Water Research Commission Project 2134

Understanding and addressing the exposure of workers, the public and the environment to pathogens during pit emptying

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Submitted by Partners in Development

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EXECUTIVE SUMMARY

Upholding the aim of sanitation throughout the life cycle of a sanitation system

The most basic purpose of sanitation is to separate humans from their own and others' excrement, thereby protecting them from the pathogens potentially contained in faeces. On-site sanitation is a desirable option in many contexts and various on-site technologies have been rolled out in South Africa, as well as other countries, as a basic standard of adequate sanitation. Most on-site sanitation systems accumulate sludge in a collection chamber which eventually becomes full and needs to be emptied; the system can then be recommissioned for another cycle of use. If, in the process of emptying the collection chamber, workers or the public are exposed to the pathogens in the sludge or the environment becomes contaminated with sludge, then the most fundamental purpose of the sanitation system has been compromised. It is therefore of paramount importance to public and environmental health that the removal of sludge from on-site systems be conducted in such a way that the risk of humans or the environment coming into contact with sludge is reduced as far as possible, and that stringent measures are put in place for decontamination should exposure occur.

Understanding the pathways of exposure and contamination during pit emptying

This document is the product of a study of the pathways of potential exposure to sludge during pit emptying and ways to reduce risks which was conducted by Partners in Development, with collaboration from the University of KwaZulu-Natal, on behalf of the Water Research Commission. The study consolidates existing knowledge of the hazards associated with sludge management and guidelines for minimizing risk. Several investigations were undertaken which expanded existing knowledge on this subject:

- A case study of pit emptying at 10 homes was conducted which included observations of pit emptying practice, interviews with householders and pit emptiers, and the analysis of samples collected from surfaces and from the pit during pit emptying to determine where contamination with representative pathogens occurred.
- Baseline data on the incidence of helminthic infections was collected on 96 adult volunteers in the Easter Cape
- Four household cleaning agents were tested for their ability to deactivate helminth eggs

Findings

The study found that the pit emptying practices used by the contractors in this case study resulted in excessive exposure of workers, the public and the environment to pathogenic sludge. Pathogens were found in pit sludge, on household surfaces in the pit emptying environment and on workers' clothing and skin. While the logistical challenges of the job made it difficult to prevent contamination and exposure in some instances, in many cases workers did not take the measures available to them to reduce exposure, indicating that either their knowledge of disease transmission or their attitude towards their own health or that of householders did not support safe work practice. In many cases workers and households could have been protected from exposure had the contractors provided the necessary equipment to do so. In addition, enforcement of health and safety protocols on the job was not adequate to ensure that safe work practice was followed. It was found that the wiping of surfaces with cloths soaked with disinfectants could be effective for physically removing helminth eggs from surfaces but 95% or higher deactivation was only obtained when the eggs were soaked for at least an hour in a sodium hypochlorite solution diluted to a minimum of 50% strength.

Recommendations

A radical shift is needed by municipalities and contractors from a "public works" attitude towards sludge management to an understanding of sludge as a hazardous material. It is incumbent upon the authorities responsible for a pit emptying programme to ensure that the health and safety budget provides for the training, equipment and supervision necessary to minimise the exposure of workers, the public and the environment to sludge during pit emptying activities. Engineering and administrative controls must be put in place by the municipality and the contractor to ensure that risks of exposure are eliminated and reduced wherever possible. Workers must be trained in a basic understanding of routes of disease transmission, hygiene and work practices and protocols that minimise exposure. Contractors must equip workers adequately with the equipment and supplies they need to protect their health and the health of the public and the environment. The contractor must supervise and enforce compliance with health and safety requirements by workers, as must the municipality with regard to the contractor.

A guideline was produced from the findings of this study to assist municipalities and contractors in minimising the health risks involved in pit emptying. This can be found in Annex D, at the end of this document.

Further development of a training programme for workers is recommended in order to facilitate compliance by municipalities and workers with worker safety and environmental health regulations.

1. INTRODUCTION

The danger we face from our own excreta is, presumably, a problem as old as the human race. Accounts of what appear to be parasitic infections have been found in China and Egypt from as early as 3000 B.C. and eggs of the intestinal worm *Ascaris lumbricoides* have been found in mummified human faeces from Peru dating from 2277 B.C. (Cox, 2010). Despite our remarkable achievements as a species on many fronts, the problem of how to safely manage our excreta is far from solved: nearly 1 in 4 of the world's population still defecates in the open (WHO/UNCF, 2008). And "the open" – empty lots or undeveloped land where people may choose to defecate if they don't have access to a toilet – is rapidly giving way to population growth, resulting in increasing risk of exposure to disease. The consequences of infection by the organisms in excreta can be dire: diarrhoeal diseases remain the second leading cause of death among children under five globally, killing more young children than AIDS, malaria and measles combined, and it estimated that 88% of diarrhoeal deaths worldwide are attributable to unsafe water, inadequate sanitation and poor hygiene (UNICEF/WHO 2009). Infections with intestinal parasites can compromise health significantly.

Efforts to put a safe distance between us and our faeces – breaking the faecal-oral transmission of disease – have taken different forms, but usually involve a toilet with some sort of "user interface" (a pedestal or squat plate) – leading to a storage chamber (pit) on-site or a pipe (sewer) which carries it off-site. On and off-site sanitation carry different challenges and risks for workers who must empty pits, maintain sewers or operate treatment works -- and different risks for the householders whose onsite systems must be serviced.

Friis (2001) comments that the work of sewage workers was essentially unchanged from that of ancient Rome until the 20th century. Although more complex treatment systems exist now than when the Cloaca Maxima drained the Roman forum into the Tiber River and the increased use of chemicals in industries and homes have brought new hazards into sanitation work in modern times, sanitation workers have faced risks through the ages. Friis (2001) recounts that in *De Morbis Artificum*, a book on occupational medicine published by Italian physician Bernardini Ramazzini in 1700, inflamation of the eyes was considered an ailment typical to pit emptiers and sewer workers. Ramazzini's theory was that an "acid" evaporating from the "awful masses" affected the eyes. He recommended the use of transparent bladders to shield the face and limited work hours. Today, sanitation workers in many parts of the world continue to work with no protection and little understanding of the nature of the hazards found in faecal matter, often suffering the consequences. A study released by the Indian Management Institute in 2012 found that of 50 sanitation workers in the city of in Ahmadabad only 1 worker wore protective gear and only 3 demonstrated an awareness of the illnesses that could result from contact with faecal matter, despite the fact that there was a high death rate among sanitation workers and that tuberculosis, asthma, cough, backache and respiratory infections were common, with workers spending 25% of their income on health care (The Indian Express, 2012).

While waterborne sewerage systems have become standard throughout the developed world, in South Africa in 2011 only 57% of households were connected to sewers (SA Stats, 2012). Due to water scarcity, dry on-site sanitation is likely to remain a permanent part of our national sanitation reality. Much of the effort around improving health through improving sanitation currently focusses on the provision of adequate toilets to all. However, if during the process of removing excreta from on-site sanitation systems workers are exposed to pathogens or the household environment becomes contaminated, the gains made through the provision of sanitation will be compromised.

The burden of disease borne by sanitation workers -- and in turn by householders if their environment becomes contaminated with the material which workers are handling -- is a function of the prevalence and intensity of infections in the population whose faecal matter is handled by these workers and might be transferred to surfaces or individuals directly or through contaminated equipment.

Status of disease

In the South African context, where rates of infection with HIV and TB are high, the consequences of diarrhoeal diseases or loss of nutrients to parasites can be dire. In studies in sub-Saharan Africa, the geographical distribution of intestinal parasites has been found to coincide with that of HIV/AIDS under conditions of poverty (Kwitshana et al, 2008). Children are particularly at risk and their stools tend to carry a higher pathogen load than do those of adults (UNICEF/WHO, 2009). In South Africa, diarrhoeal diseases are the 8th largest cause of death nationally (Lewin, 2007), accounting for 3% of total deaths, and the third largest cause of death among children under 5, responsible for 11% of deaths in this age group. Table 1.1 shows the mortality rate among South African children under 5 compared with neighbouring countries and with countries with relatively low rates.

Table 1 Comparison of mortality rate for children in (per 1000 live births) for 2008

Countries with relatively low rates		South Africa and neighbouring countries	
Sweden	3	Botswana	31
Japan	4	Namibia	42
Germany	4	Zimbabwe	57
Cuba	6	South Africa	67
United States	8	Mozambique	130

Source: (UNICEF/WHO, 2009)

Persistent diarrhoea is associated with an 11-fold increase in mortality for children with HIV compared to uninfected children (Tindyebwa, et al., 2004 in UNICEF/WHO, 2009). Checkley et al (2008) found that a higher cumulative burden of diarrhoea increased the risk of stunting for 24-month-old children. It is also the third greatest contributor to the burden of disease, constituting 8.8% of all disability-adjusted life years (DALYs) in this age group (Lewin, 2007). The estimated incidence of diarrhoeal disease in under-5s in 2004 – derived from cases presenting to primary health facilities, and therefore likely to be an underestimate of true incidence -- was 129/1 000, (Lewin, 2007) nationally. This varied widely between provinces, from 8/1000 in Gauteng to 244/1 000 in KwaZulu-Natal. In a study conducted by the eThekwini Metro Municipality (Buckley et al, 2008) the incidence of diarrhoea was found to be 3.3 per 1 000 person days. A study in Port Elizabeth found incidents of diarrhoea to be greater among children under the age of 6 who shared a toilet with more than five other households and transmission of diarrhoeal diseases at childcare facilities has been found to be significant (Lewin, 2007). Esrey et al (1991) have suggested that good hygiene may result in a 33% reduction in diarrhoeal mortality.

Mortalities resulting from parasites are difficult to quantify as infections and symptoms may not be detected or diagnosed. Estimates of deaths caused by soil-transmitted helminths (primarily *A. lumbricoides*, *T. trichiura* and hookworm species) globally range from 12 000 to as high as 135 000 per year. (Bethony et al, 2006). While helminthic infections can be asymptomatic, they represent an important cause of nutritional deficiencies as well as impaired physical and cognitive development among children (WHO, 2005). Among the resulting impacts of this are a 23% drop in school attendance and 40% lower future earnings as adults for children with helminthic infections (CWW, 2011). In 1947 an attempt was made by Norman Stoll in a paper titled *This wormy world* to estimate the number of helminthic infections worldwide (Hotez et al, 2008). Today, between 1.5 and 2 billion people – possibly as much as a third of the world's population -- are now estimated to be infected by at least one soil-transmitted helminth. In 2001, the World Health Assembly passed a resolution urging member states to implement antihelminthic drug campaigns to reduce morbidity among school-aged children (Bethony, 2006).

Sub-Saharan Africa is the area of the world most affected by soil transmitted helminths (GAHI, 2013). While estimates of numbers of helminthic infections in South Africa are not available, studies indicate that the estimated 57% of South Africans who live in poverty carry the highest burden of both HIV and helminthic infections (Mkhize-Kwitshana et al, 2011). Data on parasitic infections in KwaZulu-Natal are scarce, however in a study analysing 5 733 stool samples from 32 public hospital laboratories across KwaZulu-Natal, evidence of helminth infections were found in 21.7% of samples and protozoan infections in 6% of the samples (Kwitshana, Tsoka and Mabaso, 2008). *A. lumbricoides* (10.7%) and *T. trichiura* (6.7%) were found to be the most prevalent helminths, and *Entamoeba coli* (2.8%) the most prevalent protozoan, with infections of these parasites documented in all health regions of the province. Other studies investigating the burden of disease among children in KwaZulu-Natal confirm *A. lumbricoides* and *T. trichiura* as the most prevalent helminths in the province, although far higher infection rates are documented. This may be attributed to the fact that school children are at greatest risk for parasitic infection (Appleton and Gouws, 1996). In a study investigating the prevalence of helminthic infections among school children along a 1000km long transect through the coastal plain of KwaZulu-Natal. Appleton, Maurihungirire and Gouws (1999) found mean infection as high as 69% for *A. lumbricoides* and 89.5% for *T. trichiura.* Infection among children in a Durban slum was found to be 89.2% for *A. lumbricoides* and 71.6% for *T. trichiura* (Appleton et al 2008). Tronnberg et al (2010) found that in two rural communities in KwaZulu-Natal the provision of UD toilets and health education was associated with a 41% reduction of diarrhoea episodes but the prevalence of parasitic infections among these families remained high: in sludge samples from 120 UD toilets the most prevalent helminths were found to be *A. lumbricoides* (59%), *T. trichiura* (48%) and *Taenia spp* (18%), while *G. intestinalis* (54%) and *Cryptosporidium spp* (21%) were the most prevalent protozoans.

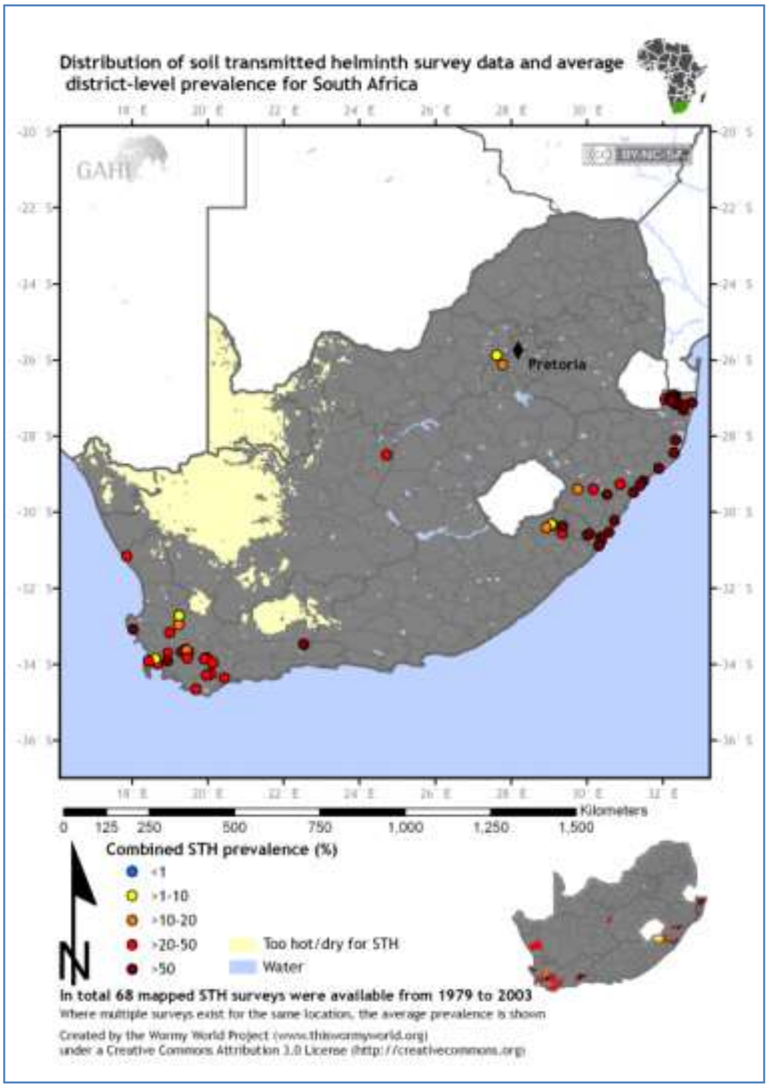

Figure 1 Mapping of 68 surveys of STHs in South Africa
(Source: Wormy World Project, 2012)

A higher burden of disease resulting from *Taenia solium* has been documented in the Eastern Cape (former Transkei) in South Africa for decades, with a 1965 study suggesting that cerebral cysticercosis (caused by *T. solium* cysts in the brain) was twice as high among people in that area than among other groups or regions in the country (Mafojane et al, 2003). Mafojane et al (2003) reports that a study in 1984 found 51% of the patients with cerebral cystercercosis at Groote Schuur hospital to be children, 43% of whom had epilepsy, 34% raised intracranial pressure, 13% meningo-encephalitis, 10% hydrocephalus; two of the children in the study died of complications caused by neurocysticercosis (ibid). An analysis conducted in 2004 found the burden of disease for the Eastern Cape Province alone to be between USD 18-34 million per annum, with epilepsy (34 662 cases) accounting for the largest overall impact (Carabin et al, 2006). As the disease is, in theory, easy to control, the International Task Force has declared *T. solium* eradicable (Carabin et al, 2006). The free ranging of pigs, poor sanitation and lack of knowledge among the public about modes of transmission combine to make disease reduction a challenge, however.

In studies conducted in the informal settlement of Kayalitsha in the Western Cape, helminthic infection rates at 12 schools were found to be over 90%; 70% of adults in the community could recall having been infected with helminths (Mkhize-Kwitshana, 2012).

In 1998, the KwaZulu-Natal Department of Health initiated a pilot programme to control helminthic infections through regular treatment of primary school children (Saathoff et al, 2004). Unfortunately this initiative did not materialise into an ongoing programme. South African hospitals typically administer single dose antihelminthic treatment to all children seen at the hospital; this however does not achieve the comprehensive treatment of children which school-based programmes would (Bishop, pers. comm., 2013). Without comprehensive, sustained chemotherapy treatment in areas where helminths are endemic, reinfection is probable. Appleton et al (2008) found that among children in a Durban slum infection with *A. lumbricoides* reached the same intensity by one year after treatment as it was pre-treatment, while for *T. trichiura* it was even higher. An analysis of 51 studies conducted by Jia et al (2012) confirmed this trend: for the three most common soil transmitted helminths (*A. lumbricoides*, *T. trichiura* and hookworm) after treatment prevalence of infection reached half of what it had been pretreatment in 6 months, and a year after treatment levels of infection had usually returned to levels close to the pretreatment figures.

Risks sanitation workers face

The results of studies investigating whether sanitation workers contract diseases from their exposure to sludge vary widely, and conclusions are sometimes contradictory. Reports on mortality among sanitation workers are few. In 1954, the German physician Anders concluded from a study of 449 sewer workers that chemicals and organisms in sewage did not pose a risk to workers (Friis, 2001). But a study conducted in the 1970s found that in Copenhagen the death rate for workers who had worked for more than 8 years in the sewer was more than twice that of the death rate for the male population of the city (ibid). Because sanitation workers often come from the same population which produces the excreta which they handle, it can be difficult to establish whether worker exposure occurred before the pathogens entered the toilet (ie. In the course of daily life amongst a population carrying these pathogens) or after they exited the toilet (ie. during the handling of sludge). Studies abound, however, which indicate increased risks of various infections for workers exposed to sludge and what is known is that faeces contains organisms which cause disease and that, in addition, sewage frequently contains harmful chemicals.

Given this knowledge, it is incumbent upon government and management to make every effort to minimise the risks workers face from contact with faecal matter. The International Labour Organisation (2012) and Water UK (2006) have identified the following categories of biological agents as risks for wastewater treatment plant workers:

- infectious agents (bacteria, viruses, protozoa, helminths and fungi)
- proteins in microorganisms which are foreign to the human body which may cause allergies
- toxins released from microorganisms
- insects (eg. sewer flies) or rodents reproducing in the sludge drying beds

Pit latrine sludge has been found to contain viable helminth eggs even after remaining for years outside of a host in the pit environment. In earlier Water Research Commission studies (Foxon, 2007) large numbers of *A. lumbricoides*, *T. trichiura* and *Taenia spp*. were recovered from the face masks of pit latrine emptying workers. In a recent Water Research Commission project (Still et al, 2012), sludge samples were taken from three levels in 10 pit latrines. *A. lumbricoides*, which was used as a marker, was found in all samples, with loadings ranging from 142 to 3937 ova per gram of sample (wet weight) with viability ranging from 20 and 40% across samples and showing no decrease in viability with length of time that the sludge had been in the pit (depth of sampling). A study relating to the similar sludges found in urine diverting toilets (Mnguni et al 2008) indicated a 100% risk of helminth infection for workers and that the use of multiple barriers (gloves, hand washing with soap) reduced the risk, but did not eliminate it. Bucket washers at Mangaung Local Municipality were found to fall into the high risk category for biological exposure, with both their gloves and their hands heavily contaminated (Lourens et al. 2002). Bacterial counts from the hands of some workers upon reporting for work in the morning showed high levels of contamination not originating from their jobs. This points to the complex interaction of factors such as personal hygiene, the availability, use and care of protective wear, and home environment which impact on the risks faced by workers.

While this study focuses on the hazards posed by the contents of sludge itself, in particular pathogens, sanitation workers face other hazards as well which bear mention. The International Labour Organisation (2012) has identified the following potential health risks which sanitation workers face which are apply to pit emptiers:

- Accidents resulting in exposure to chemicals present in sludge
- Ergonomic factors such as musculoskeletal injuries caused by overexertion or by awkward working postures (eg. frequent bending)
- Discomfort and psychological problems related to prolonged wearing of heavy or impermeable protective clothing, feeling of working with filthy materials, feeling that occupation is not respectable or apprehension caused by awareness of the dangers of the workplace

Risks householders face

Studies investigating the risk of infection to householders with on-site sanitation systems which must be routinely emptied are scarce. Pickering et al (2012) found surfaces in and around households with unimproved pit latrines in Tanzania including soil, floors, walls, cups and vegetables, to be widely contaminated with faecal pathogens. Floors of homes were more highly contaminated than the floors of latrines. Exposure to faecal pathogens therefore may be high in a household environment even before on-site sanitation systems are serviced as a result of open defecation, contaminated food brought into the home and poor hygiene practices. In dense living conditions the risk of infection due to contamination of the environment during pit emptying may be higher because of the proximity of household activities to contaminated areas.

Buckley et al (2008b) found that during the servicing of urine diversion toilets sludge was left exposed at the site in 72% of the cases. While sludge was buried on site, none of the households marked the burial area, which in 84% of the cases was in close proximity to human activity, and only 12% waited for a period of time before using the area around the buried sludge.

Improved sanitation: bridging the gap

While the South African government demonstrates a firm grasp of, and commitment to, the importance of sanitation infrastructure and hygienic practices in reducing needless disease and mortality, things can break down at a number of points. If local government lacks the resources – or fails to properly manage the resources – to train, equip and supervise its sanitation workers – the process of servicing sanitation systems may itself open up new routes of exposure. Workers who don't have an adequate understanding of the diseases in sludge or how they are transmitted are unlikely to be conscientious in their use of protective wear and their application of safe practice, thereby putting their health and the health of householders at risk. Under resourced municipalities may be unable to provide adequate training, equipment or oversight to ensure that workers have in place – and use -- well thought out protocols to guide their practice which will, firstly, prevent contamination and, secondly, deal with accidental contamination.

Scope of this study

This study aims to gather information at several levels in order to close practical gaps in terms of knowledge and logistics in order to aid both management and workers in preventing the spread of disease in the course of sanitation work.

While it was planned that two pit emptying programmes would be studied, both programmes experienced substantial delays. As a result, only one pit emptying programmed was studied (eThekwini), during which data was collected as follows:

- Sludge samples were collected and analysed for 10 households (eThekwini)
- Observations of pit emptying at 10 households (eThekwini)
- Interviews were conducted with 10 householders (eThekwini)
- Interviews were conducted with 10 pit emptiers (eThekwini)
- Surface and sludge samples were collected from 10 households during pit emptying and analysed for the presence of representative helminths and bacteria (eThekwini)

In addition, baseline data on the incidence of helminthic infections was collected for 46 pit emptiers and 50 non-sanitation workers (Eastern Cape). Monitoring of infections among these 96 volunteers could not be continued over two years as planned because the pit emptying programme was put on hold.

In addition, four household disinfectants were tested for their ability to deactivate helminth eggs, which may contaminate household surfaces or workers' clothes or skin during and after pit emptying.

Scope of this document

This report is organised as follows:

Chapter 1: Introduction
Chapter 2: What we know about the risks encountered in sludge management: a literature review

- An overview of important pathogens and other harmful materials found in sludge
- An overview of the ways in which exposure to hazards can happen
- A survey of existing policies and guidelines for reducing exposure to pathogens

Chapter 3: The design and implementation of this study, including setbacks that were encountered
Chapter 4: The results of the various investigations undertaken in the study
Chapter 5: Findings and conclusions
Chapter 6: Recommendations

The annexures at the end of this document contain the following information:
Annex A: Research tools developed for this study
Annex B: Additional laboratory data not presented in the main body of the report
Annex C: Methods used for laboratory investigations
Annex D: A HEALTH AND SAFETY PLAN FOR MUNICIPALITIES AND CONTRACTORS

Annex D consolidates the best practice gleaned from this study.

2. WHAT WE KNOW ABOUT RISKS: A REVIEW OF THE LITERATURE

The review of literature which follows explores the following angles of protecting the health of workers, the public and the environment during sludge handling:

- Hazardous components in sludge which represent a health threat
- Routes of exposure to hazardous components in sludge
- Guidance (both international and local) for reducing exposure to health hazards
- Controlling infection where exposure to pathogens may have occurred

2.1 HAZARDOUS COMPONENTS IN SLUDGE WHICH REPRESENT A HEALTH THREAT

Faecal sludge may contain a number of harmful components including:

HARMFUL COMPONENTS THAT MAY BE FOUND IN PIT SLUDGE

- Infectious organisms(bacteria, viruses, protozoa and helminths (intestinal worms)
- By-products of organisms in sludge
- Gases produced during decomposition of sludge
- Toxic materials disposed of in the pit

The type and number of organisms found in sludge will vary from one household or community to the next depending on the infections found in individuals in that community. Some organisms, such as viruses, can be shed in large quantities even by carriers who are healthy. In a study including 5,733 screened samples from across the province of KwaZulu-Natal, parasites (helminths and protozoas) were found in 20.4% of samples (Kwitshana et al, 2008). Organisms which require a host, such as viruses, cannot reproduce in sludge, but others can increase in number under favourable conditions. The risk of infection is greatest from fresh, raw sludge, but some organisms, such as the eggs of the worm *Ascaris lumbricoides*, are hardy and can survive for many years in the pit environment. Diarrhoea, which can be life threatening for vulnerable populations, is a common manifestation of infections caused by bacteria, viruses and protozoa (UNICEF/WHO, 2009). Acute watery diarrhoea, which can be caused by *V. cholerae*, pathogenic strains of *E. coli* or viruses such as the human rotavirus, can cause significant fluid loss resulting in rapid dehydration lasting for several hours or days. Bloody diarrhoea, or dysentery, is most often caused by *Shigella* spp. and can cause intestinal damage, resulting in nutrient loss and blood in the stools (UNICEF/WHO, 2009).

As some bacteria die and breakdown they release toxic substances (endotoxins) which can present a different risk later in the process of degradation. Fungi such as *Aspergillus* spp. may grow under some conditions such as composting and may cause allergic responses, lung infections or worsen existing asthma worse, particularly for workers with other health conditions (CPWR, 2012). Inhalation of particles from sewer flies (*psychoda spp*) can cause allergic asthma, with symptoms of runny nose, eye irritation, and severe wheezing (Brown, 1997).

Sludge may also contain toxic inorganic substances that are produced during the degradation of faecal matter itself. While ventilated pit latrines (VIPs) allow for some ventilation which reduces the likelihood of build-up of harmful gases, gases such as methane, hydrogen sulphide and carbon dioxide may be produced and released from pits and may be trapped in pits which do not have adequate ventilation. There are historical accounts of entire families asphyxiating as a result of gases building up in cesspits as materials decomposed (Greenberg, 2003).

In communities which do not receive reliable solid waste collection services, pits are likely to be used for disposal of hazardous or other waste. The waste from home-based businesses or industries (eg. automotive repairs) may be included.

2.1.1 Bacteria

Bacteria may cause a range of symptoms, including diarrhoea, fever, cramps, and sometimes vomiting, headache, weakness, or loss of appetite (CPWR, 2012). Gastroenteritis, which presents with stomach pains, diarrhoea and vomiting, can be caused by a number of different types of bacteria, and is a prevalent cause of loss of work time in sanitation industry (Water UK, 2006). Table 2.1 provides some examples of pathogenic bacteria that may be found in sludge and associated symptoms or diseases.

Table 2 Examples of bacteria found in sludge which may pose a health threat

Organism	Disease and typical symptoms
Salmonella spp.	Salmonellosis, gastroenteritis, typhoid fever
Leptospira spp.	Leptospirosis (Weil's disease) Headaches, muscle pain, lack of appetite, jaundice, septic meningitis. Harm to nervous, renal and respiratory systems; potentially fatal
Shigella spp.	Shigellosis, diarrhoea, bacillary dysentery
Vibrio cholerae	Cholera
Legionella pneumophilia	Pneumonia, Pontiac fever
Escherichia coli (pathogenic strains EHEC, ETEC, EPEC, EIEC, EAEC, DAEC)	Gastroenteritis; haemolytic uraemic syndrome
Campylobacter spp.	Gastroenteritis
Helicobacter pylori	Gastric cancer
Yesinia spp.	Acute gastroenteritis
Vibrio cholerae	Cholera

(Sources: Singh et al., 2011; WHO, 2011, Friis, Tiwari, CPWR, Brown)

Escherichia coli is found in all sewage systems (Brown, 1997). It is indigenous to the intestines of humans and animals, where it generally causes no harm, but in other parts of the body it may cause urinary tract infections, bacteraemia, meningitis and even death (WHO, 2011). The infective dose can be less than 100 organisms (ibid). Pathogenic strains of *Escherichia coli* have been implicated in large disease outbreaks in Europe which have typically been related to contamination from faecal matter (ibid).

Salmonella spp. has a short survival time in sludge, but illness in healthy adults has been documented after consumption of less than 100 organisms per 100g (Brown, 1997).

Shigella spp. and *Campylobacter spp.* are also commonly found in sludge, with *V. cholerae* sometimes occurring in epidemics (UNICEF/WHO, 2009). *Shigella spp* has a very low infective dose of about 10-100 organisms (WHO, 2011). In one study approximately 25% of volunteers developed dysentery after ingesting 180 cells, while another 30% showed no susceptibility to *Shigella* at all, despite not having high levels of pre-existing antibodies (Brown, 1997). *Campylobacter jejuni* is known to cause gastroenteritis worldwide (WHO, 2011*). Vibrio cholerae*, the bacterium which causes cholera, is able to reproduce in water. The most recent outbreak in KwaZulu-Natal was in 2001/2002, with 110,000 cases (Knight, pers. comm., 26 Nov 2012). Those infected acquire immunity and there are no chronic carriers of the disease.

