pollution of air, water, or soil with chemical or biological agents
- Occupational risks
- Built environments including housing, land use patterns, roads, latrines, sewage systems
- Agricultural methods and irrigation schemes
- Behavior related to the availability of safe water and sanitation facilities.

If any of these factors is sub-optimal, the result is a decrease in the health of the environment and an increase in waterborne diseases.

Decreasing this disease burden can make an important contribution to meeting the Millennium Development Goals (MDGs) (see Appendix A). Environmental factors are integral to all the MDGs, Goal 7 explicitly.

MDG 7. Ensure environmental stability

Providing sustainable sources of safe water and clean energy are key environmental interventions that contribute to this MDG. The potential health gains from these interventions can be appreciated from the global statistics for 2002: 1.1 billion people, mostly in low- and middle-income countries, were still using potentially harmful sources of water, and 2.6 billion people lacked even a simple improved latrine. Billions of people are ill with diseases that could be prevented by improved sanitation and hygiene.

Decreasing disease burden through increased access to sanitation is also an important contribution to the Tanzanian National Strategy for Growth and Reduction of Poverty, known as MKUKUTA (Mkakati wa Kukuza Uchumi na Kupunguza Umaskini Tanzania), which was approved by Cabinet in 2005 for implementation over five years. The MKUKUTA is informed by Vision 2025 and committed to the achievement of the Millennium Development Goals (MDGs) (see Appendix B). Although the time span of the plan is completed, the work continues.

The strategy identified three clusters of broad outcomes: (I) growth and reduction of income poverty; (II) improvement of quality of life and social well-being, and (III) good governance. Each cluster has a set of goals and targets. Within Cluster II is a goal including increased access to sanitation and a sustainable environment, with the aim of reducing vulnerability from environmental risks.

1.2 Conceptual Framework

This report focuses on waterborne diseases that can be transmitted through municipal sewage systems, modifiable environmental risk factors, and the expected impact of waste management through waste sedimentation ponds and constructed wetlands. To answer the question of how people can safely use waste water, we need to think of how specific diseases and injuries are impacted by environmental risks.

Following an expert meeting in Stockholm, Sweden, the World Health Organization published *Guidelines, Standards, and Health: Assessment of Risk and Risk Management for Water-related Infectious Disease* (Bartram, Fewtrell & Stenström, 2001). This document creates a harmonized framework for the development of guidelines and standards, in terms of water-related microbiological hazards.

What became known as the Stockholm Framework provides the conceptual framework for WHO water-related guidelines. The Stockholm Framework involves:

1/ Assessment of health risks prior to the setting of health-based targets

2/ Development of guideline values

3/ Definition of basic control approaches

4/ Evaluation of the impact of these combined approaches on public health.

This Framework has been adapted for the present report.

The overall aim of this paper is to provide a holistic picture of risks and benefits of urban wastewater use in agriculture. The objective of this paper is to provide a framework for the analysis of socioeconomic, health, and environmental aspects of urban wastewater use in the agricultural sector. The specific objectives of this paper are to: 1) identify various impacts (short-term and long-term) of urban wastewater use in agriculture, and 2) identify/develop approaches and methods for assessing, valuing and analyzing these impacts.

1.3 Methodology

1.3.1 Setting

The setting is Tanzania. Data are presented from four municipalities which have constructed wetlands and/or waste sedimentation ponds for municipal sewage treatment: Arusha, Iringa, Morogoro, and Moshi. Iringa, used as a case study, is in the Southern Highlands of Tanzania.

1.3.2 Data collection methods

Assessment of Health Risks

1/ Literature Review

Data about health risks were identified and collected using electronic databases including Google Scholar and PubMed. Members of the Wastewater Stabilization Ponds & Constructed Wetlands (WSP&CW) Research Group provided relevant student dissertations.

2/ Case study

i. Government monitoring parameters for Iringa Municipal wastewater treatment plant

Data from the Iringa Municipal wastewater treatment plant was obtained from Iringa Urban Water Supply and Sewerage Authority (IRUWASA). Samples were collected on a monthly basis from May to November 2012 by IRUWASA from the inlet strainer partial flume, outlet anaerobic pond 1 and anaerobic pond 2, outlet of the maturation pond and at the outlet of the constructed wetland (Fig 1.2).

ii. On-site field survey

An on-site field survey during 5th to 7th December 2012 focused on agricultural workers and people living near the Klerruu Teachers College constructed wetland. The survey questionnaire focused on assessment of health risk, water sanitation and hygiene. Respondents were requested to describe their reuse of the wastewater from Klerruu constructed wetland.

Box 1: Questions for assessing health risk from effluent from Iringa Municipal wastewater treatment plant

How is the effluent used?

Do you catch or eat fish from the ponds? How often? How much?

How much time do you spend in the water? What do you do in the water?

Do you feel any concern about the water?

For families and community members:

Where do you get your drinking and household water?

Where do you defecate and urinate?

In the last month, have you experienced ear infections, skin infections, skin rashes, diarrhoea?

iii. Observation

On-site observation was conducted and a photographic record was made. Types of effluent re-use were identified and the duration of time spent in contact with wastewater due to farming practices was recorded. Identification of crops and irrigation use of wastewater downstream of Klerruu Teachers College and the municipal wastewater treatment system were observed.

iv. Assessment of pathogen exposures

In August 2013 data were collected from the Arusha, Iringa, Morogoro and Moshi municipal sewage systems. Water samples were collected from four municipal sewage systems. Five to six samples were collected from consecutive points in each sewage system as follows: i/ influent to Pond 2 – a facultative pond, ii/center of Pond 2, iii/ effluent from Pond 2, iv/ influent to constructed wetland, v/ effluent from constructed wetland, and vi/ effluent from fishpond if there is one. For each sample ten liters of water were collected and allowed to settle for 2-3 hours. One liter of sediment was fixed with 10% formalin, then transported to the WHO supported laboratory at Muhimbili University of Health and Allied Sciences in Dar es Salaam.

1.3.3 Data analysis

1/ Literature for the review was gathered and organized by relevant categories.

2/ The case study presented in Chapter Three is comprised of

i. The parameters measured during the government monitoring of the Iringa Municipal wastewater treatment plant which include Biochemical Oxygen Demand (BOD), Chemical Oxidation Demand (COD), Nitrate (NO_3-N), Nitrite (NO_2-N), Phosphate (PO_4), Faecal Coliforms, Total Dissolved Solid (TDS), Ammonia (NH_4-N) and pH (see Appendix C).

   The performance of the system for BOD and ammonia removal is a good indicator for the reuse of effluent for aquaculture, while a level of ammonia, nitrate and phosphate provides information pertaining to the beneficial reuse of effluent for irrigation. The level of faecal coliform was mainly used in the present study to assess possible health risk associated with exposure to the wastewater.

ii. A socioeconomic survey about Klerruu constructed wetland wastewater reuse was completed. The answers were categorized and represented in percentages in pie charts and graphs.

iii. Observations and photographs were organized into the categories of the on-site questionnaire.

iv. To assess pathogen exposures, data from an unpublished student dissertation (Marwa, 2011) were re-analyzed. Data that had been presented on a linear scale was replotted on a log scale.

v. Each newly collected sample was centrifuged and in the laboratory WHO techniques were followed (Ayres & Mara, 1996). Each sample was examined for: Faecal coliforms, A*scaris lumbricoide*s, *Trichuris trichuira*, *Nector americanus*, *Hymenolepsis nana*, *Taenia*, *Schistosoma haematobium*, *Schistosoma mansonii*, *Entamoeba histoylica*, and

Entamoeba coli. When the laboratory scientist had questions about anything he was seeing, he consulted with other experts nearby.

vi. Chapter Five data of conductivity, pH, nitrate, ammonia, phosphate, calcium, magnesium and iron content in vegetables irrigated with effluents from Iringa Municipal wastewater treatment plant was obtained from a 2012 water quality laboratory report. The report was mainly based on investigation of pollution accumulation in vegetables irrigated with wastewater effluent by Kahwa.

CHAPTER TWO

2.0 Assessment of health risks of water-related diseases related to waste stabilization ponds and constructed wetlands

2.1 Introduction

There is a long list of human diseases related to water, sanitation and hygiene as described in Appendix D. The failure to properly treat and manage wastewater and excreta worldwide is directly responsible for many adverse health and environment effects. Bacterial diseases and health problems include salmonellosis, shigellosis, cholera, trachoma, skin rashes and infections, ear infections; viral diseases include infectious hepatitis and gastroenteritis; protozoans and amoebas cause health problems such as giardiasis, amoebic dysentery and cryptosporidiosis; and parasitic helminths including nematodes (roundworms), cestodes (tapeworms) and trematodes (flukes) are involved with ascariasis, trichuriasis, hookworm infection and schistosomiasis. Malaria is not usually considered a waterborne disease but is a concern in water and sanitation treatment if systems provide sites where mosquitos breed.

Table 2.1 Description of Important Water-related Diseases Important in Tanzania

Disease	Cause	Type of pathogen	Common Mode of transmission	% of disease attributable environment (% to water, sanitation and hygiene)*	Notes
Diarrhoea	*Salmonella spp* *Shigella spp* *Giardia lambia* *Antamoeba histolityca* Rotavirus Norwalk	Bacteria Protozoa	Faecal-oral	94 (88)	

Gastroenteritis		Virus			
Cholera	*Vibrio cholera*	Bacteria	Faecal-oral		usually 2^{o} to contaminated water
Trachoma	*Chlamydia trachomatis*	Bacteria	Hygiene e.g. flies, clothing	100	
Ascariasis Roundworm	*Ascaris lumbricoides*	Helminth (Nematode)	Ingestion of eggs	100 (100)	
Trichuriasis Whipworm	*Trichuris trichiura*	Helminth (Nematode)	Ingestion of eggs	100 (100)	
Hookworm infection	*Necator americanus*	Helminth (Nematode)	Larval penetration of the skin, Ingestion of eggs	100 (100)	
Schistosomiasis: (Bilharzia) Urinary Intestinal	*Schistosoma haematobium Schistosoma* *mansoni*	Helminth (Trematode)	Larval penetration of the skin	100 (100)	Intermediate host = snails
Malaria	*Plasmodium falciparum, ovale, malariae, vivax*	Protozoa	*Anopheles* mosquito bite.	42	Eggs and larvae are aquatic

*estimates by Prüss-Üstün and Corvalán, 2006.

According to Prüss-Üstün and colleagues, 13% of all deaths in Tanzania are water related. For children under five, the proportion is even higher (2008, p.52). Deaths attributable to water sanitation and hygiene in Tanzania in 2004 (the most recent year for which WHO statistics are available) were 32,665 over all, of which 21,499 were children.

However, not all these diseases strongly affect people who work in sewage treatment plants and constructed wetlands or users of effluent per se. Diarrhoea and cholera are primarily associated with untreated drinking water. Trachoma is generally associated with flies and with personal hygiene between mother and child, for example when the mother cleans the eyes of her child with an infected cloth. Malaria is a theoretical risk and certainly poses many societal and economic burdens in Tanzania, ranging from school absenteeism to low productivity in the workplace. However, it seems that sewage treatment plants are not usually important contributors to the disease. The waste stabilization ponds have fish and other predators that eat mosquito larvae, and most constructed wetlands in Tanzania are sub-surface.

In this chapter, waterborne diseases prevalent in Tanzania that are directly related to workers at waste stabilization ponds and constructed wetlands and effluent users are examined through the current literature. These include ascariasis, trichuriasis, hookworm infection, and both urinary and intestinal schistosomiasis. Special focus is placed on Arusha, Iringa, Morogoro, and Moshi regions where the WSP&CW Research Group has projects.

2.2 Helminths in Tanzania

The atlas of human helminth infections in East Africa was recently updated by Brooker and colleagues (2009). As shown on the following maps, East Africa is described as Burundi, Rwanda, Tanzania, Kenya, and Uganda. To construct these maps, empirical data collected between 1980 and 2008 were used. Details of survey population, diagnostic methods, sample size and numbers infected with schistosomes and soil-transmitted helminths were recorded. The authors attempted to identify the geographical location of each record and then assembled the data into a geographical information system.

For Tanzania alone they assembled 410 studies, 91.5% of which were published. Most of the surveys in Tanzania were conducted post-2000. As can be seen on the maps, most of the records from Tanzania were data collected in the northeast and from around Lake Victoria. There were big gaps in the data set as no studies had been conducted in many regions, including Arusha, Dodoma, Iringa, Kigoma, Lindi, Mara, Rukwa, Ruvuma and Singida (see Appendix E).

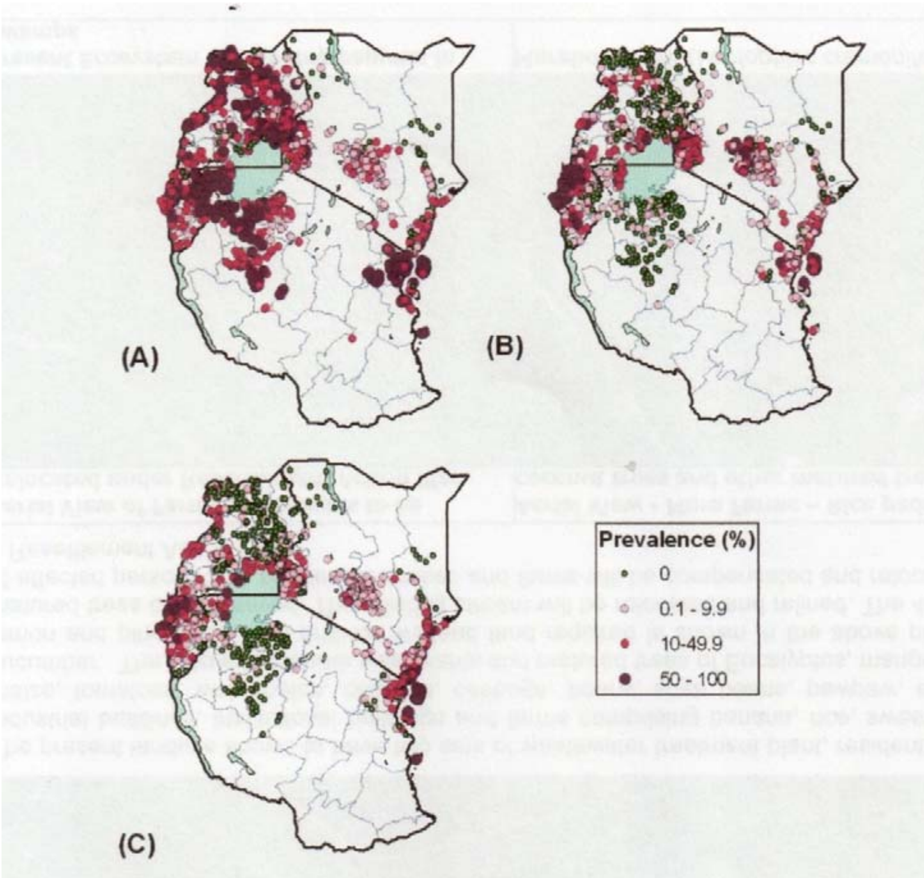

Figure 2.1 The known geographical distribution of soil-transmitted helminths in East Africa. The geographical distribution of (A) hookworm (B) Ascaris lumbricoides (C) Trichuris trichuira, based on available survey collected between 1980 and 2009 and categorized according to WHO prevalence thresholds (n=1,948)
From Brooker et al., 2009.

As shown in Appendix D, hookworm, roundworm and whipworm were found in human beings in 13 of Tanzania's 26 regions. That is, they were found in 13 of the 17 regions for which there is data. These parasites are widespread, but not everywhere.

Of these soil-transmitted helminths, hookworm was the most common. Hookworm in Tanzania has been found to be widespread along coastal Tanzania since the early twentieth century, particularly in the farms and plantations around Tanga and Dar es Salaam. It was believed to be spread chiefly among large congregations of workers and to have become widespread with the development of the plantation economy (Kopenen, 1994). In many plantation areas, 30 to 60% of Africans were carriers of the parasite. The number defined as “sick” was smaller – about 1% to 4% of the carriers. The definition of “sick” was “incapable of work as a result of hookworm”. Those who complained of “paleness of skin, pain, constipation, etc.” did not qualify.

Considering studies since 1980, the prevalence of hookworm ranged from 3.5% in Kilimanjaro to 81% to 95% in South and North Pemba, respectively. The median presence of hookworm, considering all the studies in Tanzania, was almost 50%.

Whipworm and *Ascaris* share similar prevalence and regional patterns, with high prevalence in Pemba and North Zanzibar and low prevalence in continental Tanzania. Their ranges are more restricted. In Tanzania their highest prevalence is in Pemba, where over 90% of the people are infected. On the mainland prevalence is insignificant in many places, with a high of about 7% for both worms in populations in Kilimanjaro.

The rates for helminth infection were found to be low in Ifakara, where a matched case control study focusing on diarrhoea also tested the stools of the 309 children for parasites (Gascon et al. 2000). Few children in Ifakara tested positive for parasites: 5 tested positive for hookworm, 2 for *Strongyloides stercoralis*, and one each tested positive for *Ascaris lumbricoides*, *Cryptosporidium*, and *Antamoeba histolyca*. Intestinal nematodes do not seem to play a role in diarrhoeal diseases in Ifakara. Low rates of nematodes in both patients and controls suggest a low incidence of these health problems in the Ifakara region for patients of this age (Gascon et al., 2000).

2.3 Schistosomiasis in Tanzania

Schistosomiasis was first reported in Tanzania decades ago (Mallya, 1988) and since then cases of its occurrence in other parts of the country have been confirmed. The two most common species of the blood fluke are *Schistosoma haematobium* and *Schistosoma mansoni*, both of which are endemic to East Africa. In 1988 it was estimated that 38% of the general population was infected with schistosomiasis (Mallya, 1988).

Brooker and colleagues also mapped the prevalence of *Schistosoma haematobium* and *S. mansoni* in Tanzania by using data gathered by research studies from 1980-2009.

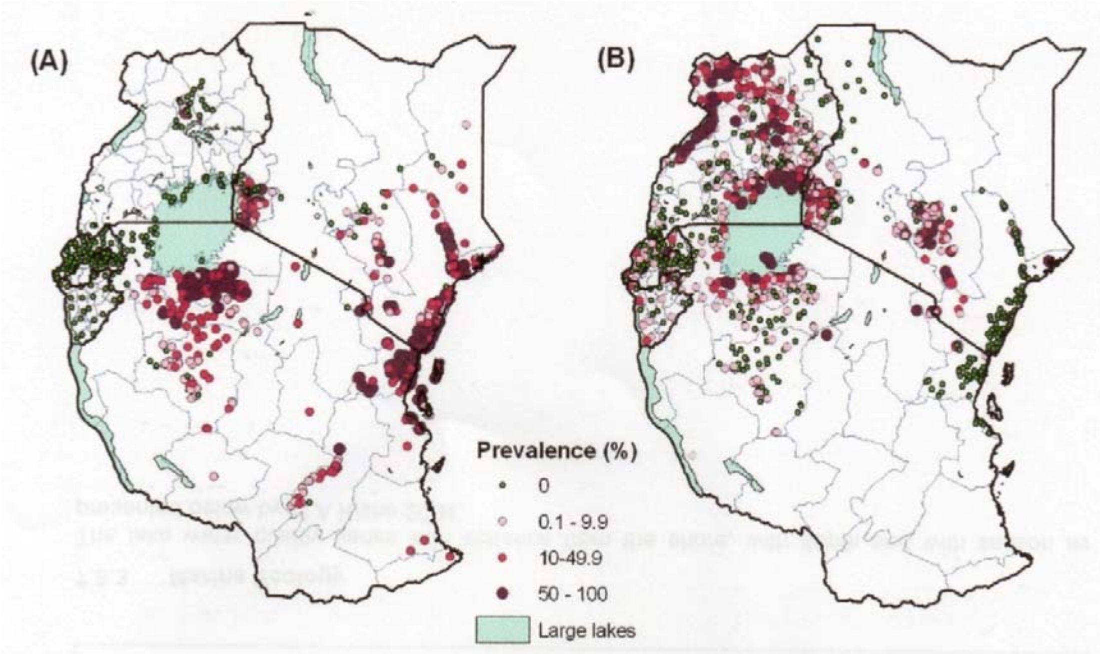

Figure 2.2: The known geographical distribution of schistosomiasis in East Africa. The geographical distribution (A) *Schistosoma haematobius* and (B) *S. mansoni* infection, based on available survey collected between 1980 and 2009 and categorized according to WHO prevalence thresholds (Brooker et al., 2009).

As shown in the above figure, many areas of Tanzania, including most of the southern regions, have not been sufficiently surveyed for schistosomiasis. Urinary schistosomiasis (*S. haematobium*) appears to be much more prevalent than intestinal schistosomiasis (*S. mansoni*). *S. haematobium* was found in 14 of Tanzania's regions with a national median prevalence of over 30%. Urinary schistosomiasis is distributed along the Indian Ocean coast and Lake Victoria. The highest mean prevalence was in Mwanza (58.3%). Interestingly Kagera had a very low prevalence recorded for both *S. haematobium* and *S. mansoni*. *S. mansoni* was found in nine of Tanzania's 26 regions but the prevalence generally appears to be comparatively low. In three regions none was found. The highest rates were found in Kilimanjaro and North Unguja.

Jared Bakuza of the Dar es Salaam University College of Education, addressed a gap in the atlas with data from his PhD dissertation. Bakuza and colleagues from Glasgow University mapped the epidemiology of intestinal schistosomiasis along the shores of Lake Tanganyika. Between January and September 2010, stool samples were collected from 235 children and 171 adults at Gombe National Park and four neighboring villages. The stools were examined for parasite ova using the Kato-Katz technique. Baboon and vervet monkey stools were also examined. High rates of *S. mansoni* were found in Kigoma region.

As shown in Table 2.2, *S. mansoni* infection was recorded at an overall prevalence of 47% across study sites.

Figure 2.3 Mwamgongo village landing site. Photo by J. Bakuza.

Two villages (Gombe and Mtanga) had adult schistosomiasis rates of 44% whilst the others had rates of 50%. The difference of a few percentage points in the adult rates of schistosomiasis infection was reflected as dramatic differences in the prevalence of schisotosomiasis among children. The children living in a village where the adults had the lower rate of *S. mansoni* infection had childhood prevalence rates of about 10%. Where the adults had rates of 50%, the children prevalence of schistosomiasis ran from 38% in Kiziba to almost 90% in Mwamgongo.

The important questions of what are the differences between villages of high and low child schistosomiasis prevalence is not yet explained. Childcare practices, hygiene practices, latrine siting, water usage, and previous exposure to praziquantel could all be partial answers and need to be urgently sorted out.

Table 2.2 Lake Tanganyika villages by Population, *S. Mansoni* prevalence, and snails infected (Bakuza, 2012).

Site	N Adults	N Child <18 yrs	N Snails	*S.mansoni* Prevalence Adult	*S.mansoni* Prevalence Child	*S.mansoni* Prevalence Snails
Bugamba	28	57	23	50	70	30
Gombe	45	10	47	44	10	0
Kiziba	16	64	27	50	38	63
Mtanga	35	49		44	11	?
Mwamgongo	46	54	96	50	89	57
Total/Average	**170**	**234**	220	47	43	47

Snails known to harbor schistosomes were also analyzed for infection. The rate of snail infection paralleled that of human adult infection so that the lowest proportion was at Gombe (zero) and the highest percentage of infected snails were at Kiziba, where 57% were infected.