Leptospira bacteria can be found in sewers or pits when excreted by rats in their urine and enter the body through broken skin or mucous membranes (Friis, 2006). In South Africa, Saif, Fraen, Roussouw and Trataris (2011) reported 19.8% (43/217) of participants in Cato Crest in Durban in a 2003-2006 study tested positive for leptospirosis; 8% (26/311) of samples collected from around the country were IgM positive. In a 2008 study, 23% of residents of Cato Crest were found to have been exposed to leptospirosis (Taylor, 2008). Leptospirosis was considered an occupational disease for sewer workers at one time and was the bacterial infection that was of most concern in the wastewater industry (Friis, 2006). Infection rates among sewer workers declined in the United States from 8% (1933-1948) to 2% (1978-1983) probably as a result of improved pest control measures, the use of protective clothing, and the increase of detergents in wastewater which effectively destroy the bacteria (Brown, 1997). In a study of past infection with *Leptospira* in Pune, India microagglutination tests showed 16.6% of workers positive, with the highest infection levels among workers in the areas of the city with the heaviest infestations rodents and stray animals (Tiwari, 2008). The disease can present with flu-like symptoms or lack of appetite, however, and can lead to aseptic meningitis. The nervous, renal and respiratory systems can be affected and in some cases the disease has led to death (Water UK, 2006).

A number of studies have reported higher incidence of gastric cancer among sewage workers (Tiwari, 2008). *Helicobacter pylori* has been identified as a significant risk factor for gastric cancer and has been labelled a class I carcinogen by the International Agency for Research on Cancer. In a study] investigating the prevalence of immunoglobulin G (IgG) antibodies against *H. pylori* in a group of 289 municipal workers (Friis, 2006), sewage workers did not show a greater prevalence of IgG antibodies against *H. pylori* over control workers.

Yesinia pestis, commonly as bubonic plague, is spread by rats. During the most recent plague (1900-1901) South Africa suffered high mortality (Taylor et al, 2008). As a major port, Durban is vulnerable to the arrival of plague on ships from plague endemic countries and ships are monitored to prevent rats from escaping. Yesinia has been detected in raw, digested and dewatered sludge; little is known about survival in soils or waters (US EPA, 2011).

While there have been reports of *Tubercle bacilli* having been found in sludge, no evidence has been found that sewage workers face an increased risk of contracting tuberculosis (Friis, 2001).

Endotoxins may be created from the cell walls of gram-negative bacteria as they die (Brown, 1997). When dry, they may become airborne as particles which can be inhaled, ingested or absorbed by mucosa and thereafter absorbed in the bloodstream, where they can cause effects ranging from inflammation, fever and other flu-like symptoms, to coughing breathlessness and even shock (US EPA, 2011).

2.1.2 Viruses

Viruses are very small, can survive for long periods of time in water and have a low infective dose (Epstein, 1998; WHO, 2011). The major viruses infecting humans are identified as rotaviruses, enteroviruses and noroviruses (WHO, 2011). Rotavirus is the leading cause of acute diarrhoea, and is responsible for about forty per cent of all hospital admissions due to diarrhoea among children under five worldwide (UNICEF/WHO, 2009). Enteroviruses, polioviruses and also the recent parechoviruses cause mild febrile illness, paralysis, meningitis and encephalitis in children (WHO, 2011). When airborne viruses are inhaled, they may become trapped in the person's nasopharynx and initiate an infection (Brown, 1997). While viruses which infect the respiratory tract may be swallowed in large numbers, these are usually destroyed by acid in the stomach or bile salts in the intestine.

Table 3 Viruses found in sludge which may pose a risk to sanitation workers

Organism	Disease and typical symptoms
Enteroviruses (67 types), Rotaviruses, Parvoviruses, Reoviruses, Astrovirus, Calicivirus, Norwalk agent	Gastroenteritis (24 hour flu)
Reovirus	Respiratory infections and gastroenteritis
Hepatitis A	Infectious Hepatitis, tiredness, abdominal pain, nausea, jaundice, diaorrhoea, loss of appetite
Hepatitis B	Serum Hepatitis (cirrhosis, liver cancer)
Coxsackiviruses,	Aseptic meningitis, pneumonia, hepatitis and fever
Adenoviruses (31 types), Reoviruses, Coronavirus	Respiratory disease
Echoviruses	Meningitis, paralysis and encephalitis fever
Polioviruses	Poliomyelitis

(Sources: Epstein, 1998; Rose *et al*., 1996; USEPA, 1999a, Friis 2001, Brown 1997, CPWR 2012)

In South Africa, Hepatitis A is endemic, however the true burden of disease is unknown as most infections are asymptomatic and illness is underreported (NICD, 2012). The main route of infection by hepatitis A is faecal-oral transmission. Hepatitis A is resilient in the environment and can persist for long periods even under adverse conditions (NICD, 2007). Infection by hepatitis A in childhood is usually asymptomatic while disease in adults is more severe (NICD, 2007). A 1994 South African study found over 90% of black adults, but only 40-60% of white adults, positive for hepatitis A virus-specific IgG (NICD, 2012). A survey conducted in 1998/9 found 80% of children from lower socio-economic communities, and 24% of children in higher socio-economic groups, to be seropositive by 11-13 years of age (NICD, 2007). Hepatitis A frequently shows no symptoms, but may cause liver disease and may manifest with symptoms such as tiredness, nausea, abdominal pain, jaundice, diarrhoea or loss of appetite (CPWR, 2012). While sanitation workers are at high risk of exposure to hepatitis A in South Africa, immunization programmes are likely to be of little value as workers are likely to have already acquired immunity following infection in childhood (NICD, 2007). Immunization following infection is considered to be lifelong (NICD, 2007) while vaccinations are considered effective for 5 years (Zondi, pers. comm. 26 Nov 2012). While there is no national vaccination programme for hepatitis A in South Africa (NICD, 2012), hospital staff in KwaZulu-Natal are routinely vaccinated (Zondi, pers. comm., 26 Nov 2012).

The Hepatitis B virus can also cause liver disease and symptoms similar to those caused by Hepatitis B (CPWR, 2012). As Hepatitis B is usually transmitted through sexual activity, sanitation workers would not be expected to be at higher risk of infection (Knight, pers. comm., 26 Nov 2012). However, in German and Greek studies sewer workers were found to have had the disease more frequently than control groups (Friis, 2001).

Current research suggests that sanitation workers are not at increased risk from HIV, polio or tuberculosis. HIV requires an intact outer membrane to remain infectious, and this membrane is easily damaged under unfavourable conditions (Brown, 1997). No cases of HIV infection from wastewater have been reported in the USA (CPWR, 2012). The Center for Disease Control (CDC) in the United States allows HIV contaminated blood and body fluids to be disposed of in a sewer because the temperature, pH shifts, chemicals, and dilution which occur in wastewater are believed to quickly inactivate the HIV virus (Brown, 1997). While poliovirus is transmitted by contact with faecal material, vaccination and improved hygiene have practically eliminated this virus from many countries; while vaccine strains are commonly found in sewage, viral strains are rare (ibid). While tubercle bacilli are persistent and has been reported in sewage, there is no evidence that sanitation work places workers at increased risk for infection (Friis, 2001).

2.1.3 Protozoa

A significant positive correlation has been found between the presence of protozoa in the faeces of sewage workers and the duration of the workers' exposure to sewage (Friis, 2001).

Giardia and *Cryptosporidium,* are able to survive for long periods in water and the infections they cause are more common and longer lasting in comparison to other genera (WHO, 2011). *Cryptosporidium* is highly resistant to oxidizing disinfectants such as chlorine (Carey *et al*., 2004).

Table 4 Protozoans found in sludge which may pose a risk to workers

Organism	Infection rate in KZN documented by Kitshwana et al, 2008 (%)
Entamoeba histolytica, entamoeba coli	2.8
Cryptosporidium	0.17
Giardia lamblia, Giardia intestinalis	0.7
Balantidium coli	0.24
Chilomastix muesli	0.3
Entamoeba histolytica	0.63
Entamoeba hartmani	0.47
Iodamoeba buscthli	0.12
Endolimax nana	0.99
Isospora species	0.38
Coccidia	0.03
Naegleria fowleri	
Acanthamoeba	
Cyclospora cayetanensis	
Toxoplasma gondii	

(Sources: Friis, 2001, Brown, 1997, CPWR, 2012)

2.1.4 Helminths

The highest prevalence of helminths is found among children, who are particularly vulnerable to the potential effects of infection, such as nutritional deficiencies and impaired physical and mental development (Saathoff et al, 2004). A study conducted in 1998 with 1017 school children in northern KwaZulu-Natal found 90% of the pupils infected with either *A. lumbricoides*, *T. trichuris* or hookworm and 31% infected with all three (Saathoff et al, 2004).

A. lumbricoides, T. trichiura and hookworm, known as soil-transmitted helminths (STHs), are responsible for a major burden of disease around the world are of particular concern in warm climates with adequate moisture. In South Africa, the highest prevalence of soil transmitted helminths is in the KwaZulu-Natal coastal area (Appleton et al, 2009), with temperature and moisture (altitude and latitude) affecting prevalence across the province. In a study of school children conducted in KwaZulu-Natal (Appleton and Gouws, 1996), the prevalence of *T. trichiura* and *A. lumbricoides* increased with decreasing altitude: at approximately 1700 metres above sea level less than 20% of subjects were infected while over 80% of participants were infected at the coast. Prevalences were highest between 1000 and 2000m, with lower temperatures probably being a limiting factor for *T. trichiura* at higher altitudes and rainfall a limiting factor for *A. lumbricoides* at lower altitudes. In a study conducted in Qwa-Qwa, a mountainous area (1500 to 3000 m above sea level) neighbouring Kwa-Zulu Natal, Mosala et al (2001) recorded *A. lumbricoides* infection levels ranging seasonally from 3.8% in summer to 2.1% in winter, and for *T. trichiura* from *0.8%* in summer to 0.2% in winter. *T. trichiura* was not found above 2000m. Appleton, Maurihungirire and Gouws (1999) found that the prevalence of *N. americanus* decreased from north to south. This was true to a lesser degree for *Strongyloides stercoralis*. Hookworm and *S. stercoralis* infections appeared to stop at 31°S.

Table 5 Helminths found in sludge which may pose a risk to workers

Organism	Disease and typical symptoms	Infection rate in KZN documented by Kitshwana et al, 2008 (%)
Ascaris lumbricoides	Ascariasis, Often none; coughing or difficulty breathing, intestinal pain, constipation.	10.69
Trichuris trichiura (whipworm)	digestive disturbances	6.7
Hookworm species (incl Necator americanus)	Often asymptomatic; gastrointestinal symptoms, blood loss leading to anaemia.	1.8
Strongyloides stercoralis	Anaemia, rashes, gastrointestinal symptoms	0.26
Enterobius vermicularis	Anal itching	0.03
Fasciola hepatica (liver fluke)	Fever, malaise, enlarged liver, abdominal pain	

Schistosoma haematobium	schistosomiasis	0.2
Taenia spp (incl Taenia solium, Taenia saginata)	Nervousness, insomnia and anorexia, epilepsy, cysticercosis	0.78
Schistosoma mansori	Nervousness, insomnia and anorexia	1.03
Hymenolepis nana	Usually asymptomatic	0.21
Dipylidium caninum	Loss of appetite; indigestion	
Ancylostoma duodenale (hookworm)	Anaemia	

(Sources: Friis, 2001, Brown, 1997, CPWR, 2012, Singh *et al*., 2011; WHO, 2011)

Ascaris lumbricoides is the largest roundworm parasitizing the human intestine, infecting an estimated 807-1,221 million people worldwide (CDC, 2012). Ascariasis is prevalent in the Durban area among poorer communities (Buckley et al, 2008b). Most infections occur in people 10 years old or younger (Mayo Clinic, 2012). Adams et al (2006) propose that infected adults may typically be in a state of immunological holoendemic equilibrium which reduces infection. Microscopic A. lumbricoides eggs are passed in the faeces of infected persons. Fertilized eggs must spend at least 18 days while they embryonate before they become infective (Mayo Clinic, 2012). The ideal conditions for this are moist, warm soil that is shaded; if these conditions are not met the embryo may take several weeks to become infective (CDC, 2012). Once infective, eggs may remain viable for up to 15 years (Buckley et al, 2008b). Infection occurs when infective eggs enter the mouth through contaminated hands or food and are swallowed. This mode of transmission was discovered by Davaine, a French scientist who in 1862 infected himself with the eggs of *A. lumbricoides* and observed eggs subsequently in his faeces (Cox, 2002). The eggs hatch in the small intestine of the host and the larvae penetrate the intestinal wall and travel to the lungs via the bloodstream or lymphatic system, where they mature for 6-14 days in the lungs (CDC, 2012, Mayo Clinic, 2012). After this they break into the airway, travel up the throat, and are then coughed up and swallowed (Mayo Clinic, 2012). The migration of larval stages of *A. lumbricoides* was discovered by Koino, a Japanese pediatrician, in 1922 when he infected himself and subsequently found large numbers of larvae in his sputum (Cox, 2002). Once the larvae have returned to the intestines, they mature into adult worms. The period from ingestion of infected eggs to production of eggs by a mature female takes 2-3 months (CDC, 2012). Females can grow to be over 40cm while males tend to be smaller (Mayo Clinic, 2012). Females can produce 200,000 eggs per day which are passed in the stools. The lifespan of *A. lumbricoides* is 1-2 years; they remain in the intestine until they die (CDC, 2012).

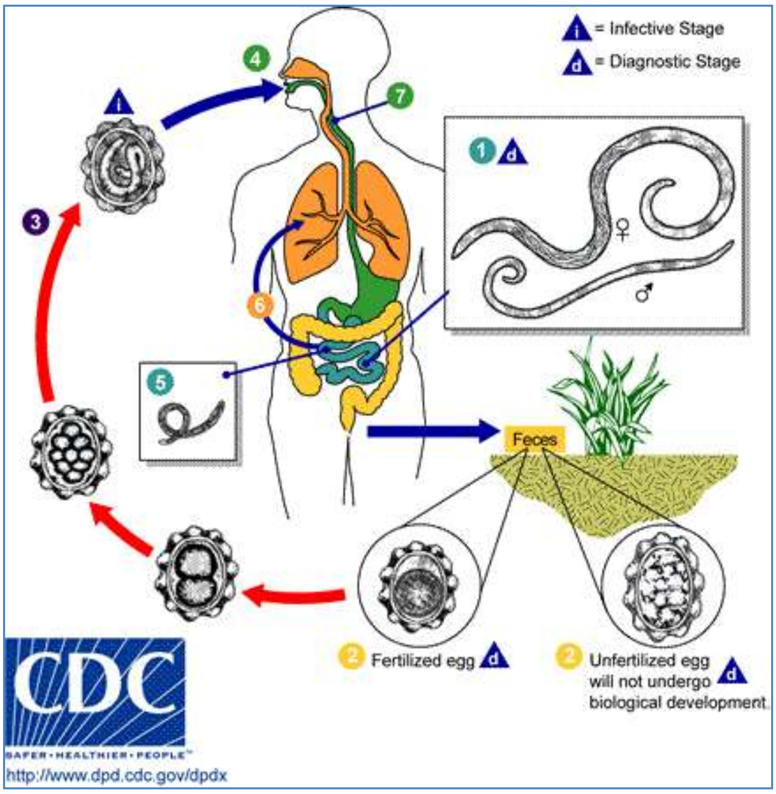

Figure 2 Lifecycle of *A. lumbricoides* (CDC, 2012)

People infected with *Ascaris* often show no symptoms. At the larvael stage, symptoms similar to asthma or pneumonia may occur, such as persistent coughing, wheezing, or shortness of breath (Mayo Clinic, 2012). Mild or moderate ascariasis can cause vague abdominal pain, nausea and vomiting and diarrhoea or bloody stools (Mayo Clinic, 2012). A heavy infestation can cause severe abdominal pain, fatigue, vomiting, weight loss. A worm may be found in vomit or a stool, or may come out of the mouth or nostrils. (Mayo Clinic, 2012).

Diagnosis is usually made from the presence of eggs in stools, which may begin to appear 40 days after infection (Mayo Clinic, 2012). Because *A. lumbricoides* eggs bond to soil particles, which may be filtered out in standard analytical procedures, prevalence is probably significantly underestimated (Buckley et al, 2008b). Some researchers (Mikhize-Kwitshana et al, 2011, Adams et al, 2006) have challenged the reliability of diagnosis exclusively on the basis of the presence in eggs in stools on the basis that helminthic infections produce different phenotypic outcomes characterised by specific immune responses. Mkhize-Kwitshana et al (2011) found that of 42 individuals with A. lumbricoides infections detected by the presence of elevated Ascaris-specific serum IgA, eggs were detected in the stools of only 21 individuals. Adams et al (2006) reported eggs found in stools for only a third to a half of individuals who exhibited an immune response to *A. lumbricoides*: in one study involving 41 women, 51.2% had elevated *Ascaris*-specific IgE while only 26.3% had eggs in faeces from multiple stool samples; in another study involving 359 children, 48% showed an immune response to *A. lumbricoides* while only 15% had eggs in faeces from two stool samples. Individuals who have ingested *A. lumbricoides* eggs which have not yet matured into reproducing female worms could exhibit immune responses without the presence of eggs in stools (Archer, pers. comm., 18 January 2013). In addition, in the case of an infection where all worms are male, no eggs would be found in the stool (Mayo Clinic, 2012). Diagnosis of *A. lumbricoides* can also be made by testing for an increase in the white blood cell eosinophils; however if elevated levels are found they could be due to other health conditions (Mayo Clinic, 2012). Treatment by Albendazole, Mebendazole, pyrantel pamoate is effective (Legesse, Erko and Medhin (2004).

Most infected individuals harbouring light infections and heavy infections occurring among only a small number of infected individuals (Jia, 2012). The effects of ascariasis can be serious, however. Children may experience loss of appetite and insufficient absorption of nutrients, resulting in nutritional deficiencies (Mayo Clinic, 2012). Blockages by masses of worms can perforate the intestinal wall or appendix, resulting in internal bleeding, or worms may block the ducts of the liver or pancreas, causing severe pain. In some cases, surgery may be required to remove worms to repair damaged tissue (ibid).

Some research has explored the relationship between helminthiasis and HIV infection. Helminthiasis can lead to an imbalanced anti-viral response while long-term non-progression of HIV has been associated with a balanced anti-viral type 1/type 2 response; there may be increased transmission of HIV to infants when the maternal immune response is unbalanced (Adams et al, 2006). Some researchers have theorised that resistance to HIV and other illnesses may be impaired and HIV may progress to AIDS more quickly where sustained exposure to pathogens results in a strong type 2 response (ibid). In a study conducted by Mkhize-Kwitshana et al (2011) involving 124 individuals co-infected with HIV and *A. lumbricoides*, individuals showed a better immune response to HIV where *A. lumbricoides*-specific serum IgE was low, while individuals with elevated *A. lumbricoides*-specific IgE showed higher viral loads and lower CD4 counts. Adams et al (2006) reports that the immune profiles of children harbouring *A. lumbricoides* infections have been found to be polarised towards type 2; this profile has been associated with an impaired response to the cholera vaccine. A weak type 2 immune response profile has been associated with susceptibility to A. lumbricoides infection; while in individuals over 11 years of old, a strong type 2 profile has been associated with greater resistance to infection by *A. lumbricoides* (Adams et al, 2006).

Because the eggs of *A lumbricoides* are extremely resistant to treatment processes, the presence of viable eggs in sludge and wastewater provides a useful marker for determining the risk of infection by helminths (Brown, 1997). In the environment, hardy *A. lumbricoides* eggs bond to particles of soil and are not easily washed away and prokaryotic biofilms are known to attach strongly to surfaces. Eggs fall into the size range of fine sand particles and in the soil may be more likely to move laterally with wind or rain than percolate downward ((Appleton and Gouws, 1996).

Trichuris trichiura

It was estimated in 2002 that 1 billion people were infected with *T. Trichiura* worldwide (CDC, 2012). Its prevalence may be as high as 95% among children in some parts of the world (Stephenson, 2000).

The eggs of *T. trichiura* pass with the stool. In the soil, they develop first into a 2-cell stage and then an advanced cleavage stage after which they embryonate, requiring 15 to 30 days to become infected (CDC, 2012). After ingestion, larvae hatch in the small intestine. Adult worms, which are approximately 4cm in length, establish themselves in the cecum and ascending colon by threading their anterior portions into the mucosa (CDC, 2012). Females begin to produce eggs 60 to 70 days after ingestion of fertile eggs and produce between 3,000 and 20,000 eggs per day (CDC, 2012). The life span of *T trichiura* is approximately 1 year.

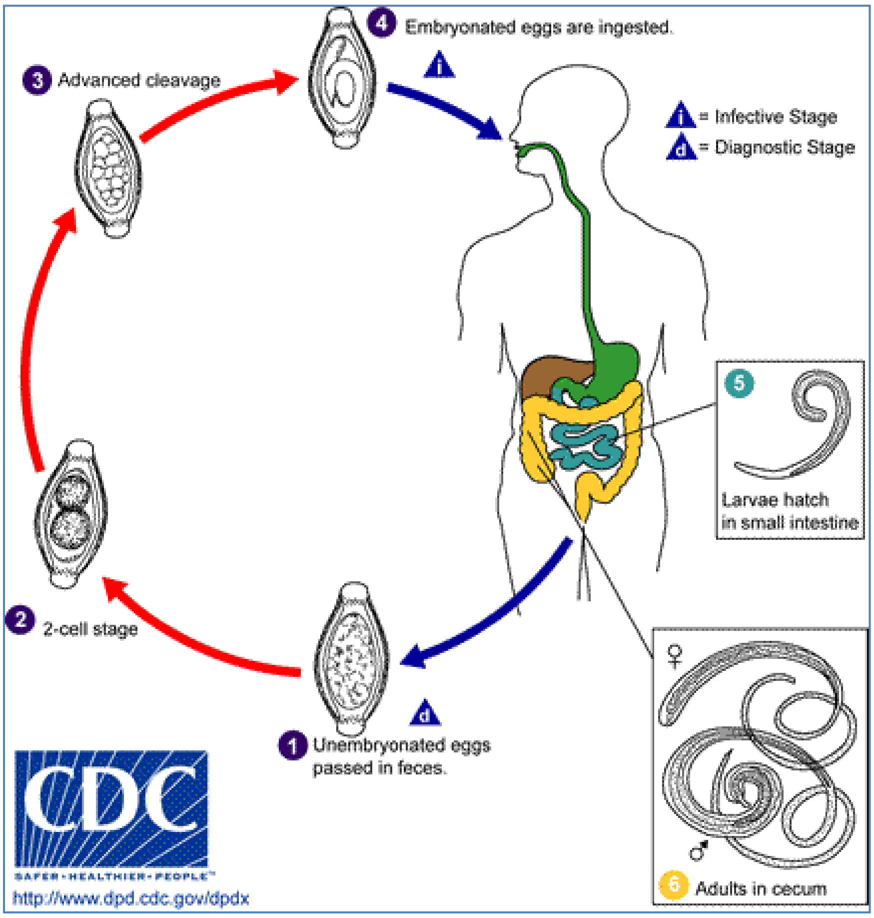

Figure 3 Lifecycle of T. trichiuris (CDC, 2012)

As with *A. lumbricoides*, only a small number of infected individuals suffer from heavy infections (Jia, 2012). Light infections are often asymptomic, while heavy infections can cause frequent, painful passage of stool which contains mucus, water, and blood. Heavy infections may result in Trichuris Dysentery Syndrome (TDS) which may cause chronic dysentery, rectal prolapse, anaemia, poor growth, and clubbing of the fingers (Stephenson, 2000). Children, in particular, with heavy infections can become severely anaemic and growth-retarded. While growth stunting has been reversed by oral iron therapy combined with repeated chemotherapy to treat infections, developmental and cognitive deficits resulting from TDS may be irreversible without significant psychosocial interventions. (Stephenson, 2000). The efficacy of chemotherapy treatments available has been variable and in some cases unsatisfactory.

Taenia spp

Eggs enter the environment when they are passed with faeces and can survive for an extended period of time outside of a host. Cattle (in the case of *T. saginata*) and pigs (in the case of *T. solium*) become infected by ingesting contaminated vegetation. In the animal's intestine, the oncospheres hatch, migrate into the muscle and develop into cysticerci. Humans consuming meat containing cysticerci which has not been cooked adequately may become infected. *T. solium* can also be passed person to person by ingesting eggs that are present on hands, surfaces, food or soil contaminated with faecal matter containing viable eggs or proglottids (Carabin, 2006). In the human host, the

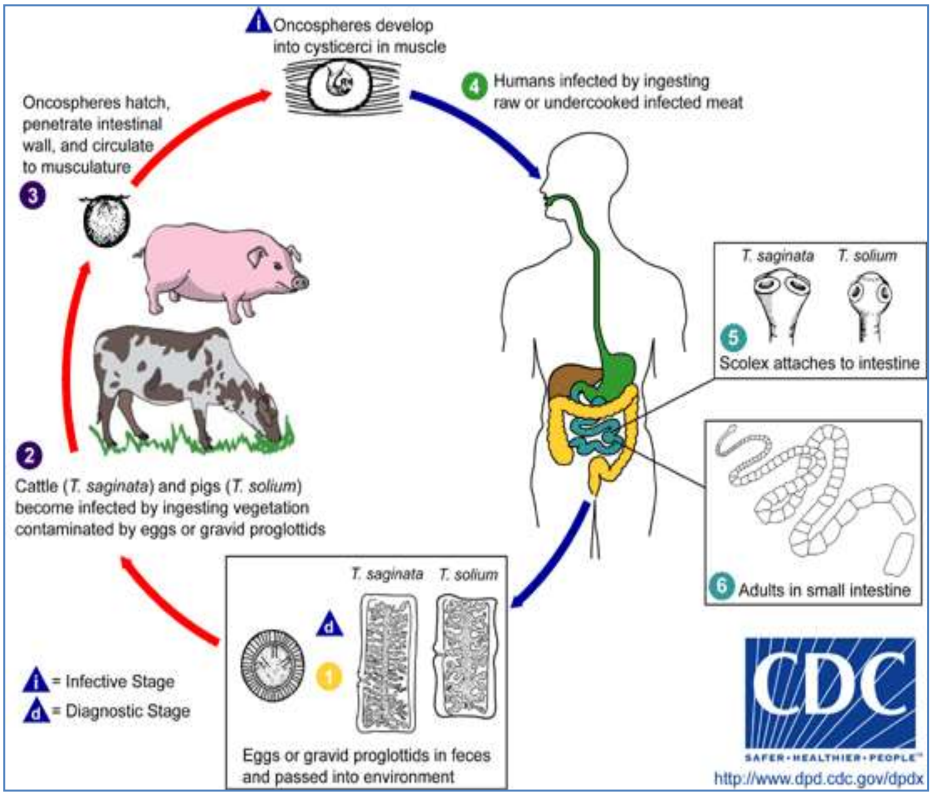

Figure 4 Lifecycle of Taenia spp (CDC, 2012)

cysticercus reaches adulthood in two months in the intestine where it attaches by its scolex. Worms can reach a length of 5 to 7m; worms as long as 25m have been documented. Proglottids containing as many as 50 000 (*T. solium*) to 100 000 (*T. saginata*) eggs detach from the worm and are passed with the faeces (CDC, 2012).

In the human host, cysts may lodge in any organ of the body, but brain involvement resulting in neurocysticercosis (NCC) is the most common cause of disease (Carabin et al, 2006). Seizures occur in 66–90% of patients with NCC; other central nervous system manifestations can occur as well, however (ibid). In severe cases, NCC can be fatal (ibid).

A higher burden of disease resulting from *T. solium* has been documented in the Eastern Cape in South Africa for decades, with a 1965 study suggesting that cerebral cysticercosis was twice as high among people in that area than among other groups or regions in the country (Mafojane et al, 2003). In a 2004 study, 76% of respondents reported having seen cysts in the pork that they ate, though only 80% of these knew what the cysts were (Carabin et al, 2006). Mafojane et al (2003) reports the practice in the Eastern Cape of placing *T. solium* eggs into a lover's drink for revenge as well as the consumption of eggs as a treatment for severe infections of *T solium*.

2.1.5 Fungi

During composting or sludge heat-treatment operations, or at land application sites, fungi may produce mycotoxins which, like endotoxins, may cause a toxic response. The fungal spores of *Aspergillus fumigatus* may be inhaled into the lungs. In a study in the US, workers exposed to composted sludge showed a consistent increase in antibodies to this mould (Brown, 1997).

2.1.6 Risk of infection by pathogens

While an individual might be exposed to pathogenic sludge, to actually to contract a disease the individual must take in an infective dose (Brown, 1997). While for some pathogens a single infectious organism may be capable of causing an infection (eg. a helminth), a single unit almost never does produce infection (Brown, 1997).

"Sewer worker's syndrome" is used to describe the symptoms of eye and skin irritation, fevers, chills, headache and malaise, as well as non-specific respiratory and gastrointestinal symptoms which appear to plague sanitation workers more than other workers (Greenberg et al, 2003). In a Swedish study, around 40% of workers reported fevers or discharge from the eyes and 13% reported episodes of diarrhoea during periods of heavy dust exposure during which gram-negative bacteria become volatised (Greenberg et al, 2003).

Many illnesses and infections are subclinical and the fact that disease has occurred can only be discovered by measuring serum antibody levels, by examining the faeces for the shedding of pathogenic organisms, or through other tests such as skin tests, liver function tests or air sampling to confirm the presence of airborne pathogens in the environment. (Brown, 1997). A number of studies have documented higher antibody levels among individuals who have worked in sanitation for less than 5 years than among experienced workers. (Brown, 1997). Infection can sometimes result in a carrier state in which the individual does not develop symptoms but can spread the disease to others. In relatively healthy individuals infections by enteric pathogen usually result in gastrointestinal illnesses, but in sensitive or immune-compromised individuals more serious illnesses can result (NIOSH, 2002).

2.1.7 Hazardous inorganic materials in sludge

In addition to pathogenic microorganisms, sludge may contain toxic inorganic substances that are produced during the degradation of faecal matter itself. While household pits do not carry the same load of contaminants as sewage containing industrial waste, where houses have no solid waste collection system toxic substances may be disposed of into the pit. Before modern sewerage systems, sludge was contained in cesspools and cases were occasionally reported of entire families asphyxiating as a result of gases building up in cesspits as materials decomposed (Greenberg, 2003). While most pit latrines today allow for some ventilation which reduces the likelihood of buildup of harmful gases, it should be borne in mind that gases such as methane, hydrogen sulphide and carbon dioxide may be produced and released from pits.

Table 2.5 describes the various type of inorganic substances which may be found in sludge and may cause adverse effects if inhaled.

Table 6 Important inhalation exposures in sewer workers (adapted from Greenberg, 2003)

Category	Examples	Clinical effects
Simple asphyxiants	Carbon dioxide, methane	*Symptoms:* Headache, altered mental status, coma, seizures, cardiopulmonary arrest *Treatment:* Reversible on removal from exposure
Chemical asphyxiants	Hydrogen sulfide*, carbon monoxide, hydrogen cyanide	*Symptoms:* Headache, altered mental status, coma, seizures, cardiopulmonary arrest, permanent or delayed neurologic sequelae in carbon monoxide exposure Severe acidosis and continued deterioration with cyanide exposure Rotten egg odour and irritant effects as well as hypoxic symptoms in hydrogen sulphide exposure *Treatment:* Carbon monoxide and cyanide exposure require specific treatment; hydrogen sulfide exposure may resolve entirely with removal from exposure and supportive care
Irritants	Ammonia, chlorine, hydrogen sulfide	*Symptoms:* Burning eyes, cough, irritation of the pharynx High concentrations act as simple asphyxiants Prolonged exposure may cause adult respiratory distress syndrome or delayed development of bronchiolitis
Solvents	Benzene, toluene	Symptoms: Solvent exposure syndrome—headache, altered mental status, difficulty concentrating, nausea, malaise Persistent neuropsychiatric sequelae may occur

*Hydrogen sulphide is an irritant and chemical asphyxiant. The threshold limit value (10 ppm) for hydrogen sulphide was designed to prevent ocular toxicity.

Water soluble chemicals are more easily air-stripped while insoluble compounds tend to attach to sewage solids and take longer to be released (ibid). When gases or other substances in the air are highly soluble, they dissolve when they come into contact with the mucous membrane lining the nose or the conjunctival membrane of the eye and individuals who are exposed may experience irritation of the upper respiratory tract and eyes almost immediately (Brown, 1997). Very poorly soluble substances may pass directly from the inhaled air into the blood stream and result in systemic poisoning or anaesthetic effects if the agent can cause central nervous system depression (ibid). As a result, the individuals may experience no localised effects alerting them the exposure and yet suffer severe systemic poisoning (ibid).

The most prevalent gases released during sewage decomposition are carbon dioxide and methane, which are simple asphyxiants. They are not toxic in nature but displace oxygen (Greenberg, 2003). Symptoms as oxygen intake decreases include headaches, malaise and exertional fatigue (Greenberg, 2003). An environment containing less than 10 percent oxygen is life threatening; a person may suffer seizures, cardiopulmonary arrest and may rapidly lose consciousness (Greenberg, 2003). Carbon dioxide is odourless and can go undetected. Methane has an unpleasant odour, which makes its presence known. It is flammable; while this makes it hazardous it can also be utilised as a fuel to power wastewater treatment operations.

Chemical asphyxiants interfere with the delivery or utilization of oxygen and thereby cause systemic toxicity. Hydrogen sulphide is the gas of greatest concern with regard to sewage and sludge; carbon monoxide and cyanide also cause adverse effects (Greenberg, 2003).

Hydrogen sulphide is produced during the anaerobic decay of faecal matter (Tiwari, 2008). It is heavier than air, and so lies on the surface of sludge in tanks or pits and easily accumulates in confined spaces (Greenberg, 2003). When ignited it burns with a blue flame, giving rise to sulphur dioxide, a highly irritating gas with a rotten egg odour (Greenberg, 2003). Mixtures of hydrogen sulphide and air in the explosive range may explode violently (Tiwari, 2008). When hydrogen sulphide contacts the membranes of eyes and respiratory tract it dissolves and forms an acid which enters the bloodstream where it is rapidly oxidized to form compounds of low toxicity (Tiwari, 2008). Because the gas detoxifies in the blood at a rapid rate, the concentration to which an individual is exposed, rather than length of exposure, is critical in terms of poisoning (Brown, 1997). In some cases, exposure to low concentrations of hydrogen sulphide may cause cardiovascular, nervous and gastrointestinal disorders such as diarrhoea, headache, fatigue, irritability and insomnia (Brown, 1997). Pain in the legs may be felt and, rarely, there may be loss of consciousness (Tiwari, 2008). In the presence of water, severe irritation of the eyes, nose throat and upper airway may occur, with the lower airway affected if exposure continues (Greenberg, 2003). Prolonged exposure may cause swelling and blistering of the epithelial cells of the cornea, eventually forming reversible ulcers, or gas eye; lower respiratory damage and pulmonary oedema may occur (Greenberg, 2003, Tiwari, 2008). Severe exposure may cause corneal scarring and permanently impair vision. Between 100 and 200 ppm nerve endings in the nasal passages become paralysed, resulting in an inability to smell the gas and therefore detect danger (Greenberg, 2003). In moderate poisoning there will be loss of consciousness lasting a few minutes but with no respiratory difficulty (Tiwari, 2008). While exposure of sanitation workers to H_2S is typically low, exposure to high concentrations is life threatening (Friis, 2006). At concentrations of 500–1,000 ppm, an individual may lose conscious on the first or second breath inhaled. (Greenberg, 2003). Long term effects may include prolonged coma, dementia or personality changes, incontinence, memory and learning defects, impaired coordination, slowed reaction time, loss of hearing or vision (Greenberg, 2003). While irritation may occur throughout the respiratory tract, the deeper areas of the lungs suffer the greatest damage (Brown, 1997).

Deaths have occurred due to exposure to hydrogen sulphide in septic tanks and pits; in some cases rescue workers too have died as they are overcome by the gas while trying to assist others (Greenberg, 2003). Deaths involving hydrogen sulphide have often been due to exposure to a mixture of gases including methane, nitrogen, carbon dioxide and ammonia (Tiwari, 2008). In an incident in Canada in which 250 workers reported hydrogen sulphide exposure, 54% lost consciousness, 26% reported headache, 25% reported nausea or vomiting, 23% reported dyspnea, and 22% reported disequilibrium (Greenberg, 2003). Seven workers died. Studies suggest that exposure to the chemical may cause increased susceptibility to infections such as pneumonia (Brown, 1997) has been found to slow the healing of minor skin wounds. While workers can build up some tolerance with regular exposure to some substances, hypersusceptibility is more likely to result with repeated low exposure to hydrogen sulphide (Brown, 1997).

Ammonia, a compound of nitrogen and hydrogen, is released from sludge as it degrades. Irritation of the nose, throat and eyes may be mild to severe depending on the concentration of the gas (Greenberg, 2003). Because of this individuals are likely to remove themselves from an area of exposure. If a person is unable to leave the area they may experience more severe health impacts, such as ulceration or other damage to the eyes, pulmonary oedema or upper airway obstruction (Greenberg, 2003).

If chlorine is used for disinfection or for odour control, humic materials in water or wastewater can react with chlorine (especially hypochlorous acid, HOCl) to form chloroform (ibid).

2.2 WAYS IN WHICH EXPOSURE TO HAZARDOUS MATERIALS CAN HAPPEN

Pathogens and harmful chemicals can enter the body through a number of routes:

ROUTES OF EXPOSURE TO PATHOGENS DURING SLUDGE HANDLING			
Inhalation	Ingestion	Contact with skin/membranes/wounds	Injection

Water UK (2006) notes that entry routes for contact and exposure may depend on site conditions and activities. Working with wet sludge carries risks of skin contact through splashes, while dry sludge may have greater risks of inhalation of dust particles containing airborne pathogens.

Harmful chemicals and microorganisms found in sludge can become airborne as gases, dust, aerosols, vapours, or droplets and inhaled. During pit emptying, this can happen as dry or wet sludge is disturbed, splashed, transferred. In confined spaces such as sewage lines, higher concentrations of harmful substances may be found in the air. Droplets can be inhaled when aerosols are generated if sludge is splashed or sprayed during handling. Dust can be raised during brushing and sweeping of contaminated surfaces, including vehicles, equipment or clothing (Brown, 1997).

Ingestion may occur through direct splashes of wastewater or sludge into the mouth, or of swallowing of airborne material which was initially inhaled. Mostly commonly, however ingestion results from contact of contaminated hands to the mouth (Water UK, 2006). Common routes of hand contamination are direct contact with sludge or touching contaminated clothing, tools, handrails, handles or other surfaces -- where contamination may not be visible. Hands may transfer contamination to the mouth during eating, smoking, drinking or wiping the face.

The most common route of exposure to pathogens is simply through dermal contact, when contaminated material (including surfaced contaminated by dirty hands) is touched with the hands and then transferred to the mouth. Materials which become airborne may also come into contact with the skin, eyes or wounds directly and cause harmful effects. Pathogens or harmful substances can also enter the body through broken skin or membranes or can affect skin directly. Contact may occur by touching contaminated surfaces or through splashes to the skin or eyes, or by contact with airborne particles or gases. Localised irritation or infection may result, or infection may spread through the tissue. Scratches, wounds, or chapped skin can provide entry points for infection (Water UK, 2006). Chemicals occurring in sludge can also be absorbed directly through the skin if there is direct contact. In one study, workers handling PDB-contaminated sludge without gloves were found to have PCB blood levels similar to those of workers at the PCB manufacturing plant served by the wastewater treatment facility (Brown, 1997).

Injection of harmful substances into the body may occur through punctures by contaminated objects, such as needles, glass or metal found in sludge (Brown, 1997).

2.3 WAYS TO REDUCE EXPOSURE TO HAZARDOUS MATERIALS

2.3.1 Regulations and guidance for protecting health from around the world

This section reviews some of the key legislation, guidelines and recommendations developed by leaders in sanitation worker health and safety internationally. In some countries, specific legislation deals with health and safety in the workplace. The extent to which legislation has been implemented or applied in terms of codes of practice or protocols is highly variable and may occur at the level of state/provincial or local government. Guidance specific to sanitation workers is rare and generally guidance for working with biological hazards, if available, must be applied to sanitation workers.

In South Africa, sanitation work is regulated and guided by the National Occupational Health and Safety Act (1993), which established the Advisory Council for Occupational Health and Safety charged with conducting research, disseminating information, promoting training and providing advice on the development of standards and regulations. The Act gives the chief inspector of the Advisory Council power to instruct any employer or category of employers to draft written policy for the protection of the workers. The Act also emphasises the protection of individuals not at work from hazards to health and safety arising from the actions of workers. The National Institute of Occupational Health provides resources and training and conducts research and hazard assessment. In 2001, the Department of Labour issued Regulations for Hazardous Biological Agents which covers sewage purification installations and can therefore be applied to pit emptiers as well.

In the United States, the Occupational Safety and Health Act (OSHA, 1970) established the Occupational Health and Safety Administration (OSHA), the National Advisory Committee on Occupational Safety and Health (NACOSH), the Occupational Safety and Health Review Commission and the National Institute for Occupational Safety and Health (NIOSH), charged with conducting research and making recommendations for standards for the prevention of work-related injury and illness. OSHA does not provide standards for wastewater treatment workers; instead employers are to institute safety measures based on a workplace evaluation (OSHA, 2005). NIOSH provides guidance for controlling health risks to workers from Class B biosolids during handling and land application.

In the United Kingdom, the Health and Safety at Work etc. Act (1974) guides occupational health. The Health and Safety Executive is a national independent watchdog which has statutory responsibility for securing the health and safety of workers and protecting the general public from work-related risks. Water UK Occupational Health and Safety Group (2006) has developed a guideline on good practice in sanitation work, titled Guidance on the health hazards of work involving exposure to sewage in the water industry which has been approved by the Health and Safety Executive.

In Sweden, the Work Environment Act (1977) guides occupational health and safety. The Swedish Work Environment Authority is the administrative authority for workplace safety and health, tasked with reducing the risks of ill-health and accidents in the workplace and improving the work environment holistically. The Work Environment Act defines the framework for provisions issued by the Work Environment Authority. Provision 2005:1, titled Microbiological Work Environment Risks – Infection, Toxigenic Effect, Hypersensitivity provides some recommendations applicable to sanitation workers.

In Canada, federal workers fall under federal legislation and provincial workers fall under provincial legislation. The Canadian Centre for Occupational Health and Safety, established by the Canadian Centre for Occupational Health and Safety Act of 1978, is the primary national agency guiding workplace health and safety. The Occupational Health and Safety Regulations of 1996 require employers to prepare and implement written plans to protect sanitation workers and other workers who are likely to be exposed to infectious material. In the Province of Saskatchewan, a guideline titled Protecting Emergency Response Workers from Infectious Diseases produced by the Department of Labour in 1999 provides guidance applicable to sanitation workers.

In Korea, The Occupational Health and Safety Act of 1990 established the Occupational Safety and Health Policy Deliberative Committee in the Ministry of Labour and made provision for inspectors. The Korea Occupational Safety and Health Agency (KOSHA) had already been established by law in 1987 and set up the Occupational Health and Safety Research Institute in 1987 and the Occupational Safety and Health Training Institute in 1989. The Chemical Safety and Health Research Center was established in 1997 and in 2006 Occupational Safety and Health and Training and Information Centers were opened (KOSHA, 2013).

In Malaysia, the Occupational Safety and Health Act (1994) established the National Council for Occupational Safety and Health and provides for the appointment of a Director General of Occupational Safety and Health The Act covers both the safety, health and welfare of persons at work and the protection of others against risks to safety or health in connection with the activities of workers. The Act also aims to facilitate progressive development of a system of regulations and industry codes of practice to improve the standards of safety and health.

In Singapore, the Workplace Safety and Health Act of 2006 (revised 2009) establishes the national Workplace Safety and Health Council to provide practical guidance and develop and promote good practice relating to safety, health and welfare, to provide support, to facilitate training and to conduct research. The Council, created in 2008, is comprised of industry leaders and is also tasked with building industry capacity to manage workplace safety and health (WSHC, 2012). The Act provides for the appointment of a Commissioner for Workplace Safety and Health to administer the act and appoint inspectors. The Commissioner may authorise the investigation of incidents or occupational diseases and may appoint an Inquiry Committee. The Ministry of Manpower, guided by the Workplace Safety and Health Act, has developed guidelines which govern wastewater management (Kan, 2012).

Singapore, which faces the challenges accompanied by dense settlement, has set perhaps the most ambitious goals with regard to sanitation and also occupational safety. The Workplace Safety and Health 2018 strategy aims to position Singapore as “A country renowned for the best practices in workplace safety and health" accompanied by one of the best safety records in the world and a “progressive and pervasive” workplace safety and health culture which is fully integrated into business. The strategies identified to achieve this include building an effective regulatory framework sharing of best practices and developing strong partnerships locally and internationally. Unfortunately, efforts to obtain copies of regulations or guidelines dealing with sanitation workers for this study were met with the following response from the Senior Manager of the Water Reclamation Department, “We regret that we are unable to share our in house procedures and safety management system as it is for our own use.” (Lock Meng Kan, pers. comm., 8 October 2012).

In Australia, the Work Health and Safety Act (2011), is one of the newest pieces of legislation dealing with worker safety, having been put into effect in June of 2012. This 245 page document is supplemented by the 456 page Work Health and Safety Regulations (2012), which provide practical application for the Act. However, while working with hazardous materials such as chemicals, lead and asbestos are covered, sanitation work and biological hazards are not. Safe Work Australia, the national agency tasked with improving worker health and safety nationally, has developed a range of codes of practice and guidelines (Safe Work Australia, 2013); none deal with sanitation work or biological agents, however.

In South Africa, the National Occupational Health and Safety Act (2003) charges employers with protecting worker health and safety in the following ways:

- providing and maintaining systems of work, plant and machinery that are safe and without risks to health wherever possible
- eliminating or mitigating any hazards before resorting to personal protective equipment
- making arrangements for ensuring safety in the use, handling, storage or transport of materials
- establishing what hazards are involved with any work process, substance or item handled,
- establishing precautionary measures to be taken
- providing the information, training and supervision necessary to ensure the health and safety of workers
- not permitting any employee to do any work or to handle, store or transport any article or substance unless the precautionary measures have been taken

The Regulations for Hazardous Biological Agents (South Africa, 2001) mandate that any person who may be exposed to a biohazard must comply with the employer's instructions in terms of:

- the prevention of an uncontrolled release of a biohazard
- following proper environmental, health, housekeeping and hygiene practices
- using personal protective equipment and clothing
- wearing personal samplers to measure exposure to airborne biohazards when necessary
- proper disposal of contaminated materials
- disinfection and decontamination of any site contaminated by an HBA;
- completing training and medical examinations
- reporting any possible accidental exposure to a biohazard

The employer must ensure that any such incident is recorded and investigated.

In Canada, the Occupational Health and Safety Regulations (1996) charge employers with ensuring to the greatest extent possible the health, safety and welfare of workers, specifically through training and in the arrangements for the use, handling, storage and transport of articles and substances which could pose a hazard. Employers are required to prepare and implement written plans which cover the following areas:

- identify workers who may be exposed to infectious material or organisms
- describe ways infectious materials or organisms can enter the body and the signs and symptoms of any infectious disease that may result
- describe infection control procedures
- describe procedures in the event of a leak or spill, and actual or suspected exposures
- describe methods to clean, disinfect, or dispose of contaminated clothing or equipment
- describe training
- require the investigation and documentation of exposure incidents
- require the investigation of infections in workers
- Every worker who is at risk of exposure to an infectious material or organism must have access to the plan. The plan must be kept current and reviewed at least every two years. Workers bear responsibility for following health and safety regulations and using protective gear.

In Singapore, the Workplace Safety and Health Act (revised 2009) charges employers with the following duties to ensure the safety and health of employees:

- providing and maintaining a work environment free of health risks
- providing adequate welfare arrangements
- ensuring that adequate safety measures are used for equipment and processes
- preventing exposure to hazards during disposal, manipulation, processing, storage and transport of materials
- developing and implementing procedures for dealing with emergencies that may arise
- providing adequate training and supervision regarding aspects of their work which may affect their safety or health

In addition, employees are charged with using effectively any protective clothing, equipment or other means provided for their health and safety. Wilful or reckless misuse of protective clothing or equipment, or negligent or other acts which endanger the safety of the worker or others are designated as offences with fines indicated for convictions.

In the United Kingdom and in Malaysia, (UK, 1974, Malaysia, 1994) legislation mandates that employers should provide and maintain systems of work that are safe and without risks to health to the extent possible, particularly with regard to the use, handling, storage and transport of materials. Employers should provide training and supervision to the extent necessary to ensure the highest degree of safety. Workers are responsible for taking reasonable care of their own health and that of others who may be affected by their actions or omissions. In Malaysia, offenders who misuse or interfere with safety, health and welfare measures may be liable for a fine and/or imprisonment.

In Korea, the Occupational Health and Safety Act (1990) charges employers with preparing and providing to workers regulations which should include safety and health management, education, accident prevention plans and investigations. Employers must take all measures necessary to prevent health problems caused by raw materials, gas, vapour, dust, mist, oxygen-deficient air, pathogens and so on.

In Australia, employers are charged with:

- providing a safe work environment, including safe systems of work and the safe use, handling, storage and transport of materials
- providing adequate and accessible facilities for the welfare of workers
- providing the information, training, and supervision necessary for workers to protect

their health and safety

- monitoring the health of workers and conditions at the workplace to prevent illness or injury
- ensuring that others are not put at risk by work conducted by workers (Australia, 2011).

Workers are charged with caring for their own safety and health as well taking care that acts or omissions do not endanger the health and safety of others.

In Sweden, responsibilities of the employer include:

- taking all precautions necessary to prevent exposure of workers to health hazards or accident risks
- providing an independent expert resource to work for the prevention and elimination of health risks
- providing information and training regarding conditions, hazards and measures to avoid of risks in the work
- Ensuring that any worker who has not been trained does not enter areas where there is risk of exposure

Responsibilities of workers include:

- using safety devices and other precautions to prevention ill-health and accidents
- reporting any situation which presents a serious risk (Sweden, 1977)

The Australian Work Health and Safety Regulations (2012) provide a hierarchy of control measures similar to those specified in the South Africa National Occupational Health and Safety Act for cases where risks cannot be eliminated and must be minimized. A combination of control measures can be used where one fails to be effective:

- substitute (wholly or in part) the hazard giving rise to the risk with something that gives rise to a lesser risk
- isolate the hazard from human exposure
- implement engineering controls
- if this does not eliminate the risk, implement administrative controls
- If this does not eliminate the risk, provide, and ensure the use of, suitable personal protective equipment

As in the case of sanitation work controls in all of these areas are needed simultaneously, they will form the structure of the remainder of this chapter.

2.3.2 Engineering controls

Water UK (2006) states that the first line of responsibility of employers in terms of protecting workers is to limit entry routes for contact and exposure; wherever possible this should be achieved by workplace design. For workers who deal with on-site sanitation or sewers, the same options for adapting the environment will not be available, but solutions which are implemented in the wastewater treatment works should be adapted for on-site work wherever possible. Facilities and equipment for personal hygiene and for the decontamination and safe collection of contaminated materials must accompany mobile teams so that immediate intervention can be made to minimise the period of exposure when exposure occurs (Saskatchenwan Labour, 1999).

> Facilities, fittings and equipment shall be designed in such a way that risks associated with biological agents are avoided, the spread of biological agents is limited and the necessary decontamination facilitated.
>
> -- Swedish Work Environment

Water UK (2006) recommends that contamination-free areas should be available to sanitation workers for eating, resting and smoking. A plan must be made for welfare facilities (including toilets) for mobile work teams as well. Showers and laundry facilities should also be available at the place of work so that workers do not carry pathogens home on their bodies and so that contaminated laundry is not washed at home. For on-site work, adequate water should be carried along for the cleaning needs throughout the day, including for a full shower if there is no opportunity to return to facilities at the place of employment before going home (DWAF, 2007).

2.3.3 Administrative controls

Saskatchewan Labour (1999) recommends that an administrative system be drawn up in writing and implemented for ongoing monitoring and evaluation of worker health and safety. Supervisors must be held accountable for ensuring that workers follow procedures and mechanisms must be put in place to enable procedures to be modified as needed (ibid). In addition to the screening, hiring and oversight of workers, management must ensure that proper systems are in place to maintain and monitor the stocking of tools, protective equipment and supplies for disinfection. In addition, health care for workers must be proactive.

Screening workers

Still and Foxon (2012) recommend that pit emptying workers be medically screened before employment and that those with highly compromised immune systems should not be selected for this work. Water UK (2006) recommends that prospective workers found during screening to have these additional conditions should be evaluated by an occupational health professional before beginning work with sludge:

- Pregnant or breastfeeding
- Conditions which might present a risk of collapse in hazardous conditions (eg. epilepsy, diabetes
- Skin disorders that cannot be protected adequately with a waterproof dressing

Monitoring and accountability

Australia's Work Health and Safety Regulations (2012) stipulate that the measures that are implemented for controlling risk must be maintained in order to ensure that they remain appropriate, effective and operational. Control measures should be reviewed regularly and when there is a change in the work process or if a new hazard is identified in the work process; it should be revised if it is found to no longer control the risk for which it was implemented.

In South Africa, the National Occupational Health and Safety Act (2003) Act empowers the health and safety representative at a company to inspect the workplace, identify potential hazards and review the effectiveness of health and safety measures, examine the causes of incidents at the workplace and investigate health or safety related complaints by any employee. Health and safety committees may make recommendations to employers or inspectors on health and safety issues. The South African Regulations for Hazardous Biological Agents (2001) state that an employer must conduct a risk assessment every two years and monitor the exposure of employees to biohazards using a procedure that is "standardised, sufficiently sensitive and of proven effectiveness."

In Singapore, every workplace is required to appoint a workplace safety and health officer, a workplace safety and health committee comprised of employees and employers is charged with monitoring aspects of work which may affect the safety or health of workers and to investigate accidents or incidents. A workplace safety and health auditor is charged with auditing the safety and health management system, risk assessments and work processes (Singapore, 2006). In Malaysia, an employer is required to employ a safety and health officer and appoint a safety and health committee to monitor health and safety measures at the workplace and investigate any matter which poses a potential threat to health or safety. In Sweden, the Work Environment Act (1977) provides for the establishment of services, inspection of the workplace and the appointment of safety delegates and safety committees comprised of representatives of the employer and employees. In Australia, in contrast to the countries mentioned above, the employer is only obligated to facilitate the election of a health and safety representative if requested to do by a worker, and to establish a health and safety committee if requested to do so by a health and safety representative for a work group (2011).

Stocking supplies

Management must ensure that protective equipment or tools that are damaged, perished or lost are replaced and that supplies for handwashing and disinfection of surfaces and equipment are provided for both mobile work and at the work station. An anti-bacterial liquid soap which lathers well, rather than bar soap, should be provided, along with paper towel for drying hands, to prevent transmission of pathogens; soap containers should be designed for operation by elbow or wrist to prevent recontamination of the hands (KZN DOH, 2012). If refillable containers are used they should not be topped up; the container and pump should be washed and dried thoroughly before reuse (KZN DOH, 2012). Hand cream should be provided to workers to protect the integrity of the skin; this again should be provided in a pump container to prevent contamination of the cream (KZN DOH, 2012).

Reporting

In South Africa, workers are required to report to the employer or health and safety representative any incident or situation which is unsafe or unhealthy before the end of the work shift, or as soon as possible thereafter. In Sweden, employees are required to report a supervisor without delay illness or unwanted events potentially caused by biological agents occurring in the workplace (Sweden, 1977).

Saskatchewan Labour (1999) stresses that procedures must be put in place for investigating and documenting incidents of exposure and ensuring prompt and effective follow up. These must include:

- procedures for the investigation of exposure incidents
- arrangements for follow-up (which should include medical evaluation, treatment, and counseling) for an exposed person
- documentation of the results of the investigation and follow-up

- designating a competent person to investigate and assess exposures immediately
- criteria for exposures that should be referred for medical evaluation

Medical monitoring and intervention

The International Labour Organisation recommends that all workers be examined regularly by an occupational physician for early detection of chronic effects or allergies resulting from sanitation work (ILO, 2012). PRG (2012) and Still and Foxon (2012) recommend semi-annual antihelminthic treatment for pit emptiers. Still and Foxon (2012) recommend that workers be evaluated upon termination of employment as well. In Sweden, an employer is required to offer medical preventive measures and checks to workers free of charge if they may have been exposed to a biohazard (Sweden, 1977). In South Africa, an employer must ensure that an employee is under medical surveillance if he/she may have been exposed to a biohazard (South Africa, 2001).

2.3.4 Training

In South Africa, the Occupational Health and Safety Act (South Africa, 2003) states that an employer is responsible for ensuring that every employee understands any hazards associated with the substances, tools and processes of his/her work as well as precautionary measures that should be used. The Australian Work Health and Safety Regulations (2012) mandate that an employer must provide adequate information, training and instruction to workers regarding the nature of their work, the risks associated with their work and the control measures they are required to implement. The employer may be subject to a penalty if this is not carried out.

The South African Regulations for Hazardous Biological Agents (2001) provides a more comprehensive list of training topics to be covered before any employee engages in work where he/she may be exposed to a biohazardous material:

- contents and scope of the Regulations
- potential health risks in the event of exposure
- measures to be taken by the employer to protect employees against risk of exposure
- precautions to be taken by an employee to prevent exposure
- necessity, correct use and maintenance of safety equipment, facilities and engineering controls
- importance of good housekeeping at the workplace and personal hygiene requirements
- the necessity of medical surveillance
- safe working procedures regarding the use, handling, storage, labelling, and disposal of biohazardous material
- procedures to be followed in the event of exposure, spillage, leakage, injury or any similar emergency situation, and decontaminating or disinfecting contaminated areas
- potential detrimental effect of exposure on the human reproductive process

Furthermore, the Regulations stipulate that written procedures should be provided for work processes where there is the potential for incidents which result in exposure to biohazards as follows:

- the safe handling, use and disposal of hazardous materials
- the proper use and maintenance of process machinery, installations, equipment and tools
- the regular cleaning of machinery and work areas by vacuum cleaners fitted with a suitable filter that prevents contamination of the environment
- a system whereby needed changes or corrective action in work procedures and processes can be identified

In Canada, the Occupational Health and Safety Act (1996) requires employers to provide workers with the necessary training to protect their health and safety and all precautions to be used with regard to physical, chemical or biological hazards. Training must be provided when a worker commences employment or first begins sanitation work; no worker must be allowed to work without proper training. Saskatchewan Labour (1999) advises that a written plan be developed indicating how training of new workers before exposure will be conducted and what the content of the training will include.

Training topics recommended by a number of sources include:

- risk of exposure to an infectious material or organism during work (modes of transmission, infectious/harmful dose, survival/impact of the infectious organism in the environment)
- symptoms of infectious diseases
- proper use and maintenance of any engineering controls and other preventative measures
- emergency procedures
- proper use and removal of personal protective equipment
- hygiene and storage and cleaning of laundry, tools and equipment
- exercises for practical situations faced by workers in both everyday work and in exceptional circumstances
- exercises for solving problems of infection control
- motivate workers to monitor and evaluate their practices on an ongoing basis
- availability and associated risks of vaccines
- procedures for reporting and investigating incidents of exposure/contamination (Saskatchewan Labour, 1999, NIOSH 2002, Water UK 2006)

> The employer shall see to it that the person directing the work and all employees who may come to be exposed to microbiological work environment risks have sufficient training and sufficient knowledge concerning the biological agents occurring in the activity.
>
> Everyone doing work which can entail risks caused by biological agents in the workplace shall be sufficiently informed of these risks and how to avoid them.
>
> - Swedish Work Environment Authority

In Australia, the employer is required to allow the health and safety representative to attend approved courses of training in work health and safety, allow time off work and pay fees associated with attending the training (Australia, 2012).

The Swedish Work Environment Authority mandates that instruction shall be repeated when necessary and reviewed jointly by the employer and employees in order to accommodate changes or amend shortcomings. Written instructions should be provided for the safe handling of infectious agents and to prevent ill-health and accidents. Measures to be taken in the event of incidents or accidents should be provided in writing and practiced regularly, with variation to cover all possible events (2005).

2.3.5 Personal protective equipment (PPE)

Water UK (2006) stresses that protective equipment should be considered a last result and all other means of avoiding exposure should be explored first. Still and Foxon (2012) emphasise that even with the use of protective equipment, pit emptying workers are at a high risk of infection.

The Australian Work Health and Safety Regulations (2012) specify that an employer must ensure that safety equipment is:

- selected to minimise risk
- appropriate for the nature of work
- adequately fitted and reasonably comfortable
- maintained, repaired or replaced as needed so to continue to be effective
- used by the worker

Furthermore, the employer must train the worker to use, store and maintain the protective equipment appropriately. The worker is responsible for using the equipment appropriately and reporting defective or damaged equipment or the need to clean or decontaminate equipment. Either party is subject to a fine if these requirements are not met.

Selecting protective clothing

Necessary protective equipment may include goggles, splash-proof face shields (also may be used where there may be aerosolized sludge particles), respirators, liquid-repellent coveralls, boots and gloves (NIOSH, 2002). Waterproof clothing may be necessary and chemical resistant clothing may be required for sanitation workers exposed to corrosive materials (ILO, 2012).

The South African Department of Water Affairs (2007) recommends that pit emptiers be issued with gloves, masks, boots and overalls and that the use of these on the job should be enforced. The South African Regulations for Hazardous Biological Agents (2001) require that for airborne biohazards, respiratory protective equipment be selected on the basis of efficacy with regard to preventing exposure to the biohazard in question; protective clothing should also be provided. For biohazards which can be absorbed through the skin, workers should be provided with impermeable protective equipment. Employers must also provide workers with the necessary information and training in order to use the protective equipment effectively.