While none of the 16 vervet monkeys appeared to be infected with S. haematobium, the stools of 13% of 136 baboons harbored S. mansoni. Moreover the DNA tests imply that the baboons were probably becoming infected with schistosomiasis through closer interaction with humans and their waste. Baboons spend more time than vervets on the ground. Baboons are also more willing to cavort in the water giving the *Schistosoma* cercariae time to burrow into their skin.

Table 2.3 Treatment of humans living in villages around Gombe National Park, for *S. mansoni* treated with praziquantel (Bakuza, 2012).

S. mansoni	**Before Treatment**	**After treatment**
Prevalence (%)	79.10	19.40
Intensity (epg)	574	22.22

Praziquantel, the standard and recommended drug of choice, as part of their ethical obligations was given to people in villages in which more than half the population was infected with schistosomiasis. The praziquantel showed itself to be an effective drug, yet also it cleared only about 75% of the infections and heavily reduced egg intensity by 96%. It needs to be noted that treatment is not 100% effective and a significant minority of the treated population were left harboring schistosomes.

Tanzania is one of the initial six focal countries for the international Schistosomiasis Control Project. To make baseline data for use in this project, answers were obtained from 2,586,140 schoolchildren, between 7 and 14 years old, in 12,399 schools located in 2373 wards in 116 districts (Clements, Brooker, Nyandindi, Fenwick, Blair, 2008). They were asked if they have schistosomiasis, and/or if they had blood in their urine (a common symptom in urinary schistosomiasis).

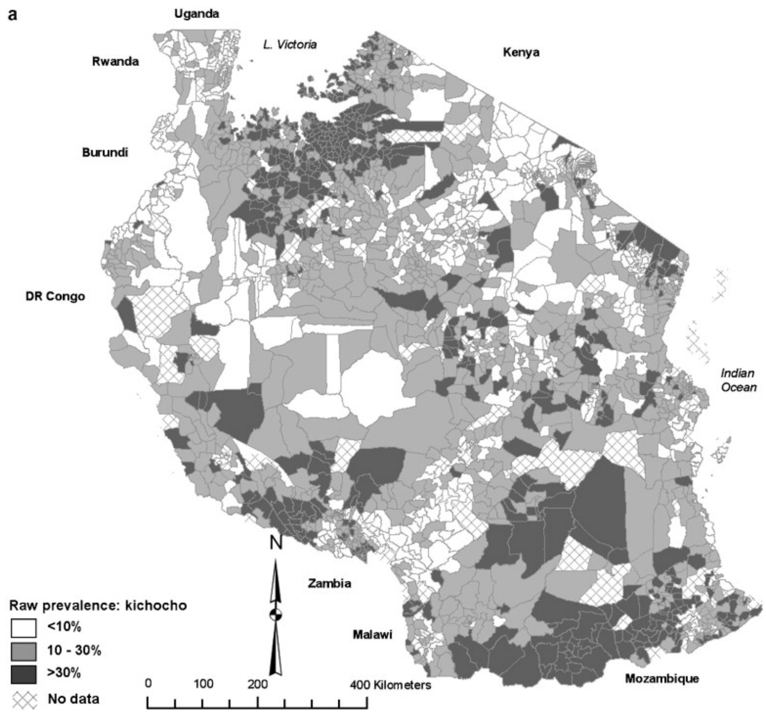

Figure 2.4. Raw prevalence of self-reported schistosomiasis (a) and blood in urine (b) in Tanzanian wards.

Overall, the prevalence of self-reported schistosomiasis was 24.8% and prevalence of self-reported blood in the urine was 20.5%. Maps based on the children's answers and maps based on geostatistical prediction from other data show a lot of similarity. These maps will be used to prioritize praziquantel distribution.

The SCI in Tanzania will be treating seven neglected tropical diseases with this program: schistosomiasis, lymphatic filarial, onchoceriasis, trachoma, hookworm infection, ascariasis, and trichuriasis. Although they state that the problem is due to poor sanitation and lack of water, and they expect high re-infection rates, the approach is primarily pharmaceutic including Praziquantel for the schistosomiasis and albendazole for the other helminths.

2.4 Gaps

Many of the disease study sites were chosen to be generally illustrative of the condition of many Tanzanian citizens. But geographic disease data from many regions in Tanzania is sparse or absent, especially in the southeast part of the country. There is also a lack of data on urban and peri-urban populations. None of the studies reported here included communities or individuals connected to municipal sewage systems or constructed wetlands.

2.4.1 Challenges Affecting Prevalence

Access to safe drinking water and improved sanitation

The table below based on WHO data shows that the proportion of the population with access to improved drinking water sources has decreased overall since 1995. Slightly more than half of Tanzanians had improved drinking water in both 1995 and 2010. The proportion of the population with improved sanitation facilities has increased slightly, but the total by year 2010 was only 10% of the population overall and 20% in urban areas.

Table 2.4 Population using improved drinking water sources and sanitation facilities

		Population using improved drinking-water sources (%)[i]			Population using improved sanitation facilities (%)[i]		
		Rural	**Urban**	**Total**	**Rural**	**Urban**	**Total**
United Republic of Tanzania	**2010**	44	79	53	7	20	10
	2005	45	83	54	7	18	10
	2000	45	86	54	7	15	9
	1995	46	90	55	7	13	8

Source: World Health Organization, n.d

While the population has increased, the proportion of people with improved drinking water sources has decreased and the fraction of the population connected to a sewer system has very minimally increased. During this period, bottled water became widely available, especially in urban areas. Corporations including Coca Cola (Kilimanjaro brand) and Pepsi (Dasani brand) have participated in increasing access to drinking water for those who can afford it even as public access has fallen. In the case of water connections especially, perhaps project-provided hardware broke and could not be repaired, or the projects were built poorly and could not be fixed.

It is important to note that in the last fifteen years, the proportion of people with access to clean water has decreased and improved sanitation has barely increased, and then only in urban areas. These data may also be pointing to the fragility of the existing systems and incomplete planning for follow-up and maintenance.

2.4.2 Challenges Preventing Treatment

The persistently high case fatality rate in the WHO Africa Region reflects general problems in access to effective health care.

Infrastructure

Access to health facilities is often difficult. There is often no readily available transportation for patients too ill to walk. In 1999, a median of only 12% of roads in Africa were paved (Gaffga, Tauxe, Mintz, 2007).

Access to health care

The average health care bed/population ratio in the WHO Africa Region was one tenth the average for high-income countries and half the average seen in other low- and middle-income countries. With only 2.3 health workers per 100,000 people, Africa also has a smaller health workforce than any other region (WHO, n.d.).

Access to proper treatment

A patient can arrive at the hospital only to meet inadequate care. For example, use of oral rehydration therapy and proper case management of diarrhoea in Africa is suboptimal. Recent data from Demographic and Health Surveys conducted in Africa from 1988-2003 indicate that the proportion of children under 5 years old with diarrhoea who did not receive oral rehydration solution or increased fluids during diarrhoea episodes actually rose in nine of ten African countries during this period (Gaffga et al., 2007).

Assessment of health risks

Water borne diseases in Tanzania are common and widespread. There also appears to be wide variability in community prevalence of these diseases. Overall in the short term, widespread morbidity reduces agricultural production and other economic outputs. In the long-term, the accumulated effect certainly decreases national economic capacity and development. The burden of one or more of these diseases downgrades the quality of life.

There are many collateral effects of waterborne diseases. For example, all these diseases can lead to malnutrition and anaemia. Individual nutritional status depends on the food that an individual eats, his or her general health, and the physical environment. In all three aspects, poor water and sanitation play an important role and diseases caused by intestinal parasites are related to poor water, sanitation, hygiene and food safety (Martorell, Mendoza and Castillo, 1988; Prüss-Üstün et al., 2006). It has also been shown that the levels of water and sanitation services significantly affect weight gain in infants (Esrey, Habicht and Casella, 1992; Esrey, 1996).

2.5 Conclusion

Overwhelmingly, while there is geographic variability in prevalence for reasons that are not always clear, the overall high rates of these diseases in Tanzania highlight that the environment is conducive to diseases related to water, sanitation, and hygiene. In every city, town, and almost every village, Tanzanians are at high risk for ill health due to infectious disease. Due to deficiencies in basic sewerage and hygiene, waterborne diseases including helminths are leading causes of morbidity and mortality among all age groups in Tanzania. This has profound results in terms of quality of life, and weighs heavily on the health system.

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How people are exposed to those diseases in Tanzania is the focus of the next chapter.

CHAPTER THREE

3.0 Assessment of Exposures

3.1 Theoretical Assessment of Exposures

The process of microbiological risk assessment was considered to comprise three phases, namely problem formulation, analysis, and risk characterization (ILSI, 2000). The analysis phase consisted of two elements: the characterization of exposure and characterization of human health effects (ILSI, 2000). The characterization of exposure requires an evaluation of the interaction between the pathogen, the environment and the human population.

Generally, the major health risks for people in direct contact with wastewater are diarrhoeal diseases, skin problems and worm infections. The most affected groups are those who are work in fields irrigated with wastewater and consumers of wastewater-irrigated produce. Quantitative microbial risk assessment studies indicate that this is a significant threat for farmers and consumers (Seidu et al. 2008). In Ouagadougou, the capital of Burkina Faso in West Africa, soil, crop leaves and vegetables including carrots, lettuce, and tomatoes were found to be heavily contaminated by faecal coliforms and helminth eggs (Cissé et al. 2002). The authors also reported that family members of market gardeners were often ill. Similar vegetable contamination was reported in other areas including Ghana (Amoah et al., 2006), Turkey (Erdogrul and Sener, 2005), and Morocco (Amahmid et al., 1999).

For unrestricted crop irrigation, it is very important to remove the pathogens from the wastewater. As recently as the 1970s, wastewater reuse standards were based on a "zero-risk" concept with the intent of achieving a pathogen- or microbial-free effluent without accounting for pathogen-host relationships or epidemiological evidence of disease transmission caused by using wastewater for irrigation (Hespanhol and Proust, 1994). These zero-risk technology-based standards could be met, so countries with this advanced level of technology set extremely rigorous standards for wastewater reuse. In the United States, for example, the California State Health Department adopted a bacterial standard for unrestricted wastewater irrigation of less than 2.2 total coliforms/100 ml, close to the existing drinking water standard (FAO, 1997). The prohibitively high costs of treating wastewater to this level prior to reuse for crop irrigation may not be justified on economic, social, or political grounds. Nevertheless, valuation of public health risk should be an important decision variable in wastewater irrigation policy analysis.

Effluent limits represent the maximum allowable concentrations of pollutants in wastewater. These limits vary between countries due to geography, climate and socio-economic differences. They also vary depending on the final destination of the wastewater: effluent limits for wastewater discharged to the ocean are less stringent than effluent limits for wastewater used for agriculture. Effluent limits define the quality of the discharged wastewater, so these limits are used as water quality objectives when designing local wastewater treatment plants.

Table 3.1 Effluent limits for water discharged from a wastewater treatment plant

	E.U. (mg/l)	**India (mg/l)**	**Tanzania (mg/l)**
BOD_5	25	30	30
COD	125	250	60
Total suspended solids (TSS)	150	100	100
Total Nitrogen	15 (10)*	100	15**
Total Phosphorus	2 (1)*	5	6

*If city population exceeds 100,000.

**Total Kjeldahl Nitrogen (as N) including organic nitrogen, ammoniacal nitrogen – not including nitrate and nitrite nitrogen and not necessarily including all organically bound nitrogen.

Fecal coliform limits are highly variable. The EU standards are as follows: "Depending on the water quality standards, the fecal coliform limits for municipal wastewater range from less than 2.2 colonies/100ml up to 5000 colonies/100 ml, with 200 colonies/100ml being the most common limit." In India, "the standard for fecal coliforms in the effluent from sewage treatment plants are 1000 MPN /100 ml (desirable) and 10, 000 MPN/100 ml (permissible)." In Tanzania, the limits are 10,000 MPN/100 ml.

The European Union effluent standards are for wastewater discharged into surface and coastal waters; in India, the effluent standards for the discharge of treated wastewaters into inland surface waters are given in the Environment Protection Rules (CPCB, 1996, Ramadan and Ponce, 2013). In Tanzania, the effluent standards are for wastewater discharged into water receiving bodies (Tanzania Bureau of Standards, 2005). Parameters to assess these limits are discussed in Appendix C.

3.2 Parameters for Assessments to Exposures

Since it is expensive and time consuming to detect different types of microbial pollutants in wastewater, faecal coliforms are used as an indicator organism to determine if other contaminants associated with faeces, like parasitic protozoa or bacteria, are likely to be present in wastewater (Paillard et al., 2005). In Ifakara, Tanzania *Escherichia coli* was found more than any other enteropathogen. However none of the many strains of *E. coli* were an absolute measure of the presence of pathogenic microbes, but rather a measure of the potential for the presence of pathogens that might be associated with faecal material (Cooper, 1991).

There are benefits to using effluent for irrigation, but there are real risks as well. Effluent quality is a critical factor, but since effluent limits are typically set to protect the health of the waterways, most of the parameters used to characterize wastewater address the impacts of effluent on the waterways rather than on human health.

The World Health Organization recommended microbiological quality guidelines for wastewater used for irrigating crops in 1989. These irrigation standards require that effluent contain less than 1 intestinal nematode per liter, and less than 1,000 faecal coliforms per 100ml.

Table 3.2: Different categories, reuse conditions, exposure groups and wastewater treatment expected to achieve required quality Source: Westcot, 1997.

Cat	Reuse Conditions	Exposed Group	Intestinal Nematodes[1] (/liter*)	Faecal coliforms (/100ml**)	Wastewater treatment expected to achieve required quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks[2]	Workers, consumers, public	<1	<1000	A series of stabilization ponds designed to achieve the microbial quality indicated, or equivalent
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[3]	Workers	<1	None set	Retention in stabilization ponds for 8-10 days or equivalent helminth removal
C	Localised irrigation of crops if category B exposure of workers and the public does not occur	None	n/a	n/a	Pretreatment as required by irrigation technology, but not less than primary sedimentation

In 2006, the WHO revised their guidelines for the safe use of wastewater, faecal material and sludge in agriculture and aquaculture. Rather than setting absolute limits on the number of helminth ova allowed in water used for irrigation, the revised

[1] In specific cases, local epidemiological, sociocultural and environmental factors should be taken into account, and the guidelines modified accordingly.
[2] *Ascaris* and *Trichuris* species and hookworms
[3] A more stringent guideline (< 200 faecal coliforms/100ml) is appropriate for public lawns with which the public may come into direct contact
[4] In the case of fruit trees, irrigation should cease two weeks before the fruit is picked and none should be picked off the ground.

*Arithmetic Mean during the irrigation period
**Geometric mean during the irrigation period

WHO effluent limits are based on the fraction of helminth ova that are removed during the wastewater treatment process. For example, if the influent to a wastewater treatment plant has 1000 helminth ova and the effluent has 100 helminth ova, then wastewater treatment has resulted in a 90% reduction of the contaminant or a 1-log removal. With an influent containing 1000 helminth eggs per liter and an effluent with 10 helminth eggs per liter, the reduction is 99% or a 2-log removal. With an influent containing 1000 helminth ova per liter and an effluent containing 1 helminth ovum per liter, the wastewater treatment process has removed 99.9% of the contaminant, a 3-log removal. In low and middle income countries, the WHO recommends treatment methods with 1-3 log removal for acceptable helminth ova content in effluent used for irrigation.

Table 3.3 WHO guidelines for wastewater used to irrigate crops, 2006

Effluent for Use in	Helminth Eggs (#/liter)	*E. Coli* (#/100 ml)
Restricted irrigation	<1/liter	$<10^5$ Relaxed to $<10^6$ when exposure is limited or re-growth is likely
Unrestricted irrigation	<1/liter	<1000 Relaxed to $<10^4$ for high-growing leaf crops or drip irrigation

Some countries apply raw or partially treated wastewater without regulations or guidelines, while others have either implemented their own regulations/guidelines or have adopted quality criteria based on international regulations (Carr, 2005). According to the World Health Organization, most countries have adopted the WHO guidelines for wastewater reuse (WHO, 1989).

According to the assistant director of the Ministry of Health and Social Welfare, Elias B. M. Chinamo, “Tanzania has no guidelines or standards for the use of wastewater in agriculture … While the WHO standards are somewhat flexible, the capability of Tanzania to attain them is limited by cost, knowledge and skills.”

In many low- and middle-income areas, non-built up urban lands – especially those lying along the courses of urban drainage systems – are seen as ideal locations for the production of agricultural products that are in high demand by urban dwellers, such as vegetables. Several researchers have shown that a significant proportion of a city’s food requirements in low- and middle-income countries are supplied from within the urban boundaries, because within those areas substantial amounts of wastewater from homes and industries is available to irrigate lands along the urban drainage courses, and the markets are close (WHO 2006).

The following sections of this chapter will use complementary data to bring insight as to how these ideas translate to Tanzania. Data from Iringa Municipal wastewater treatment plant describes important parameters of wastewater (see Appendix C), and data from the Kleruu constructed wetland show behaviors of people that may put them at risk for becoming infected with waterborne diseases. Data from Arusha describes pathogen pathways through the municipal sewage systems, while additional data from Arusha, Iringa, Morogoro, and Moshi give insight into the current ability of sedimentation ponds and constructed wetlands to clear pathogens from the wastewater.

3.3 Assessment of Socio-economic and Water Quality Exposures. Case Study Iringa.

3.3.1 Iringa Municipal wastewater treatment plant

The main wastewater production in Iringa is from domestic and municipal sources; there is very little industrial wastewater production in the collection area. The most commonly used sanitary facilities in Iringa are traditional pit latrines, septic tanks and central sewers. Septic tanks and soak away pits are used to treat wastewater at the household level. Waste stabilization ponds and constructed wetland systems are used at the institution and municipal levels.

There is only one set of waste stabilization ponds at the Iringa Municipal wastewater treatment plant, which is mainly used to treat the wastewater collected through the sewers and septic tank sludge. The Iringa Municipal wastewater treatment plant receives septage from the local septage haulers. During some months, much of the flow is composed of septage.

As can be seen in Figure 3.1, the treatment plant is comprised of anaerobic ponds, facultative ponds and maturation ponds.

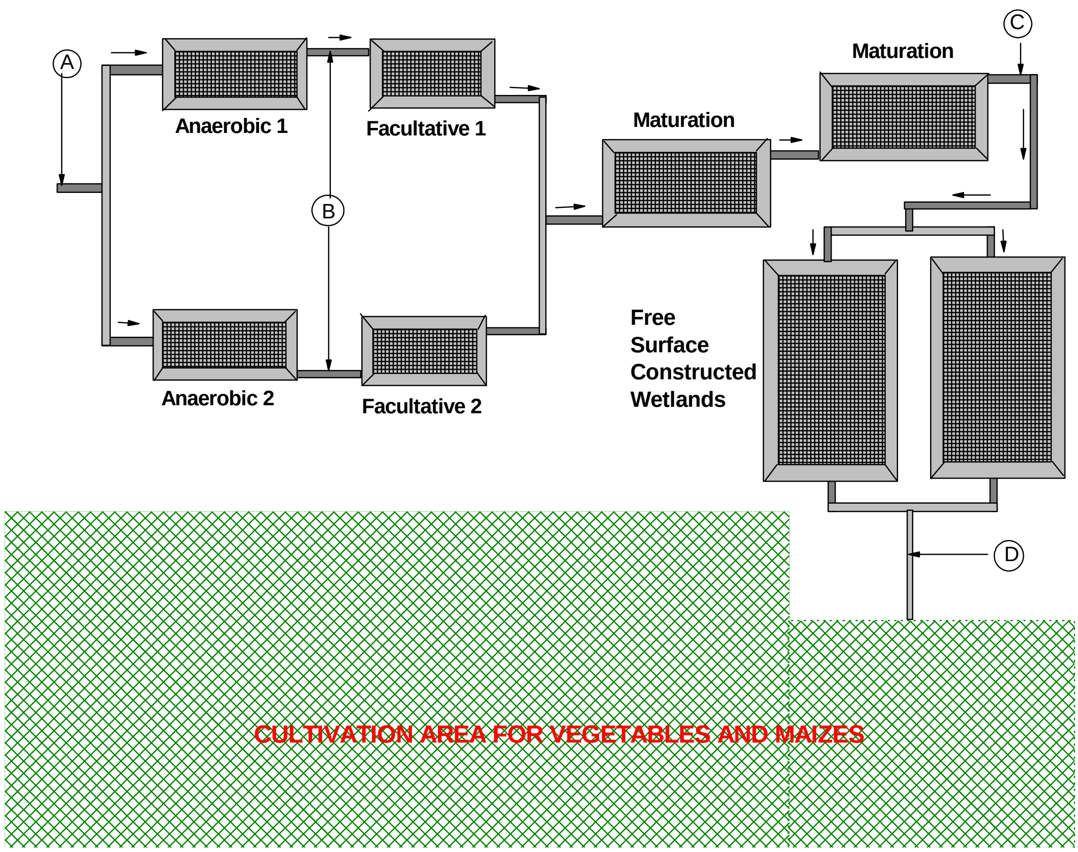

Figure 3.1 The layout of Iringa Municipal wastewater treatment plant comprises sampling points (A) inlet strainer partial flume (B) outlet of anaerobic pond 1 and 2,

(C) outlet of the maturation ponds and (D) the outlet of constructed wetlands (On-site survey, 2012)

The Iringa Municipal wastewater treatment plant receives a huge amount of wastewater and effluent from septic tanks. Due to the low quality of the effluent from the maturation ponds, a free surface constructed wetland was added to the end of the maturation pond in 2012 to polish the effluent from the maturation ponds.

3.3.2 Reuse of Municipal Wastewater Treatment plant effluent

The effluent from free surface constructed wetland is discharged at Hoho Street. People use effluent from the Iringa Municipal wastewater treatment plant downstream to irrigate several crops (Figure 3.2)

(a) Free surface constructed wetland

(b) Cultivation of vegetables downstream of free surface constructed wetland

Figure 3.2 Free surface constructed wetland (a) at Iringa Municipal wastewater treatment plant polishes effluent used for irrigation (b).

Downstream of the Iringa Municipal wastewater treatment plant, leafy vegetables like lettuce, matembele, and spinach are usually irrigated even on the day of harvest, resulting in high risk to consumers. Each day without watering allows natural pathogen die-off, especially for bacteria and viruses.

3.3.3 The Performance of Iringa Municipal Wastewater Treatment Plant

According to Metcalf and Eddy (1991), typical values for the five-day biological oxygen demand (BOD_5) of untreated domestic wastewater are between 110 mg O_2/L and 400 mg O_2/L for weak to strong wastewater, while the BOD_5 of typical septage varies between 2,000 mg O_2/liter and 30,000 mg O_2/liter. The influent to the Iringa Municipal wastewater treatment plant has BOD_5 levels that vary from 700 mg O_2/L to 3600 mg O_2/L. The influent to the Iringa Municipal WWTP contains unusually high levels of organic matter, and during some months could be classified as septage rather than untreated wastewater influent.