Saskatchewan Labour (1999) recommends that written safety plans indicate the personal protective equipment needed for different sanitation work and when and how gloves should be replaced and disposed of. Water UK (2006) recommends that overalls be used where gross contamination is unlikely to occur and impervious waterproof suits and footwear be used where gross contamination is likely. Clothing provided should be capable of being washed at the temperatures necessary for disinfection (Water UK, 2006).

Gloves should be chosen on the basis of appropriateness for the task in terms of durability, impermeability, size, length and tightness of cuff, thickness, flexibility, elasticity, and length of wearing time (Saskatchewan Labour, 1999). The potential extent of contamination and likely damage should be considered: PVC gauntlets may be recommended for heavier work on contaminated equipment while disposable gloves may be adequate for other work (Water UK, 2006). Gloves with knitted or canvas cuffs are inappropriate for sanitation work as they became easily contaminated when wet (Water UK, 2006). The possibility of a worker developing allergies to latex gloves must be accommodated; where latex gloves are necessary the non-powdered type can be used to reduce irritation (Saskatchewan Labour, 1999). For some procedures, it may be advisable to double glove or to change worn gloves before punctures or tears develop (Saskatchewan Labour, 1999).

The level of face and eye protection required should be determined by risk assessment (Water UK, 2006). The International Labour Organisation (2012) recommends that sanitation workers use safety goggles wherever splashes or airborne particles may occur and respirators or gas masks wherever there is risk of exposure to harmful aerosols, dusts, vapours or gases. Saskatchewan Labour (1999) recommends in cases where contact with TB is possible that masks be selected with filter particles 1 micron in size, with a 95% filter efficiency tested in the unloaded state, and with a less than 10% facial seal leak. In some situations respiratory protection may be required. For dust, a disposable FFP2 disposable half mask respirator may be adequate; where oxygen deficiency is a concern a breathing apparatus may be required (Water UK, 2006).

Use of personal protective equipment

Water UK (2006) mandates personal protective equipment should be dedicated to a single worker and labelled accordingly to avoid the spread of contamination. In South Africa, an employer may only issue personal protective equipment which has been previously used if it has been effectively decontaminated and sterilised (South Africa, 2001). Extra work clothes should be transported with workers in the event that protective clothing becomes soaked with sludge or sludge enters gloves or boots (Saskatchewan Labour, 1999). Gloves should not be regarded as a substitute for hand washing and hands must be washed before and after the use of gloves as micro punctures may allow pathogens to enter gloves where they may multiply in the warm environment (KZN DOH, 2012).

Handling contaminated clothing

Protocols should be written indicating how contaminated personal equipment should be removed, collected and transported (Saskatchewan Labour, 1999). As much debris as possible should be removed from contaminated clothing before undressing (Water UK, 2006). Protocols are needed for the removal of contaminated clothing so as to avoid contact between contaminated surfaces and skin or clean clothing. If contamination is significant, protection of airways (mask/respirator), eyes (googles/shield) and hands (gloves) should be kept on until clothing is removed to avoid the possible of contact with airborne or loosened particles (Water UK, 2006). Gloves should be washed before attempting to remove clothing, and again after clothing has been removed. Protective clothing should be stored separately from other clothing (Swedish Work Environment Authority, 2005). Bins or bags containing contaminated gear should be clearly marked (Saskatchewan Labour, 1999). In South Africa, workers must be provide with two separate lockers labelled “protective clothing” and “personal clothing” (South Africa, 2001). Separate “clean” and “dirty” change rooms may be required if there is risk endangering others (ibid).

Cleaning contaminated clothing

Protocols should be written indicating where and how contaminated personal and protective equipment is cleaned. If it is cleaned at the place of work, procedures should be put in place for laundry workers, cleaners, and those who dispose of waste after cleaning (Saskatchewan Labour, 1999). Contaminated personal protective equipment should not be taken home by workers for cleaning because of the risk this poses of contaminating the home environment (Water UK, 2006).

In South Africa, the following regulations apply:

- If cleaning is handled on site, care must be taken to prevent contamination during handling, transporting and cleaning
- if cleaning is handled off site by a contractor, the equipment must be placed in impermeable, tightly sealed colour coded containers with a biohazard designation

> *… an employer shall ensure that no person removes dirty or contaminated personal protective equipment and personal protective clothing from the premises.*
>
> - South Africa, 2001

- in the event that protective equipment is damaged, it must be disposed of as hazardous biological waste

Clothing and boots which have become contaminated should be hosed down, scrubbed and dried as soon as possible (Water UK, 2006). Boots or waterproof clothing which have become contaminated on the inside and cannot be properly cleaned should be replaced (Water UK, 2006). The KwaZulu-Natal Department of Health requires aprons to be washed with a cleansing agent and hot water and then wiped down with Chlorhexidine in alcohol (KZN DOH, 2012). For laundering soiled linen, the Department of Health provides the following time/temperature guidelines in order to kill pathogens:

- 65^0C for 10 minutes for used soiled linen
- 71^0C for 3 minutes for used soiled linen
- 40^0C for 10 minutes, with the addition of hypochlorite in penultimate rinse

The wash cycle of domestic machines which heat to 40-60^0C may not achieve satisfactory heat disinfection (KZN DOH, 2012). The Department of Health disinfects rubber face masks by autoclaving on the rubber cycle (KZN DOH, 2012).

2.3.6 Hygiene

Safety plans should cover the following aspects of hygiene while working with faecal matter:

- when and how hand washing is required

- when and how gloves and masks should be donned
- contain work clothes and boots to the immediate work environment
- avoid touching face, mouth, eyes, nose, genitalia, or open sores and cuts
- prevent eating, drinking, chewing gum or smoking while working – use of designated areas for these activities
- care of wounds (clean, dry bandages) or damaged skin (gloves) (Saskatchewan Labour, 1999, NIOSH, 2002).

The South African Regulations for Hazardous Biological Agents mandate that no person shall:

- use compressed air to remove biohazardous material from any surface or person
- eat, drink, smoke, keep food or beverages or apply cosmetics in workplace where biohazards are present
- leave a controlled area without removing contaminated clothing and equipment

Handwashing

Water UK (2006) states that:

Hands are the principle route by which microorganisms are transmitted to both self and others. Educating persons who come into contact with sewage about appropriate personal hygiene practices and good hand washing techniques is essential in preventing illnesses.

The KwaZulu-Natal Department of Health (2012) has the following to say about handwashing:

Handwashing is the simplest and most cost-effective way of preventing the transmission of infection. Effective handwashing is known to reduce patient morbidity and mortality from healthcare acquired infections. It causes a significant decrease in the carriage of potential pathogens on the hands. Unfortunately hand hygiene is one of the most neglected practices.

Hands should be washed as soon as possible in the following situations:

- before and after using the toilet
- after working with sewage, sludge or touching a contaminated surface
- if a glove tears
- as soon as gloves are removed before eating, smoking, using the telephone, rolling or smoking a cigarette
- after cleaning equipment

(Saskatchewan Labour, 1999, Water UK, 2006).

> *In connection with work entailing a risk of infection, hand-washing facilities and a skin disinfectant shall be provided in immediate conjunction with the workplace. In connection with work which can entail exposure of the eyes, an eyewash facility shall be readily available.*
>
> - *Swedish Work Environment Authority, 2005*

The following guidance is provided for effective handwashing:

- Wet hands with warm running water
- Dispense one measure of liquid soap onto hands
- Rub palms, back of hands, fingers and thumbs and web spaces between fingers, wrists and forearms vigorously for 15 seconds
- Rinse hands thoroughly to prevent chapping from soap residue
- Dry hands well with paper towel as wet hands more easily transfer organisms
- Rub an alcohol-based lotion into all surfaces of the hands till dry
- Use a conditioning cream with emollients to maintain skin integrity despite frequent washing
- Cover cuts and abrasions with a waterproof dressing (KZN DOH, 2012, Water UK, 2006)

For pit emptiers working on site, Saskatchewan Labour (1999) recommends the use of a waterless antiseptic while NIOSH (2002) recommends portable sanitation equipment that includes clean water and soap. Alcohol-based hand rubs do not remove dirt but can be used after dirt is removed to reduce organisms present on hands (Water UK, 2006).

As the majority of micro-organisms are found under or around the fingernails and jewelry, nails should be kept short and clean. Nail polish, acrylic nails and hand jewelry should not be worn as they harbour organisms (KZN DOH, 2012). Workers should not bite their nails (Water UK, 2006). If hands become heavily soiled personal nailbrushes should be used and stored dry when not in use (Water UK, 2006).

2.3.7 Tools

Water UK (2006) states that in all situations where contact is required with sludge a tool should be used rather than contact if possible. Saskatchenwan Labour (1999) advises that equipment should be designed to ventilate or segregate as appropriate in order to reduce contamination.

> "If you can't see where you are putting your hand, don't put it there."
>
> - Water UK, 2006

Saskatchewan Labour (1999) advises that protocols should be written for the routine cleaning, disinfection, and sterilization procedures for equipment and reusable supplies or receptacles. This includes the regular cleaning of reusable receptacles used for contaminated materials. The South African Department of Water Affairs (DWAF, 2007) advises that all equipment should also be properly cleaned at the end of each working day. Dedicated cleaning equipment should be used to clean tools and protective equipment should be worn during cleaning (PRG, 2012).

2.3.8 Transport

> Waste and other contaminated material shall be handled and transferred in accordance with predefined routines, in such a way that risks to health are avoided. The party transporting or disposing of such material shall previously be supplied with necessary information concerning the material, the risks entailed by handling it and the need for protective measures.
>
> - Swedish Work Environment Authority, 2005

To prevent contamination, it is preferable to have the cab separated from the storage area of the vehicle by a bulkhead (Water UK, 2006). A system for the segregation of dirty equipment and clothing should be established within vehicles (Water UK, 2006). The cab should be kept clean and free from contamination by removing contaminated overalls and washing hands (Water UK, 2006). The fact that eggs, endotoxins or other hazardous materials may have settled on clothing should be borne in mind during transport; the heating or air-conditioning system should be set to a non-recirculating system (Saskatechewan Labour, 1999). NIOSH (2002) recommends that the steering wheel and interior of vehicles used by workers handling sludge be wiped down frequently to remove settled dust or traces of sludge which may contain pathogens. Disposable, waterproof seat covers could be considered where there is a possibility of contamination (Water UK, 2006). Eating, drinking and smoking should be discouraged within vehicles used for sanitation work (Water UK, 2006).

The South African Regulations for Hazardous Biological Agents (2001) mandate the following with regard to the transport of biohazardous material:

- it must be stored in colour-coded containers marked with a biohazard sign
- all employees involved in the collection, transport and disposal of biohazardous material are provided with appropriate protective equipment
- drivers must be trained and equipped for dealing with any potential emergency
- any surfaces which have been in contact with biohazardous material must be disinfected and decontaminated in such a manner that it does not cause a hazard inside or outside the premises concerned

3. PLANNING AND CONDUCTING THE STUDY

The methodology and research tools for the study were developed as described in section 3.1. However as the study experienced serious setbacks over the duration of the research period, the study could not be implemented in full as planned and modifications were required, as described in section 3.2.

3.1 Designing the study

The study was designed to include two case studies of pit emptying programmes currently operating in South Africa from a health and safety perspective. Five sanitation programmes were considered, however only two involved the desludging of dry pit latrines. The programme run by eThekwini Metro Municipality in KwaZulu-Natal emptying household VIPs and Amanz'abantu's programme emptying school VIPs in Amathole District Municipality in the Eastern Cape were selected. Both organisations agreed to participate in the study. The case studies were designed to include two main aspects:

- Studying of pit emptying exercises at 20 households (10 in each pit emptying programme) including observations, interviews with householders and pit emptiers, and the analysis of surface and sludge samples collected during pit emptying for the presence of selected pathogens indication contamination

- Monitoring over two years of the incidence of helminth infections among 80 pit emptiers and among a control group (of 80) not involved in sanitation work who were from a similar community

For these two activities involving human subjects, a research protocol was submitted to the Humanities and Social Science Research Ethics Committee of the University of KwaZulu-Natal which was approved on 15 August 2013.

In addition to the two activities involving human subjects, a study of various household disinfectants was planned in order to identify a disinfectant that could be used by pit emptiers and householders to disinfect surfaces contaminated with sludge.

These activities are described below.

3.1.1 Studying pit emptying exercises

Ten pit emptying exercises (ie. the emptying of pits at 10 homes) would be studied for each of the two pit emptying programmes. A range of research tools were developed in order to collect data that could be triangulated from the points of view of workers, managers, householders and compromise safe work practice. The research tools which were developed to collect this data can be found in Annex A. Data would be collected as follows:

- A composite sludge sample would be collected from the corners and centre of each pit and analysed for the presence of the 6 indicator organisms (see Section 3.1.4).

- An observation would be conducted of each pit emptying exercise, which would involving taking notes and photographs to document work practice and examples of key health and safety issues.

- An interview would be conducted with one sanitation worker at each of the 10 homes
- An interview would be conducted with a householder at each of the 10 homes
- Duplicate samples would be collected from selected surfaces at each pit emptying site, include surfaces in the household environment and workers' skin/protective wear; in some cases pairs of samples were taken from the same surface before and after pit emptying for comparison.
- Managers would be interviewed to learn about administrative and monitoring systems.

3.1.2 Monitoring the incidence of helminthic infections

Volunteers would be solicited from among the pit emptiers working for the two programmes and from among householders from the same communities as the pit emptiers who were not involved in sanitation work, with a total of 80 pit emptiers and 80 control volunteers enrolled. After an initial presentation of the project and obtaining of informed consent from volunteers, baseline data on helminth infections among volunteers would be collected. To determine the incidence of pre-existing infections, stool samples would be collected and analysed for all volunteers. Deworming medicine (a single dose of Mebendazole 500mg) would be provided to any workers found to be infected. Stool sampling would be repeated two weeks after deworming to establish a baseline with both groups after treatment of pre-existing infections. The same process would be repeated at one and two years after the baseline date to track patterns of reinfection among the two groups. All volunteers would be offered a R50 cash incentive in exchange for providing a stool sample on each occasion. Monitoring of infections was planned to commence by November 2012 and be completed in November 2014.

3.1.3 Analysing and work shopping results

It was planned that after the data had been analysed, the general findings of the case studies would be presented to workers and managers at both programmes and the key issues that were identified would be work shopped. From this a framework for policy and procedures to address the risks and needs identified would be developed. The final product was hoped to be a draft policy/protocol for emptying pits with minimum risk to workers, the public and the environment.

3.1.4 Finding an effective disinfectant

As there is little existing knowledge of how effective household cleaning products are in killing the worm eggs that may be found in faecal matter, a study was conducted by UKZN honours student Danica Naidoo to identify affordable, readily available household disinfectants capable of deactivating helminth eggs and determine the dilutions and exposure times required for these agents to be effective.

Domestos, Jik, Jeyes Fluid and Miracle Mom Pine Gel were tested. The active ingredient in both Domestos and Jik is sodium hypochlorite, and carbolic acid in Jeyes Fluid. Although the active ingredient for both Domestos and Jik is the same, Domestos contains soap-based detergents as well, and is much more viscous than Jik. The exact chemical composition of Pine Gel is unknown. It is more commonly used in an industrial environment, and franchise operators claimed that it was provided to pit emptiers for cleaning of PPE, tools and spills. Tap water was used as the negative control.

Eggs from *A. lumbricoides* were obtained from stool samples. Eggs from positive stool samples were used for experimentation in preference to eggs from pit latrine faecal sludge, as there was a possibility that faecal matter from sludge may have been pre-exposed to detergents. Treatments were processed using standard helminth egg enumeration methods for soil and sludge. Samples were analysed via light microscopy, and eggs were assessed and categorised.

Egg solutions were exposed to the disinfectants at three concentrations: the recommended dilution (as indicated on the bottle), a 50% dilution and a undiluted concentration. For the first experiment, eggs were inoculated into two different surface types, i.e. plastic and glass, and were wiped off with disinfectant-saturated cloths. Viable eggs recovered from the control samples (surfaces wiped with water-saturated cloth) ranged from 40% to 50% for the first replicate and from 35% to– 45% in the second replicate. Any variation from the control viability ranges was then assumed to be due to the disinfectants used. In the case of Pine Gel, the 50% dilution was not tested because of the extremely viscous nature of the product.

A preliminary experiment was performed to determine a suitable contact time for the disinfectants with the eggs. Two exposure times were selected: 1 hour, representing a practical soaking time for spilled pit sludge, and 12 hours, which is likely to be impractical in a field situation but represents conditions highly likely to inactivate eggs. After exposure and processing, the samples were distributed evenly into two plastic test tubes, with one test tube used for immediate assessment, and the second test tube being incubated for a period of 28 – 30 days to determine if undeveloped eggs either developed further or became non-viable.

3.1.5 Selecting indicator organisms

Because the cost of identifying all potential pathogens present in a faecal sample is prohibitive, selected indicator organisms are often used in risk assessments in order to determine the presence of other faecal pathogens (Maimon *et al*., 2010). For this study, the helminths *Ascaris lumbricoides* (roundworm), *Trichuris trichiura* (whipworm) and *Taenia spp* (tapeworm) were selected. As described in section 2.1.4, these are the most common helminths found in the area selected for the study. In addition, *A. lumbricoides* is frequently used as an indicator because of the resilience of its eggs under adverse conditions. For the study of the deactivation of helminth eggs by household disinfectants, only *A. lumbricoides* was selected because of its importance and hardiness and because it is difficult to determine viability of eggs of *T. trichiura, Taenia saginata* and *Taenia solium*. In addition, the bacteria *E. coli*, *Salmonella spp* and *Staphylococcus* spp. were selected as indicators. Viruses were excluded as indicators due to the extensive molecular work involved and protozoans due to the need for specialised equipment which was not available within the scope of this project. Pathogenic bacteria types were not differentiated as the cost of the nucleic acid targeting techniques required to do so are prohibitive. *E. coli* has been found to persist on hand surfaces for time periods ranging from 6 to 90 minutes (Fryklund *et al*., 1995) and on inanimate surfaces for 2 hours to 16 months (Maule, 2000).

3.2 Implementing the study: Obstacles encountered and revisions to the design

In mid-2012 when the two pit emptying programmes agreed to participate in this study, Ethekwini Municipality was planning to begin a new 5 year cycle of pit emptying in January 2013. The programme would involve 8 sub-contractors each leading a team of 10 pit emptiers, providing a pool of 80 pit emptiers from which to recruit 40 participants in the helminth infection monitoring study. In the Eastern Cape, Amanz'abantu anticipated beginning a 31 month contract to empty school toilets in April 2013. They planned to partner with 5 franchisees in each of 4 areas, each with 4 to 8 pit emptiers on the team, providing a pool of 80 to 160 pit emptiers from which to recruit volunteers. Both of these programmes experienced repeated delays however, and as of the end date of this project, March 2015, neither pit emptying programme has yet commenced. This has made it impossible to conduct the two full case studies as intended. Nevertheless, opportunities were found to conduct some of the envisioned activities as follows.

3.2.1 Case study of eThekwini pit emptying programme

While eThekwini's long-term pit emptying programme continued to be on hold pending environmental authorisation for the operation of the LaDePa plants, where sludge removed from pits would be processed into pasteurized pellets, in November 2013 eThekwini began an emergency pit emptying programme designed to empty full pits over the course of a few months. While the short term nature of this programme did not allow for volunteers to be recruited for monitoring of helminth infections over a significant period of time, it did create an opportunity to conduct a case study of eThekwini's pit emptying programme, even though it was not operating under normal conditions. The study methodology and research tools were piloted during two pit emptying exercises conducted by the pit emptying team. The pit emptying programme was then put on hold due to funding issues and finally resumed in March. The fieldwork team was trained and the 10 observations were conducted in KwaMashu, a community in eThekwini Municipality which is served by VIP toilets, in March 2013. As per the protocol found in Annex A, the study of each pit emptying exercise was conducted by a team of 3 fieldworkers. During the exercise one fieldworker conducted an observation for the duration of the exercise. The other two fieldworkers collected pre-pit emptying samples, then conducted interviews with the householder and one sanitation worker, and then collected duplicate post-pit emptying surface samples.

Samples were stored in a cooler box on ice. Health and hygiene education materials which had been developed in English, Zulu and Xhosa were provided to householders (see Annex A). Deworming medication (Mebendazole) was provided for all members of the household excluding pregnant women and children under two years of age. At the end of the fieldwork day, one set of samples was delivered to the School of Life Sciences at UKZN, Westville Campus for analysis for the presence of eggs of selected helminth eggs by Val Kelly and Colleen Archer, and the other set of samples was delivered to the School of Microbiology at UKZN, Pietermaritzburg Campus for analysis for the presence of selected bacteria by PhD student Lorika Beukes. Details on the protocols followed for analysis can be found in Annex C.

3.2.2 Baseline data collected for helminth infections monitoring in Eastern Cape

In late 2013 the Amanz'abantu pit emptying programme finally began. Phase 1 involved assessments of schools followed by pit emptying in Phase 2. By February 2014 the programme was nearing the end of Phase 1. In preparation for the beginning of Phase 2, when workers would begin emptying pits, workers and a control group were recruited for monitoring of helminthic infections. Stool samples were collected from 46 pit emptiers working with Impilo ya Bantu in the Eastern Cape and 50 volunteers drawn from non-sanitation departments of Amathole District Municipality, who constituted a control group. All stool donors originated from a large hinterland of the East London area in the Eastern Cape. Deworming was carried out for those found to carry infections and stool samples were taken two weeks later to establish a baseline. Soon after that, however, the programme was halted due to payment issues and it was not resumed during the course of the study period. It was therefore impossible to monitor re-infection among the pit emptiers over a period of time that they worked with sludge.

3.2.3 Finding an effective disinfectant

4. RESULTS

4.1 Prevalence of helminthic infections within the community from which pit emptiers were drawn

Stool samples from 46 pit emptier recruits and 50 non-sanitation workers from the Eastern Cape hinterland were analysed for the presence of ova of *Ascaris lumbricoides*, *Trichuris trichiura* and *Taenia spp* prior to the expected commencement of pit emptying in order to establish a pre-treatment and post-treatment baseline. Three of the 46 pit emptiers (7%) were found to have *A. lumbricoides* eggs in their stool samples, with numbers of eggs per gram ranging between 432 and 8112. No ova of *T. trichiura* and *Taenia spp* were found in the stools samples of pit emptiers. Helminth ova were found in the stools of 11 of the 50 municipal workers (22%), with 9 (18%) infected with *A. lumbricoides* with numbers of eggs per gram ranging from 264 to 1968, 2 (4%) infected with *T. trichiura* (number of eggs per gram 72 and 144) and 2 (4%) infected with *Taenia spp* (number of eggs per gram 144 and 1224). Two were co-infected with two helminths.

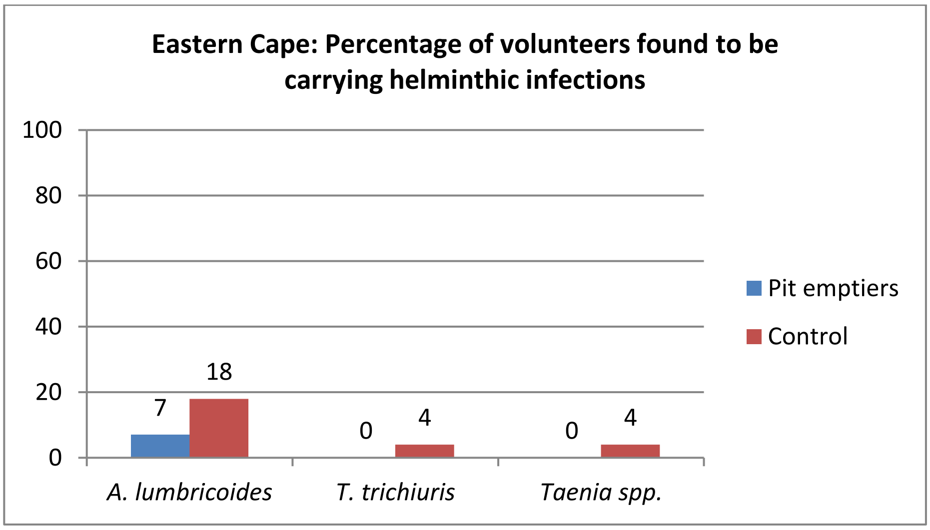

Figure 5 Helminthic infections among 46 pit emptiers and 50 control volunteers

Infections of *A. lumbricoides* and *T. trichiura* can be classified as low, medium or heavy intensity depending on the number of eggs found per gram as indicated below:

Table 7 Categorisation of intensity of *A. lumbricoides* and *T. trichiura* infections on the basis of eggs per gram (E.P.G.)

CATEGORY	*A. lumbricoides*	*T. trichiura*
Light	1 – 4 999 e.p.g.	1 – 999 e.p.g.
Moderate	5 000 – 49 999 e.p.g.	1 000 – 9 999 e.p.g.
Heavy	≥ 50 000 e.p.g.	≥ 10 000 e.p.g.

Of the 14 volunteers found to have helminthic infections, all were light with the exception of one pit emptier who had a moderate *A. lumbricoides* infection.

Table 8 Number of helminth infections among volunteers noting intensity

	A. lumbricoides		*T. trichiura*		*Taenia spp.*	*Total*
	Light	Moderate	Light	Moderate	Present	
Pit emptiers (46)	2 (4%)	1 (3%)	0	0	0	3 (7%)
Control group (50)	9 (18%)	0	2 (4%)	0	2 (4%)	11 (22%)*
Total	**11 (11%)**	**1**	**2 (2%)**		**2 (2%)**	**14 (15%)**

*16 infections occurred in 14 volunteers (22% of control group) as 2 were infected by 2 helminths simultaneously.

Microscopic analysis of the samples indicated varying distributions of the egg categories through the two populations. The samples from the control group contained a markedly greater distribution of undeveloped eggs, as compared to the worker group. The eggs from the samples taken from pit emptiers, however, were in a much better condition, as they appeared healthier and less damaged.

The 14 volunteers who were found to be infected with helminths were provided with a single dose of 500mg Mebendazole (Wormstop). After treatment, stool samples were collected from all volunteers again. Four were found to still have helminth infections: 2 with *A. lumbricoides*, one with *T. trichiura* and one with *Taenia spp*. These volunteers were provided with a follow up deworming treatment.

4.2 Profile of selected pathogens in sludge originating from target households

A 10g sample of sludge was collected from the corners and centre of the pit at 10 households. These samples were analysed for the presence of eggs from selected helminthis: *A. lumbricoides*, *T. trichiura and Taenia spp and selected microorganisms.* Helminth eggs were found in 9 of the 10 pits in the study. Viable *A. lumbricoides* eggs were found in 7 (70%) of the pits, viable *T. trichiura eggs in 3 (30%)* of the pits and potentially viable *Taenia spp* eggs in 4 (40%) of the pits. The numbers and viability of eggs found in the sludge sample from each pit are shown in Table 9.

Table 9 Number and viability of helminth eggs found in 10g sludge samples from 8 pits

	A. lumbricoides						***T.trichiura***		***Taenia spp***
	Possibly VIABLE *A. lumbricoides*			**Definitely NON-VIABLE *ASCARIS***			**Potentially VIABLE Eggs**	**NON VIABLE Eggs**	**Potentially VIABLE Eggs**
Site no	**UNDEVELOPED Eggs**	**MOTILE Larva in Egg**	**IMMOTILE Larva in Egg**	**NECROTIC Larva in Egg**	**DEAD Eggs**	**INFERTILE Eggs**			
1	983	0	2361	4039	2240	0	15	41	5
2	5	0	0	9	5	0	0	0	592
3	327	6	176	259	63	21	24	95	0
4	0	0	0	0	0	0	29	240	0
5	633	0	4	46	15	31	0	0	0
6	6	0	2	0	6	0	0	0	0
7	7	0	2	0	5	0	0	0	2
9	411	0	6	2	17	13	0	0	28
10	0	0	0	1	0	0	0	0	
No of pits	7	1	6	6	7	3	3	3	4

The profile of eggs from selected helminths in the 10g sludge samples from each household (D1-D10) are shown in Figure 2 below.

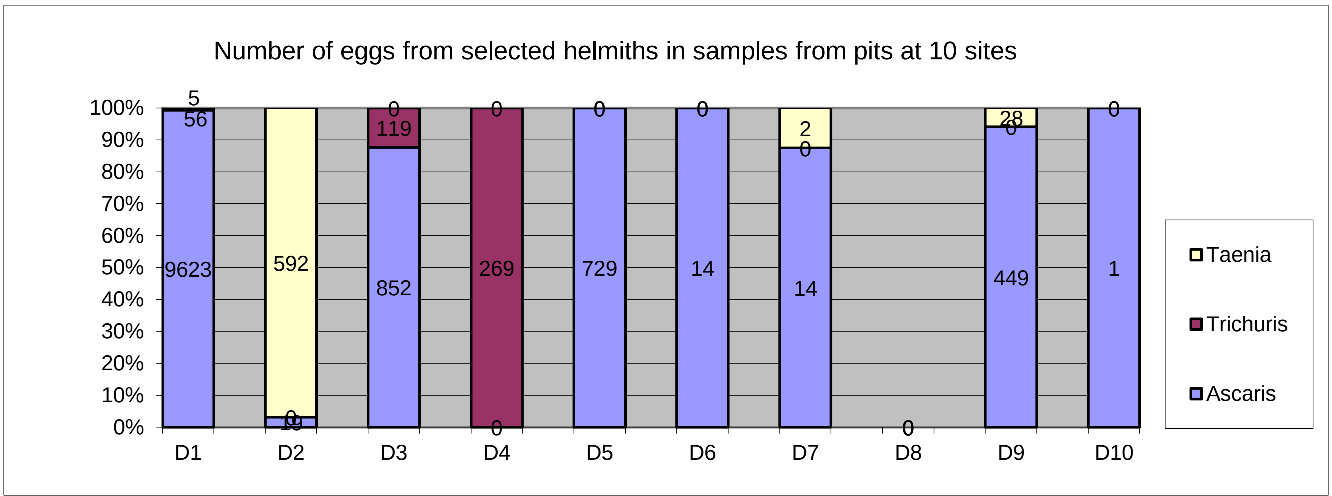

Figure 6 Profile of selected helminths in 10g samples from 10 households (D1-D10)

It is interesting to note that *Taenia spp* eggs were present in sludge samples from only 3 of 10 pits but were found in the environment at 7 of 10 sites. Similarly, *T. trichuris* eggs were present in sludge samples from 2 of 10 pits but found at 6 of 10 sites and *A. lumbricoides* eggs were present in samples from 8 of 10 pits but found at 10 of 10 sites.

E. coli was found in all 10 of the sludge samples, with log MPN/g ranging from 0.04 to 5.2.

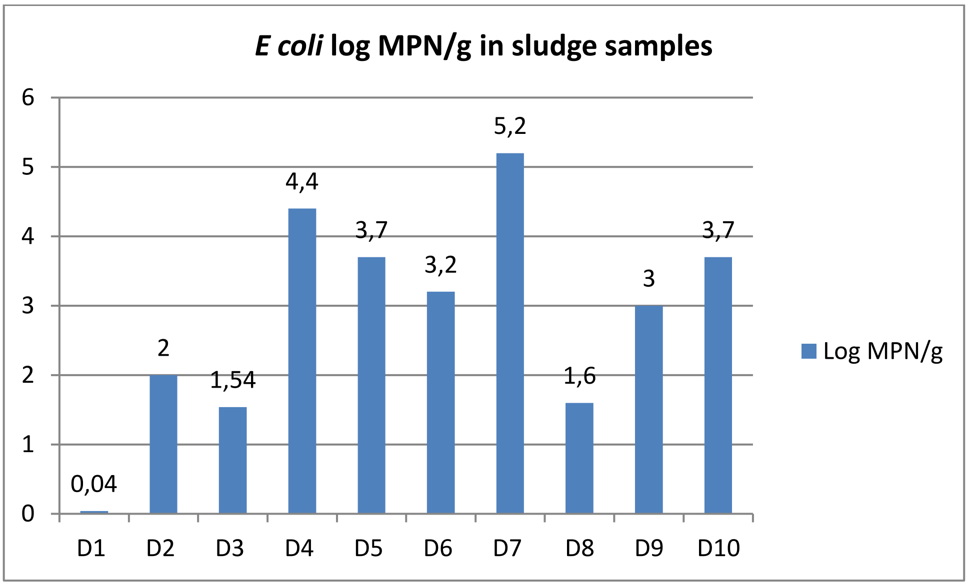

Figure 7 E coli levels found in 1g samples of sludge from pits at 10 households (D1-D10).

The potential addition of household disinfectants to the pit could have impacted viability of bacteria in the pit.

4.3 Observed exposure of workers or the household environment to pathogens during pit emptying

During fieldwork, one fieldworker was assigned to observe and record worker behaviour and practices. Workers were found to expose both themselves and the environment to sludge frequently. In many cases this was due to the logistical difficulties of the work which they were unable to overcome safely while in other cases workers did not take the measures that were available to protect themselves or the environment. This could be the result of either a lack of understanding of the risks to which they were exposing themselves or a disregard for this information.

The following sections examine the various activities that took place during pit emptying and observations made with regard to workers putting themselves, householders or the environment at risk for exposure to the pathogens found in sludge.

4.3.1 Appropriate use of Personal Protective Equipment (PPE)

Workers were observed frequently working without items of their protective clothing. Some used PPE which was damaged and no longer provided a barrier to pathogens. As a result they worked with exposed skin which sometimes came into contact with sludge. Some used their own hats for shade; they sometimes touched these with contaminated gloves, thereby contaminating them as well. Some women preferred to wear work skirts instead of pants for cultural reasons; this also resulted in their legs being exposed above their boots. Some tied rubbish bags around their waists to protect their pants from being splashed with sludge.

Figure 8 A torn glove (left) and boot (right) which no longer provide an effective barrier between skin and sludge.

Figure 9 A worker works without a PPE jacket and sludge is visible on her bare arm. She wears her own hat and by carrying contaminated bin lids on her head contaminates her hat. She ties a rubbish bag around her waist to protect her PPE skirt from sludge.

Figure 10 Left: A worker smokes while sludge is visible on his hand. Right: A worker wears her own shoes during pit emptying. The level of contact she is in with sludge is evident from the visible sludge on her work pants.

While donning and doffing contaminated PPE, skin or the inside of the PPE was frequently touched by the contaminated PPE, thereby contaminated these surfaces. For example, if a worker removed one glove and then used the exposed hand to remove the other glove, the exposed hand would then become contaminated. If this hand was not washed before the glove is put on again, contamination would be transferred to the inside of the glove. Another example is the removal of face masks. If a gloved finger was inserted under the rim of the mask to remove it, the face and inside of the mask would become contaminated. If a clean hand was used to remove the mask, the hand would become contaminated.

Figure 11 Skin and the inside surfaces of PPE easily became contaminated during doffing and donning

On some occasions workers handled sludge directly with their gloves. For example, trash in the sludge such as string or hair extensions sometimes hung off of the shovel or out of the bins, and in some cases workers handled this with their gloves to get it into the bin, resulting in heavy contamination of their gloves. Similarly, they sometimes climbed into the pit in order to empty it more easily, resulting in heavy soiling of their boots.

Figure 12 A worker handles trash in the sludge directly with her hands, heavily soiling her gloves.

4.3.2 Protecting householders and the environment

Upon arriving at a household selected for pit emptying, a member of the pit emptying team informed the home owner that the pit would be emptied. In some cases washing was hanging to dry in the path that would be used to transport sludge from the pit to the vehicle. There were often buckets, water containers and other household objects in the area used by the pit emptying team. In addition, quarters were often cramped, with workers having to work in close proximity with walls or household objects. The logistical challenges of working with sludge under such conditions without contaminating the household environment were therefore obvious, however the pit emptiers did not attempt to protect the household environment by asking householders to move objects, by avoiding contact of gloves, boots, tools or bins with household surfaces, or by refraining from use of the household tap. Workers routinely leaned against household surfaces, either unaware or unconcerned that they were contaminating them. On two occasions workers were observed requesting water from the householder; in one case a jug was provided which workers then used with contaminated hands; on another occasion a worker was given a glass of water from the house. The glass can be assumed to have been contaminated when it was returned to the house. In addition, on some occasions workers used the household tap to obtain water to clean their hands, clothes or gloves, using contaminated gloves or hands to open the tap. Because taps were not always designed with drainage systems, the water rinsing away sludge from hands or gloves in some cases soaked the area around the tap or flowed along a path, potentially spreading pathogens with it. At many homes the outside tap is often the only source of water on the site and is therefore also effectively the "kitchen sink", where dishes are washed, this raises the possibility of householders coming into contact with pathogens from the tap and tap area. In addition, workers carried no supplies with them that would enable them to protect household surfaces – for example, a tarpaulin on which to place contaminated tools, or disinfectants to clean surfaces where contact occurred.

Figure 13 At this home, workers brushed against washing hanging on lines repeatedly as they carried bins of sludge off site

Figure 14 Pit emptiers working in cramped conditions placed their bins directly under washing drying on a line at this home.

Figure 15 At this site workers worked amongst household objects and building rubble, risking greater contamination of the site.

Figure 16 Workers typically demonstrated no awareness or concern that contact between their PPE and household surfaces could spread contamination.

Figure 17 LEFT: A worker causally rests his contaminated gloves on a wall; RIGHT: A visible quantity of sludge is left on a wall after a worker leans against it.

Figure 18 Workers had no option but to place contaminated tools on household surfaces, thereby contaminating them, as they carried no tarpaulins with them on which to lay their tools.

Figure 19 Soil and grass contaminated with sludge at a home where the pit is being emptied

3.3.3 Emptying the pit

Workers opened the pit using a shovel and pick and laid the cover top down face up on the grass/soil next to the pit. Workers took turns removing the sludge from pit with long handled shovels and rakes and transferring it to rubbish bins. Observation found that the edges of the pit and the area between the pit and the bins became heavily contaminated during transfer of sludge from the pit to the bin. Access to the pit was often difficult as the opening hatch was small. In many cases it was difficult to extract the sludge from the pit from ground level – and at some sites the slope made this difficulty even more extreme. When the access pit was large enough, workers frequently climbed into the pit to access the sludge more easily, despite the fact that they had been instructed not to. This resulted in the bottoms and sides of their boots becoming heavily contaminated, which then contaminated the ground when they climbed out of the pit. Sometimes the worker in the pit did not have a protective jacket or mask on, thereby risking exposure while working in such close proximity to the sludge.

Figure 20 Access to the pit was sometimes very limited

Figure 21 It was difficult for workers to lift sludge from the pit while standing above the pit. In some cases sloping terrain made this even more difficult.

Figure 22: These workers have entered the pit without a mask or protective jacket, putting themselves at unnecessary risk of infection in order to more easily remove the sludge. When they climb out of the pit their boots will track sludge around the household environment, into the vehicle and into their home, putting others at risk of infection as well.

Figure 23: The lip of the pit typically became heavily soiled during emptying

Figure 24 At these two sites sludge can be seen contaminating the lip of the pit and the area between the pit and the bin. There was no provision made to protect the earth between the pit and the bin.

As the bins were carried to the site stacked together, their exterior surfaces were heavily contaminated. These bins were stood aroud the household site with no protection for the earth, potentially introducing contamination into the household environment in many places. To remove the stacked bins from each other sometimes proved difficult, and workers were observed bracing themselves with their boots in the bins, thereby contaminating them and later the soil as they walked around.

Figure 25 Bins were stacked together to aid transport, resulting in their exteriors becoming heavily contaminated

Figure 26 In the cramped conditions at many sites, the presence of numerous grossly contaminated bins represented a large potential contamination "footprint" at the site. Workers carried with them no barriers on which they could place the bins to protect the earth.

4.3.4 Transporting the sludge after removal

Filled rubbish bins were carried to the nearest vehicle access point. Vehicle access was only occasionally at the boundary of the property and in most cases there was a distance of 250m or more that the bins had to be carried, sometimes along narrow ledges or down steep pathways. Workers sometimes chose the shortest or easiest path for themselves even where it raised the risk of contamination of the household environment. For example, bins were dragged through a food garden as this was easier than carrying them around the garden. The houses were very close together and workers in some cases needed to support themselves by leaning their hands on the walls of houses as they passed. Workers sometimes set the bins down in order to rest or adjust their grip. In numerous cases sludge was spilled out of the bins onto the earth. As workers were not carrying tools with them as they carried the bins, they had no means to remediate this spills immediately. In some cases they attempted to collect the sludge later, although sometimes only after it had been stepped on numerous times, increasing the spread of contamination. Workers carried no disinfectants with them with which they could decontaminate surfaces where sludge had spilled, or the bottoms of boots that had stepped in sludge, and had only contaminated tools with which they could attempt to remove the sludge. In some cases they attempted to use discarded objects around the household to collect the sludge. If these objects were then left behind at the site, they represented an ongoing threat of contamination in the household environment.

Figure 27: The heavy bins often had to be carried long distances across difficult terrain

Figure 28 ABOVE AND LEFT: Sludge was often spilled on the ground in the process of transfer and transport.

Figure 30 At one site contaminated bins were dragged through this vegetable garden because it was the shortest route to the road.

Figure 29 LEFT: Small children, who were barefoot, were attracted to the pit emptying activities and hung around on the pathway on which workers were transporting full bins to the truck. BELOW: Children on their way home from school had to share the pathway with pit emptiers transporting bins of sludge.

Figure 31 A vehicle from a local hardware was hired to transport the bins to the disposal site. Several people from the community passed through the area where sludge was being loaded or empty bins off loaded. Potential contamination of the vehicle (as well as the environment) can be seen from workers' gloves, boots and the contaminated bins.

Figure 32 In some instances workers attempted to remove sludge that had fallen on the ground. They did not however have any equipment for sanitising the contaminated area.

4.3.5 Workers' welfare needs on site

Over the course of the day workers needed to eat, drink, smoke or use their phones repeatedly. In most cases they removed their work gloves to do this. Once they had removed their gloves, there was no provision made for a place to put them that wouldn't contaminate the ground. They therefore placed them directly on the ground, contaminating the ground. If they did not remove their gloves, it is likely that they transferred pathogens from their contaminated gloves to the objects they touched and then possibly to their mouths. None of the workers was observed using a hand sanitiser. Some washed their hands at the household tap – often the only water source at the household where dishes, clothes, and anything else are also washed. If their hands were contaminated, pathogens may have been transferred to the tap handle or the area around the tap. Most, however, did not attempt to wash their hands before proceeding to use their phone, drink, eat or smoke. If their hands were contaminated they may have transferred pathogens to their faces or mouths. Workers handled the jug with their soiled work gloves, thereby risking the transfer of pathogens from the pit to the kitchen. Few workers carried water with them to site despite the fact that the weather was very hot; wearing PPE increased the discomfort of working in the heat. On some occasions workers asked for water from the householder. On one occasion water was provided in a glass, on another occasion in a jug.

Figure 33 Workers typically removed work gloves while taking a break but had no means to sanitise their hands other than rinsing them at the household tap, risking contaminating the tap

Figure 34 LEFT: A worker wearing inner gloves (representing skin for sampling procedures) uses wrappers as a barrier between her hands and a cup and bottle. RIGHT: A worker drinks from a householder's glass.

4.3.6 Welfare after work

There was no provision for workers to shower or to wash and store their equipment after work. Workers wore their PPE home from work and washed them there. Some attempted to rinse their equipment at the household tap. A brush obtained from the household was used to scrub boots in one instance and a cloth believed by the researchers to have also been obtained from the household was used to scrub sludge from a T-shirt in another instance. This potentially exposed their home environment and family members to pathogens on their protective equipment. At householders where washing is done with cold water at a tap which is also shared for washing dishes and the water used for washing clothes may drain into the surrounding area, this may also spread pathogens into the home environment.

Figure 35 A worker attempts to clean sludge from her T-shirt using a cloth believed to belong to the householder

Figure 36 Workers rinse sludge from their gloves at the household tap

Figure 37 A worker scrubs sludge off of her work boots with a brush and bucket obtained from the householder and with her bare hands.

4.4 Laboratory evidence of exposure of workers or the household environment to selected pathogens during pit emptying

Samples were taken as follows to look for contamination by selected helminths (*Ascaris lumbricoides, Taenia spp* and *Trichuris trichiura*)and bacteria (*Salmonella spp, E. coli* and *Staphylococcus spp.*) before and after pit emptying:

Table 10 Selected locations where samples were collected before and/or after pit emptying

Surface	Before	After
Sludge from pit (sampled from 5 points)	x	
Surfaces in the household environment 30cmx30cm area swabbed / soil lifted)		
Pit cover	x	
Walkway to and from the pit to the road	x	x
Tap handle	x	x
VIP door handle	x	X
Lip of pit		x
Sampling of PPE or worker's skin (identified area swabbed or item collected)		
Hands	x	
Outer and inner gloves		x
Face, inner mask		x
Outer mask		x
Bottom of boot		x

The results of the analysis of these samples are presented below. As mentioned in the introduction, these results provide less clear evidence of contamination by sludge than that obtained by direct observation for the following reasons:

- ***In the case of helminths, the presence of one or more eggs from one of the selected helminths in a sample verifies contamination of that sample site by faeces. The absence of a helminth egg in a sample does not, however, verify that the area sampled was NOT contaminated with sludge – it is possible that sludge was collected in the sample which happened to not contain eggs***. On some occasions a helminth egg of one type was found present on a surface before pit emptying, and of another type after pit emptying, indicated that sampling may have "cleaned" the sample site. While *A. lumbricoides* and *T. trichiura* are strictly human parasites, and the presence of their eggs on a surface therefore confirms that it is contaminated by human faeces, in the case of *Taenia* spp, the two species of which can infect cows or pigs, there is a remote possibility that the contamination originated from one of these animals either present on the site or whose dung was brought onto the site as manure or tracked in on shoes. As the area where the study took place was densely settled and no free ranging pigs or cows were observed in the area, this is, however, a very remote possibility.

- The selected bacteria, on the other hand, are found in the faeces of a number of animals which could be present at a household, such as birds or geckos, as well as in the faeces of humans. ***The presence of bacteria in a sample does not verify that it was contaminated with pit sludge, therefore, while the absence of bacteria shows that the specific sample site was probably not contaminated by sludge***. The occasional presence of bacteria in a "before" sample and absence in an "after" sample again points to the sampling methodology, whereby the collection of the first sample may have "cleaned" the sampling site. A more costly analysis would be required in order to verify the species of origin.

- With regard to unexpected contamination of samples, in addition to the possibility of pre-existing contamination of the environment by either animal faeces or by human faces spread through poor hygiene, there is also a possibility that pit emptiers contaminated walkways at the households with their boots when they visited them in the morning to inform the householder that their pit had been identified for emptying that day – a fact which researchers weren't aware of until the last day of fieldwork. Researchers therefore collected pre-pit empyting samples believing that no one from the pit emptying team had yet set foot on the site.

- With regard to samples not revealing contamination when it was visually observed, a further weakness of the sampling methodology also may contribute to the low occurrence of selected pathogens in samples relative to the occurrence of contamination of these surfaces that was observed in the field: the swabbing of a 30cm x 30cm area for the collection of a sample is a small area and contamination such as spilled sludge may have occurred on either side of the sample (ie. the walkway may indeed have been contaminated in multiple locations) but on the exact location where the sample was collected. In addition, the sampling wipe may have become saturated with sample material before the swabbing of the 30cm x 30cm sample site was complete, with the result that an even smaller representation of the selected area (eg. walkway) was actually sampled. In addition, samples were only collected from one worker per site; there is a possibility that other workers were exposed while the selected worker avoided exposure to a greater extent, possibly as a result of having been singled out for sampling and having had his/her consciousness of hygiene raised by the pre-pit emptying sample collection from his/her clothes and skin.

4.4.1 Contamination of the household environment

Pit cover

The numbers of eggs recovered from the pit cover at each site for the 3 target helminths before and after are shown below in Figure 33. Helminth eggs were four on pit covers at 4 homes before pit emptying, and at 7 after; at one home two helminth eggs were found before and none after, possibly due to the sampling procedure "cleaning" the sampling site.

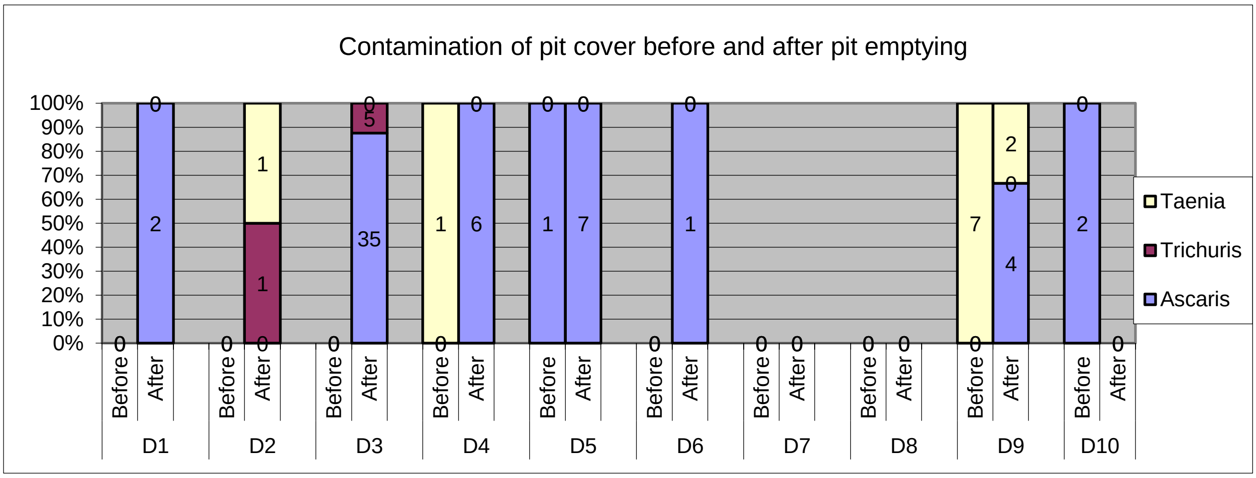

Figure 38 Numbers of eggs of selected helminths recovered from the cover of the pit at households D1-D10

Table 11 Number of households at which selected pathogens were found on the pit cover

	A. lumbricoides	*T. trichiuris*	*Taenia spp*	*E.coli*	*Salmonella spp.*	*Staphylococcus spp.*
Before pit emptying	2	0	2	7	5	6
After pit emptying	6	2	2*	8	8	6

*contamination appeared on samples at different households before pit emptying than after pit emptying

While contamination was found on the pit cover at more sites after pit emptying than before, the number of sites at which contamination was found before pit emptying was extremely high. Helminth eggs were found on the pit cover at 8 homes during this exercise.

Walkway

The numbers of eggs recovered from the walkway at each site before and after pit emptying is shown in figure 34.

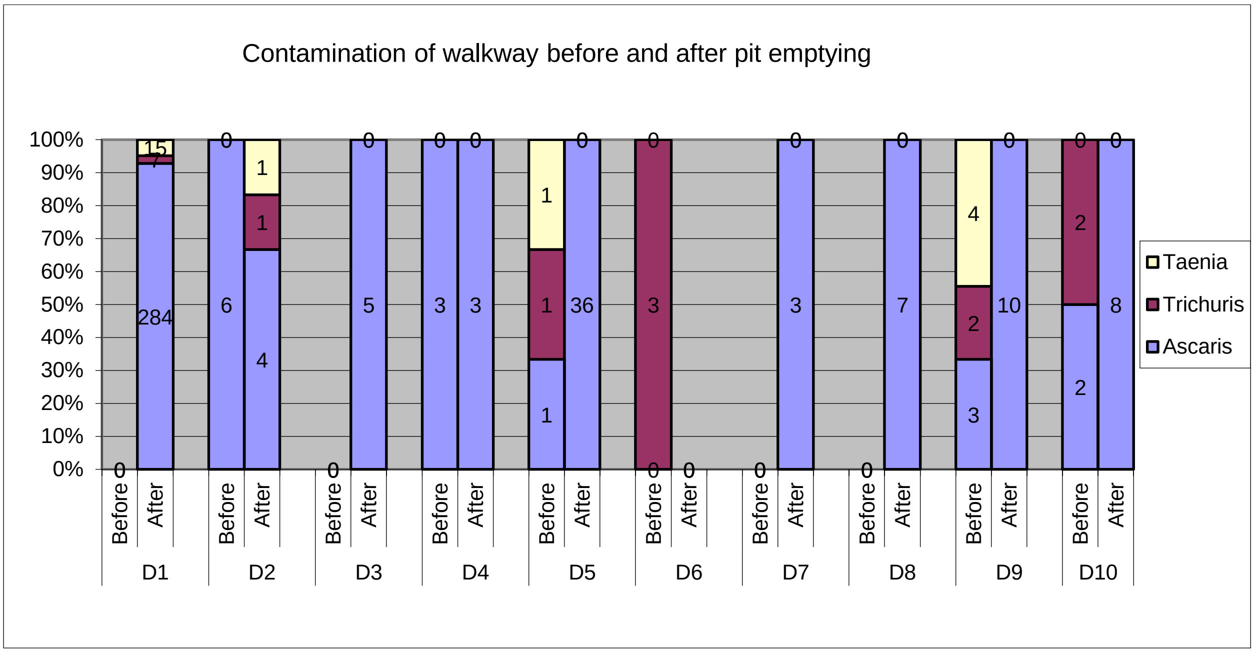

Figure 39 Numbers of eggs of selected helminths recovered from the walkway at households D1-D10

At one household the walkway was found to be contaminated with helminth eggs before pit emptying but not after, while at half (5) of the households contamination of the walkway with helminth eggs was found both before and after pit emptying, and at only 4 households was it not found before pit emptying but was found after.

The number of households at which the selected pathogens were found on the walkway is shown in Table 5.

Table 12 Number of households at which selected pathogens were found on the walkway

	A. lumbricoides	*T. trichiuris*	*Taenia spp.*	*E.coli*	*Salmonella spp.*	*Staphylococcus spp.*
Before pit emptying	5	4	2	7	7	7
After pit emptying	9	2	2	9	4	8

T. trichiuris and *Salmonella spp.* were found on the walkways at more houses before pit emptying than after.

Lip of the pit

The numbers of eggs recovered from the lip of the pit at each site before and after pit emptying is shown in Figure 36.

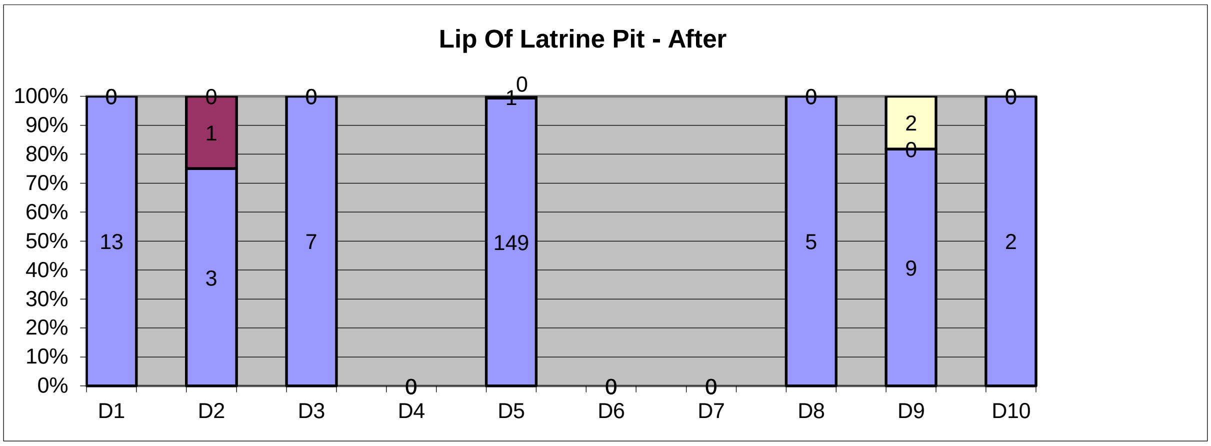

Figure 40 Numbers of eggs of selected helminths recovered from the lip of the pit at households D1-D10

While gross contamination of the lip of the pit was observed at pit emptying at all 10 households, helminth eggs were only recovered from the lip of the pit after emptying at 7 households. *A. lumbricoides eggs* were recovered at all 7 of these, while one *T. trichiuris egg* was recovered at one site and 2 *Taenia spp.* eggs at another site. The number of households at which the selected pathogens were found on the lip of the pit is shown in Table 6.

Table 13 Number of households at which selected pathogens were found on the pit lip

	A lumbricoides	*T. trichuris*	*Taenia spp*	*E.coli*	*Salmonella spp.*	*Staphylococcus spp.*
After pit emptying	7	1	1	5	5	4

Tap handle

The numbers of eggs recovered from the tap handle at each site before and after pit emptying is shown in Figure 36.

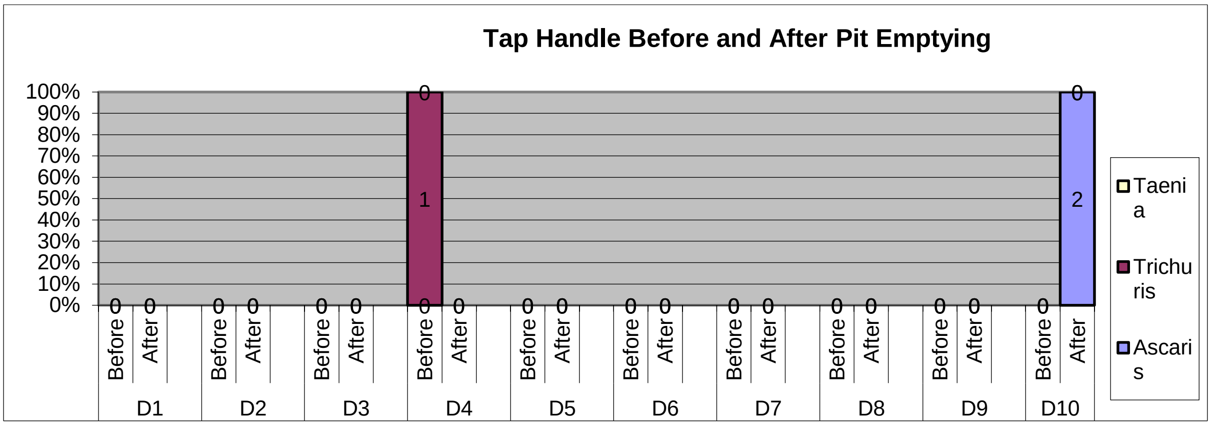

Figure 41 Numbers of eggs of selected helminths recovered from the tap handle at households D1 - D10

One *T. trichiuris* egg was recovered from a tap handle before pit emptying and 2 *A. lumbricoides* eggs were retrieved from a tap handle at a different site after pit emptying.

Figure 42 Number of households at which selected pathogens were found on the tap handle

	A. lumbricoides	*T. trichiuris*	*Taenia spp.*	*E..coli*	*Salmonella spp.*	*Staphylococcus spp.*
Before pit emptying	0	1	0	4	2	5
After pit emptying	1	0	0	2	5	4

Contamination was found on tap handles at more households before pit emptying than after. One tap handle was found contaminated before and not after – possibly due to "cleaning" by the sampling procedure.

VIP door handle

No use of the VIP by workers was observed during pit emptying at any of the households. One door handle was found to be contaminated with 1 *T. trichiurus* egg before pit emptying; nothing was recovered from the handle when it was wiped again after pit emptying. Table 7 indicates the number of households at which selected pathogens were recovered from the handle of the VIP before and after pit emptying. As pit emptiers were not observed entering the VIPs contamination of toilet door handles can probably be attributed to poor hygiene practices of householders. Even though handles were "cleaned" by wiping before pit emptying, contamination was found on door handles at 9 households after pit emptying.

Table 14 Number of households at which selected pathogens were found on the toilet door handle

	A. lumbricoides	*T. trichiuris*	*Taenia spp*	*E. coli*	*Salmonella spp.*	*Staphylococcus spp.*

Before pit emptying	0	1	0	2	3	3
After pit emptying	0	0	0	2	9	6

4.4.2 Contamination of the workers' PPE and skin

Face and mask

The numbers of eggs recovered from the face and interior of the mask and from the exterior of the mask after pit emptying is shown in Figures 39 and 40.