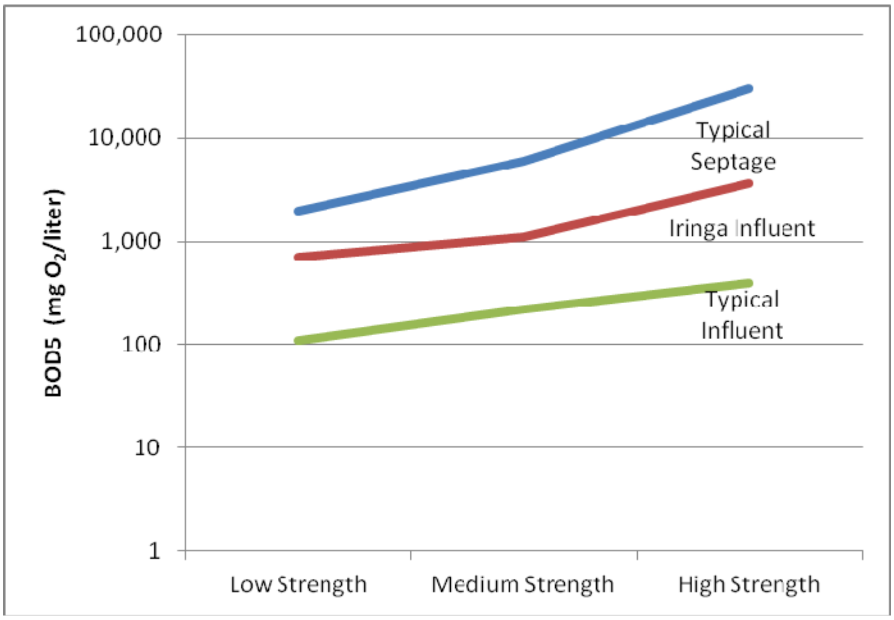

Figure 3.4 The influent to the Iringa Municipal wastewater treatment plant has unusually high BOD_5, plotted on a logarithmic scale

As shown in Figure 3.4, the waste stabilization ponds at the Iringa Municipal wastewater treatment plant are responsible for a large reduction in BOD_5, while constructed wetlands do not significantly reduce the BOD_5. Influent is more concentrated in May, and more dilute in October. In order to analyze data with such a large variation in BOD_5, it is necessary to plot the influent and effluent on a logarithmic scale.

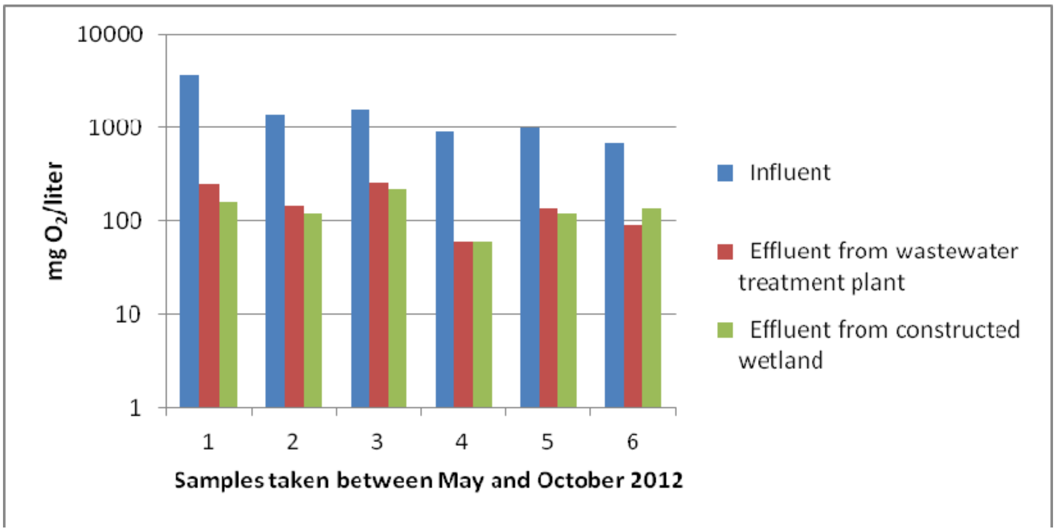

Figure 3.5 Iringa Municipal wastewater treatment plant, BOD_5 in the influent and effluent plotted on a logarithmic scale

The reduction in the five-day biological oxygen demand in the effluent as it passes through the constructed wetlands is so slight that it is necessary to plot the effluent data on a linear scale, as shown in Figure 3.5. Replotting the effluent data shows that most months the constructed wetlands cause some reduction in the BOD_5 of the effluent. Averaging the results for all months shows that the constructed wetlands reduce the BOD_5 of the effluent by an average of 5% during this period. According to Professor K. Njau (personal communication, 2013) this is attributed to wrong placement of the CW which is receiving effluent from the last maturation pond. This pond is full of algae and the algae tend to decompose as it travels through the CW releasing BOD in the system. The sampling is also a problem because the water samples for analysis of BOD are not filtered. This will contain both the dissolved organic and the suspended organic particles in form of algae. During BOD determination the algae will tend to decompose again releasing BOD_5 into the sample. The net reduction observed is therefore very low.

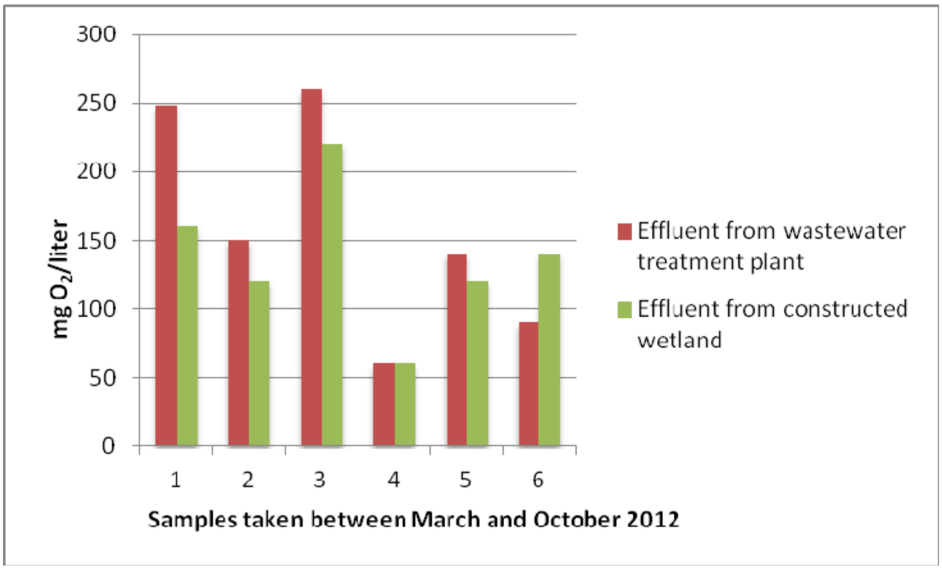

Figure 3.6 Iringa Municipal wastewater treatment plant effluent BOD_5 (mg O_2/liter) from the wastewater treatment plant and the constructed wetlands plotted on a linear scale

By comparing Figure 3.7 with Figure 3.5, we can see that the chemical oxygen demand (COD) of the influent appears to be barely higher than the BOD_5, indicating that nearly all of the organic matter in the influent flow is biologically active.

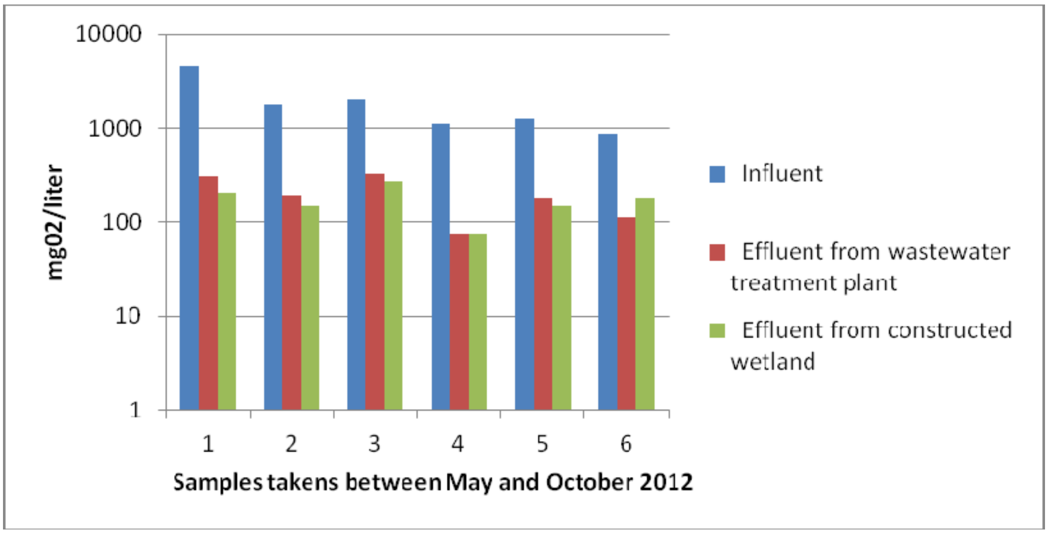

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Figure 3.7 Iringa Municipal wastewater treatment plant chemical oxygen demand (mg O_2/liter) in influent and effluent plotted on a logarithmic scale

As shown in Figure 3.7, the waste stabilization ponds in Iringa are responsible for a one-log reduction in chemical oxygen demand, while the constructed wetlands do not significantly reduce the chemical oxygen demand of the effluent.

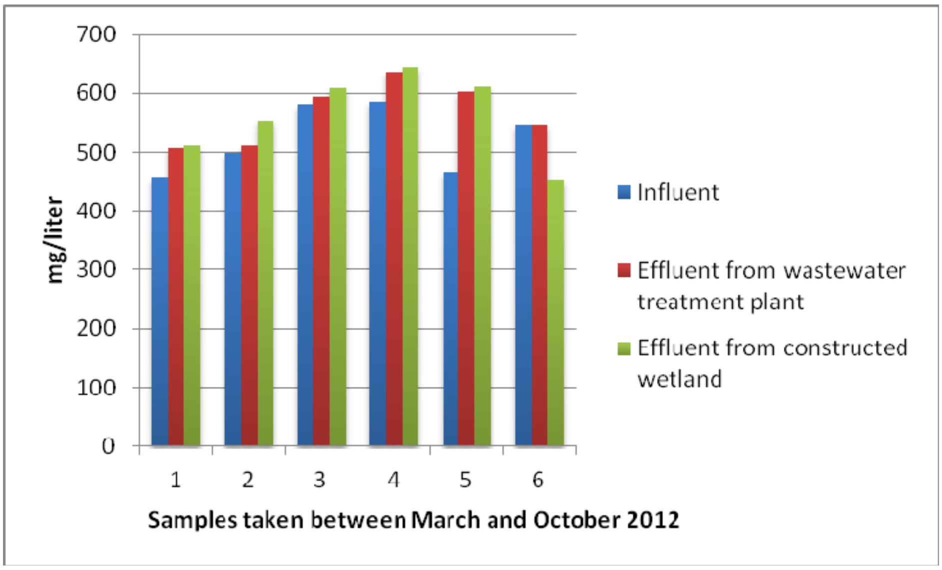

Figure 3.8 Iringa Municipal wastewater treatment plant Total Dissolved Solids (mg/liter) in influent and effluent

According to Metcalf and Eddy (1991), the influent total dissolved solids (TDS) for wastewater ranges from 250 mg/L to 850 mg/L, depending on whether the influent is weak or strong. We can see in Figure 3.8 that the level of total dissolved solids in the influent to the Iringa Municipal wastewater treatment plant is comparable to a medium strength wastewater. Referring back to Figure 3.4, where the five-day biological oxygen demand of the influent flows is shown to be comparable to low strength septage, we can see that the total dissolved solids of this influent is surprisingly modest, and usually increases as the wastewater makes its way through the waste stabilization ponds and the constructed wetlands.

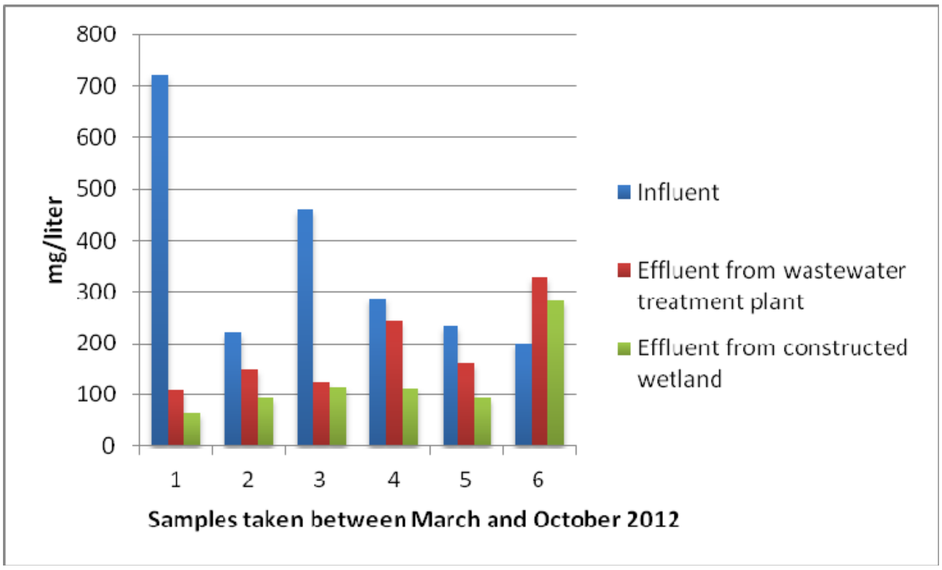

Figure 3.9 Iringa Municipal wastewater treatment plant Nitrogen levels (mg/liter) in influent and effluent, plotted on a linear scale.

As shown in Figure 3.9, most months the total nitrogen content of the Iringa wastewater is reduced by wastewater treatment and the constructed wetlands.

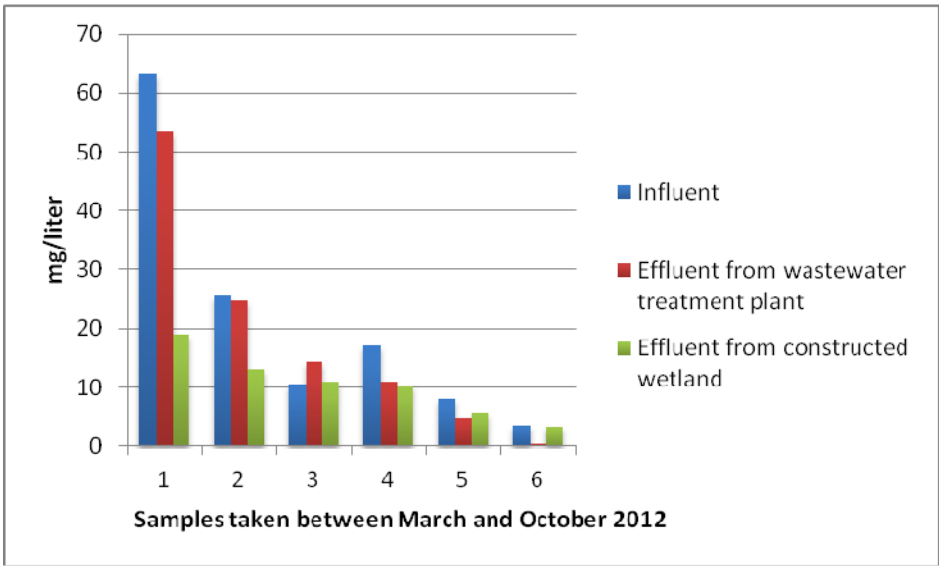

Figure 3.10 Iringa Municipal wastewater treatment plant Phosphate levels (mg/liter) in influent and effluent plotted on a linear scale.

The phosphates in the Iringa wastewater are shown in Figure 3.10. Like the total nitrogen, another fertilizer, the phosphate levels are modestly reduced by the wastewater treatment plant and the constructed wetlands.

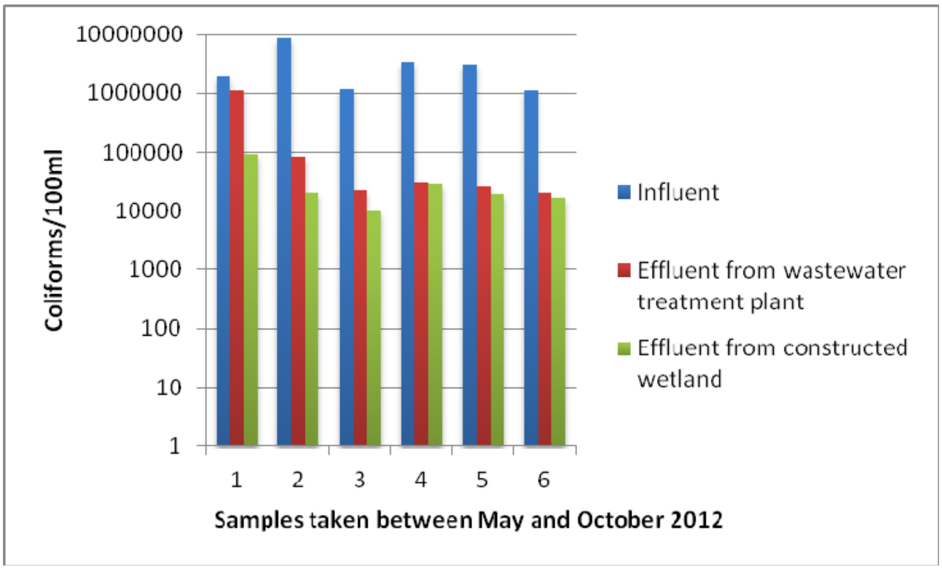

Figure 3.11 Iringa Municipal wastewater treatment plant coliform counts (coliforms/100ml) in influent and effluent

As shown in Figure 3.11, faecal coliform counts at the Iringa Municipal wastewater treatment plant are far above the 1,000 coliforms/100ml allowed by the WHO standards. However, we can also see that the coliform counts have been reduced by roughly 99%, or 2-logs. In addition, we see the constructed wetlands are particularly helpful in reducing the faecal coliform count. Some months, the effluent from the constructed wetlands is substantially cleaner than the effluent from the waste stabilization ponds.

Generally the reuse of the wastewater in Iringa can be widely viewed as an agricultural source of water supply and fertilizer. According to FAO (1992), the estimated typical wastewater effluent from domestic sources could supply all of the nitrogen and much of phosphorus and potassium that are normally required for agriculture production. However, there are disadvantages and risks related to wastewater reuse: irrigation workers and food consumer are exposed to faecal borne pathogens. The use of partially treated of wastewater from the Iringa Municipal wastewater treatment plant can pose health risks even though the gross contaminants have been removed by wastewater processing and the effluent appears to be relatively clean. If the water users and consumers are unaware of the pollution content of the effluent, they are less likely to protect themselves from possible adverse effects.

3.3.4 Kleruu Teachers' College Constructed Wetland

Kleruu Teachers' College is one of two schools in Iringa treating typical domestic water using constructed wetlands. The Klerruu constructed wetlands system is comprised of a pretreatment unit and constructed wetland units planted with phragmites (Figure 3.12).

(a) Pretreatment of wastewater before the constructed wetland system at Klerruu Teachers' College

(b) Constructed wetland at Klerruu Teachers' College

Figure 3.12 The pretreatment facility (a) and (b) the constructed wetland at Klerruu Teachers' College in December 2012. The phragmites are healthy, implying the possibility of good performance of the system.

The effluent from the Klerruu constructed wetland system is directed downstream into the receiving body, which is a storm drain that connects with a stream.

According to data collection and observations, there are multiple uses of the effluent downstream of the constructed wetland in Klerruu Teachers' College as shown in Figure 3.13. The wastewater from the wetlands was mostly used for agricultural irrigation (58.8%), followed by illegal recreation for children (23.5%) and brickwork construction (11.8%). Other uses included watering flowers and drinking water for cattle weighted by 5.8%. Reuse of effluent for domestic uses and for aquaculture were not observed (0%).

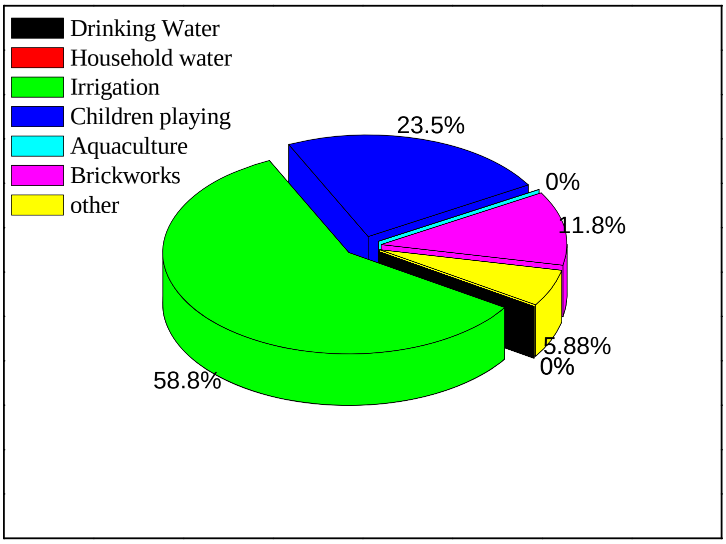

Figure 3.13 Reuse of effluent downstream of Klerruu Teachers' College (On-site survey, 2012).

The reuse of effluent for irrigating vegetables downstream of the Klerruu constructed wetland varies between the dry and rainy seasons. In the dry season, the irrigation practices were mainly depending on the wastewater, while in the rainy season the effluent was diluted by rain, reducing the concentration of wastewater and hence the associated health risk. As can be seen in Figure 3.14, the effluent from the wastewater treatment plant has a higher BOD_5 in the dry season than in the rainy season.

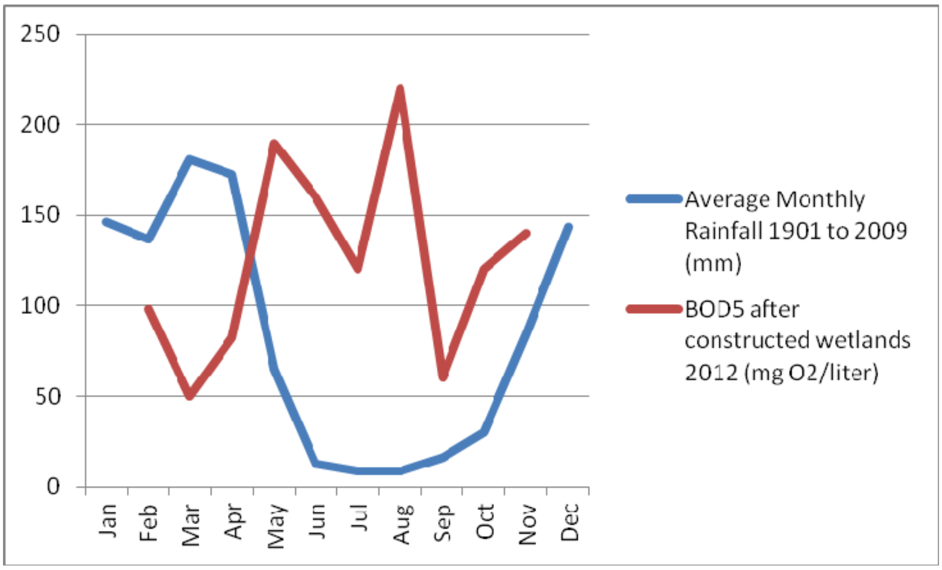

Figure 3.14 Wastewater concentration by month in 2012, and average monthly rainfall in Tanzania 1901 to 2009. (Source: World Bank Climate Change Knowledge Portal, Climate Research Unit, University of East Anglia; IRUWASA effluent data.)