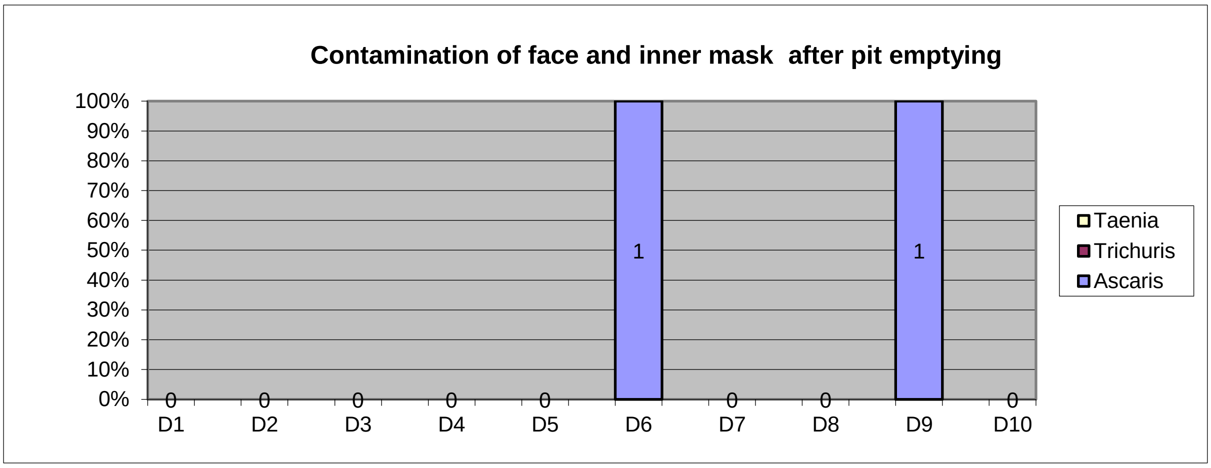

Figure 43 Numbers of eggs of recovered from inside 1 worker's mask after pit emptying at each of households D1-D10

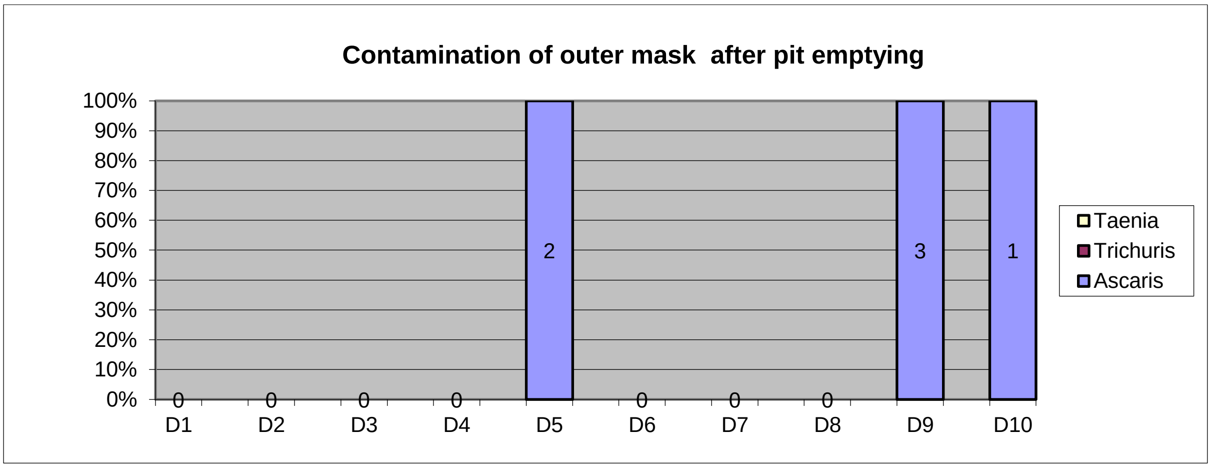

Figure 44 Numbers of eggs of recovered from the outside of 1 worker's mask after pit emptying at each of households D1-D10

The number of households at which contamination with selected pathogens was found the interior and exterior of the mask of one worker after pit emptying is shown in Table 8.

Table 15 Number of households at which pathogens were found on the interior and exterior of 1 worker's mask

	A. lumbricoides	*T. trichiuris*	*Taenia spp*	*E. coli*	*Salmonella spp.*	*Staphylococcus spp.*
Interior	2	0	0	2	5	5
Exterior	3	0	0	6	4	7

Hands and gloves

The numbers of eggs recovered from one worker's hands before pit emptying and from his/her inner gloves (representing hands) and outer gloves after pit emptying is shown in Figures 41-43.

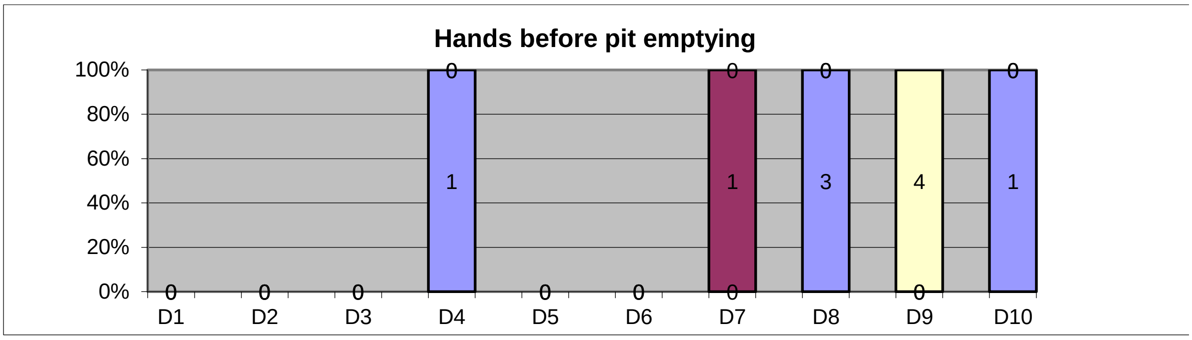

Figure 45 Numbers of eggs of recovered from the hands of 1 worker before pit emptying at each of households D1-D10

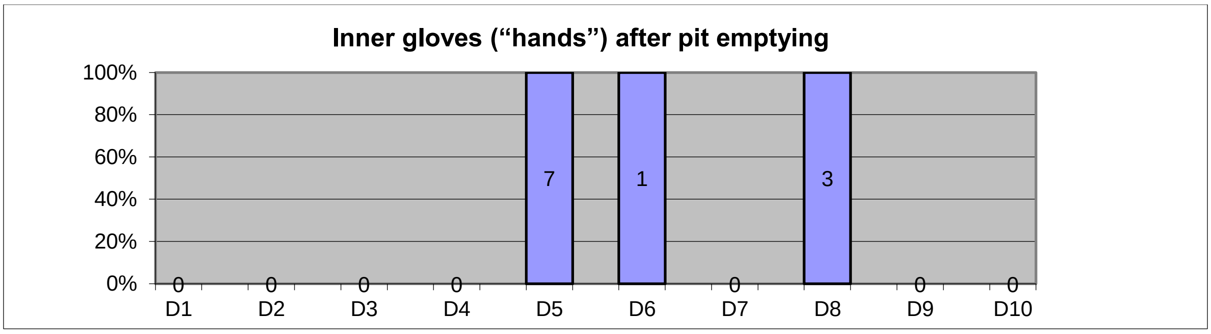

Figure 46 Numbers of eggs of recovered from the hands of 1 worker after pit emptying at each of households D1-D10

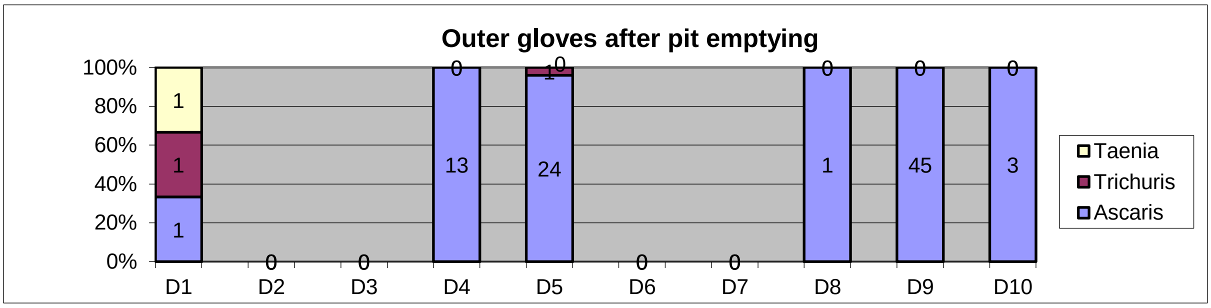

Figure 47 Numbers of eggs of recovered from the gloves of 1 worker after pit emptying at each of households D1-D10

The worker who was selected for sampling at half of the pit emptying exercises already had helminth eggs on his or her hands. These eggs are likely to have originated from pit sludge which the worker had come into contact with earlier in the day, although it is not impossible that they were present on his/her hands from home. After his/her hands were wiped during sampling, the worker donned surgical gloves to represent skin and then work gloves and completed the pit emptying exercise.

Afterwards eggs were found on the surgical gloves of one pit emptier at the same site as before and of 2 pit emptiers at other sites. This could be due to new or pre-existing contamination of the interior of the gloves from placing contaminated hands into gloves (ie. using gloves intermittently during pit emptying).

The number of households at which contamination with selected pathogens was found on the hands and gloves of one worker before and after pit emptying is shown in Table 9.

Table 16 Number of households at which selected pathogens were found on the hands and gloves of 1 worker before and after pit emptying

	A. lumbricoides	*T. trichiuris*	*Taenia spp.*	*E..coli*	*Salmonella spp.*	*Staphylococcus spp.*
Hands before	3	1	1	2	5	6
"Hands" after	3	0	0	3	4	3
Gloves after	6	2	1	6	4	6

Bottom of boot

The numbers of eggs recovered from the bottom of one worker's boot after pit emptying is shown in Figure 44.

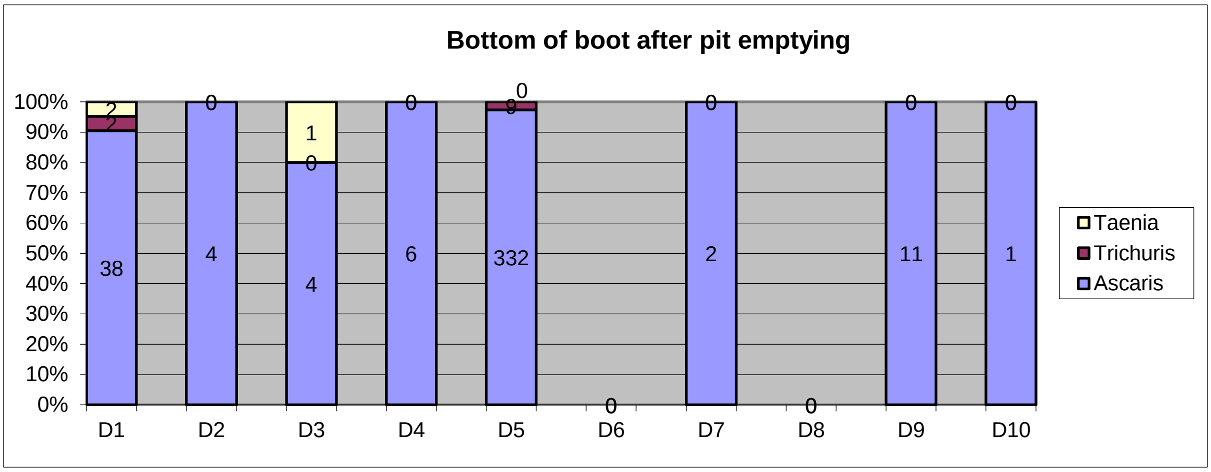

Figure 48 Numbers of eggs of recovered from the bottom of 1 worker's boot after pit emptying at each of households D1-D10

Helminth eggs were recovered from the bottom of one worker's boot at 8 of the 10 pit emptying exercises.

The number of households at which contamination with selected pathogens was found on bottom of a boot of one worker after pit emptying is shown in Table 9.

Table 17 Number of households at which selected pathogens were found on the bottom of 1 worker's boot before and after pit emptying						
	A. lumbricoides	*T. trichiuris*	*Taenia spp.*	*E..coli*	*Salmonella spp.*	*Staphylococcus spp.*
Bottom of boot after	3	1	1	2	5	6

Figure 45 below contrasts the incidence of contamination by helminth eggs of a single sample from selected surfaces at the pit emptying site before and after pit emptying.

Figure 49 Number of the 10 pit emptying sites at which different surfaces were found to be contaminated with helminth eggs before and after the pit emptying exercise

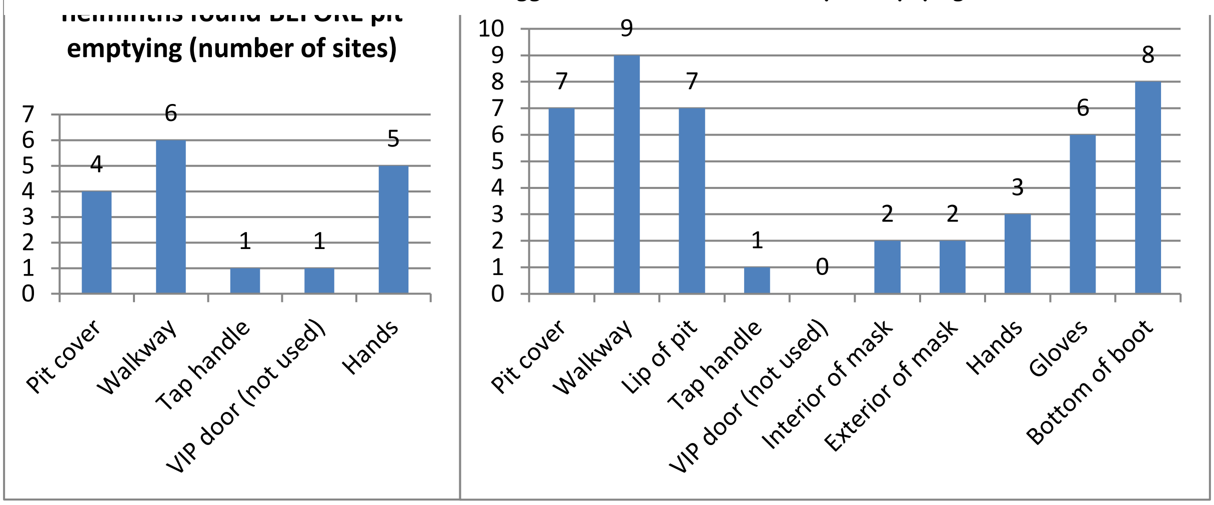

Figure 46 below shows the incidence of contamination by helminth eggs of a single sample from selected surfaces at the pit emptying site in total, including both before and after pit emptying.

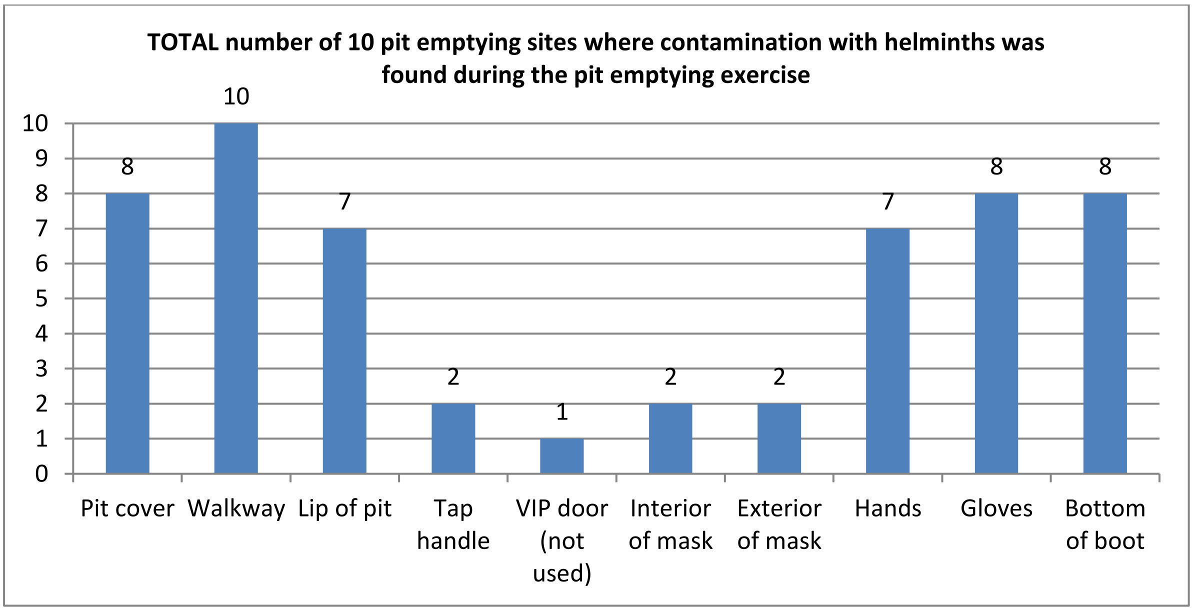

Figure 50 Number of the 10 pit emptying sites at which different surfaces were found to be contaminated with helminth eggs in total, both before and after the pit emptying exercise

Helminth eggs were found on the walkway at 100% of the sites and on the pit cover and lip of the pit at 80% and 70% sites respectively. Helminth eggs were found on the gloves and bottom of the boots of 80% of the pit emptiers sampled, on the hands of 70% and inside the masks of 20% of pit emptiers sampled. If these percentages held true in a statistically significant sample, they would be very high.

4.5 Knowledge and attitudes of workers and householders with regard to health risks involved in pit emptying

As was evident in data presented in Chapter 4, workers frequently did not protect themselves or the environment from exposure to sludge. While in many cases logistical challenges had not been adequately addressed by means of protocols and equipment in order to protect workers and the environment, observations of work practice found that workers frequently did not take the steps that were available to them to protect themselves or the environment. This indicated either a lack of adequate knowledge about the hazards contained in sludge and how to contain them, or a lack of commitment or motivation to apply what they knew. This section explores workers' knowledge with regard to disease transmission and health/hygiene practices, as well as attitudes of workers towards the health risks involved in their jobs. In addition, it explores the knowledge and attitudes of the householders who had their pits emptied by the workers.

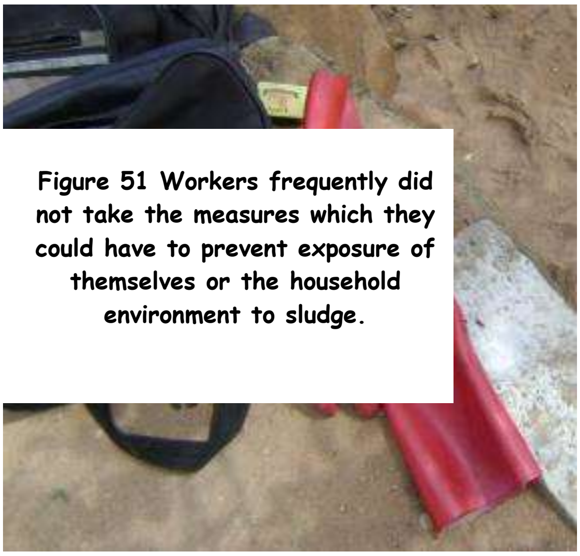

Figure 51 Workers frequently did not take the measures which they could have to prevent exposure of themselves or the household environment to sludge.

Workers and householders in this study were from the same community. Responses to questions regarding the risks to workers and householders/the household environment indicated that understanding of disease transmission by both groups was generally low accompanied by a low sensitivity to the potential health threats implied in pit emptying. Tables 11 and 12 below compare the responses of workers and householders to questions probing their views of the risks involved in pit emptying.

Table 18: Workers' perceptions of health issues during pit emptying

Question	Yes	No
Were you able to protect your health on the job?	4	1
Were you able to protect the household while you worked?	5	1
Does the municipality do enough to protect your health?	3	3
Is there anything that should be changed?	6	3

Table 19: Householders' perceptions of health issues during pit emptying

Question	Yes	No
Were you satisfied with the job done by the pit emptiers?	7	2
Was there anything that bothered you during the pit emptying?	2	8
Did the workers protect themselves adequately?	4	6

Do you think the workers kept your home environment clean?	4	4

While gross contamination of the household environment by pit emptiers was witnessed by researchers at each household and verified by laboratory findings, pit emptiers and householders did not register a high level of concern that the health of either group was put at risk during the exercise. The perception that health was put at risk was stronger among householders for both pit emptiers and householder health than for pit emptiers. Keeping in mind that the sample size was very small, 60% (6/10) of householders indicated that they did not think that workers protected themselves adequately during the activity, while only 20% of workers (1/6) indicated that they did not think they were able to protect their health. Workers were equally divided (3-3) on the question of whether the municipality did enough to protect their health. While the 8 householders were equally divided on the question of whether the workers had kept their home environment clean, 5/6 of the workers believed that they had been able to protect the household while they worked.

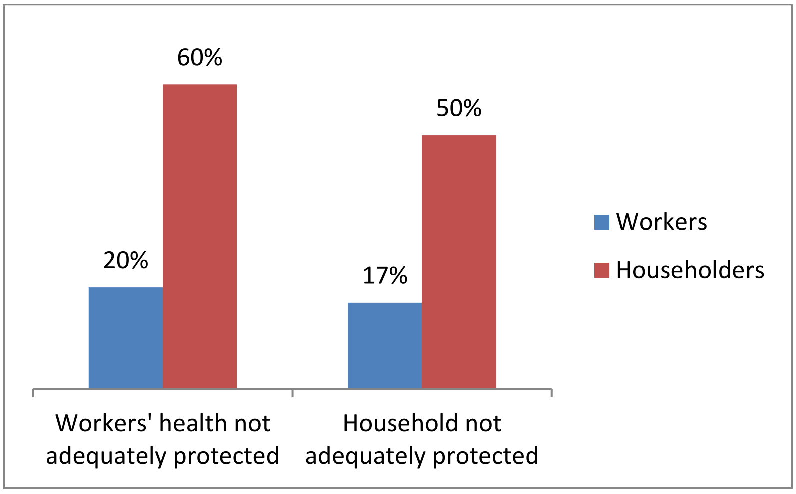

Figure 52 Householders viewed both the household and workers as less protected during pit emptying than did pit emptiers

Comments and suggestions made by individual workers and householders included the following:

Table 20: Changes needed to work practice as identified by workers
Provide a spray to reduce the smell of the sludge as it is overwhelming.
Each worker should be given soap for washing.
The team should be given disinfectants to carry with them.
New gloves should be issued monthly.
An alternative to the masks is needed because it is too difficult to breathe with them on.
A better system is needed for carrying the bins.

Table 21: Comments and suggestions from householders
It would be better to have flush toilets so that this isn't needed.
The pit emptying helps us but it is not healthy.
It is a problem that the workers drop sludge on the ground, even though they pick it up.
The workers should not use the household tap.
Because the houses are so dense here there is not much the workers could do differently.
The workers should be given long sleeved gloves.

The workers should be given more protective clothing, such as waterproof jackets and masks.
The workers spilled sludge on the ground because they did not put lids on the bins.

Knowledge about pathogens found in sludge and their transmission

When asked about diarrhoea and helminthic infections, no distinction could be made between responses from workers and householders, both groups expressed a range of accurate and inaccurate views. Responses have been combined in Table 15 to illustrate the views held by this sample of the community.

Table 22: Understanding of diseases transmission among workers and householders
What causes diarrhoea?
Drinking dirty water (5)
Dirty environment (5)
Worms (1)
Sludge blowing in the wind (1)
Dirty hands or body (2)
Eating rotten meat or other spoiled food (2)
Having too much to drink (1)
Not washing hands before handling food or after using the toilet (1)
What causes worms?
Eating soil (2)
Contact with the soil (1)
Poor hygiene (2)
Not washing food before cooking (1)
Eating unhealthy food (2)
Eating maas (4)
Drinking fresh milk (1)
Worms are a natural occurrence in the body (1)
Don’t know (2)
How can you prevent worms?
Keep the environment clean (2)
Be careful of what you eat and touch (2)
Take medicine or go to a doctor (5)
Don’t know (6)

When asked what causes diarrhoea and worms respondents identified behaviours that they believed resulted in disease transmission, rather than naming pathogens. Answers were more accurate for diarrhoea than for helminthic infections. Two of the workers and five of the householders reported that they or someone in their family had had worms, identified by symptoms such as seeing worms come of someone’s mouth or anus, weight loss, loss of appetite, grinding of teeth while sleeping, tiredness, moodiness, dry cough, vomiting, sweating or yellow, weepy eyes. Causes given for worms included inaccurate answers such as eating maas or milk and believing that worms occur naturally in the body. Knowledge of how to prevent helminthic infections was poor, with the most common responses being that you should go to a doctor or take medicine or that they did not know.

4.6 Supervision, compliance and enforcement of safety requirements

In terms of health and safety, workers frequently were missing items of their protective clothing or chose not to use them while working, although they indicated that they were required to wear them. They also indicated that they were not allowed to climb into the pit, but this and other requirements to protect workers’ health or the household environment were not enforced by team leaders on the job.

4.7 Efficacy of selected disinfectants with regard to selected helminth eggs

Egg solutions were exposed to the disinfectants at three concentrations: the recommended dilution (as indicated on the bottle), a 50% dilution and a undiluted concentration.

Testing of effectiveness of disinfectants when used for wiping surfaces

In the first experiment, eggs were inoculated into two different surface types, i.e. plastic and glass, and were wiped off with cloths saturated with the different disinfectants as well as with water, as a control. Eggs recovered from the water-soaked cloths ranged from 40% to 50% for the first replicate and from 35% to– 45% in the second replicate. Figure 49 shows that wiping of both surfaces with disinfectants at the respective recommended dilutions showed little reduction in egg viability from the control. Jeyes Fluid was found to be particularly ineffective for removing eggs off the surface of the petri dishes, with particularly poor performance on glass surfaces. Thus egg counts were lower not because of the efficiency of the disinfectant in destroying the eggs but because a significant proportion remained on the wiped surface. Although viability decreased somewhat when wiped with a Pine Gel solution, the viability was still too high to be considered effective. Egg viability above 5% is considered unsafe and potentially infectious.

The 50% dilutions also showed little change in egg viability. In the case of Pine Gel, the 50% dilution was not tested because of the extremely viscous nature of the product. No differences were seen between the two types of surfaces.

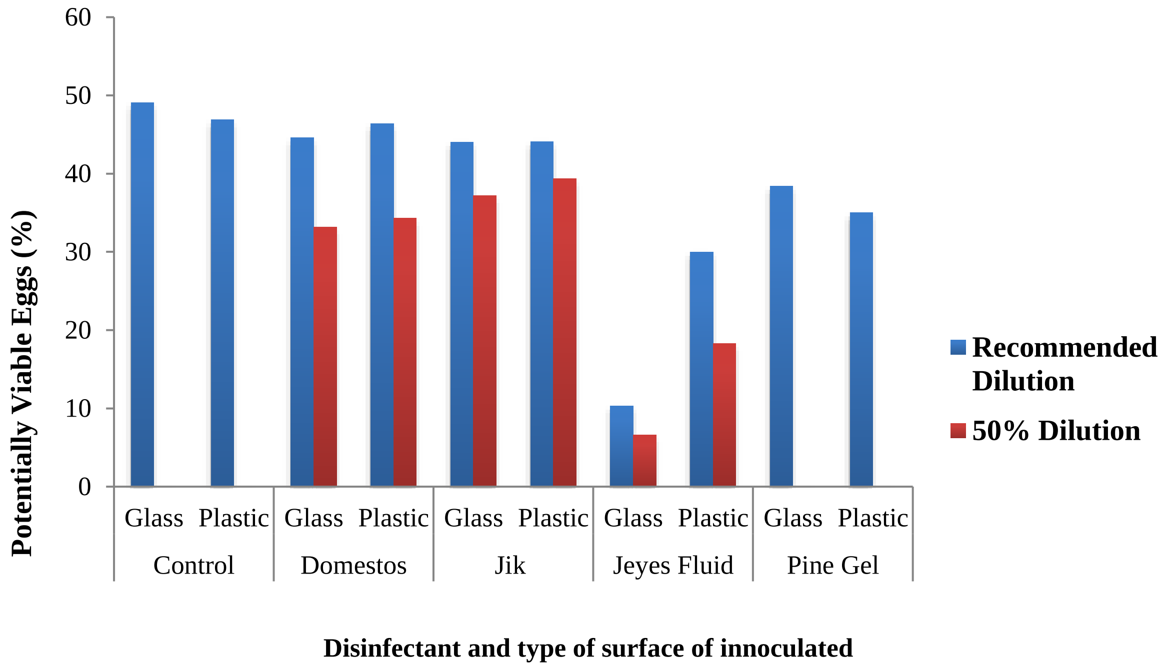

Figure 53 Mean egg viability (%) after treatment with various household disinfectants at two concentrations, when wiped off two different surfaces (n=3)

Testing of effectiveness of disinfectants when used for soaking contaminated materials

The effect of soaking with selected disinfectants at 50% dilutions on the viability of eggs was tested for exposure periods of 1 and 12 hours. Results for the 1 hour exposure are shown in Figure 50.

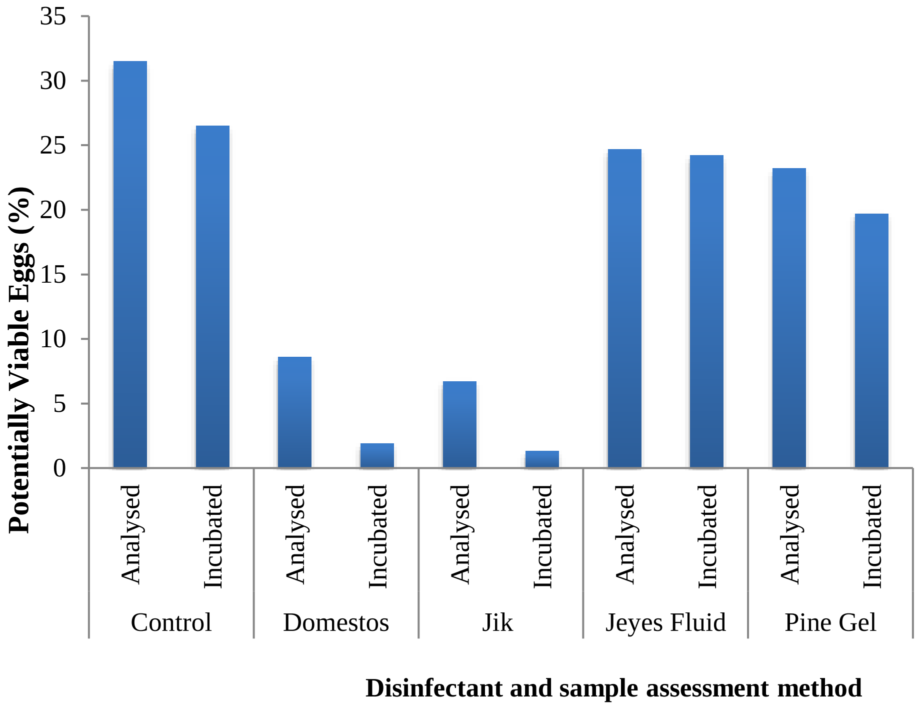

Figure 54 Mean egg viability (%) after exposure for 1 hour to various household disinfectants at 50 % dilution, either immediately analysed or analysed after incubation (n=3)

Egg viability percentages of the controls ranged from 25% to 35%, pre- and post-incubation. Eggs treated with Domestos or Jik showed a very marked decline in percentage viability. Eggs appeared extremely decorticated upon prolonged exposure to these disinfectants. There was also a shift in viability, when comparing the samples examined immediately upon completion of the experiment and those incubated before examination: fewer viable eggs were present after incubation than without incubation. This could mean that embryonated eggs with healthy larvae or undeveloped eggs shifted towards a nonviable state (necrotic or dead). An interesting observation was that many developed viable eggs hatched upon exposure to Domestos or Jik at 50% concentrations, which may be related to pH changes which may be similar to those occurring within the small intestine of human hosts. Jeyes Fluid and Pine Gel solutions proved ineffective in the inactivation of helminth eggs, once again.