(a) Some tomatoes irrigated with effluent downstream of Klerruu Teachers' College constructed wetlands

(b) The mixture of maize and vegetables downstream of the Klerruu Teachers' College constructed wetlands

Figure 3.15 Crops irrigated by the effluent from constructed wetlands at Klerruu Teachers' College observed December 2012.

There is a diversity of crops irrigated with effluent downstream of the Kleruu constructed wetlands. The most common crops were tomatoes, maize, bananas, taro, potatoes, onions, cabbage, eggplant, and spinach (Fig. 3.13).

Another considerable use of the effluent observed was the manufacture of bricks (11.8%). A local construction company has been established downstream, and it uses the effluent from the constructed wetland for construction activities. According the manager of the company, the reuse of the effluent for the construction work has saved a lot of money. The workers in this company are not using any protective gear.

Although the reuse of wastewater for aquaculture is not common in this region, some fish species were found in the effluent downstream of Klerruu constructed wetland, and children from nearby schools like to catch the fish by using local nets and the mosquito nets. During the survey done in the present study, the children from Lugalo Secondary School were found fishing in the effluent without protective gear (Figure 3.16). It is a normal tendency for students close to the stream to practice fishing during the tea break and lunchtime, which accounts for 23.5% of the effluent reuse from the constructed wetland. This practice exposes schoolchildren to wastewater.

(a) Students fishing in effluent stream (b) Students playing in the garden

Figure 3.16 Some students from Lugalo Secondary Schools near stream (a) fishing while others are (b) playing in the garden irrigated with effluent downstream from the constructed wetland.

Other reuse of effluent includes drinking water for cattle and construction works. (Fig 3.13).

3.4 Assessment of exposure to workers downstream of Kleruu constructed wetland

There is no regular monitoring of the performance of Kleruu constructed wetland. Since wetlands have not been proved to remove all pathogens in wastewater, there is a possibility that the effluent poses health risks to consumers. The irrigation practices and types of crops cultivated were examined downstream of Kleruu constructed wetlands.

The present study revealed that the reuse of effluent varies between rainy season and dry season. During the dry season, the effluent from the constructed wetlands is used as irrigation water. In this period the vegetables are more valuable to farmers and consumers. Generally, in dry season the availability of the vegetables is very low resulting in high prices. Therefore most of the farmers shift to vegetable cultivation in the dry season. The intensive cultivation of vegetables in the dry season increases the health risk to farmers from exposure to wastewater since they are in contact with wastewater from farm preparation to harvest.

During the rainy season, the water availability is high and the price of vegetables is lower. This situation encourages the farmers downstream to grow maize instead of vegetables. This implies that in the dry season, the health risk is higher to farmers due to the exposure to wastewater, and to the consumer since the crops are directly consumed as salads. The exposure risk to the farmer is minimal during the rainy season. The effluent from the wetland is weaker since it is highly diluted with the storm water. The consumer risk also is very minimal due to the type of crops produced: maize is not consumed directly until it has been processed.

Apart from workers and consumers, the students and children playing in the effluent and gardens downstream of the constructed wetlands may be at high risk of contracting diseases associated with wastewater.

3.4.1 Exposure time of Workers to effluent from the constructed wetlands

Exposure time in the present study is defined as the duration of time workers spend in contact with wastewater during the reuse of wastewater. The exposure time depends on how the wastewater is reused. For instance in aquaculture, the worker spends more time in contact with the effluent than during fishing. When effluent is used for irrigation, the exposure time depends on the type of crops and the stage of cultivation, while in the brick works the exposure time depends on the production of bricks per day. From the questionnaire conducted downstream at Kleruu Teachers' College constructed wetlands, the workers spend between 2 and 5 hours per day in the preparation of their farms. However during this time they do not effectively utilize the effluent from the constructed wetlands (Table 3.4). The most vulnerable time for the workers is during irrigation where the effluent is used to water the plants. During irrigation, the workers spend between 2 and 4 hours in contact with the wastewater.

Table 3.4 Exposure time for workers using wastewater for irrigation at different stages of cultivation

Cultivation Stages	Exposure time (Hrs/day/person)
Preparation of farms	2-5
Planting	1-3
Irrigation	2-4
Weeding	1-3
Harvesting	2-4

In general people living downstream of the Iringa Municipal wastewater treatment plant and Klerruu Teachers' College constructed wetlands benefit economically from reuse of wastewater effluent in irrigation. Availability of water is the most important determining factor for whether the farmer cultivates seasonally or year round. Downstream from the wastewater treatment plant, the effluent is available throughout the year. This explains why vegetable growers in Iringa are mostly located downstream of the Iringa Municipal wastewater treatment plant and constructed wetlands. The greatest benefit of using wastewater for irrigation, apart from its nutrient load, is that effluent flows are reliable and easily accessed. Cultivating vegetables downstream from constructed wetlands and wastewater treatment plant makes it easier for the farmer to obtain much needed water for irrigation.

3.4.2 Assessment of Exposure Arusha: Wastewater Helminths

A primary exposure route for urban populations in general is the consumption of raw vegetables that have been irrigated with urban wastewater (Scott et al., 2004). Therefore, factors needing to be considered include survival of the pathogens in the environment and numbers of pathogens present before wastewater reuse.

If wastewater has a high faecal coliform count, there is the possibility that this wastewater carries disease associated with human faeces. While the faecal coliform count is an indirect marker for the health risk associated with wastewater, the number of helminth eggs in a wastewater sample is a direct marker for the level of helminth infestation in the sewered population (Seidu, 2011).

In Arusha, Tanzania, wastewater samples were analyzed for the presence of helminth eggs (Marwa, 2011). A rich and varied assortment of thousands of helminth eggs was found in wastewater samples taken in Arusha (Figure 3.17).

Helminth eggs resist chlorine disinfection and are relatively large (Metcalf and Eddy, 2003). Helminth ova measure between 20 and 80 μm, and their gelatinous outer layer makes them sticky. The size and stickiness of the helminth eggs determines how they behave during wastewater treatment.

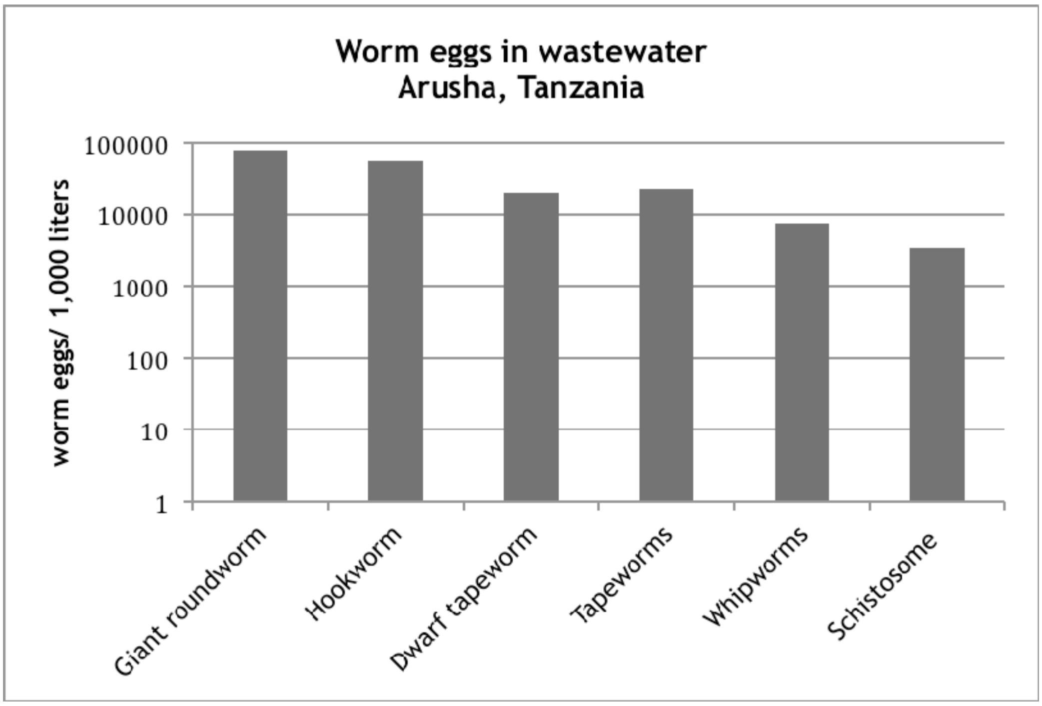

Figure 3.17 Helminth eggs found in municipal wastewater treatment plant in Arusha, Tanzania

The helminth egg has multiple layers of protection. The outer one or two layers are made of mucopolysacharides and proteins. The middle chitinous layers provide structure and mechanical support to the eggs, while the inner layer of lipids and proteins maintain the egg's moisture content while physically protecting the protoplasm. These combined layers protect the eggs in many environmental conditions, including strong acids and bases, oxidants and reductive agents as well as detergent and proteolytic compounds (Jimenez-Cisneros, 2007). Helminth eggs are unaffected by lime (calcium carbonate), mesophilic digestion or vermi-composting (composting with earthworms).

All of the commonly used wastewater treatment processes have been analyzed with respect to their removal rates for bacteria, helminths, protozoa and bacteria. Some processes are more effective than others at pathogen removal, and the waste stabilization ponds are particularly efficient at removing all kinds of pathogens.
According to Feachem et al. (1983), waste stabilization ponds remove up to 6 log units of helminths ova and bacteria compared to 1 to 4 log units removal of virusesand five-day biological oxygen demand. Helminth ova settle out through sedimentation. Removing helminth ova requires a minimum retention time of 5–20 days, depending on the initial content.

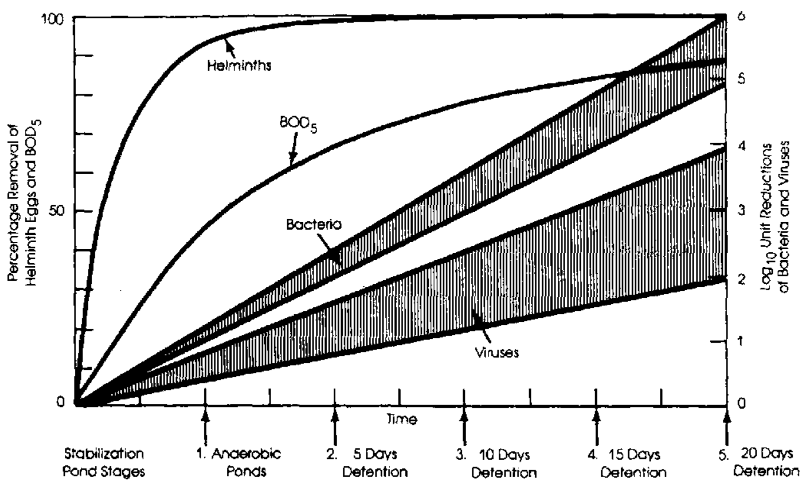

Figure 3.18 Percentage removal of helminth eggs and BOD_5 in waste stabilization ponds; log removal of bacteria and viruses (Feacham, 1983)

When a helminth egg enters the waste stabilization pond, its sticky surface attracts other suspended solids and the clump sinks to the bottom of the pond. The reduction in total suspended solids is the best proxy for helminth removal, and the reduction in BOD_5 is another stand-in for direct measurement of helminth removal from the effluent. When it comes to waste stabilization ponds, helminth eggs come in, and they don't come out.

Schistosoma eggs on the other hand hatch as soon as they find fresh water. The miracidia which emerge from the egg are viable for about 48 hours (IARC, n.d.). If they cannot find *Bulinus, Biomphalaria*, or *Oncomelaria* snails, the life cycle ends.

Wastewater from Arusha, Tanzania was tested as influent at two points during wastewater treatment, and at the exit of the waste stabilization pond system (Marwa, 2011). We find the reduction of helminth eggs in wastewater to be more complicated than the simple theoretical curve sketched above.

The whipworm eggs from Trichuris trichuira were completely eradicated. The dwarf tape worm and the tapeworm eggs from Hymenolepis nana and Taenia were very responsive to treatment, and well within WHO standards for unlimited irrigation. Likewise, the giant roundworm eggs and hookworm eggs were initially exceedingly plentiful, and were reduced to levels that met the WHO standards for unlimited irrigation. But all helminth eggs are not the same. Of the six type of worm eggs that were tested for, two types of worm eggs appeared particularly persistent: *Schistosoma haematobium* and *Schistosoma mansoni* eggs. While all of the other worm eggs experienced reduction from 99.3% to 100%, the eggs associated with schistosomiasis seemed to show a reduction of roughly 82%.

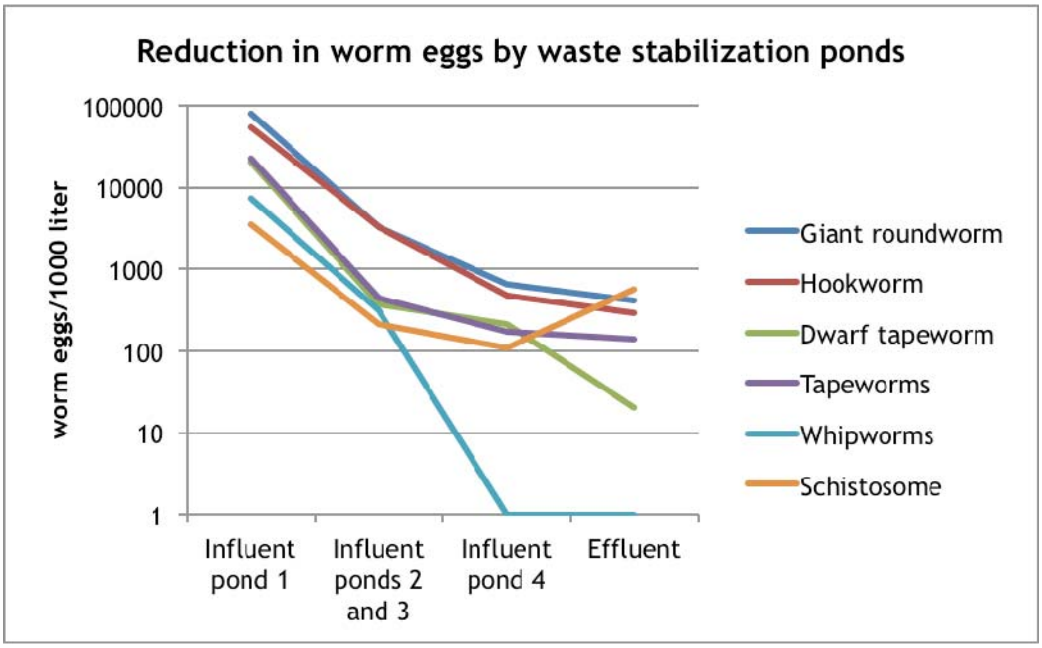

Figure 3.19 Reduction in helminth ova in wastewater before, during and after treatment in waste stabilization ponds

It is important to note that this effluent meets the WHO standards for unrestricted irrigation used for every type of worm eggs that were tested for. However, *Schistosoma* eggs appeared to be the *least* common worm eggs in the influent, and seemed to be the *most* common worm eggs found in the effluent. Processing the wastewater through waste stabilization ponds seemed to effectively select for the eggs of worms associated with schistosomiasis.

3.4.3 Rapid Assessment of Pathogen Exposure in four Municipal Waste Stabilization Ponds

In order to understand the implications of Marwa's data better, a rapid assessment of the four municipal sewer systems of Arusha, Iringa, Moshi, and Morogoro was conducted. No pathogens were found in the samples of Arusha, Iringa, and Moshi. This may because the samples were only ten litres and/or the parasite load is not heavy. In Arusha, the same site as Marwa reported from, the influent now includes industrial wastewater with foam as shown in the photos below.

Figure 3.20 Photos taken in August 2013 at the Arusha Municipal Sewage Treatment System showing evidence of industrial effluent.

This may have affected the biological residents of the sewage treatment ponds.

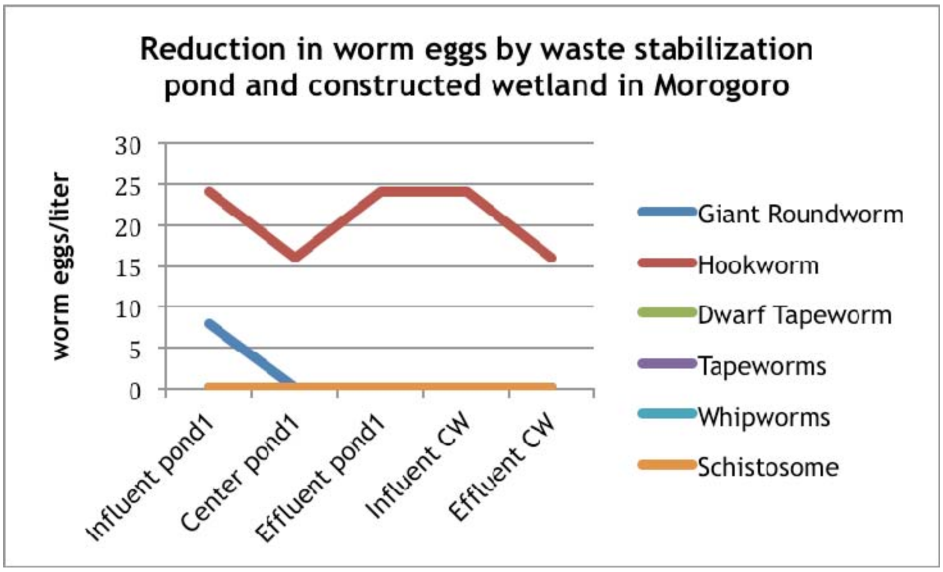

Figure 3.21. Reduction in worm eggs by waste stabilization ponds and constructed wetlands in Morogoro

The figures above shows that the samples from Morogoro contained the same pathogens, and in the same order of frequency as were observed by Marwa in her study with larger samples (1000 liters) from Arusha.

Also reported in Morogoro were *E.histolytica*, rat tapeworm, *Isospora belli*, as well as *E. coli*. Hookworm eggs were the most plentiful and most persistent. That they survived passage all through the constructed wetland is discouraging. This may partially be attributed to the fact that the wetland was only planted three months earlier and is not working efficiently yet.

Intact *Schistosoma* eggs were not found in Morogoro sewage treatment system. The MUHAS laboratory scientist A. Zachariah reported seeing numerous “things” that resembled *Schistosoma haemotobium* eggs as shown in the photos below.

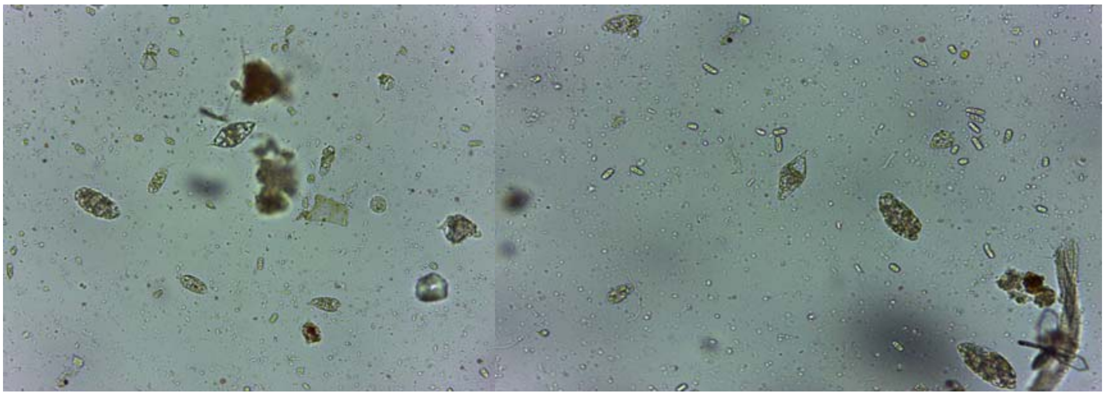

Figure 3.22. Wastewater Samples from Morogoro, focusing on possible *Schistoma* molts/shells. Photo by Abdallah Zachariah.

Zachariah reported, and as can be seen in the above photo, that:

1. They were seen to be small in size under the Microscope compared to the normal *Schistosoma haemotobium* eggs
2. Their shape and size are not uniform
3. They lack internal structures of the normal *Schistosoma haemotobium* eggs.

For the life cycle of the schistosome to continue, the eggs in the stool or urine must find fresh water. The eggs hatch when they come into contact with water. Could these irregular “egg shapes” be molts left behind when the eggs hatched and the miracidia swam off to find a snail host?

Miracidia are viable for about 48 hours. If they do not find an appropriate snail host, the life cycle ends. This demonstrates the importance of identifying if there are snail hosts living in the sewage treatment ponds. If there are no *Biomphalaria*, *Bulinus, or Oncomelaria* snails (Mazigo et al., 2012), wastewater treatment ponds could be an effective way of ending the *Schistosoma* life cycle. Unfortunately we do not know if there are snails in the sedimentation ponds at any of the municipal sites.

3.5 Diseases Associated with the Exposure risk

These data sets confirm that people are exposed to potential harm as a result of contact with wastewater. The major concerns are helminths including schistosomiasis. It seems that wastewater treatment workers, users of the effluent such as farmers, their families, children, brick makers, fishermen and the consumers of vegetables irrigated with effluent are at risk for becoming infected with helminths, either through people ingesting helminth eggs or through the hookworm larvae or *Schistosoma* cercariae penetrating the skin.

They also confirm that danger is mitigated through the treatment system in Iringa. In Iringa, irrigators watered their fields through diversions or by carrying buckets to the fields, so their exposure was probably minimal.

Despite the potential risk and ignorance of potential danger, the wastewater from Iringa and Arusha Municipal wastewater treatment plants offer a livelihood to many of the urban poor, and fields irrigated with this nutrient-rich water are an important source of fresh produce.

Limitations

Unfortunately we have no records of the health status of the people exposed to these specific risks. The updated atlas for helminth infections also has no data recorded from Iringa or Arusha regions. In addition, sludge was not measured for helminth ova. It is not known if *Bulinus* or *Biomphalaria* snails are in any of the sewage treatment ponds.

CHAPTER FOUR

4.0 Defining control approaches

4.1 Prevention

Amidst all the data and studies reported in Chapter 2, the practical experience in Chapter 3 provides an urgent message towards prevention of disease. Prevention, where actions are taken to prevent the occurrence of disease, is the most just and equitable way of dealing with disease threats (Prüss-Üstün and Corvalán, 2006). Primary prevention seeks to prevent the onset of disease by altering behaviors or exposures that can lead to disease, or by enhancing resistance to the effects of exposure to a disease agent (AFMC, 2013). Preventing disease before it arises diminishes the health burden borne by the population and eliminates associated health-care treatment costs. Prevention is the most humane and cost effective approach to care.