For the 12 hour contact period, egg viability in the control treatment was in the range 25 – 35% both pre- and post-incubation. Domestos and Jik were again seen to be the most effective in reducing the viability of the recovered eggs, with a shift from viable to nonviable during incubation. Hatching of developed eggs was also observed after 12 hour exposures. Both Jeyes Fluid and Pine Gel exposures were again ineffective in inactivating helminth eggs. Based on the results of the preliminary experiment, Jeyes Fluid and Pine Gel were excluded from the second experiment, due to their inability to reduce egg viability sufficiently. The selected contact time was one hour because substantial reductions in egg viability was seen for Domestos and Jik treatments after one hour, and because a 12 hour soaking time of a pit sludge spill would be impractical in a household environment.

Figure 20 shows that treatment with both Domestos and Jik at 50% dilution resulted in egg viability of less than 5%, indicating successful inactivation. There was little difference between pre- and post-incubation samples. The undiluted disinfectant yielded even lower viability percentages, with less than 1% viable eggs post-incubation. The number of eggs recovered from both 50% and undiluted treatments were minimal, with developed eggs being highly decorticated. Larvae within developed eggs were highly motile. Hatching also occurred at both 50% and undiluted treatments for both pre- and post-incubation samples.

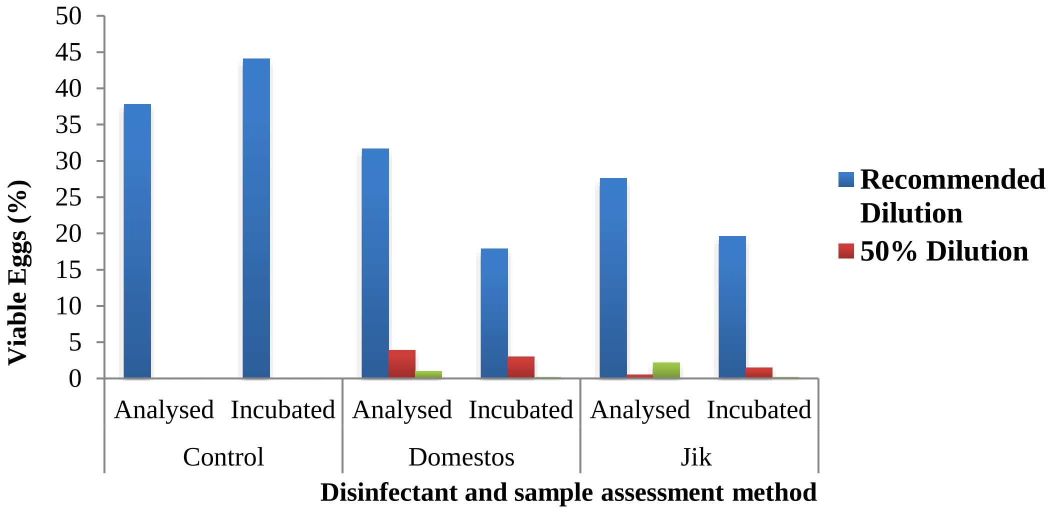

Figure 55 Mean egg viability (%) after exposure for 1 hour to various household disinfectants at three concenctrations, either immediately analysed or analysed after incubation (n=3)

5. FINDINGS AND CONCLUSIONS

FINDING 1: Stool samples from residents and sludge samples from pit latrines in the target communities showed the presence of helminth infections in these communities.

- 15% of the 96 adults from the rural Eastern Cape that were sampled were infected with at least one type of helminth.
- Helminth eggs were found in 10g samples from 9 of 10 pits and at 10 of 10 households where pit emptying was conducted in eThekwini Municipality in KwaZulu-Natal.

CONCLUSION: All workers should be considered to be potentially infected with helminths and all pits should be assumed to contain helminth eggs.

FINDING 2: Extensive contamination of household surfaces and exposure of workers to sludge occurred during pit emptying activities observed in this study.

- Visual observations of pit emptying revealed extensive and repetitive contamination of household environments and workers' protective wear (boots, gloves) with sludge as well as repeated contact between contaminated surfaces (eg. tools and bins) and household surfaces, as well as between contaminated surfaces or equipment and workers' bodies (in particular, hands).
- The laboratory analysis of samples for the presence of 6 selected pathogens for selected microorganisms and helminth eggs was limited in that bacterial indicators may have originated from non-human organisms in the household environment and while the presence of a helminth egg on a sample did indicate faecal contamination of the sample, the absence of helminth eggs in a sample did not verify that it was not contaminated by pit sludge. Despite this, the laboratory analysis found helminth eggs contaminating surfaces at all ten households, with the prevalence of contamination of samples from specific areas of the pit emptying site over the course of the exercise as follows:

Table 23 Number of pit emptying sites (out of 10) at which helminth eggs were found on surfaces

Pit cover	Walkway	Lip of pit	Tap handle	Face/ interior of mask	Exterior of mask	Hands	Exterior of gloves	Bottom of boot
8	10	7	2	2	4	5	6	8

CONCLUSION: While the purpose of the sanitation delivery programmes which provided toilets to communities in this study was to reduce contact between householders and the pathogens found in faeces, the pit emptying phase of the on-site sanitation cycle, as it was practiced in this exercise, undermines the purpose of sanitation by introducing pathogenic faecal matter into the home environment and increasing the risk of infection to householders, sludge handlers and the public.

FINDING 3: A number of factors interact which result in the environmental contamination and exposure of workers and the public to sludge documented in this study:

Table 24 Factors contributing to contamination of surfaces and exposure of workers to pit sludge during pit emptying
Workers were not given clear health and safety requirements for the job
Logistical challenges made it extremely difficult to handle sludge without workers exposing themselves or contaminating the environment
Workers were not provided with the necessary safety equipment, supplies and facilities to minimise their contact with sludge and to minimise the exposure of the environment and the public to sludge
Workers were not equipped with the knowledge of routes of exposure to pathogens, epidemiology of pathogens, and viability of pathogens in sludge and in the environment that would be necessary for them to be able to know when there was a risk of exposure and which course of action would best minimise it.
Workers were not equipped with effective strategies and protocols to enable them to overcome specific logistical challenges
Workers demonstrated a lack of concern for their own health and safety which may not be entirely attributable to their lack of health knowledge.
Workers demonstrated a lack of concern for the health and safety of householders and the environment which may not be entirely attributable to their lack of health knowledge.
Workers' practice was not effectively supervised and no enforcement of the few health and safety requirements of which workers were aware was observed.

A number of logistical challenges were identified which, if not resolved, can be expected to compromise the safety of workers or the community. These are listed in Table 18.

Table 25 Logistical challenges which contribute to exposure of workers, the public and the environment to sludge
Personal protective equipment (PPE)
• PPE gets lost and broken. Without a rigorous system of inspection, reporting and issuing of replacement PPE, workers soon end up working without all of their PPE. • PPE such as gloves deteriorates. Microtears can allow pathogens to penetrate the surface. • Donning and doffing PPE without contaminating oneself is difficult; it is likely that contamination will occur unless rigorous donning and doffing protocols are developed and followed. • Donning and doffing PPE without contaminating the inside of PPE (eg. gloves and masks) is difficult. Again, it is likely to quickly become contaminated inside unless rigorous protocols are followed. • PPE is costly. Contractors are unlikely to provide it unless they are required to and unless this requirement is enforced/monitored. • Special facilities are needed for cleaning PPE. If it is cleaned at the household where pit emptying occurs or at the workers' home contamination of the home environment is likely. • Even after cleaning, PPE cannot be expected to ever be completely pathogen free. Allowing workers to take their PPE home when the job is completed opens up possibilities for others to come into contact with pathogens.
Site conditions
• Weather may be hot and the discomfort of workers exacerbated by the wearing of PPE • The environment around the pit may contain household laundry, tools, buckets, water containers, toys or rubble which can easily become contaminated during pit emptying but can be difficult to safely move. • It is difficult for workers to operate in a cramped environment without their contaminated PPE or tools coming into contact with household surfaces.
Pit emptying
• Access to the pit can be extremely limited due to a small access hatch, uneven terrain or the close proximity of other buildings. • It is difficult to lift sludge from the height of the ground above the pit. • It is difficult to move a shovel full of sludge from the pit across to the bin without sludge spilling on the lip of the pit or on the ground. • In some places the pit could only be fully emptied by climbing in to it. • String and rubbish in the sludge can trail over the edge of the bins; it is difficult not to use hands to put these into bin • It is impossible to carry work tools at all times as a means of preventing contamination of the ground.
Transport
• The distance between the pit and the transport vehicle may be great and the terrain difficult, resulting in workers frequently setting down the bins on the pathway • The outside of bins transported in the vehicle, or the occurance of sludge spilling out of the bins while in the vehicle, may result in the contamination of the vehicle • It is difficult to find an alternative to wearing contaminated PPE in the transport vehicle while transporting sludge, thereby contaminating the inside of the vehicle. • It is difficult to transport empty bins individually back to the pit emptying site – stacking them together (which contaminated their exteriors) saves considerable time.
Welfare needs

• Workers need to eat, drink, use the toilet, use their telephones or smoke while on site, however their use of the household tap to clean their hands risks spread of contamination to the household environment. • Workers need to shower and clean and store their equipment before returning to their homes to avoid carrying pathogens back into their homes. • Because of the prevalence of helminths in pit sludge, workers risk infection and require the opportunity to take deworming medication regularly (6 monthly) to reduce the risk of becoming heavily infected over time.

Not all instances of workers potentially exposing themselves, the public or the environment to sludge resulted from a logistical challenge, however. Below are some of the behaviours observed which could only be attributed to either a lack of understanding of the health risks or a lack of concern for their own or others' health

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Table 26: Instances of workers potentially causing exposure to sludge due to lack of understanding or lack of concern
• Opting to work without protective wear (own clothes or bare skin). • Carrying bins with bare hands and later putting gloves back on. • Carrying bin lids on their heads. • Holding a shared water jug with contaminated gloves. • Removing/replacing mask with contaminated gloves. • Failing to ask householders to remove laundry, toys or other objects from the work area. • Asking for cups/jugs from the householder and handling these with contaminated hands. • Placing contaminated equipment on their personal possessions. • Using householders' tools to clean their equipment.

CONCLUSIONS:

- **Workers are unable to perform their work safely without their employer providing and maintaining safety equipment/supplies/facilities**
- **Workers are unable to perform their work safely without adequate health knowledge to understand risks of disease and transmission and be able to choose an effective response to mitigate them.**
- **Workers are unable to perform their work safely without their employer developing safety protocols to address every logistical challenge encountered on the job, ensuring workers' proficiency in these protocols and enforcing good practice on the job.**
- **Workers may not choose to comply with good practice in order to minimize exposure of themselves, the public or the environment to sludge without strict supervision on the job and a system to enforce required safety practices**

FINDING 4: Wiping contaminated surfaces with cloths soaked with water, Jik, Domestos or Pine Gel was found to manually remove eggs. but did not deactivate *A. lumbricoides* eggs. Soaking with Domestos or Jik for at least an hour at a dilution of at least 50% was required in order to achieve deactivation of at least 95% of the eggs.

It was found that the criterion of < 10% viable eggs remaining after treatment was not met for all four disinfectants when used to wipe contaminated surfaces. Wiping of a surface did, however, successfully transfer eggs from the surface to the wiping cloth (with the exception of Jeyes Fluid).

The eggs required a prolonged exposure to disinfectants, at concentrations of 50% and above, in order to reach significant inactivation numbers. Sodium hypochlorite-based disinfectants were the most successful for inactivation, as eggs were completely decorticated, allowing for easier access of the disinfectant to the larva within potentially viable eggs. Domestos and Jik were most effective against *Ascaris* eggs, whilst Jeyes Fluid and Pine Gel appeared to have little to no effect.

It was found that at 50% dilution, and undiluted, both Jik and Domestos were effective in inactivating *Ascaris* eggs, with viability percentages of recovered eggs ranging from 5 to 10%. The exposed *Ascaris* eggs appeared highly decorticated at these concentrations, facilitating hatching of the eggs, which rendered them non-viable.

CONCLUSION: Contaminated surfaces or spills should be exposed to either Domestos or Jik at at 50% dilution or stronger for at least 1 hour. Surfaces that cannot be soaked for a prolonged period of time can be wiped with a disinfectant-saturated cloth and the cloth should then be soaked for an hour or more in Domestos or Jik at concentrations at or above 50%. Disinfectants may be poured directly onto sludge spills, however they will be quickly deactivated by the presence of organic material and cannot be assumed to fully sanitise the spilled sludge.

6. RECOMMENDATIONS

The following recommendations are made from the findings of this study.

1. A radical shift is needed by municipalities and contractors from a "public works" attitude towards sludge management to an understanding of sludge as a hazardous material.

It is incumbent upon the authorities responsible for a pit emptying programme to ensure that the health and safety budget provides for the training, equipment and supervision necessary to minimise the exposure of workers, the public and the environment to sludge during pit emptying activities.

2. An employer must ensure that the following key elements are in place before a pit emptying programme commences:

- The employer must provide TRAINING to workers on disease transmission and effective ways to reduce risk.
- The employer must provide and maintain appropriate SAFETY EQUIPMENT, SUPPLIES AND FACILITIES.
- The employer must develop SAFETY PROTOCOLS to address every logistical challenge encountered on the job and ensure workers' proficiency in these protocols.
- The employer must ENFORCE good practice on the job.

Figure 56: Addressing key obstacles to the safe handling of sludge

OBSTACLE: INADEQUATE KNOWLEDGE AND SKILLS

Workers lack knowledge of hazards in sludge, routes of transmission and barriers to transmission, sound hygiene practices. Without this they are unable to:

1) accurately assess hazards on the job
2) accurately assess the impact of their actions on the health and safety of themselves, others and the environment

RESPONSES:

DRAFT SAFE WORK PRACTICES

TRAIN WORKERS about risks in sludge, risk assessment, risk reduction through barriers and hygiene, and provide practical training in safe work practices for each and every situation encountered on the job.

CHALLENGE: SAFETY EQUIPMENT IS NEEDED

Workers cannot follow good work practices without the equipment needed to do so.

RESPONSE: PROVIDE REQUIRED EQUIPMENT AND FACILITIES

Provide PPE and other barriers, cleaning supplies, and welfare facilities

CHA

Workers may
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replaced,

RESPONSE: MONITORING AND ENFORCEMENT

- Appoint a health and safety officer to manage monitoring and enforcement
- Develop administrative systems to ensure that training, equipment and supplies are kept in order
- Develop monitoring and reporting systems with penalties and incentives to enforce regulations.

3. The approach to protecting the health of people and the environment during pit emptying should follow the chain below:

- Design the pit emptying programme to eliminate exposure routes wherever possible
- Develop work practice to eliminate
- Provide barriers in order to protect workers and the environment from contact with sludge
- Remediate contamination by removing the contaminated soil. Wipe a contaminated surface with a sodium hypochlorite solution at 50% dilution (Jik or Domestos). Clean exposed skin with ethanol. Soak contaminated equipment in 50% dilution of Jik or Domestos for at least 1 hour after removing visible contamination.
- Do not allow workers to return home with work equipment or without showering.

4. Further study should be undertaken to support municipalities and contractors in following the recommendations given above:

- A detailed training programme should be developed for workers
- Detailed safety procotols should be developed for pit emptying
- Administrative tools should be developed to support health and safety
- The effect of sodium hypochlorite agents and acid-based disinfectants on A. lumbricoides eggs suspended in faecal sludge should be studied in order to improve disinfection procedures in the event of the exposure of a worker or the environment to sludge.

GUIDELINES FOR MUNICIPALITIES AND CONTRACTORS FOR MANAGING HEALTH RISKS

Guidelines detailing responsibilities with regard to managing health risks for workers, the public and the environment during pit emptying are provided for municipalities and for contractors in Annex D.

7. SOURCES

The list of sources cited in this report is still under revision and will be provided in the final draft of this report.

ANNEX A: RESEARCH TOOLS

SITE CHECK LIST

Site number: ______ Site name: _______________________ Researcher name: _________________________

BUY ICE AND DIVIDE BETWEEN TWO COOLER BOXES AT THE BEGINNING OF THE DAY.

Team responsibilities

Fieldworker 1 (team leader):

- Collect samples
- Householder sign consent; interview householder (two stages – before and after pit emptying)
- Interview worker

Fieldworker 2: Observe and record pit emptying procedure (including photos and video)

Fieldworker 3: Assist fieldworker 1 with sample collection and interviews

Introduce yourself to workers/householders and explain the project. Wipe down outside door handles and steering wheel of vehicle transporting pit emptiers with alcohol upon arrival at pit emptying site.

	FIELDWORKER 1 AND ASSISTANT		**FIELDWORKER 2**
	BEFORE THE PIT EMPTYING TEAM ENTERS THE SITE		
☐	Have all workers sign consent	☐	Have the householder sign the consent
☐	Collect first page of samples	☐	Do the first part of the household interview
	DURING PIT EMPTYING		
☐	Collect pit sludge sample	☐	Complete pit emptying observation template and take photos
☐	Interview worker	☐	
	AFTER PIT EMPTYING		
☐	Collect surface samples after pit emptying (pages 2 and 3)	☐	Complete householder interview
☐	Collect samples from car (3 times for 10 pits)	☐	Provide and explain health education materials and deworming med

SUPPLY CHECK LIST FOR EACH SITE:

__ **50 gloves (1 box)**
__ **35 empty bags (4 big jar, 25 med soil, 6 small)**
__ **35 small bags with wipes**
__ **15 scoops**
__ **4 jars**
__ **camera**
__ **team leader and fieldworker folders**
__ **paper towel**

__ Helminth cooler box
__ Micro cooler box
__ extra labels
__ markers/pens
__ rubbish bags (5 clear, 2 black)
__ alcohol spray
__ saline spray

PID Workers' health sampling form

Site address: ____ Site number ______ Date :__________

I. SAMPLES TO BE COLLECTED BEFORE PIT EMPTYING

1. *Walkway used by pit emptiers between vehicle and pit*

__ /1H ☐ (HELMINTHS): Don new gloves. Select a 30cmx30cm area on the walkway. If the walkway is concrete, swab thoroughly with a wet wipe and place in a bag. If the walkway is soil, skim the area inside the 30cmx30cm area with a scoop and place the soil in an empty bag.

__ /1M ☐ (MICRO): Using the same gloves, select a new 30cmx30cm section of the walkway. If the pit cover is concrete, swab thoroughly with a wet wipe and place in bag. If the walkway is soil, skim the area with the same scoop and place the soil in an empty bag.

2. *Pit cover*

__ /2H ☐ (HELMINTHS): Don new gloves. Select a 30cmx30cm area of the pit cover, including the opening edge. If the pit cover is concrete, swab thoroughly with a wet wipe and place in a bag. If the pit cover is soil, skim the area with a scoop and place the soil in an empty bag.

__ /2M ☐ Sample 4: (MICRO): Using the same gloves, select a fresh section of the pit cover, including the opening edge. If the pit cover is concrete, swab thoroughly with a wet wipe and place in bag. If pit cover is soil, skim the area with the same scoop and place the soil in an empty bag.

3. *Tap handle (which may be used by pit emptiers)*

__ /3H ☐ (HELMINTHS): Don new gloves. Spray a dry wipe with saline and wipe the tap handle thoroughly. Tear the wipe in half. Put half in a bag.

__ /3M ☐ (MICRO): Place the other half in a bag.

4. *Attach cloth to workclothes*

__ /4H ☐ (HELMINTHS): Don new gloves. Wipe the handle thoroughly with a wet wipe. Tear the wipe in half. Put half in a bag.

__ /4M ☐ (MICRO): Place the other half in a bag.

5. *Pit sludge*

__/5H ☐ (HELMINTHS): Using the same gloves, a workers' spade and a scoop, collect half a scoop of sludge from each of 5 collection points on the surface (centre and each corner) and place in the collection jar. If it is not possible to sample from the surface before the pit is disturbed, take a sample from the first spade/bucket of sludge taken from the pit if possible.

__/5M ☐ (MICRO): Using the same gloves, shovel and scoop, repeat.

6. Hands

__/6H ☐ (HELMINTHS): Have the volunteer wipe hands thoroughly with a wet wipe and place the wipe in a bag. Spray his hands with alcohol and have him don one pair of new gloves (provided by us) and then his regular gloves.

__/6M ☐ (MICRO): Have a second volunteer wipe hands thoroughly with a wet wipe and place the wipe in a bag. Spray his hands with alcohol and have him don one pair of new gloves (provided by us) and then his regular gloves.

7. Areas where open defecation occurs (IF REPORTED BY RESPONDENT)

__/7H ☐ (HELMINTHS): Using the same gloves and a plastic scoop, collect soil from within a 30cmx30cm area to a depth of 1cm and place in a jar.

__/7M ☐ (MICRO): Using the same gloves and scoop, select a new area and repeat.

8. Area where soil is eaten (IF REPORTED BY RESPONDENT)

__/8H ☐ (HELMINTHS): Using the same gloves and a new plastic scoop, collect soil from within a 30cmx30cm area to a depth of 1cm and place in a bag.

__/8M ☐ (MICRO): Using the same gloves and a new plastic scoop, collect soil from within a nearby 30cmx30cm area to a depth of 1cm and place in a bag.

II. SAMPLES FROM VOLUNTEER AFTER PIT EMPTYING

9. Face and inner mask

__/9H ☐ (HELMINTHS): Have the volunteer don one new glove and with a wet wipe wipe his lips and then the area between his nose and lips and entire nose, then wipe the entire inside of the mask thoroughly. Place wipe in a bag.

__/9M ☐ (MICRO): Ask a second volunteer to wipe his upper lip with a wet wipe. Don a glove and, using the same wipe, wipe the inside of the mask. Place wipe in a bag and squirt.

10. Outer mask

__ /10H ☐ (HELMINTHS): Don gloves and using a wet wipe, wipe the entire outside of the mask thoroughly. Place the wet wipe back in the bag.

__ /10M ☐ (MICRO): Using a new glove and a wet wipe, wipe the outer mask of a second volunteer and place in a bag and squirt with saline.

11. Outer gloves

__ /11H ☐ (HELMINTHS): Using new gloves, wipe down the first volunteer's outer gloves with a wet wipe and place in a bag. Remove the volunteer's outer gloves.

__ /11M ☐ (MICRO): Using the same gloves, wipe down the second volunteer's outer gloves with a wet wipe and place in a bag. Remove the volunteer's outer gloves.

12. Inner gloves

__ /12H ☐ (HELMINTHS): Using new gloves, remove the first volunteer's inner gloves and place in a bag with some water. Swab the volunteer's hands well and place wipe in same bag with gloves.

__ /12M ☐ (MICRO): Using the same gloves, remove the second volunteer's inner gloves and place in a bag and squirt with saline. Swab the volunteer's hands well with a saline wipe and place wipe in same bag with gloves.

13. Bottom of boot

__ /13H ☐ (HELMINTHS): Using a new glove and a wet wipe, wipe the entire bottom of one volunteer's boots thoroughly. Place the wet wipe in a bag.

__ /13M ☐ (MICRO): Using the same glove and a wet wipe, wipe the entire bottom of one volunteer's boots thoroughly. Place the wet wipe in a bag.

III. SURFACE SAMPLES TO BE COLLECTED AFTER PIT EMPTYING

14. Walkway used by pit emptiers between vehicle and pit

__ /14H ☐ (HELMINTHS): Don new gloves. Return to the same section of walkway sampled before pit emptying. If the walkway is concrete, swab thoroughly with a wet wipe and place in a bag. If the walkway is soil, skim the area inside the template with a scoop and place the soil in empty bag.

__ /14M ☐ (MICRO): Using the same gloves, select the same section of walkway sampled before pit emptying. If the pit cover is concrete, swab thoroughly with a wet wipe and place in bag. If the walkway is soil, skim the area inside the template with a scoop and place the soil in empty bag.

15. Pit cover (edges which may have been touched)

__ /15H ☐ (HELMINTHS): Don new gloves. Sample the same section of pit cover sampled before pit emptying. If the pit cover is concrete, swab thoroughly with a wet wipe and place in a jar half full of water. If the pit cover is soil, skim the area inside the template with a scoop and place the soil in an empty bag.

__ /15M ☐ (MICRO): Using the same gloves. Sample the same section of pit cover sampled before pit emptying. If the pit cover is concrete, swab thoroughly with a stick swab and place in cold bag. If pit cover is soil, skim the area inside the template with a scoop and place the soil in empty bag.

16. Tap handle (which may have been touched by pit emptiers)

__ /16H ☐ (HELMINTHS): Don new gloves. Swab tap handle thoroughly with a wipe and tear in half. Put half in a bag.

__ /16M ☐ (MICRO): Place the other half in a bag.

17. VIP door handle (which may have been touched by pit emptiers)

__ /17H ☐ (HELMINTHS): Don new gloves. Swab tap handle thoroughly with a wet wipe and tear in half. Put half in a bag.

__ /17M ☐ (MICRO): Place the other half in a bag.

18. Lip of latrine pit

__ /18H ☐ (HELMINTHS): Don new gloves. Select a 30cmx30cm area. Skim the area with a scoop and place the soil in an empty bag.

__ /18M ☐ (MICRO): Using the same gloves, move to a fresh 30cmx30cm section of the lip. Skim the area with the same scoop and place the soil in an empty bag.

19. Lip of disposal pit

__ /19H ☐ (HELMINTHS): Use same gloves. Select a 30cmx30cm area. Skim the area with a scoop and place the soil in an empty bag.

__ /19M ☐ (MICRO): Using the same gloves, move to a fresh 30cmx30cm section of the lip. Skim the area with the same scoop and place the soil in an empty bag.

20. Area away from activity

__/20H ☐ (HELMINTHS): Use same gloves. Select a 30cmx30cm area. Skim the area with a scoop and place the soil in an empty bag.

__/20M ☐ (MICRO): Using the same gloves, move the template to a fresh area. Skim the area with the same scoop and place the soil in an empty bag.

21. Vehicle handle

__/21H ☐ (HELMINTHS): Don new gloves. Swab the front door handles with a wet wipe and place in a bag.

__/21M ☐ (MICRO): Using the same gloves, swab the rear door handles with a wet wipe and place in a bag.

22. As observed 1

__/22H ☐ (HELMINTHS): Follow protocol for 17 or 18 depending whether it is hard surface or soil.

__/22M ☐ (MICRO): Follow protocol for 17 or 18 depending whether it is hard surface or soil.

23. As observed 2

__/23H ☐ (HELMINTHS): Follow protocol for 17 or 18 depending whether it is hard surface or soil.

__/23M ☐ (MICRO): Follow protocol for 17 or 18 depending whether it is hard surface or soil.

24. As observed 3

NOTES

Problems encountered during data collection:

Observations/suggestions/recommendations:

Water Research Commission research project:

Controlled study to establish pathways of exposure in the handling and desludging of onsite sanitation systems

Project leader: Bobbie Louton   033 342 3012 or 073 766 1139

Interview questions for householders

Municipality ________________________________ Site: ____________________________________

Interviewee:______________________________ Age: ______ Sex: ____ Role in household:_________________

Household size: _______ Number of children under 12: ____

Interviewer:______________________________________ Date: ____________

A. Introduction

My name is _________. I work for Partners in Development, which is an engineering firm in Pietermaritzburg. We are doing a research project with the University of KwaZulu-Natal and the Water Research Commission. The project is about protecting workers and the household environment from diseases getting spread during pit emptying. We would like to take a sample from your pit now to see what it can show us about these diseases found in sludge. We would also like to take some soil and surface samples from the garden to see if there is any contamination before and after pit emptying. Then we would like to come back in 6 months to check the soil and surfaces again. Is that ok with you?

Health

I would like to ask you some questions about the health of your family and your ideas about diseases. Please feel free to skip any question that you would rather not answer. We won't be using your name with any information you give us.

1. Have you or anyone in your family had incidents of diarrhoea in the past year? Y / N

2. What do you think causes diarrhoea?

3. Have you or anyone in your family ever had worms? Y / N

   How did you know?

   What happened?

   How did the worms affect them?

   What did you do about it?

4. How do you think people get worms?

   What do worms do to you?

   How can you get rid of the worms?

   How can you keep them from coming back?

5. Do you think most of the people in your family wash hands after using the toilet and use soap? Y / N

   Where do you wash hands?

   Where do you get the water?

   Do you usually have soap? Y / N What kind?

6. Does anyone in your family eat soil? Y / N

   Why?

7. Can you show me where they like to take it from?

8. Does anyone in your family defecate outside?

   Who?

   Can you show me where?

After the pit emptying I would like to ask you some more questions.

AFTER PIT EMPTYING:

I would like to ask you some questions about the pit emptying:

9. How did you find the pit emptying?

10. Is there anything that you saw that bothered you?

11. Do you think the workers protected themselves enough? Y / N

    Anything they should have done differently?

12. Do you think the workers kept your home environment clean? Y / N

    Anything they should have done differently?

13. If you emptied your pit yourself, how would you do it?

14. We have brought deworming treatment for everyone in your household. This is how you use it.

15. Here is a brochure with some information about diseases and how to prevent them. (Go through brochure in detail).

Direct observation template

Area ______________________ Site: _____ Householder name__________________________

Researcher:____ Date: _____________________

1. **Description of site**			
Type:	School	Household	Other
Pit Location:	Behind toilet	Next to toilet	In front of toilet
Location of water source:			
Vehicle access :	Next to pit	Boundary of property	Distance from property:
Other observations:			

2. **Preparation of site by workers**		
Were sheets put down to place equipment on?	Yes	No
Was a sheet put down along the edge of the pit?	Yes	No
Was a pit dug for sludge to be buried?	Yes	No
Was a sheet put down along the edge of the burial pit?	Yes	No
Comments:		

3. Document protective equipment worn/not worn by each worker on arrival at the site: D = disposable P = permanent

Worker	Mask (D/P)	Hat	Gloves (D/P)	Protective pants	Protective shirt	Boots
1						
2						
3						
4						
5						

Comments:

4. Describe the emptying of the pit

5. Document removal of protective equipment during the period at the site

6. Document disposal of sludge
On site: Y / N If transported, describe how it is carried to the vehicle and how it is loaded on the vehicle and transported:

7. Document transport of equipment
Protective clothing worn in vehicle?

8. Supervision/enforcement of policy observed:

9. Describe cleanup of site:
Any use of household tap: Y / N Describe:

10. Describe communication by workers with householders
Arrival at site
Completion of pit emptying
Was contamination discussed? Y / N
Was health and hygiene discussed? Y / N

11. Extra samples collected from contaminated surfaces for analyses:

Sample no	**Collection site/surface**	**Description**
/		
/		
/		
/		
/		
/		
/		
/		

Other observations and comments:

12. Instances of possible contamination of site or exposure of workers and any interventions taken by workers:	
INCIDENT	RESPONSE
Comments:	

Water Research Commission research project:
Controlled study to establish pathways of exposure in the handling and desludging of onsite sanitation systems

Project leader: Bobbie Louton 033 342 3012 or 073 766 1139

Interview questions for sanitation workers

Municipality ______________________________ Type of sanitation work: __________________

Interviewee:______________________ Age: ____ Sex: ____ Interviewer:_______ Date: ________

Introduction

This research project is being conducted by Partners in Development and the University of Kwa-Zulu Natal for the Water Research Commission. The goal of the project is to look at how diseases might be transmitted during sanitation work and what policies and procedures best prevent diseases from being transmitted. I would like to ask you some questions about how your job works. You are completely free to skip any question you do not feel like answering.