Environmental modification to improve human health has many advantages over attempting to "cure" people once they become ill (Prüss-Üstün and Corvalán, 2006). Diseases (including most of Tanzania's top killers) can be prevented before they arise, saving on treatment costs. In addition, such interventions are generally more sustainable than treatment, and have longer-term impact. Environmental modification is often the most equitable option, with benefits felt across broad groups and populations.

Communicable diseases and toxins are especially susceptible to community standards. For example in Egypt, level of schistosomiasis infection has been shown to be related to the proportion of households with sewage connections, but sewage connection cannot be correlated to non-infection at the household level (El Katsha and Watts, 1997). In other words, schistosomiasis was shown to be a social disease that correlated to the number of people in the community who were connected to sewerage, but not to actions taken at the individual or household level.

The prevalence of helminth infections in the world correlates clearly with sanitation coverage. The infection rates of the population, particularly children, in low-income countries can be very high. The primary objective of wastewater treatment in low-income countries such as Tanzania is to remove pathogens--disease-causing organisms including bacteria, viruses, fungi, protozoans, and helminths--from the effluent. Wastewater treatment systems can be effective as preventive environmental modifications that protect human health.

4.2 Interventions

4.2.1 Reducing helminth ova in wastewater effluent

One method of reducing helminthiasis in Tanzania is to reduce the concentration of helminth ova in wastewater effluent used for irrigation. Waste stabilization ponds and constructed wetlands are two methods of wastewater treatment that remove helminth ova from the effluent.

4.3 Waste Stabilization Ponds

Waste stabilization ponds are large manmade water bodies that are filled with wastewater that is then treated by naturally occurring processes. The ponds can be used individually, or they can be linked in a series for improved treatment. There are three types of ponds: anaerobic, facultative and aerobic, each with a different treatment modality and design characteristics. Anaerobic ponds are two to five meters deep with detention times of one to seven days. Anaerobic bacteria convert organic carbon in the wastewater into methane and remove up to 60% of the biological oxygen demand in the process; they are capable of treating strong wastewater. The second pond is typically a facultative pond of one to two and a half meters with detention times of five to thirty days. Both aerobic and anaerobic processes occur: the top layer of the pond receives oxygen from wind mixing, natural diffusion, and algae-driven photosynthesis, while the lower layer is anaerobic. Solids settle out and accumulate in the bottom of the pool, and the biological oxygen demand of the wastewater is decreased up to 75%. A third aerobic pond is the shallowest pond in the series with a depth of one half to one and a half meters. This ensures that sunlight penetrates the full depth of the pond, driving photosynthesis. The first two ponds are designed to reduce BOD while the third pond, or polishing pond, reduces pathogens in the effluent (von Sperlin and de Lemos, 2005; Crites and Tchobanoglous, 1998).

The use of waste stabilization ponds to recycle wastewater for agriculture is recommended in low and middle income countries with warm climates if land is available at a reasonable price (Jimenez-Cisneros, 2007). The pond system is characterized by minimal energy requirements, and functions well during changes in wastewater volumes and load. Waste stabilization ponds have been used for the treatment of various kinds of wastewaters, including industrial and domestic, in low-income as well as high-income countries (Kouraa et al., 2002).

Waste stabilization ponds can be very efficient at removing all kinds of pathogens. They remove up to 6 bacteria log, up to 5 viruses log and almost all the protozoa and helminth ova. These performances are higher than those observed in conventional processes (12 bacteria log and 70-99% of protozoa and helminth ova) without disinfection, as is the case of the activated sludge process. Several factors contribute to producing this efficiency, including sedimentation, temperature, sunlight, pH, microorganism predation, adsorption and absorption. Helminth ova are typically removed by sedimentation. To effectively remove helminth ova in waste stabilization ponds requires a minimum retention time of 5 to 20 days, depending on the initial content.

4.4 The use of Constructed wetlands for Wastewater treatment

In the 1950s, Dr. Seidel in Germany was the first researcher to experiment with using wetland plants to treat wastewater, and the first full-scale systems were built in the late 1960s. Since then, subsurface systems have become common in Europe while free water surface systems are more popular in Australia and North America. Constructed wetland technology spread slowly, but since the 1990s the technology has become international. Today, constructed wetlands are recognized as a reliable wastewater treatment technology and are used to treat many types of wastewater (Vymazal, 2010).

Constructed wetlands can successfully remove a variety of pollutants from the water that passes through them, including pathogenic bacteria, viruses, and protozoa (Stott et al., 2002). Constructed wetlands have medium bacterial and viral removal efficacy, and pathogen removal is variable, depending upon a variety of factors. Removal rates for faecal coliforms (commonly greater than 99%) generally equal or exceed those described for conventional biological wastewater treatment processes (Nuttall et al., 1998). According to WHO Guidelines (2006), constructed wetlands may not be as effective in cleaning wastewater as waste stabilization ponds; instead, constructed wetlands have an added effect or polishing effect on the effluent from waste stabilization ponds. Subsurface flow wetlands are more effective than free-surface flow wetlands at removing human pathogens.

A variety of processes are involved in removing pathogens and parasites from wastewater in constructed wetlands. According to Stott et al. (2002) these include: mechanical filtration through the substrate and attached biofilm, sedimentation, aggregation, oxidation, exposure to natural biocides, antibiosis, predation, attachment by lytic bacteria and viruses, natural die-off and competition for limiting nutrients or trace elements. One of the main capacity limitations of horizontal subsurface flow constructed wetlands systems is their tendency to clog when subjected to high levels of organics and suspended solids (Winter and Goetz, 2003). Since most important degradation processes require aerobic conditions, clogging of the substrate matrix hinders oxygen transport and can result in failure of the performance of the system (Harbel et al., 2002).

4.4.1 Reduce Helminth Ova in Sludge

Using a series of waste stabilization ponds followed by filtration in constructed wetlands can provide high quality effluent that is suitable for reuse as irrigation water. However, the helminth ova removed from the effluent are transferred to the biosolids that settle at the bottom of the waste stabilization ponds. These biosolids are a high quality soil amendment and are sought by farmers for land application to improve soil structure and crop yields. Unless the sludge is treated before land application, it will serve as a pathway for helminth transmission to farmers and to people who purchase crops grown on sludge-amended soil (Strauss, 2000).

Table 4.1 Helminth ova in sludge from waste stabilization ponds

Country	**Source of sludge**	**Helminth eggs/gram total solids (% viable)**
Campina Grande, Brazil	Waste stabilization ponds in series	1400-40000 eggs/gram total solids (2% to 8%)
Toluca, Mexico	Waste stabilization pond	48-136 eggs/gram total solids (0% - 50%)
Bangkok, Thailand	Waste stabilization ponds in series	170 eggs/gram total solids (0.2% to 3.1%) after 3.5 years
Chiclayo, Peru	Primary facultative ponds	60-260 eggs/gram total solids (1% to 5%) after 4-5 years

(Source: Modified from Jimenez-Cisneros and Maya-Rendon, 2007.)

As we can see in Table 4.1, sludge from waste stabilization ponds typically contains large numbers of helminth ova that remain viable after years of underwater storage.

Without further processing, land application of this sludge will allow these helminth ova to contaminate the soil. The farmer hoping to increase crop yields by amending fields with this sludge is probably not considering the probability of increased helminth infections as well.

4.4.2 Long-Term Sludge Storage

Possible treatment methods to inactivate helminth eggs in sludge include long-term dry storage and thermophilic composting (WHO, 2006, volume 4).

Table 4.2 The reduction of the viability of helminth eggs in sludge stored for different periods

Type of Sample	Treatment	Reduction of helminth egg viability
Sludge artificially infected with *Toxocara canis, Trichuris vulpis, Trichuris suis, Ascaris suum* and *Hymenolepis diminuta*	Storage for 3 month at 25°C	5% -40%
	Storage for 1 year at 25°C	70%-100%
Ascaris eggs in sludge	7 months of storage at 0 to 20°C	10%
Ascaris eggs in sludge	storage for 1 year	50%
	storage for 3 years	100%

(Source: Modified from Gallizzi, 2003.)

As shown in Table 4.2, storing the sludge at temperatures ranging from 0°C to 20°C for three years or at 25°C for over one year can completely eradicate the viable helminth eggs in sewage sludge. If there is sufficient land area to stockpile sludge for an extended period of time, the rate of helminth infection caused by the land application of sludge can be reduced to zero.

4.4.3 Thermophilic composting of sludge

To inactivate helminth eggs in less than a year, it is recommended to either compost or dry the sludge. More specifically, the sludge temperature must exceed 40ºC, or sludge moisture must be reduced to below 5% (Jiménez, 2008). In parts of the world with a regular rainy season, including Tanzania, it may be impractical to dry sewage sludge. Therefore we will look more closely at sludge composting.

The most commonly used method of composting is the windrow process, where sewage sludge is mixed with organic wastes and stacked into long windrows that are regularly turned. Windrows should be 3 to 5 feet tall and have a base width of about 10 to 15 feet. Air moves through the porous composting material from the bottom up through the top, removing released moisture and excess heat.

To promote aeration, composting materials need to have enough pore space to allow air to flow freely through the matrix, and they need added carbon to help microorganisms break down the organic matter. Bulking agents are used to increase the porosity of fine-textured sewage sludge and to absorb excess moisture. Suitable bulking agents include sawdust, peanut hulls, corncobs, wood chips, rice hulls and brush trimmings. Depending on the particle size and the initial moisture content of the sludge, the amount of bulking agent can range from less than 1:1 by volume to more than 5:1 (Outwater, 1994).

Aerobic, thermophilic composting is said to begin when the temperature reaches 45 degrees C. After that, the temperature usually rises rapidly as heat is released by the breakdown of complex molecules or organic matter to simpler compounds. The peak temperature may exceed 65 degrees C. As pile temperatures approach 70 degrees C the piles should be turned, cooled the composting sludge and increasing the aeration.

The windrows should be turned several times per week initially, and less often later in the composting process. The compost is then stockpiled for curing, during which final degradation occurs. During composting, susceptible pathogens are almost completely destroyed by high temperatures and competition with thermophilic organisms. The

U.S. Environmental Protection Agency regards composting temperatures of 40 degrees C for 5 days as a “process to significantly reduce pathogens” in sewage sludge. To be classified as a “process to further reduce pathogens,” which is considered equivalent to pasteurization, a temperature of 55 degrees C must be attained for 15 days within windrows being turned at least five times (USEPA, 2002).

A 2007 study in Ghana examined the effects of windrow composting on helminth eggs in sewage sludge (Koné et al., 2007). Public toilet sludge and septage were mixed at a 1:2 ratio and dewatered on a drying bed. The biosolids had initial loads of 25-83 helminth eggs per gram of total solids. This material was mixed with solid waste as a bulking agent at a 1:2 volume ratio. Two sets of windrows were created, with one being turned every 3 days during the active composting process, and one turned every 10 days. Turning frequency had no effect on the helminth egg removal efficiency, and in both cases the helminth eggs were reduced to less than 1 viable egg per gram total solids, meeting the 2006 WHO guidelines for safe reuse of sewage sludge.

4.5 Changing agricultural practices to reduce helminth infections

When effluent from a wastewater treatment plant is used for irrigation and when wastewater sludge is used as a soil amendment, it is inevitable that some helminth eggs will come in contact with the farmers growing the crops, and with the crops themselves. Helminth eggs are sticky, and can adhere to fruit, vegetables, fingers, money, door handles, furniture and utensils (Kagei, 1983). The routes of transmission can be reduced by the measures listed in Table 4.3.

Table 4.3 Pathogen reductions achievable by selected health-protection measures

Control measures	Reduction (log units)	Comments
Drip irrigation for Low growing crops	2	Root crops and crops such as lettuce that grow just above, but partially in contact with, the soil
High growing crops	4	Crops such as tomatoes that grow above, but partially in contact with the soil
Pathogen die-off	0.5-2 per day	Die off on crop surfaces that occurs between last irrigation and consumption. The log unit reduction achieved depends on climate (temperature, sunlight intensity, humidity)

		time, crop type, etc.
Produce-washing with water	1	Washing salad crops, vegetables and fruit with clean water
Produce-washing with disinfection	2-3	Washing salad crops, vegetables and fruit with a weak chlorine solution and rinsing with fresh water
Produce peeling	1-2	Fruits, cabbage, root crops
Produce cooking	6-7	Immersion in boiling or close-to-boiling water until the food is cooked

Source: Adapted and modified from WHO (2006)

Drip irrigation is a method of irrigation where water is delivered directly to the plants through a series of valves, pipes, tubing and emitters. Using drip irrigation instead of flood irrigation can reduce the transmission of helminth eggs by two log units for root crops and lettuce or other crops that grow directly above the soil. For crops like tomatoes, using drip irrigation instead of flood irrigation can reduce the transmission of helminth eggs by four log units. Although it is a very efficient method of irrigation and is well suited to delivering effluent to crops, it is expensive to set up drip irrigation systems. Furrow irrigation can also protect crops from direct exposure to wastewater, and is a less costly to install than drip irrigation.

Some pathogens will start to die off as soon as the surface dries out. Many bacteria can see reductions of 0.5 to 2 log per day of drying time. However, helminth ova are well protected, and their transmission rate is unlikely to be affected by stopping irrigation a few days before harvest.

Washing produce with clean water can reduce pathogen transmission by up to one log, but helminth eggs are sticky and are not likely to be affected by washing. Likewise, produce washing with disinfectant can reduce pathogens by 2 to 3 log, but helminth eggs are notoriously impervious to weak solutions of disinfectant.

Peeling fruits, vegetables and root crops can reduce pathogen transmission by 2 to 3 log, and may reduce the number of helminth eggs that are consumed.

Cooking produce reduces the transmission of pathogens by 6 to 7 log, and will certainly inactivate helminth ova. This is the gold standard for crops that are irrigated with effluent: if there are possibly helminth ova on a crop, it should be cooked before it is consumed.

CHAPTER FIVE

5.0 Effects of Sewage Treatment on the Health of the People

Wastewater is a complex resource, with both risks and benefits to its use. In most high-income countries, wastewater is treated before reuse. Many low- and middle-income countries use wastewater with and without treatment; if the wastewater is untreated, it may be used undiluted or diluted (Raschid-Sally & Jayakody, 2008). Rough estimates indicate that at least 20 million hectares in 50 countries are irrigated with raw or partially treated wastewater (Hussain, Raschid, Hanjra, Marikar, van der Hoek, 2001).

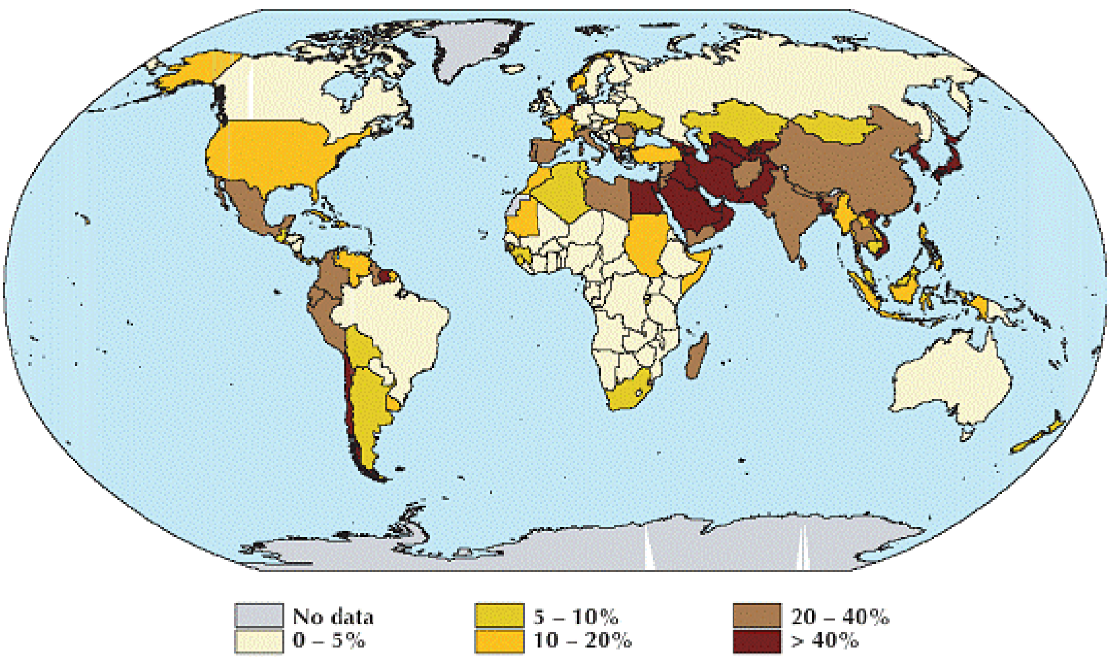

Figure 5.1 Freshwater withdrawals for agricultural use in the year 2000 and countries reporting the use of wastewater or polluted water for irrigation
Source: Lenntech BV, Rotterdamseweg 402 M, 2629 HH Delft, The Netherlands

As described in the previous chapters, waste water treatment has profound effects on human health in terms of disease burden, accompanying malnutrition and anemia, as well as overall quality of life. In addition, when treated, wastewater used for irrigation can safely improve soil structure, increase crop yields, and increase food nutrients that improves health indirectly.

Soil structure

Over time, irrigating with wastewater increases the capacity of a field to absorb and retain water.

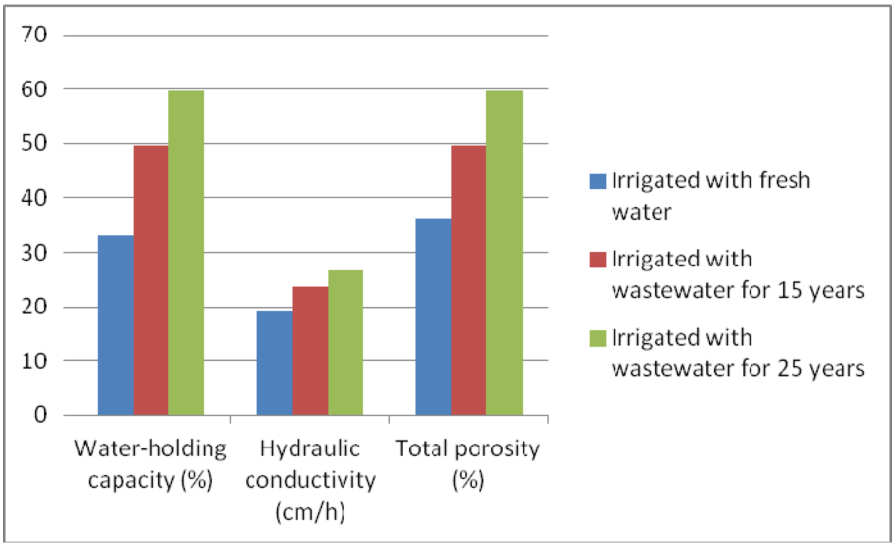

Figure 5.2 Soil parameters in Nagpur, India after irrigation with freshwater and wastewater. Source: Modified from Jayaraman et al. (1983); Minhas and Samra (2004)

In Nagpur, India, the soil structure in farm plots irrigated with wastewater for 15 and 25 years, respectively, was compared to soil structure in a nearby plot that had been irrigated with fresh water. The total porosity, hydraulic conductivity and water-holding capacity of the soil was enhanced by wastewater irrigation.

Crop yields

Wastewater is a rich source of plant food nutrients. Wastewater contains nitrogen and phosphates as well as a complex of micronutrients. The organic matter in effluent improves the tilth of the soil and the complexity of the soil microflora. If crops have been undersupplied with essential plant food nutrients, wastewater irrigation will act as a complex fertilizer (Ul-Hassan and Ali, 2002). Higher than average crop yields are possible with wastewater irrigation.

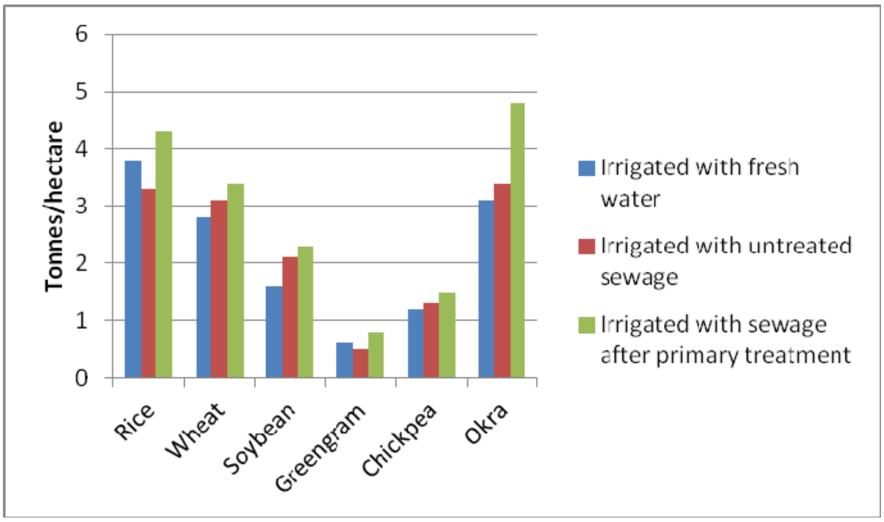

Figure 5.3 Crop Yields in Nagpur, India after irrigating with fresh water, untreated sewage, and sewage after primary treatment

As soil structure improves, so do crop yields. In Nagpur, India, fields irrigated with untreated wastewater produced more food per hectare than land irrigated with clean water. Fields that were irrigated with effluent that had undergone primary treatment were even more productive.

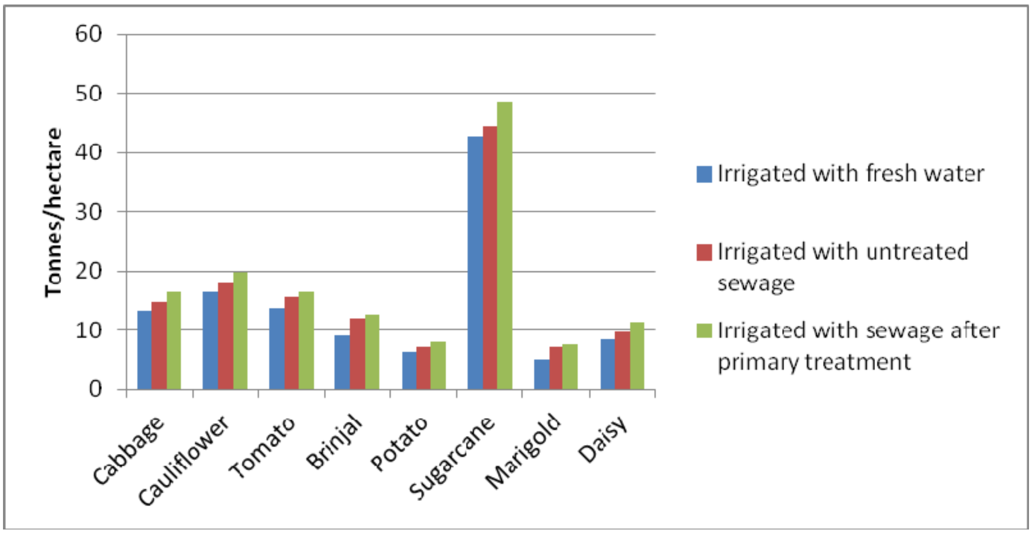

Figure 5.4 Crop Yields in Nagpur, India after irrigating with fresh water, untreated sewage, and sewage after primary treatment

For most crops, there was more than 10% increase in crop yields when irrigating with treated wastewater. As a rule these farmers were able to increase crop yields while using lower value water that reduced their need for purchased fertilizer (Ul-Hassan 2002; Ul-Hassan and Ali 2002).

In Tanzania most agriculture is rain-fed. Therefore wastewater in Tanzania, as illustrated in the case study of Iringa, can allow a farmer two crops per year rather than one. In addition, a steady supply of wastewater can allow farmers to produce water-loving crops in the dry season that can fetch a higher price. Therefore access to wastewater can easily double a farmers' income.

Food nutrients

Many wastewaters have significant value as a source of plant nutrients. FAO (1992) estimated that typical wastewater effluent from domestic sources could supply all of the nitrogen and much of the phosphorus and potassium normally required for crop production, while micronutrients and organic matter provide additional benefits (FAO, 1997). When effluent is land applied instead of discharged into the receiving waters, the nitrogen, phosphates and organic matter in the effluent improve crop yields rather than fueling algae blooms. Given the options, irrigating with wastewater is likely to result in healthier waterways and soils.

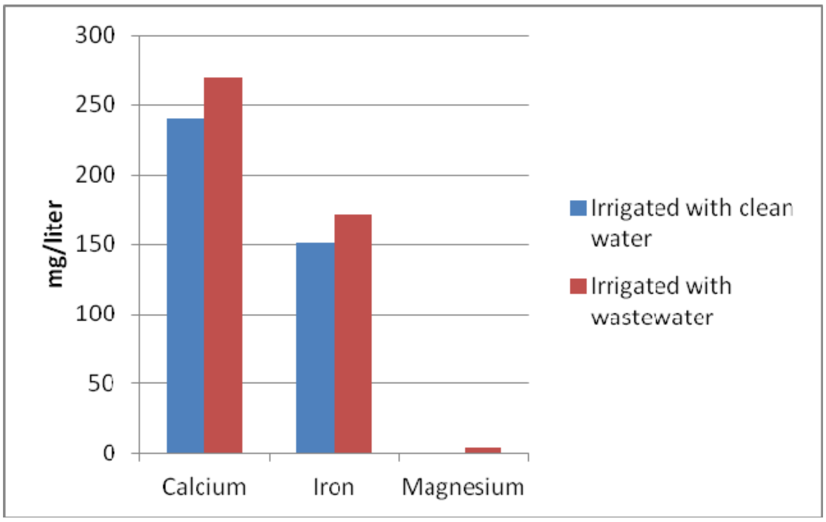

Figure 5.5 Nutrients in Chinese Cabbage irrigated with clean water and wastewater, Iringa, Tanzania

In Iringa, Tanzania, the nutrient content of Chinese cabbage irrigated with wastewater was compared to Chinese cabbage irrigated with clean water. The calcium and iron content of the Chinese cabbage grown on land irrigated with wastewater increased by more than 10%, while the magnesium content went from 0.0 to 4.4 mg/liter.

Diseases

Besides being productive of the health benefits discussed above, widespread use of untreated wastewater for irrigation may increase the incidence of the waterborne diseases described in Chapter Two.

The Iringa Municipal wastewater treatment plant, where waste stabilization ponds are followed by constructed wetlands, is well designed to meet the revised WHO guidelines for irrigation water.

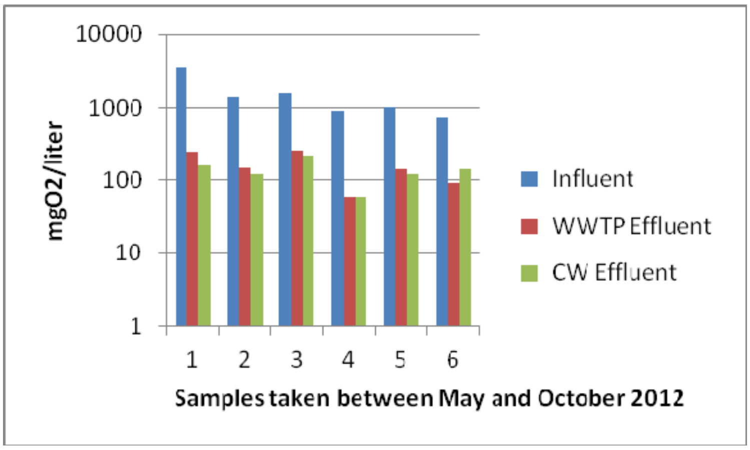

Figure 5.6 Iringa Municipal wastewater treatment plant, BOD_5 removal

We see that the treatment process has 1-3 log removal of faecal coliforms. Using BOD_5 reduction as a proxy for helminth removal, we see that the reduction of BOD_5 in the wastewater treatment process exceeds 1 log, meeting the WHO requirements of 1-3 log reduction.

Good elimination of helminth eggs can be achieved by sedimentation in a pond with a long residence time as pre-treatment, followed by filtration in constructed wetlands (WHO, 2006, volume 4). However, the helminth eggs that are removed from the effluent are not destroyed. When waste stabilization ponds are followed by constructed wetlands, the helminth eggs are sequestered in the biosolids that build up at the bottom of the ponds. The eggs can survive for more than 10 years in the sludge of waste stabilization ponds and other sedimentation processes (Metcalf and Eddy, 2003).

Sewage biosolids are regularly land applied by farmers who value it as a soil amendment. This rich source of organic matter is not appropriate for agricultural application without long-term storage or careful thermophilic composting.

Finally, crops that are eaten raw are more likely to transmit helminth eggs than crops that are cooked, and crops that grow close to the ground are more likely to serve as vectors than crops that grow well above the ground.

In conclusion, wastewater is potentially dangerous. However, to a large extent the the IRUWASA system is effectively treating wastewater to WHO irrigation standards. Because of this, the farmers' use of this effluent is increasing crop yields, increasing food nutrients, and improving soil structure. Further research needs to be conducted on the sludge of the wastewater treatment system. If the sludge contains helminth eggs, (and it may be heavily laden), it is improper to give it to farmers for application to their fields without storage or thermophilic composting.

CHAPTER SIX

6.0 Recommendations

Reclaimed water is an increasingly important water source. Even if it is polluted, it is not practically possible to prohibit people from using the water. Therefore it is important to work with sewage treatment workers, farmers and end-users so that they and their products are protected from contamination.

People should be encouraged to use wastewater, and to use it sensibly and carefully. Effective technologies such as waste stabilization ponds and constructed wetlands are needed to decrease disease burden. Recommendations are divided into five categories to be implemented during planning, design, construction, implementation, and monitoring.

Planning

Emphasize prevention

Amidst all these data and studies is an urgent message towards prevention. If a person gets infected with a waterborne disease it is problematic. It is often difficult to get to health care centres. Even when the patient arrives, the centre may be understaffed, or the staff untrained for the roles they need to take (Gaffga, Tauxe, Mintz, 2007). In some cases the disease cannot be well identified (Gascon et al., 2000). And then after all that the patient may get the correct drug, but it does not work (Bakuza, 2013).

Evaluate disease prevalence

It is important to evaluate local disease prevalence of human beings and other animals. High background disease levels indicate that risk management procedures have not been adequately implemented and need to be strengthened.

Geographically targeted control programmes

There is considerable geographical variation in the occurrence of waterborne diseases in Tanzania. The maps presented in this report are of fine enough quality that they can contribute to a rational basis for geographically targeted control programmes and in some sites can serve as baseline assessments. These particular maps describe an urgent need for surveillance in southern Tanzania, especially in the east, which is not mountainous. They also demonstrate an urgent need for improved sewage control, pharmaceutical intervention, and health education in Pemba and North Zanzibar. Our own data points to the need for intervention in Morogoro.

Use broad based multisectorial approach and multidisciplinary teams

Emphasis on multisectoralism is crucial (see King, 2009). The experience in Brazil demonstrates that besides the environment, the context of the prevailing demographic, health and social systems need to be considered in order to address health concerns effectively (Utzinger et al, 2009).

In terms of ecosystem health, it is particularly important that the health sector is integrated with the engineering sector and vice versa. Engineering designs will be incomplete and even detrimental if they do not take into consideration the biological aspects of pathogens and their diseases. Likewise, if health workers depend on drugs alone and miss out on the preventive aspects inherent to well-engineered sewage treatment systems, these diseases will not be controlled.

The experiences shown in Bakuza's study (2012) of villages around Gombe National Park show a wide range in childhood disease prevalence. The reasons for this range are unknown, and it is important to understand the differences between the low and high prevalence villages. Moreover, human beings are infecting baboons and vervets. Effective research to solve the problem will need a multisectorial team of health workers, engineers, architects, wildlife ecologists, and water/land use planners.

A health component should be injected into all sewage treatment projects by testing people, water and sludge for faecal coliforms, helminth eggs, and the snail hosts of *Schistosoma*.

Evaluate the need for pre-treatment

Some institutions such as hospitals and industries may need to pre-treat their effluent before releasing it into the municipal sewage treatment system.

Plan an educational campaign

Educational campaigns must be built with the aim of improving knowledge and actions over the long term. Health education campaigns need to be long lasting. Permanent exhibits for schools and natural history museums, for example, would be preferable to posters.

Design

Constructed wetlands in Tanzania should generally be subsurface to decrease the possibility of providing habitat for mosquito larvae that as adults could carry malaria and other diseases.

Fish should be encouraged in waste stabilization ponds as predators in case mosquitoes lay eggs there.

Sludge needs long-term storage or composting before it is applied to farmland. A site needs to be designated for sludge composting or storage.

Workers working in direct contact with sludge and effluent are at highest risk for coming into contact with pathogens and bringing them to their families. Therefore a place to shower and disinfect after work should be incorporated into the design.

Construction

Local construction workers, especially in remote settings, should be trained on the job about building and maintaining constructed wetlands.

Implementation

Proper handling of sewage and sludge

People directly handling biosolids are at high risk because the sludge is loaded with helminth eggs. Therefore, clothing that can be cleaned in boiling water should be worn by people who are in direct contact with the sludge, and their feet should be protected by rubber boots.

Proper treatment of sludge from waste sedimentation ponds

Since the helminth eggs are partitioned into the sludge, sludge must be appropriately and effectively treated before being given to farmers for land application. Storage and thermophilic composting are effective and appropriate treatments.

Education

Farmers also need education. Recommendations to farmers should be data based and tailored to their situation. If the effluent fails to meet standards, then different crops should be grown, or crops should be grown in different ways. For example, if the crops grown are cooked then the presence of helminth eggs may not affect the consumer. Therefore if the water is not clean, irrigated crops should include maize, rice that is eaten cooked or tree crops that are not in direct contact with irrigation water rather than greens like lettuce that are eaten raw. Crops can be grown on raised beds with furrow irrigation, so that the polluted water does not come in direct contact with the leaves.

Income generation

It is possible that farmers would buy sludge that has been properly treated. It is possible that crops grown with effluent have higher value than those grown with fresh water since it has been shown that the crops absorb the effluent nutrients.

Monitoring

Periodic data collection

Data on the levels of disease incidence and prevalence need to be collected periodically. Otherwise it is not possible to know where to focus activities or to know if risk management actions were effective.

Government testing of sewage treatment systems is a positive development but the testing should be tailored to the site. For example in Iringa where the effluent is almost completely used for irrigation, emphasis on BOD is not as important as in Mwanza where the effluent is discharged into Lake Victoria. In Iringa it is important to test faecal coliforms.

Pond monitoring should include periodic checks for the Biomphalaria, Bulinus and Oncomelaria snails needed to complete the *Schistosoma* life cycle.

All systems discharging into the environment should be monitored regularly for fecal coliforms and helminth eggs. In addition, the influent should be tested periodically for total petroleum hydrocarbons, heavy metals and other priority pollutants.

Proper sizing and integration of treatment systems to improve the final water quality

Different treatment techniques are good for handling different wastewater pollutants. Waste stabilization ponds are good for handling BOD and pathogens in wastewater especially in the maturation ponds where a combination of sunlight effects and pH kills micro-organisms contained in wastewater. Constructed wetlands are good for BOD and nutrient removals if properly designed. Surface flow systems are good for nitrification while subsurface sustems are good for BOD removal. A combination of systems can assist in ensuring that treated wastewater is properly disinfected before reuse.

Further Research

- Expand studies on behaviour of helminth eggs in water and sludge, in the sedimentation ponds and the constructed wetlands.
- Role of natural predators (fish and birds) in helminth ecology
- Localized schistosomiasis eradication with a multi-disciplinary intervention team.
- To optimize the performance of wetlands in pathogen removal to meet effluent reuse standards.
- Evaluate ability of natural landmarks such as mangrove forests, and *Phragmites* marshes to cleanse sewage laden streams and rivers.

Noting that municipal sewage treatment will not directly help those whose sewage or septage does not reach the municipal system, although it may help indirectly by decreasing the background prevalence rates.

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APPENDICES

Appendix A. Millennium Development Goals and Targets

Goal 1: Eradicate extreme poverty and hunger

Target 1A: Halve, between 1990 and 2015, the proportion of people living on less than $1.25 a day

Target 1B: Achieve decent employment for women, men, and young people

Target 1C: Halve, between 1990 and 2015, the proportion of people who suffer from hunger

Goal 2: Achieve universal primary education

Target 2A: By 2015, all children can complete a full course of primary schooling, girls and boys

Goal 3: Promote gender equality and empower women

Target 3A: Eliminate gender disparity in primary and secondary education preferably by 2005, and at all levels by 2015

Goal 4: Reduce child mortality rates

Target 4A: Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate

Goal 5: Improve maternal health

Target 5A: Reduce by three quarters, between 1990 and 2015, the maternal mortality ratio

Target 5B: Achieve, by 2015, universal access to reproductive health

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

Target 6A: Have halted by 2015 and begun to reverse the spread of HIV/AIDS

Target 6B: Achieve, by 2010, universal access to treatment for HIV/AIDS for all those who need it

Target 6C: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases

Goal 7: Ensure environmental sustainability

Target 7A: Integrate the principles of sustainable development into country policies and programs; reverse loss of environmental resources

Target 7B: Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss

Target 7C: Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation

Target 7D: By 2020, to have achieved a significant improvement in the lives of at least 100 million slum-dwellers

Goal 8: Develop a global partnership for development

Target 8A: Develop further an open, rule-based, predictable, non-discriminatory trading and financial system

Target 8B: Address the special needs of the least developed countries

Target 8C: Address the special needs of landlocked developing countries and small island developing states

Target 8D: Deal comprehensively with the debt problems of developing countries through national and international measures in order to make debt sustainable in the long term

Target 8E: In co-operation with pharmaceutical companies, provide access to affordable, essential drugs in developing countries

Target 8F: In co-operation with the private sector, make available the benefits of new technologies, especially information and communications

Appendix B. MKUKUTA Goals and Targets

CLUSTER I – GROWTH AND REDUCTION OF POVERTY

Goal 1: Ensuring sound economic management

1.1 Maintained macro-economic stability: inflation rate at maximum of 4%, maintaining official reserves of at least six months of imports, achieving debt sustainability (containing the external debt to GDP ratio at 50 percent or less).

1.2 Reduced unemployment from 12.9 % in 2000/01 to 6.9% by 2010 and address underemployment in rural areas

Goal 2: Promoting sustainable and broad -based growth

2.1 Accelerated GDP growth rate to attain a growth rate of 6% to 8% per annum by 2010

2.2 Scaled up participation of the informal sector and small and medium enterprises (including cooperatives).

2.3 Increased growth of manufacturing sector from 8.6% to 15% by 2010

2.4 Increased agricultural growth from 5% in 2002/03 to 10% by 2010.

2.5 Increased growth rate for livestock sub sector from 2.7% in 2000/01 to 9% by 2010.

2.6 Increased technological innovation, upgrading and use of technologies.

2.7 Promoted regional equity in development and capacity for growth and infrastructure that enables investment and livelihoods diversification

2.8 Repaired 15,000 km of rural roads annually by 2010 from 4,500 km in 2003.

2.9 Reduced negative impacts on environment and peoples' livelihoods.

2.10 Reduced land degradation and loss of biodiversity.

2.11Increased export proportion of value added minerals from the current 0.5% to 3.0% by 2010.

Goal 3: Improving food availability and accessibility in urban and rural areas

3.1 Increased food crops production from 9 million in 2003/04 tons to 12 million in 2010.

3.2 Maintained Strategic Grain Reserve of at least 4 month of national food requirement

Goal 4: Reducing income poverty of men and women in rural areas
4.1 Reduced proportion of rural population (men and women) below the basic needs poverty line from 38.6% in 2000/01 to 24% in 2010
4.2 Reduced proportion of rural food poor (men and women) from 27% in 2000/01 to 14% by 2010.
4.3 Increased productivity and profitability both within agriculture and outside agriculture sector.
4.4 Increased sustainable off-farm income generating activities
4.5 Secured and facilitated marketing of agricultural products.
4.6 Increased contributions from wildlife, forestry, and fisheries, to incomes of rural communities.

Goal 5: Reducing income poverty of men and women in urban areas
5.1 Reduced proportion of the urban population (men and women) below the basic needs poverty line from 25.8% in 2000/01 to 12.9% in 2010.
5.2 Reducing the proportion of the urban food poor (men and women) from 13.2% in 2000/01 to 6.6%.

Goal 6: Provision of reliable and affordable energy to consumers
6.1 Liberalization of the power sub -sector affected by 2010
6.2 At least three (3) Production Sharing Agreements (PSA) negotiated, concluded and signed by June 2010

CLUSTER II – IMPROVEMENT IN QUALITY OF LIFE AND SOCIAL WELL BEING
Goal 1: Ensuring equitable access to quality primary and secondary education for boys and girls, universal literacy among women and men and expansion of higher, technical and vocational education
1.1 Increase in the number of young children prepared for school and life

1.2 Increased gross and net enrolment of boys and girls, including children with disabilities, in primary
1.3 Schools from 90.5% in 2004 to 99% in 2010
1.4 Increased proportion of orphans and other vulnerable children enrolled, attending and completing primary education from 2% in 2000 to 30% in 2010
1.5 Increased percentage of girls and boys with disabilities and OVCs who qualify for secondary education enroll and complete secondary schools by 2010
1.6 At least 50% of boys and girls aged 14 -17 years are enrolled in ordinary level secondary schools by 2010
1.7 At least 60% of girls and boys pass Standard VII examinations by 2010
1.8 At least 25% of boys and girls are enrolled in advance level secondary schools by 2010
1.9 Achieving an average daily attendance in primary schools of at least 85%
1.10 At least 95% of cohort completes standard IV
1.11 At least 90% of cohort completes standard VII.
1.12 At least 70% of girls and boys pass at Division I-III in Form IV examinations.
1.13 Improved learning environment for all children in all schools, with all education institutions safe, violence free, child friendly and gender sensitive
1.14 Regulate access to and quality of education in government and non-government schools
1.15 90% of primary and secondary schools have adequate, competent and skilled teachers by 2010
1.16 Primary and secondary education is of a high quality and promotes the acquisition of critical knowledge, real skills and progressive values
1.17 Increased enrolment in higher and technical education in universities and in technical colleges to 30,000 full time students, 10,000 part time, and 15,000 distance learners by 2008
1.18 Improved knowledge on entrepreneurship skills amongst youth
1.19 Effective HIV and AIDS education and life skills programmes offered in all primary, secondary schools and teachers colleges
1.20 At least 80% of adults, especially women in rural areas, are literate

1.21 Reduced number of illiterate adults from 3.8 million (2004/05) to 1.5 million (2007/08)
1.22 Reduced numbers of young people involved in COBET from 234,000 in 2004/5 to 70,566 in 2007/08
1.23 Expanded and improved public participation in cultural activities.
1.24 Increased numbers of students/youth who are service orientated

Goal 2: Improved survival, health and well-being of all children and women and of especially vulnerable groups
2.1 Reduced infant mortality from 95 in 2002 to 50 in 2010 per 1,000 live births.
2.2 Reduced child (under five) mortality from 154 to 79 in 2010 per 1,000 live births.
2.3 Reduced hospital-based malaria-related mortality amongst under fives from 12% in 2002 to 8% in 2010
2.4 Reduced prevalence of stunting in under fives from 43.8 %to 20% in 2010
2.5 Reduced prevalence of wasting in under fives from 5.4% to 2% in 2010
2.6 Reduced maternal mortality from 529 to 265 in 2010 per 100,000
2.7 Increased coverage of births attended by trained personnel from 50% to 80% in 2010
2.8 Reduced HIV prevalence among 15 -24 year pregnant women from 11% in 2004 to 5% in 2010
2.9 Reduced HIV prevalence from 11% in 2004 to 10% in 2010 between the ages of 15 and 24 years
2.10 Reduce HIV and AIDS prevalence among women and men with disabilities (among age group 15-35 yrs)
2.11 Increased the knowledge of HIV/AIDS transmission in the general population TACAIDS
2.12 Reduce HIV/AIDS stigmatisation
2.12 Health boards and facility committees in place and operational in all districts
2.13 Service delivery agreements operational and effective
2.14 Regional Health Management Teams in place and operational

2.15 Promoted knowledge-based care among health workers for attending among others, people with disabilities and elderly

CLUSTER II – IMPROVEMENT IN QUALITY OF LIFE AND SOCIAL WELL BEING

Goal 3: increased access to clean, affordable and safe water, sanitation, decent shelter and a safe and sustainable environment and thereby, reduced vulnerability from environmental risk

3.1 Increased proportion of rural population with access to clean and safe water from 53% in 2003 to 65% 2009/10 within 30 minutes of time spent on collection of water

3.2 Increased urban population with access to clean and safe water from 73% in 2003 to 90% by 2009/10

3.3 Increased access to improved sewerage facilities from 17% in 2003 to 30% in 2010 in respective urban areas

3.4 Reduce households living in slums without adequate basic essential utilities.

3.5 100% of schools to have adequate sanitary facilities by 2010

3.6 95% of people with access to basic sanitation by 2010

3.7 Cholera out-breaks cut by half by 2010

3.8 Reduced water related environmental pollution levels from 20% in 2003 to 10% in 2010

3.9 Reduction in harmful industrial and agricultural effluents

3.10 Planned and serviced urban settlements with functioning town planning procedures in place

3.11 Increased number of people having secure tenure of land and properties that can be mortgaged, and women and men have equal rights to access, ownership and inheritance

3.12 Reduced vulnerability to environmental disasters

3.13 Soil, forest and aquatic ecosystems that people depend upon for production and reproduction conserved

3.14 Reduction in land degradation and loss of biodiversity

Goal 4: Adequate social protection and rights of the vulnerable and needy groups with basic needs and services

4.1 Increased number of orphans and most vulnerable children reached with effective social protection measures by 2010

4.2 20% of children and adults with disabilities reached with effective social protection measures by 2010

4.3 40% of eligible older people reached with effective social protection measures by 2010

4.4 Reduce violence against women

4.5 Increased support to poor households and communities to care for vulnerable groups targeting older people, orphans, other vulnerable children and people living with HIV and AIDS

4.6 Reduce proportion of children in labour country wide from 25% to less than 10% by 2010 and avail to them alternatives including enrolment in primary education, COBET and employable vocational education skills training

4.7 Institutional arrangement for rural energy development established and strengthened

4.8 Contribution of solar, wind and biomass and coal for electricity generation increased from the current 0.5% in 2003 to 3% by June 2010

4.9 At least 10% of the population using alternative s to wood fuels for cooking by 2010

Goal 5: Effective systems to ensure universal access to quality and affordable public services

5.1 Improve passable (good/fair condition) rural roads from 50% in 2003 to at least 75% in 2010

5.2 90% of schools and 80% of health facilities in the urban and rural areas have the required mix of skilled and motivated workers in place

5.3 Skilled personnel in social sectors infrastructure and utilities are attending to their tasks and executing their obligations accordingly

5.4 Improve accessibility to health services by geographical coverage. Household to be within 5 km of health service units.
5.5 100% of eligible older people provided with free medical care and attended by specialized medical personnel by 2010
5.6 Optimal partnerships with CSOs and the private sector in expansion and provision of quality social services are in place
5.7 Realistic, streamlined and useful systems for planning and data analysis are in place

CLUSTER III: GOVERNANCE AND ACCOUNTABILITY
Goal 1: Structures and systems of governance as well as the rule of law are democratic, participatory, representative, accountable and inclusive
1.1 Ensure representative, inclusive (poor and vulnerable groups) and accountable governance institutions operating at all levels
Goal 2: Equitable allocation of public resources with corruption effectively addressed
2.1 Public resources are allocated, accessible and used in an equitable, accountable and transparent manner
2.2 Institute effective regulations and mechanisms regarding petty and grand corruption
Goal 3: Effective public service framework in place to provide foundation for service delivery improvements and poverty reduction
3.1 Administrative systems of public institutions are managed transparently and in the best interests of the people they serve
Goal 4: Rights of the poor and vulnerable groups are protected and promoted in the justice system
4.1 Ensure timely and appropriate justice for all especially the poor and vulnerable groups

Goal 5: Reduction of political and social exclusion and intolerance
5.1 Develop political and social systems and institutions which allow for full participation of all citizens including the poor and vulnerable groups

Goal 6: Improved personal and material security, reduced crime, eliminate sexual abuse and domestic violence
6.1 Ensure institutions and agents of government such as the police, courts and prisons observe human rights and ensure justice and security of all citizens

Goal 7: National cultural identities enhanced and promoted
7.1 Policies, strategies and legal frameworks for national language, cultural and moral development are in place and operational

Appendix C. Parameters for Assessments of Water Quality through BOD, COD, TSS, Nitrogen and Phosphorus

The five-day biological oxygen demand (BOD_5) is a measure of the organic content of the water, and a primary pollutant. Technically, it is the amount of dissolved oxygen required by aerobic biological organisms in water to break down the organic material in a sample at specific temperature over five days, most commonly expressed in milligrams of oxygen consumed per liter of sample during five days of incubation at 20°C. The main focus of a wastewater treatment plant is to reduce the BOD_5 in the effluent to protect the receiving waters. If effluent with high BOD levels is discharged into a stream or river, it will accelerate bacterial growth in the river and may reduce the oxygen levels in the river to levels that are lethal for most fish.

Chemical oxygen demand (COD), another primary pollutant, is a measure of the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water. Since it does not differentiate between biologically available and inert organic matter, COD values are always higher than BOD_5 values, but COD measurements can be made in a few hours while BOD measurements take five days.

Total Suspended Solids (TSS) are solids in water that can be trapped by a filter. TSS is a primary pollutant that can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. Helminth eggs are part of the total suspended solids in wastewater, and tracking the reduction in TSS is a proxy for the reduction in helminth egg concentration in the effluent. High concentrations of suspended solids can degrade the aquatic environment and negatively impact stream health and aquatic life.

The nitrogen compounds in wastewater are pollutants in the stream, river or lake that the effluent is discharged into, or a fertilizer when the effluent is land-applied. Because nitrogen in wastewater can be found in four major forms (excluding trace amounts of nitrogen gas), each major form is generally analyzed as a separate component, with Total Nitrogen calculated from the sum of the four forms. In freshly polluted water, nitrogen is in the form of organic nitrogen and ammonia. Natural biochemical processes convert the organic nitrogen into ammonia, which is the form of nitrogen most easily used as a nutrient by microorganisms during wastewater treatment. Under aerobic conditions, the conversion of organic nitrogen into ammonia reaches a peak and is biochemically oxidized first into nitrite, then into nitrate.

Phosphorus, another fertilizer, is usually the limiting nutrient in freshwater ecosystems and is the main driver of eutrophication in streams, lakes and rivers (Burks and Minnis, 1994). Phosphorus is a primary pollutant.

Appendix D. Review of Water-borne Diseases in Tanzania

The following descriptions of water-borne diseases in Tanzania are only the most well known and common: diarrhoea including cholera, trachoma, helminthiasis (including roundworm, whipworm, hookworm, and tapeworm infections), schistosomiasis (including urinary and intestinal) and malaria. Some important diseases such as infectious hepatitis and cryptosporidiosis are not included here in detail because little data is available.

Each disease is described as to: 1/ cause (how infection occurs), 2/ disease process and associated problems, 3/ how many people are infected, 4/ the proportion of the disease attributable to modifiable environmental factors, and 5/ international programmes addressing them. The status of each disease in Tanzania is also included for those not addressed fully in Chapter Two.

Diarrhoea, gastroenteritis

1. Diarrhoea is a symptom rather than a specific disease. Diarrhoea can be caused by bacterial, viral, and protozoan pathogens. These pathogens are ingested orally, and cysts and oocysts are excreted via human faeces. Faecal pathogens are therefore common in wastewater.

Transmission routes are affected by interactions between physical infrastructure and human behaviors. If sanitation or related hygiene is poor, e.g. when hand washing is inadequate or when faeces are disposed of improperly, human excreta may contaminate hands and then contaminate food or other humans. Faecal pathogens are transferred to the sewage system through flush toilets or latrines. They may contaminate surface waters and groundwater. Irrigation using contaminated water can lead to vegetables carrying pathogens to the farmers, their families, and consumers of the vegetables. Human excreta also can directly contaminate the soil and enter into contact with people. Flies may carry pathogens from excreta to food.

Through these many common pathways, water or food can be contaminated and cause diarrhoeal disease following ingestion.

2. Diarrhoea has a significant impact on persons with compromised immune systems.

3. The World Health Organization (WHO) estimates that almost 1.8 million deaths per year are caused by diarrhoea, and almost all of these diarrhoeal deaths occur in low- and middle-income countries. About 90% of the people killed by diarrhoea are children, totaling approximately 1,512,000 children or about 12.8% of all childhood deaths (WHO, 2006, Vol. 1). Africa has the highest mortality rate for diarrhoeal diseases.

4. Very little diarrhoeal disease is transmitted through pathways other than those associated with water, sanitation and hygiene, or food (e.g. airborne transmission). It is estimated that 84% to 98% of all cases of diarrhoea around the world are attributable to the environment (WHO, 2002; Prüss-Üstün et al., 2004a).

In Tanzania, some excellent studies have been conducted that aid understanding of diarrhoeal diseases. The data brings little good news.

The Adult Morbidity and Mortality Project (AMMP) collected mortality data through community-based surveillance using verbal autopsies with family members of 10,517 recently deceased adults. Samples were chosen from populations in three regions of Tanzania: Dar es Salaam (urban), Hai in Kilimanjaro (non-poor rural), and Morogoro (poor rural). Cause-specific death rates were calculated by study area for the years 1992-1996 for the 10 leading causes of death for men and women. HIV/AIDS, tuberculosis (TB), malaria, and diarrhoea were major causes of death.

The table below shows the diarrhoea mortality rate of adults by sex, age group and site.

Table 2.2 Death rate per 100,000 for Diarrhoea and percent among all deaths among people aged 15-59 years by sex, selected sites, Tanzania 1992-1998

Age groups		**15-29**			**30-44**			**45-59**			**Total**	
	DSM	Moro-goro	Hai	DSM	Moro-goro	Hai	DSM	Moro-goro	Hai	DSM	Moro goro	Hai
Women												
Acute Diarrhea	38	81	13	55	157	27	67	252	63	49	141	28
Percent all cause death rate	4.9	7.9	2.7	3.1	9.4	2.9	2.9	16.6	7.4	3.7	10.6	4
Men												
Acute Diarrhoea	30	127	23	34	165	51	82	325	78	42	179	43
Percent all cause death rate	5.5	15.5	2.7	2.3	8.7	3.8	3.7	12	4.7	3.6	11.6	4.3

From Tanzania Essential Health Intervention Project. 1992-1998. (Setel et al., 2005)

The data reflect large variations by sex and geographic area. Among men, for example, acute diarrhoeal disease was more than four times higher in the poor rural area of Morogoro than in the other two districts. Diarrhoea mortality rates were highest in Morogoro, where a shocking 11% of the adult population died of diarrhoea.

In a survey focusing on children under five years old, the Tanzania Demographic and Health Survey 2004-05 (National Bureau of Statistics, 2005) discovered that nationally the percentage of children under five years of age (n = 7,976) who were reported by their mothers to have had diarrhoea in the previous two weeks was 12.6%. In Arusha region, 10.8% of the children had been afflicted with diarrhoea; in Iringa, 18.3%; in Morogoro, 12.1%; and in Kilimanjaro, 7.7%. Mothers reported that stools were contained in a toilet or pit latrine or buried 74.6% of the time, and otherwise were uncontained by being thrown outside the dwelling, thrown outside the yard, rinsed away, or disposed of with diapers (0.1%).

Another study focusing on children under five years old found that even though diarrhoea is common in Tanzania, it is difficult to diagnose the cause of a specific episode. This was shown by a matched case control study in Ifakara in Morogoro Region by the well known Ifakara Health Research and Development Center. The objectives of the study were to clarify risk factors for and cause of diarrhoeal diseases in children less than five years old (Gascon et al., 2000).

The study included 309 children; 103 children had severe cases of diarrhea and 206 children did not have diarrhea. Their stools were examined for *Giardia lamblia*, *Salmonella*, *Shigella flexneri* and *Shigella sonnei*, *Antamoeba histolyca*, rotavirus and several strains of *Escherichia coli*.

It was found that a higher number of siblings, a higher number of living siblings, an increased distance from the water source and having a latrine at home were each related to a decreased risk of diarrhoea. Risk of diarrhoea was much greater if the water source was nearby – that is, less than 1 minute away from the house than if it was more than 10 minutes away from the house. Surprisingly, simple latrines were less frequently associated with diarrhoea than ventilated improved pit latrines. Non-risk factors included religion, birth weight, type of house, type of water source (tap water, covered well, river), type of water (boiled drinking water, filtered drinking water), or having a toilet cover.

Of the above-mentioned faecal pathogens, only one was significantly associated with an increased risk of diarrhoea: *Shigella*. Asymptomatic infection was common; in fact 52% of children with positive stool samples did not have diarrhoea. These results were attributed possibly to acquired immunity. On the other hand, no enteropathogens were isolated in 38 (37%) of the children with severe diarrhea and 96 (47%) of the children without diarrhoea.

E.coli were found in more study participants (53 children with diarrhoea, or 51% and 98 without diarrhoea, or 48%) than any other enteropathogen. Although it is not clear from the published results which enteropathogens were most closely associated with *E. coli*, these results suggest that *E. coli* is not a robust predictor of the presence of faecal pathogens.

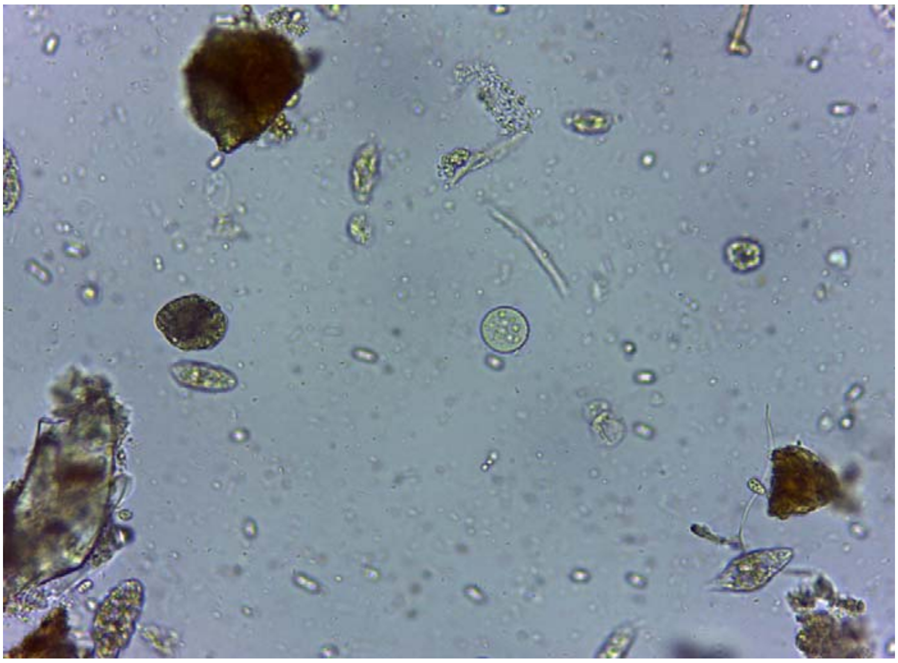


Figure (appendix D1) *Entamoeba coli* cyst, center, found in Morogoro Municipal Sewage System. Photo by Abdallah Zachariah.

Of all the bacterial, viral, and parasitic causes of diarrhoea tested, only *Shigella* was significantly associated with an increase in diarrhea – 13 isolates were found in cases and 8 in controls. All others, including *E. coli* strains, rotavirus and *G. lambia*, had no statistical significance to cases of diarrhoea.

5. Cholera

1. Most cholera cases are caused by contaminated drinking water. Cholera is an acute, diarrhoeal illness caused by infection of the intestine with the toxigenic bacterium *Vibrio cholera.* This disease is reported separately because there is a

large potential for epidemic cholera where adequate water and sanitation infrastructure is lacking (Gaffga, Tauxe, Mintz, 2007).

2. Infection can be asymptomatic, mild, or severe: approximately 1 in 20 infected persons have severe disease characterized by profuse watery diarrhoea, vomiting, and leg cramps. The cholera fatality rate has decreased in Africa —from 10.4% in the 1970s to 1.8% in 2005— yet still progress lags behind other areas of the world. In 2005, the cholera case fatality rate in Africa (1.8%) was 3 times higher than that in Asia (0.6%). No cholera deaths were reported in Latin America.

3. Historically, cholera epidemics were not uncommon. A cholera epidemic in Zanzibar is believed to have killed one-third of the entire population in 1869-70 (Sheriff, 1987); 1000 people were recorded as dying in a 1912 epidemic in Zanzibar (Koponen, 1994).

As shown in Figure 1, cholera is a disease that has been addressed and virtually eradicated in most parts of the world. The WHO Africa Region has reported more than 94% of the total global cholera cases since 2001. In 2005, 94.8% of the 131,943 reported cases of cholera and 98.2% of the 2,272 reported cholera deaths occurred in Africa. The reported incidence of cholera in Africa in 2005 (166 cases/million population) was 95 times higher than the reported incidence in Asia (1.74 cases/million population) and 16,600 times higher than the reported incidence in Latin America (0.01 cases/million population).

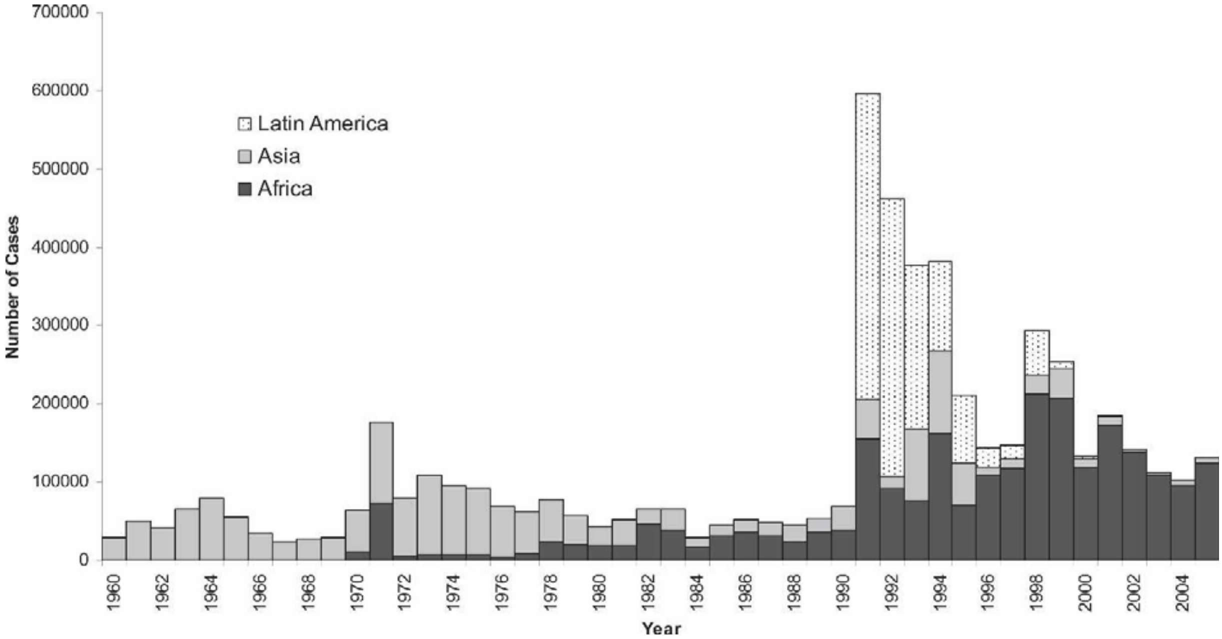


Figure (Appendix D2) Number of cases of cholera reported to WHO by region (Africa, Asia, Latin America) and year, 1960–2005 (Gaffka, Tauxe, Mintz, 2007)

Among the 39 African countries that reported cases of cholera to WHO in any year from 2000 through 2005, 18 countries (46%) reported cases in all 6 years: Benin, Burundi, Cameroon, Democratic Republic of the Congo, Ghana, Guinea, Liberia, Malawi, Mozambique, Niger, Nigeria, South Africa, Swaziland, Togo, Uganda, United Republic of Tanzania, Zambia, and Zimbabwe (Gaffka Tauxe, Mintz, 2007). The weakest part of the above study is that cases reported to WHO is not the same as actual cases: the number of cholera cases is certainly higher than indicated by the graph, particularly in regions where reporting is unreliable.

4. The causal agent of epidemic cholera can persist indefinitely in marine, estuarine, and riverine environments. However, ensuring universal access to safe drinking water and the separation of human faecal wastes from food and water sources is sufficient to prevent widespread cholera transmission.

5. Cholera is a public health concern because of its ability to become an epidemic. Reporting of cholera to the World Health Organization is mandatory under

international health regulations. In the event of cholera outbreaks, influent and effluent of water sewage treatment systems should be monitored frequently.

The median incidence per million persons reported in Tanzania between 2000 and 2005 was 100, which was higher than the mean rate for East Africa. Likewise in Tanzania the case fatality rate of 3.4 was one of the highest in the world, and much higher than the East Africa region mean cholera fatality rate of 1.8 (Gaffka et al., 2007).

Trachoma

1. Trachoma is a chronic contagious eye disease caused by the bacterium *Chlamydia trachomatis*. Trachoma is easily spread through direct personal contact, shared towels and cloths, and flies that have come in contact with the eyes or nose of an infected person. For example if a mother wipes her baby's face, and if that small gesture of caring is done with an infected cloth, she can easily transmit the bacteria. Risk factors for the disease include lack of facial cleanliness, poor access to water supplies, lack of latrines, and a large number of flies (Prüss-Üstün et al., 2004a).

2. If left untreated, repeated trachoma infections can cause severe scarring of the inside of the eyelid and can cause the eyelashes to scratch the cornea (trichiasis). In addition to causing pain, trichiasis permanently damages the cornea and can lead to irreversible blindness. Trachoma, which spreads in areas that lack adequate access to water and sanitation, affects the most marginalized communities in the world.

3. There are about 8 million people irreversibly visually impaired by trachoma; an estimated 84 million cases of active disease in need of treatment, if blindness is to be prevented (WHO, 2013).

4. All transmission routes are hygiene related. The bacteria can be through flies, sharing infected towels and during such acts as when a mother uses a corner of her clothes to "clean" her children's eyes. Several environmental control measures are

effective in reducing transmission of trachoma including education and improvements to water, sanitation and hygiene (Sutter and Ballard, 1983; Esrey et al., 1991; Prüss and Mariotti, 2000).

5. The World Health Organization has targeted trachoma for elimination by 2020 through a multi-faceted public health strategy known as SAFE:

- **S**urgery to correct the advanced, blinding stage of the disease (trichiasis),
- **A**ntibiotics to treat active infection,
- **F**acial cleanliness and,
- **E**nvironmental improvements in the areas of water and sanitation to reduce disease transmission

Trachoma is endemic to Tanzania as shown in the map below.

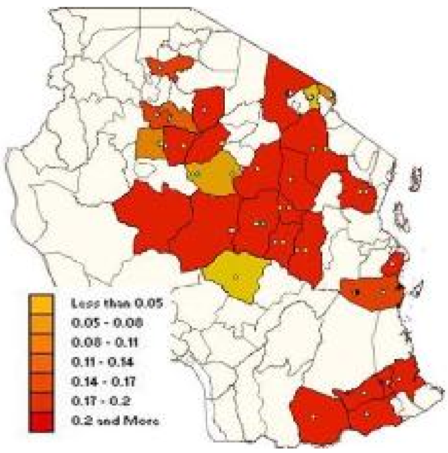


Figure (Appendix D3)Trachoma distribution in Tanzania

Helminthiasis

1. Roundworm (*Ascaris lumbricoides*), whipworm (*Trichuris trichuira*), hookworm (*Ancylostoma duodenale*) and tapeworm (*Hymenolepis nana* and *Taenia*) are transmitted in many different ways. Some helminths lay staggering numbers of eggs: *Ascaris lumbricoides*, for example, lays approximately 200,000 eggs per day for a year. Helminth eggs can survive in the environment for a long time.

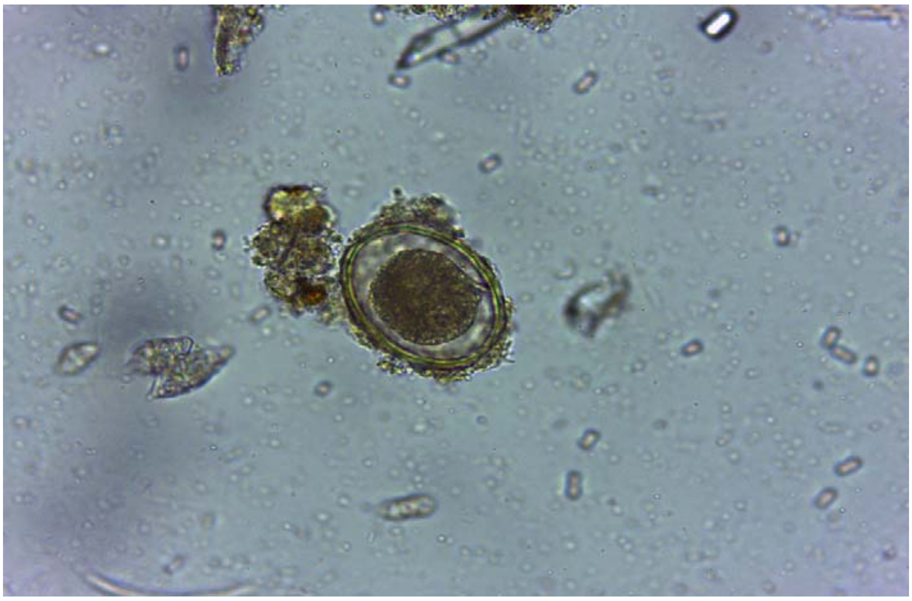


Figure (Appendix D4) *Ascaris lumbricoides* egg found in Morogoro Municipal Sewage Treatment System. Photo by Abdallah Zachariah.

The simplest method of transmission is by ingesting infective eggs found in soil or on food that is contaminated with excreta (roundworms, whipworms, hookworms and some tapeworms). Transmission may take place in or near the home, or in a communal area with inadequate sanitation facilities contaminated with faeces. Transmission does not occur from person-to-person contact or from fresh faeces. Even if freshly excreted faeces are contaminated, it takes time for the eggs to embryonate and for the faeces to become infectious. In addition to transmission via embryonated eggs, hookworm larvae can actively penetrate the skin.

Some tapeworm species are transmitted via eggs, while others require an intermediate host.

Figure (Appendix C5) *Hymenolepis diminuta* egg found in Morogoro Municipal Sewage System. Photo by Abdallah Zachariah.

Hymenolepis nana, the dwarf tapeworm, is about 40 mm long and prefers to live in children. This tapeworm can be transmitted by eggs or by an insect, usually a flea, that is an intermediate host. Many species of Taenia are typically several meters long in humans, and can only be transmitted by eating the uncooked meat of the intermediate host. Depending on the tapeworm species, the intermediate hosts include a wide variety of domesticated and wild animals including fish (Medical Microbiology, 1996).

Ancylostoma duodenale eggs and *Necator americanus* eggs are identical and cannot be differentiated by looking through the microscope. According to geographical distribution of hookworm infection, *Ancylostoma duodenale* are not found in Tanzania.

2. Many manifestations of helminthiasis produce few or no clinical symptoms. But depending on the quantity of worms and the general conditions of the host, helminthiasis may also lead to severe anaemia and death.

3. Although it is estimated that only about 3,000 people die every year from roundworm infestation, an estimated 1.45 billion people are infected (Vol. 1, WHO guidelines). Of these about 150 million are suffering from high intensity infections (World Health Organization, 2010).

The hookworm is a mere 1 cm, but this small worm is a leading cause of maternal and child morbidity in the tropics and sub-tropics. Hookworm deaths are estimated to be about 3,000 per year, but the estimated number of infections is 1.3 billion of which 150 million suffer adverse health effects. Depending on the adult worm load, hookworm infection can cause anorexia, fever, diarrhea, weight loss and anaemia (Medical Microbiology, 1996).

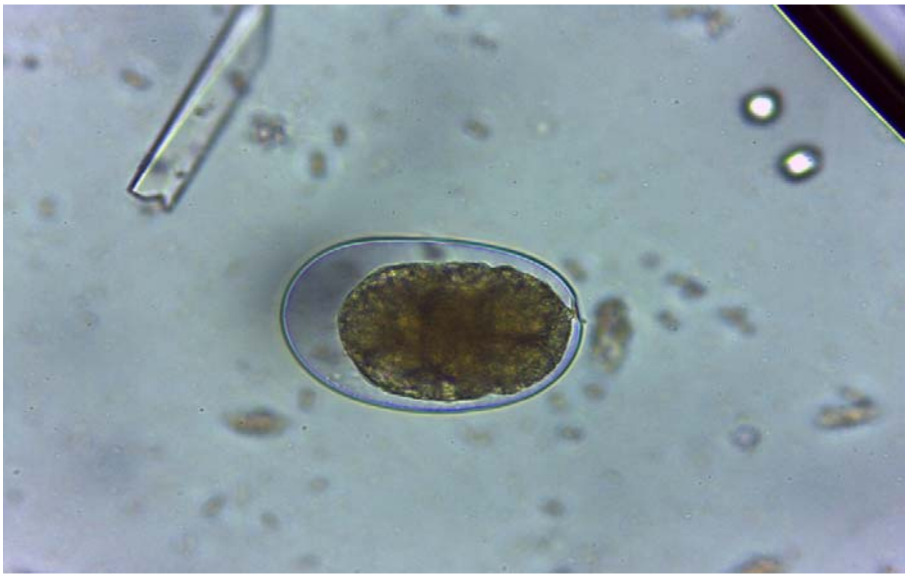


Figure (Appendix D6) Hookworm ova found in the Morogoro Municipal Sewage System. Photo by Abdallah Zachariah.

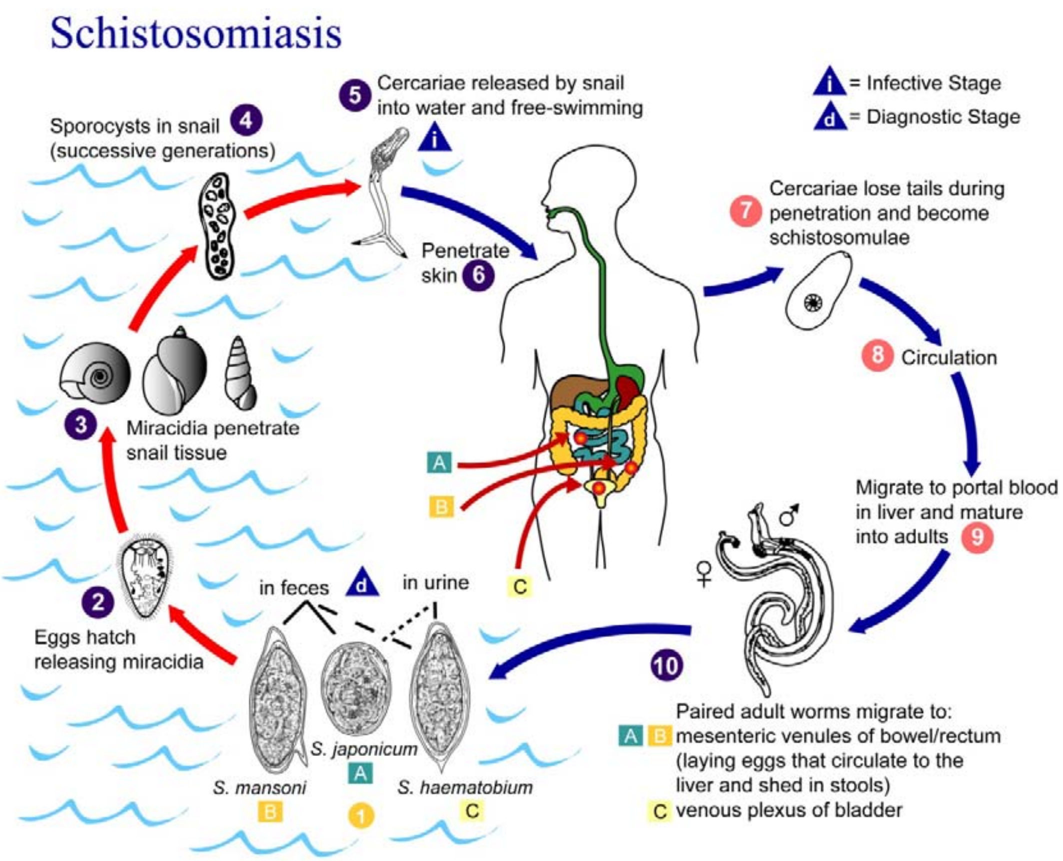
4/ These nematode infections occur because of a lack of excreta management and inadequate hygiene practices (Prüss-Üstün et al., 2004a). They are considered a major risk in agriculture, especially when untreated wastewater and excreta are used and sanitation standards are low. Hookworm spreads when farmers do not wear adequate footwear.

Schistosomiasis

1. Schistosomiasis caused by infection with trematodes of the *Schistosoma* species. WHO considers Schistosomiasis the most important water-based disease in modern populations. WHO estimates that 90 million people are infected with the parasites and that 150,000 people die each year from resultant renal failure, while an unknown but significant number of people die from bladder and other genitourinary cancers related to schistosomiasis. The overall mortality rate is estimated to be at least 2 per 1,000 infected patients per year (Hibbs et al., 2011). Symptoms of urinary schistosomiasis include abdominal pain, diarrhoea, undernutrition, and anaemia. There can be chronic infection leading to liver/spleen damage, stunted growth and impaired cognitive abilities in children.

These parasitic worms have a complicated life cycle. The adult worms live and mate inside human beings, and the eggs they lay are pointed. Using that point like a spear, the eggs move into the liver and other organs including the bladder and the intestines. Much of the damage caused by schistosomiasis is from the movement of eggs through host tissue. Eventually eggs are released when the human being urinates or defecates, and if the faeces or urine enter a body of water, the eggs hatch quickly into miracidia and are attracted to certain species of snails inside which they develop further. *Biomphalaria* and *Bulinus* (types of Ram's horn snails) are aquatic and *Oncomelaria* (a snail distantly related to the marine periwinkle) is amphibious. After about six weeks, the larval trematodes leave the snails in another form called cercariae, which swim and float. At this point they search for humans who are wading in shallow water. The cercariae are floating in the water and when they come in contact with a host, penetrate through the skin into the body. People can be infected within fifteen minutes if they are wading, swimming, playing, or working in water infected with cercariae (Outwater and Mpangala, 2005).

2.



Accessed at: http://www.dpd.cdc.gov/dpdx/HTML/Schistosomiasis.htm on 6 September 2013

3. Schistosomiasis infection occurs through exposure to water sources contaminated by communities of people (not through ingesting eggs which is common with other helminthes). Irrigated agriculture increases the habitat for the vector snails and the risk of exposure. Human alteration of the environment has been associated with increased prevalence of schistosomiasis in ancient and modern populations that use irrigation (Hibbs et al, 2011;

Utzinger et al., 2009). Current understanding of disease transmission indicates that disease burden is fully attributable to risk factors associated with water, sanitation and hygiene (Prüss-Üstün et al., 2004a).

4. It is estimated that schistosomiasis is 100% related to attributable modifiable factors.
5. The 2002 launch of the Schistosomiasis Control Initiative (SCI) was the most significant response to the call for action put forth in World Health Assembly Resolution 54. SCI was at the root of assisting six African countries with the highest rates of Schistosomiasis (Burkina Faso, Mali, Niger, Uganda, United Republic of Tanzania and Zambia).

There is a consensus of opinion that the control of the disease should be integrated into all sectors of society (Mazigo et al., 2012). King (2009) identified the applicable approaches to schistosomiasis control as: population based chemotherapy, snail control, proper sewage treatment, good environmental engineering designs, provision of clean and safe piped water, and health education.

In Brazil, it has been shown that important decreases in schistosomiasis can occur in a hyperendemic area. A multi-sectorial approach was used. They simultaneously integrated social development and decreased contact with bodies of water infected with cercariae. This was accomplished by treating the population pharmacologically, constructing privies, supplying water in the houses, and improving socioeconomic conditions." (Sarvel, Oliveira, Silva, Lima, Katz, 2011). If the snails remain infected and transmission route are still intact, chemotherapy alone is unlikely to be a long-term solution (Aagaard-Hansen, Mwanga, and Bruun, 2009). In the long run, decreasing schistosomiasis depends on structural changes including improved sewage treatment systems.

In Egypt, China, and Brazil, it has been shown that schistosomiasis eradication programs can be effective. In those countries great strides have been made in decreasing and in some places eliminating the detrimental effects of schistosomiasis (Stothard, Chitsulo, Kristensen, Utzinger ,2009). It can be done.

There is a lot of emphasis by WHO and SCI on drugs (Stothard, Chitsulo, Kristensen, Utzinger ,2009) because, one suspects, it seems easier. But the complicatedness of the creature behind the disease demands a thoughtful, multidimensional, long-term approach.

Malaria

1/ Malaria is not usually categorized as a waterborne disease, but it must be treated as a potential concern because sewage treatment systems can provide sites for mosquito egg laying and larval maturation (Njau, Mwegoha, and Mahenge, 2009).

Human malaria is caused by four species of plasmodia parasites (*Plasmodia falciparum*, *P. malariae, P.vivax,* and *P.ovale*) that are transmitted by *Anopheles* mosquitoes.

2/ *Plasmodium falciparum*causes severe malaria, and is the most lethal of the plasmodium parasites. Most malaria infections and deaths are due to *P. falciparum*, which is fatal if not promptly recognized and properly managed.

In the life cycle of *Plasmodium*, a female *Anopheles* mosquito transmits a sporozoite to a vertebrate host such as a human. A sporozoite travels through the blood vessels to liver cells, where it reproduces asexually producing thousands of merozoites. These infect new red blood cells and initiate a series of asexual multiplication cycles that produce 8 to 24 new infective merozoites, at which point the cells burst and the infective cycle begins anew. Other merozoites develop into immature gametes, or gametocytes. When a fertilised mosquito bites an infected person, gametocytes are taken up with the blood and mature in the mosquito gut. The male and female gametocytes fuse and form zygotes that develop into new sporozoites. The sporozoites migrate to the insect's salivary glands, ready to infect a new vertebrate host. The sporozoites are injected into the skin, alongside saliva, when the mosquito takes a subsequent blood meal (Wikipedia.org, accessed September 24, 2013.)

Worldwide about 1.44 billion people live in areas of stable malaria transmission and stable rates of infection. In Africa the median predicted prevalence within the areas of stable risk and ongoing transmission was 33% (WHO, 2010).

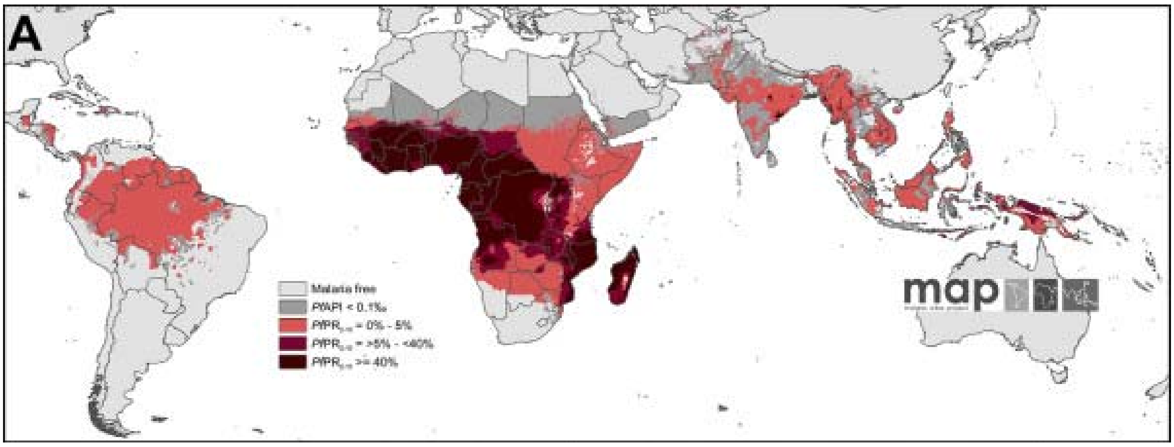


Figure (Appendix D7) *P. falciparum* rates. Figure from Gething et al., (Permission granted to use the figure)

Researchers compiled information on the number of cases reported by National Malaria Control Programmes around the world in 2009, and found that 78% of the malaria cases were in the WHO Africa Region. Based on that data, malaria case incidence for the Africa Region was estimated to be 176 (110–248) million cases in 2009, of which 173 million were attributed to infection with *P. falciparum* (Cibulski, Aregawi, Williams, Otten and Dye, 2011).

The most severe cases occur among persons who have not yet developed any immunity to malaria through previous exposure. Children under age five are at highest risk, followed by pregnant women because of their reduced natural immunity. Malaria during pregnancy is common among women who live in countries that are malaria-endemic, and a major cause of anemia. Malaria placental infection is a major contributor to low birth weight, infant mortality, maternal anaemia, spontaneous abortion, and stillbirth.

4/ WHO estimates that malaria infections attributable to modifiable environmental factors (42%) are associated with policies and practices regarding land use, deforestation, water resource management, settlement siting and house design (Prüss-Üstün and Corvalán, 2006).

5/ Internationally, the Roll Back Malaria Initiative works to reduce the malaria burden by increasing access to suitable and affordable protective measures such as use of insecticide-treated mosquito nets, and by increasing coverage of prompt and effective treatment for malaria. Malaria rates are declining worldwide. By far, the highest rates of malaria infection are still in Africa.

Tanzania is one of 85 countries in which malaria is endemic. Malaria is still a major health concern in Tanzania. It has been a leading cause of morbidity and mortality in Tanzania. For many years malaria has accounted for around 40% of overall inpatient hospital admissions and outpatient clinic attendances (MOHSW, 2008).

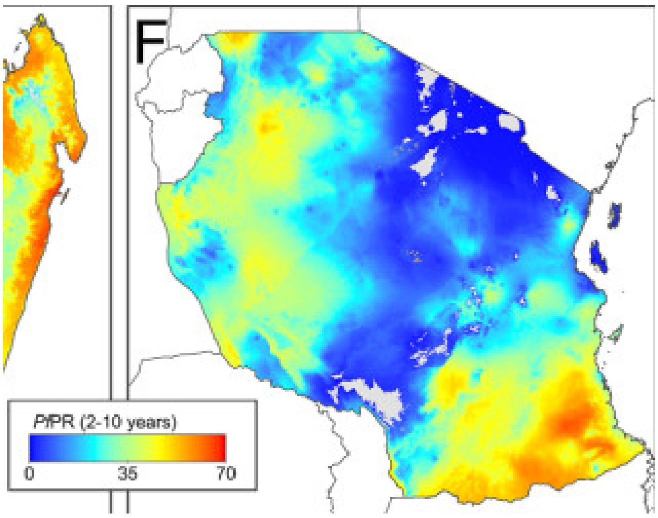


Figure 2.9 The Spatial Limits of *Plasmodium falciparum* in Tanzania 2010 (Gething et al., 2011)

The most common way of measuring malaria transmission is the parasite rate – that is, the proportions of individuals infected at a given point in time. This map defines the spatial limits of *P. falciparum* in Tanzania in 2010 (Gething et al., 2011). Changes in prevalence rates are partially driven by ecological variables such as altitude and moisture availability. In the above map, the lowest *P. falciparum* rates appear to be in the mountainous regions of the country with the highest rates in the southeast.

In 2007-08 through the Tanzania HIV/AIDS and Malaria survey 2008, blood samples were collected across the country from 6,390 children of age 6 months to age 59 months to detect the presence of malaria parasites. Nationwide 17.7% of children under five years of age tested positive for malaria. Of these children in the four regions of focus in this report only 0.4% tested positive in Arusha; 2.6% of children tested positive in Iringa; 15.7% in Morogoro; and 1.0% in Kilimanjaro (TACAIDS, 2008).
The government of Tanzania is committed to the control and prevention of malaria as part of the international Roll Back Malaria initiative.

The National Malaria Strategy includes vector control and epidemic prevention and control as well as improved access to effective treatment and insecticide-treated bed nets. By 2012 malaria rates were decreasingly rapidly.

Appendix E. The median prevalence of helminth species infection (inter-quartile range, minimum and maximum) (*n*) by region for Tanzania, 1980-2009. (From Brooker et al., 2009).

	Hookworm	*A. lumbricoides*	*T. trichuira*	*S. haematobium*	*S. mansoni*
Tanzania	**49.6 (30-73, 0, 100) (321)**	**0 (0-11, 0, 94) (319)**	**0.0 (0-13, 0, 100) (319)**	**31.1 (7-55, 0, 96) (345)**	**1.6 (0-5, 0, 95) (267)**
Arusha	-	-	-	-	-
Dar-es-Salaam	19.6 (7-32, 7, 32) (2)	4.0 (1)	0.0 (1)	16.2 (13-43, 5, 55) (13)	-
Dodoma	-	-	-	-	-
Iringa	-	-	-	-	-
Kagera	71.7 (60-78, 27, 93) (33)	3.3 (0-10, 0, 53) (33)	1.7 (0-13, 0, 55) (33)	0.0 (0-8, 0, 67) (33)	1.7 (0-7, 0, 78) (33)
Kigoma	-	-	-	-	-
Kilimanjaro	3.5 (3-9, 2, 14) (4)	7.2 (4-10, 1, 13) (4)	6.7 (3-13, 0, 18) (4)	35.1 (1-44, 0, 53) (6)	29.4 (23-51, 1, 73) (5)
Lindi	-	-	-	-	-
Mara	-	-	-	-	-
Mbeya	-	-	-	-	-
Morogoro	21.0 (1)	-	-	10.7 (5-24, 0, 67) (33)	-
Mtwara	-	-	-	25.8 (1)	-
Mwanza	40.2 (30-53, 7, 95) (78)	0 (0-0, 0, 7) (78)	0.0 (0-0, 0, 3) (78)	58.3 (43-72, 5, 92) (79)	5.0 (2-17, 0, 95) (83)
Pwani	59.3 (43-74,	5.6 (2-7, 0,	5.7 (0-11,	52.0 (39-62,	0.0 (0-0,

	35, 88) (9)	15) (9)	0, 61) (9)	29, 65) (7)	0, 0) (9)
Rukwa	-	-	-	-	-
Ruvuma	-	-	-	-	-
Shinyanga	20.0 (5-47, 0, 90) (35)	0 (0-0, 0, 3) (35)	0.0 (0-0, 0, 0) (35)	36.1 (25-57, 2, 90) (35)	0.0 (0-2, 0, 7) (35)
Singida	-	-	-	-	-
Tabora	43.3 (37-53, 2, 73) (51)	0 (0-0, 0, 3) (51)	0.0 (0-0, 0, 3) (51)	5.0 (2-12, 0, 43) (51)	0.0 (0-2, 0, 3) (51)
Tanga	67.7 (44-80, 16, 100)(52)	10.1 (4-21, 0, 61) (52)	4.9 (1-14, 0, 61) (52)	48.0 (31-67, 11, 96) (69)	0.0 (0-0, 0, 52) (49)
North Pemba	95.1 (86-97, 71, 99) (11)	50.0 (31-62, 5, 82) (11)	91.4 (78-95, 68,100) (11)	1.6 (1)	1.6 (1)
South Pemba	81.2 (52-93, 11, 97) (30)	56.4 (43-67, 19, 94) (30)	90.1 (79-96, 66, 99) (30)	-	-
Unguja North	9.1 (0-16, 0, 22) (8)	25.0 (12-37, 8, 50) (8)	35.1 (27-56, 19, 73) (8)	5.3 (0-54, 0, 83) (8)	73.3 (1)
Unguja South	9.1 (7-12, 7, 12) (2)	5.7 (2-9, 2, 9) (2)	41.7 (39-44, 39, 44) (2)	1.0 (0-4, 0, 15) (8)	-
Unguja Urban W	4.8 (5-13, 0, 16) (5)	0 (0-0, 0, 6) (5)	19.6 (5-20, 0, 29) (5)	42.5 (1)	-
Mjini-Magharibi	-	-	-	-	-