A. Worker education

1. When you started your job, what kind of training or orientation did you receive about the work you would be doing? (Probe: education regarding pathogens, infections, routes of transmission, protocols for protecting themselves, protocols for protecting the environment).
2. What risks do you believe are involved in working in sanitation? (Probe understanding of how disease is transmitted via faecal-oral route)
3. What do you personally feel is the most effective way to protect workers and the environment from diseases found in sludge?

B. Health interventions

4. What medical care does the municipality provide?
5. Since you started doing this kind of work, do you feel you have been healthier, less healthy, the same?
6. Is deworming medication provided routinely to workers? Is deworming medication available free of charge to workers who request it? Have you ever been told at the clinic you have worms or thought you had worms? What symptoms did you have? Did you get treated? Did you feel better?

C. Protective clothing

7. What protective equipment have you been given? What happens if it breaks or is lost?
8. Are you advised to wear it or told you have to wear it? What happens if you don't?
9. Do you wear it?
10. What tools are you given for your work?

A. Daily work routine

11. Please describe your work day in as much detail as possible: (Probe for details on the following: When protective clothing is put on/taken off, how site is prepared, how pit is emptied -- tools used, method of extraction and transport of sludge)
12. What do you do if you get sludge on your skin?
13. What do you do if sludge is spilled anywhere at the site?
14. What do you do if you step in sludge? (any intervention to prevent sludge from being tracked around the site and subsequent site on contaminated boots?)
15. Have you every had any major incidents of spills or other contamination? What happened and what did you do?
16. What do you tell the household if contamination occurs?
17. Where do you wash your hands?
18. How do you transport sludge, tools and gear? (provision for contamination?)

19. Is there any provision for you to clean your equipment/clothing or wash yourself at your work base? Do you ever take your work clothes home?

B. Perceptions and behaviour around disease transmission and prevention

Could you tell me more about how you understand diseases work and how they can be prevented:

20. What do you think causes diahrrea?
21. Do you think most of the people in your family wash hands after using the toilet? Where would you wash hands? Where do you get the water? Do you usually have soap?
22. How do you think people get worms? What effect do the worms have? How can you get rid of the worms? How can you keep them from coming back?
23. Do you feel the municipality does enough to protect your health?
24. Do you feel you are able to protect your health while you do your job?
25. Do you feel you are able to protect the household while you empty the pit?
26. Are there any changes that you think are needed?

PROTECTING YOUR HEALTH AT HOME

HOW CAN I AVOID GETTING WORMS?

- Wash your hands with soap before eating or preparing food and after going to the toilet or touching the soil.
- Don't let kids poo outside – poo must always go in the toilet.
- Don't let kids play where animals have pooed.
- Don't eat soil or anything strange that you see in meat.
- Don't pour water that might have poo in it on vegetables or

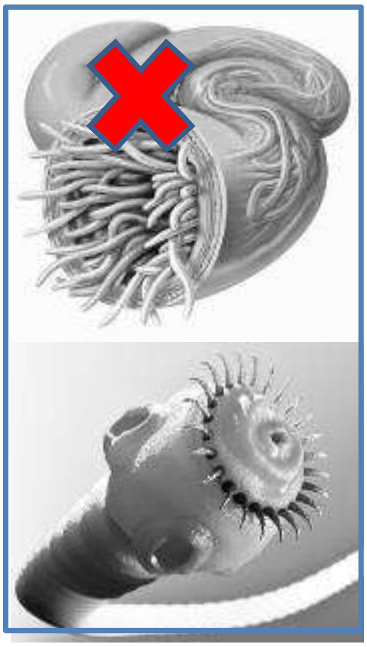
get many different sicknesses. Some the soil and onto surfaces from poo. it and they can make you sick.

MS

LEVER

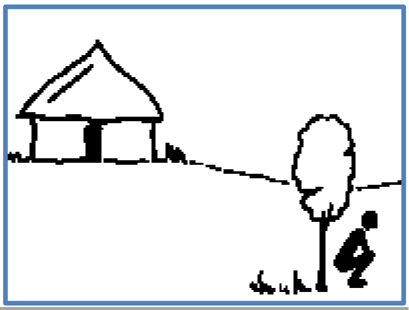
n,

which can migrate into your brain and cause seizures or other problems.



WHAT CAN I DO TO GET RID OF WORMS?

Buy deworming treatment or get it free at a clinic. It's a good idea to take it twice a year. It is called Mebendazole. Babies and anyone who might be pregnant should not take it.

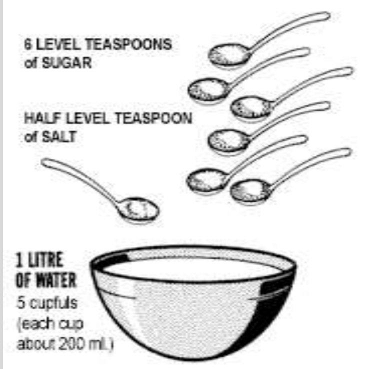


DIARRHOEA

Diarrhoae can be deadly for young kids, old people and sick people. Protect your family by always washing your hands with soap before eating and preparing food, and after using the toilet or touching soil. Don't let them poo outside. It is important for anyone who has diarrhea to drink lots of fluids and go to the clinic.

If someone in your family has diarrhoea, make this recipe for them:

1 litre water
½ spoon salt (2.5ml)
6 spoons sugar (30ml)



EMPTYING YOUR PIT

Harmful organisms can survive in the pit of your toilet for a long time. When you empty your pit, even if the poo isn't smelly any more, it can contain organisms which cause disease. Sometimes these organisms, as well as worm eggs, can even get into the air. Make sure anyone who handles the sludge wears a mask and gloves. Any tools that are used will become dirty and should be kept in plastic bags and not used for anything else. If any sludge gets spilled, remove the soil carefully in a plastic packet and clean any surfaces well with Jik.

Annex B: ADDITIONAL DATA

Table 1 Number and viability of helminth eggs found in 10g sludge samples from 8 pits

	A. lumbricoides						*T.trichiura*		*Taenia* spp
	Possibly VIABLE *ASCARIS*			Definitely NON-VIABLE *ASCARIS*			Potentially VIABLE Eggs	NON VIABLE Eggs	Potentially VIABLE Eggs
Site no	UNDEVELOPED Eggs	MOTILE Larva in Egg	IMMOTILE Larva in Egg	NECROTIC Larva in Egg	DEAD Eggs	INFERTILE Eggs			
D_1	983	0	2361	4039	2240	0	15	41	5
D_2	5	0	0	9	5	0	0	0	592
D_3	327	6	176	259	63	21	24	95	0
D_4	0	0	0	0	0	0	29	240	0
D_5	633	0	4	46	15	31	0	0	0
D_6	6	0	2	0	6	0	0	0	0
D_7	7	0	2	0	5	0	0	0	2
D_9	411	0	6	2	17	13	0	0	28
8 sites	**7**	**1**	**6**	**5**	**7**	**3**	**3**	**3**	**4**

Table 2 Number of sites at which eggs of selected helminths were found, in potentially viable or non-viable states, in samples taken from different surfaces at the pit emptying site before and after pit emptying

	SAMPLE	Possibly VIABLE *A. Lumbricoides*			Definitely NON-VIABLE *A.lumbricoides*			*T. Trichiura*		*Taenia spp*
Sample site	**% of samples positive for helminth eggs**	**UNDEVELOPED Eggs**	**MOTILE Larva in Egg**	**IMMOTILE Larva in Egg**	**NECROTIC Larva in Egg**	**DEAD Eggs**	**INFERTILE Eggs**	**Potentially VIABLE Eggs**	**NON VIABLE Eggs**	**Potentially VIABLE Eggs**
Walkway before pit emptying	40%	2	0	0	2	4	1	0	2	2
Walkway after pit emptying	60%	4	2	2	6	5	1	0	2	2
Pit cover before emptying	20%	0	0	0	0	0	0	0	0	2
Pit cover after emptying	60%	4	1	1	3	5	0	1	2	2
Tap handle before emptying	10%	0	0	0	0	0	0	1	0	0
Tap handle after emptying	0%	0	0	0	0	0	0	0	0	0
Hands before emptying	30%	1	0	0	0	0	0	1	0	1
Outer gloves	40%	3	0	1	2	3	0	1	1	1
Inner gloves	10%	1	0	1	1	1	0	0	0	0
Boot after emptying	50%	3	2	3	5	5	1	2	2	2
Pit cover after emptying	60%	4	1	1	3	5	1	1	2	2
Door handle lafter emptying	0%	0	0	0	0	0	0	0	0	0
Lip of latrine after emptying	60%	4	0	3	5	6	2	0	2	1
Site of open defecation	10%	1	0	1	1	1	0	0	0	0

Table 27 Absence (-) or presence (+) of selected bacteria on selected surfaces at 10 households (D1-D10) before (B) and after (A) pit emptying

Absence/Presence			D1		D2		D3		D4		D5		D6		D7		D8		D9		D10	
Sample	Description		B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
M1	Walkway between vehicle and pit before pit emptying	*E. coli*	+	+	+	+	-	+	-	+	+	+	+	+	+	+	-	-	+	-	+	+
		Salmonella spp.	+	-	-	-	+	+	+	+	+	+	+	+	+	-	-	-	-	-	+	-
		Staphylococcus spp.	+	+	+	+	+	+	-	+	+	+	+	+	+	+	-	-	-	-	-	-
M2	Pit cover before pit emptying	*E. coli*	+	+	+	-	-	-	+	-	+	+	-	+	+	+	-	+	-	-	+	+
		Salmonella spp.	+	+	+	+	-	+	+	+	+	-	+	+	-	+	-	-	-	+	-	-
		Staphylococcus spp.	+	+	+	+	-	-	-	-	+	+	+	+	+	+	-	-	-	-	-	-
M3	Tap handle before pit emptying	*E. coli*	+	-	-	-	-	-	+	-	+	+	-	-	-	-	-	-	-	-	+	+
		Salmonella spp.	-	+	-	+	+	+	-	+	+	+	-	-	-	-	+	-	-	-	-	-
		Staphylococcus spp.	-	+	+	+	+	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-
M4	VIP door handle before pit emptying	*E. coli*	+	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	+
		Salmonella spp.	+	+	-	+	+	+	+	+	-	+	-	+	-	+	-	-	-	-	-	+
		Staphylococcus spp.	-	+	+	+	+	+	-	+	-	-	+	-	-	+	-	-	-	-	-	-
M5	Pit sludge	*E. coli*	+	NS	+	NS	+	NS	+	NS	+	NS	+	NS	+	NS	+	NS	+	NS	+	NS
		Salmonella spp.	-	NS	-	NS	-	NS	+	NS	+	NS	-	NS	-	NS	+	NS	-	NS	-	NS
		Staphylococcus spp.	-	NS	+	NS	+	NS	+	NS	+	NS	-	NS	+	NS	+	NS	+	NS	+	NS
M6	Hands before pit emptying	*E. coli*	-	NS	-	NS	-	NS	-	NS	-	NS	-	NS	+	NS	-	NS	-	NS	-	NS
		Salmonella spp.	+	NS	+	NS	-	NS	+	NS	+	NS	+	NS	-	NS	+	NS	-	NS	-	NS
		Staphylococcus spp.	+	NS	+	NS	+	NS	-	NS	+	NS	+	NS	-	NS	-	NS	-	NS	-	NS
M7	Soil (areas where open defecation occurs)	*E. coli*	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
		Salmonella spp.	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
		Staphylococcus spp.	NS	NS	NS	NS	NS	NS	NS	NS	+	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
M8	Soil (areas where soil is eaten)	*E. coli*	NS	NS	-	NS	+	NS	NS	NS	+	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
		Salmonella spp.	NS	NS	-	NS	-	NS	NS	NS	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
		Staphylococcus spp.	NS	NS	-	NS	-	NS	NS	NS	+	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
M9	Face and Inner mask after pit emptying	*E. coli*	NS	-	NS	-	NS	-	NS	-	NS	+	NS	-	NS	-	NS	-	NS	-	NS	+
		Salmonella spp.	NS	+	NS	+	NS	+	NS	+	NS	+	NS	-	NS	-	NS	-	NS	-	NS	-
		Staphylococcus spp.	NS	-	NS	+	NS	+	NS	+	NS	+	NS	+	NS	-	NS	-	NS	-	NS	-
M10		*E. coli*	NS	+	NS	-	NS	-	NS	-	NS	+	NS	+	NS	+	NS	+	NS	-	NS	-

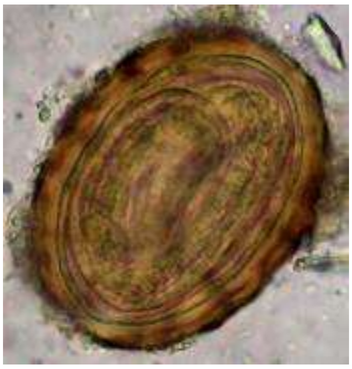
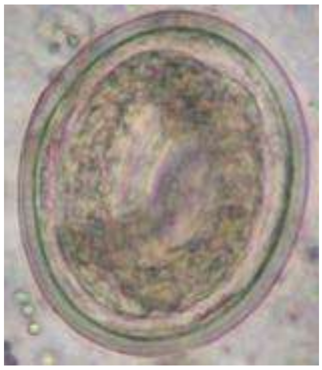
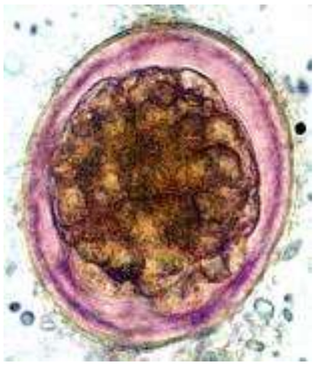
	Outer mask of volunteer after pit emptying	*Salmonella* spp.	NS	+	NS	+	NS	+	NS	+	NS	-	NS	-	NS	-	NS	+	NS	-	NS	-
		Staphylococcus spp.	NS	+	NS	-	NS	+	NS	-	NS	+	NS	-	NS	+	NS	-	NS	+	NS	-
M11	Outer gloves after pit emptying	*E. coli*	NS	-	NS	+	NS	-	NS	-	NS	+	NS	+	NS	-	NS	+	NS	+	NS	+
		Salmonella spp.	NS	-	NS	+	NS	-	NS	+	NS	+	NS	+	NS	-	NS	-	NS	-	NS	+
		Staphylococcus spp.	NS	+	NS	-	NS	-	NS	+	NS	+	NS	-	NS	+	NS	-	NS	+	NS	-
M12	Inner gloves after pit emptying	*E. coli*	NS	+	NS	-	NS	-	NS	-	NS	+	NS	+	NS	-	NS	-	NS	-	NS	-
		Salmonella spp.	NS	+	NS	-	NS	+	NS	+	NS	+	NS	+	NS	-	NS	-	NS	-	NS	-
		Staphylococcus spp.	NS	+	NS	+	NS	-	NS	-	NS	-	NS	+	NS	-	NS	-	NS	-	NS	-
M13	Bottom of boot after pit emptying	*E. coli*	NS	-	NS	-	NS	-	NS	-	NS	+	NS	+	NS	+	NS	-	NS	+	NS	+
		Salmonella spp.	NS	-	NS	-	NS	+	NS	+	NS	+	NS	+	NS	-	NS	+	NS	-	NS	-
		Staphylococcus spp.	NS	+	NS	+	NS	-	NS	+	NS	+	NS	-	NS	+	NS	-	NS	-	NS	-
M18	Lip of latrine after pit emptying	*E. coli*	NS	-	NS	-	NS	-	NS	+	NS	+	NS	+	NS	-	NS	+	NS	-	NS	+
		Salmonella spp.	NS	+	NS	+	NS	+	NS	+	NS	+	NS	-	NS	-	NS	-	NS	-	NS	-
		Staphylococcus spp.	NS	+	NS	-	NS	+	NS	-	NS	+	NS	+	NS	-	NS	-	NS	-	NS	-
M20	Area away from activity	*E. coli*	NS	NS	NS	-	NS	-	NS	-	NS	+	NS	-	NS	+	NS	+	NS	-	NS	-
		Salmonella spp.	NS	NS	NS	+	NS	+	NS	-	NS	+	NS	+	NS	+	NS	+	NS	-	NS	-
		Staphylococcus spp.	NS	NS	NS	+	NS	+	NS	-	NS	+	NS	-	NS	+	NS	-	NS	-	NS	-
M21	Vehicle handle	*E. coli*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-
		Salmonella spp.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	+
		Staphylococcus spp.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-
	A/P = ABSENCE (-)/PRESENCE(+) NS = Not sampled																					

Annex C: METHODS USED FOR LABORATORY

1. ANALYSIS FOR THE PRESENCE OF SELECTED HELMINTHS

Eggs were recovered using the Kato Katz method and the AMBIC protocol (Moodley, Archer and Hawksworth, 2008) was used to recover eggs from stool or sludge samples. The AMBIC protocol has been found to recover eggs of A. lumbricoides and T. trichiura more effectively than standard flotation protocols and, to a lesser extent, the Visser Filter® Method. The sample is mixed with ammonium bicarbonate (AMBIC) solution which separates ova from the sand particles to which they bond. Ova are then recovered with an adjusted zinc sulphate flotation procedure. Helminth ova were counted and the development stage and condition of the ova noted. *For T. Trichiurus* and *Taenia spp.*, ova were designated as potentially viable or non-viable. For *A. lumbricoides*, the status of larvae in eggs was determined according to 6 states, 3 of which were potentially viable (undeveloped, motile and non-motile) and 3 of which were for definitely non-viable states (necrotic, dead or infertile). Table 1 below provides examples of what ova and larvae look like under the microscope in each of these states.

Table 1 States of viability of *A. lumbricoides* larvae and ova

POSSIBLY VIABLE STATES		
Undeveloped	Motile	Non-motile
		
DEFINITELY NON-VIABLE STATES		
Necrotic	Dead	Infertile
		

For the study of the efficacy of disinfectants to deactivate helminth eggs, faecal material from the stool samples collected in the Eastern Cape was combined to yield a sufficient egg load for the study.

2. ANALYSIS FOR THE PRESENCE OF SELECTED BACTERIA

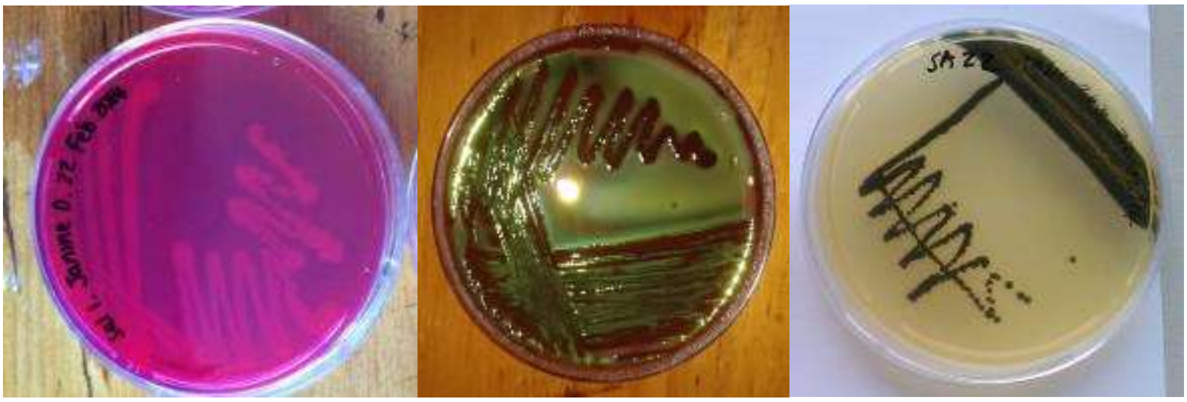


Figure 2 Representatives of pure cultures of *Salmonella spp*. (left) *E. coli* (centre) and *S. aureus* (right)

Bacterial isolates of *Salmonella spp, Staphylococcus aureus and Escherichia coli* were obtained from the samples. Pure cultures were obtained for each organism for the purpose of correct identification during the study and for submission to GENBANK in the event that information is published on the specific strains isolated.

Samples were cultivated in nutrient broth for 48 hours and thereafter streaked onto nutrient agar specific to their genus and incubated for a further 48 hours. Nutrient agar plates were checked for any contamination from foreign bacterial species and if contamination was found, bacterial cultures were streaked onto fresh nutrient agar to obtain pure cultures.

Samples were refrigerated immediately when they were received after collection. A dilution series of samples was prepared for use in *E.coli* and *Staphylococcs* tests.

Faecal sludge and stool samples were analysed for the presence of total and faecal coliforms. For the quantitative analysis of total and faecal coliforms and E. coli the MPN (most probable number) method MFHPB-19 (Health Canada, 2002) was employed. This involves initially the use of Lauryl Sulphate

Tryptose broth (LST), followed by using Brilliant-green lactose bile broth (BGLB) inoculated from gas-positive LST tubes, with E. coli being quantified by EC broth plus added MUG inoculated from positive LST. This is then followed by inoculation of Levine-Eosin Methylene Blue agar and the prescribed biochemical tests as well as by using a PCR based confirmation of presumptive E. coli isolates (Gemmell and Schmidt, 2012).

Procedures for the enumeration of Salmonella spp. in samples were carried out according to the ISO 6579 guideline (ISO, 2002).

Annex D: HEALTH AND SAFETY PLAN FOR THE DESLUDGING OF ON-SITE SANITATION SYSTEMS

This plan addresses the duties of the municipality

(represented by the health and safety officer)

and the contractor undertaking the desludging programme.

A. RESPONSIBILITIES OF THE HEALTH AND SAFETY OFFICER

The municipality is required to appoint a health and safety officer (HSO) to monitor and enforce the fulfilment of the contractor's responsibilities with regard to protecting the health and safety of workers, the public and the environment as specified in the Health and Safety Plan, which is to be included in the service level contract.

1. DEVELOPMENT OF ADMINISTRATIVE SYSTEMS

To aid the contractor in the effective management of the health and safety aspects of the desludging programme, the HSO should develop protocols to govern the following administrative tasks:

- Screening and hiring of workers (in terms of health considerations)
- Health care of workers: immunisation and deworming programmes, reporting and analysis of work-related accidents and illnesses; reporting of changes in worker health status (eg. pregnancy) which could increase vulnerabilities to pathogens found in sludge
- Training and skill proficiency testing/requirements
- Inspection and restocking/replacement of facilities, tools and equipment
- Reporting and follow-up: lost/damaged tools, incidents/accidents (significant exposures of workers or environment to sludge, eg. spills, puncture wounds), work-related illnesses
- Supervision and enforcement: roles and responsibilities for monitoring that correct work practices is followed; incentives and penalties for compliance/non-compliance

2. DEVELOPMENT AND REVISION OF WORK PRACTICES AND PROTOCOLS

The HSO must ensure that the Health and Safety Plan which is included in the service level contract contains detailed safety protocols for every aspect of the desludging programme. While examples of these have been included in the plan provided in Annex B, these should be tailored or developed as needed to meet the individual requirements and field conditions of the specific desludging programme.

Due to the fact that desludging programmes have to date been unregulated in much of the world and the need for stringent health and safety practices is now becoming widely recognised, the HSO should make every effort to share the protocols that are developed with other municipalities and with the sludge management sector internationally so as to contribute to the development of best practice.

3. TRAINING

The duties of the HSO with regard to training are as follows:

- Ensures that the contractor provides training upon induction to all workers (including those who are hired after the programme commences) as well as bi-annual in-service training.
- Ensure that the training programme adequately covers the areas indicated in Annex 1 of the Health and Safety Plan.
- Test the knowledge and proficiency of workers to follow safety protocols accurately after training and before commencing work and sign off on workers' training card.
- Feedback weaknesses identified during testing to the training programme.
- On a quarterly basis make unannounced site visits and observe worker practice. Identify where bad practice has developed and demonstrate best practice. Sign off on workers' training card after demonstration that practice has been corrected.

4. PROVISION OF FACILITIES, EQUIPMENT AND SUPPLIES

The HSO shall inspect all facilities, equipment and supplies provided by the contractor before the programme commences and at unannounced times on a quarterly basis at a minimum to ensure that the contractor complies with the requirements of the Health and Safety Plan. Specifically, the HSO shall ensure that:

- Every worker has the required PPE items and that they are of acceptable quality, in functional condition as a barrier to pathogens and that they are appropriately sized.
- The contractor has provided other equipment and supplies necessary to protect the household environment during desludging (barriers and disinfectants) and personal disinfectants for use by workers on site.
- The contractor employs a system for inspecting and inventorying PPE, tools and other equipment and providing immediate replacement of any lost or damaged items.
- Safe procedures are being followed for the transport, cleaning and storage of PPE, tools and other equipment.
- An area depot is provided for workers to shower, store their personal belongings and clean their work equipment and these are maintained in proper condition and kept stocked with necessary supplies.
- When an area depot is decommissioned it is disinfected effectively.

5. MONITORING AND ENFORCEMENT

Compliance by the contractor with health and safety regulations will be monitored and enforced by the HSO. Monitoring and enforcement will include the following:

- Making unannounced site visits to all pit emptying teams on a quarterly basis at minimum.
- Making unannounced visits to worker depots on a quarterly basis at minimum.
- Document violations of health and safety regulations found on unannounced visits and fining the contractor accordingly.
- Investigate instances of significant contamination by/exposure to sludge reported by the contractor

- Review monthly report by contractor of violations or exemplary conduct by workers and supervisors and corresponding penalties or incentives.

The Health and Safety Plan must include a schedule of fines corresponding to specific violations of the health and safety requirements indicated in the Plan. Appendix 3 of the Contractor's obligations provides a list of violations which must be included in this schedule; the HSO officer must however assess which additional violations are relevant to the specific pit emptying programme.

B. REQUIREMENTS FOR THE CONTRACTOR

This specification details the responsibilities of the contractor with regard to minimising the risks to workers, the public and to the environment during the handling of sludge from on-site systems and must be included in every service level contract. The Employer will not tolerate the presence on site of any workers, team leaders, supervisors or subcontractors who prove unwilling or unable to adhere to this specification.

1. TRAINING

Research investigating the knowledge of workers hired to handle sludge and members of the communities where they live indicates that workers can be expected to have a poor understanding of disease transmission and how to reduce risks of infection. In addition, sludge handlers face many logistical challenges in their work. Both theoretical and practical training is therefore necessary in order for workers to be able to protect themselves, others and the environment during their work.

Training is required as follows:

- All workers must receive training before commencing the sludge management programme.
- Provision must be made to train workers who join the programme after the initial training.
- Regular bi-annual in-service training is required in order to refresh knowledge, correct bad practice, trouble shoot problems and maintain a work culture in which a commitment to protecting people and the environment is foremost.

A card will be issued to each worker on which training must be recorded. Demonstration of correct practice will be signed off and dated by the employer's health and safety officer after induction training, in-service training and on-site visits.

The provision of the training will be by a nominated sub-contractor with the cost of the training is covered in the bill of quantities by a provisional sum, or by the employer's health and safety officer, as agreed upon in the contract.

The training will take place on site at a local venue hired for the purpose. The contractor's responsibility is to ensure that all workers receive the training, and to pay the workers for their time while they are being trained. The time allowance that must be made for this training is two days on induction and one day every six months thereafter.

Appendix 1 to this specification gives an indication of the scope of the training required.

2. PROVISION OF FACILITIES, EQUIPMENT AND SUPPLIES

2.1 Personal protective equipment

All workers who handle sludge are to be issued with the personal protective equipment listed in Table 1 below.

Table 1: PROTECTIVE EQUIPMENT REQUIRED FOR WORKERS

Calf high waterproof gumboots (no boots with laces / fabric)

Protective jackets and pants

Elbow length durable waterproof gloves

Disposable or permanent mask (disposable is more comfortable but must be replaced daily)

Equipment must be properly sized to fit each worker and must not be shared between workers. If any item of PPE is damaged to the extent that it no longer provides protection, it must be replaced before the next working day. Regular inspections (eg. weekly) of PPE must be done to ensure that each worker is equipped with full PPE in acceptable condition.

Gloves which are damaged and have been contaminated on the inside (to the worker's knowledge) must be disposed of as should items such as masks or boots which become damaged and no longer provide a reliable barrier. If a worker resigns or is fired, his/her workwear can be recommissioned for another worker only if it can be completely sanitized. Masks and gloves should not be recommissioned and gloves should not be allowed to be taken home because of the possibility that they are contaminated inside.

2.2 Tools and equipment needed for safety while emptying vaults

In addition to the regular tools which workers use for manually moving sludge from vault to bin and from bin to pit or processing facility, the following equipment and tools are required in order to protect the environment:

Table 2: EQUIPMENT NEEDED ON SITE	
Tarpaulin/plastic sheeting	Plastic sheeting is required for use at the lip of the vault and disposal pit and for the placement of bins or tools. [Note: After use this sheet must be folded with the contaminated side inward, so that the bottom of the sheet does not become contaminated, and must be stored in a plastic bag.]
Bins with lids or covers that prevent access by flies.	Each work team will require a number of bins for transporting sludge, either from the vault to the disposal pit, or from the pit to the sludge processing facility. In the case of on-site disposal 3 bins should suffice. In the case of off-site disposal a single team will require approximately 30 bins for a typical day's work. These bins will be of a size that, when filled, they can be wheeled by a single person (where a trolley is used for moving the bin) or carried by no more than two persons. The bins will have secure lids which cover the sludge during transport and prevent access by flies.
Clean shovel – not for use with sludge	This is required for digging and covering the sludge disposal pit and covering areas where contaminated soil has been removed. The clean shovel is not to be used for sludge and should be stored in a bin bag to avoid contamination by other tools.

In addition, the following supplies are to be carried by work teams and restocked as required:

Table 3: SUPPLIES NEEDED ON SITE	
Disinfectant spray	An ethanol based solution must be provided in a spray bottle for disinfecting any skin, masks, handles etc. which are accidentally contaminated.
Disinfectant solution	A lime or sodium hypochlorite solution must be provided for cleaning other surfaces where accidental spills have occurred.
Bucket	For preparing lime or sodium hypochlorite solution.
Paper towel	For wiping contaminated surfaces after being sprayed or wiping face and mask after spraying with ethanol-based solution
Roll of bin bags	For disposing of contaminated paper towels or other rubbish.
Box of disposable gloves	In the event that a work glove becomes torn or contaminated.

An inventory of safety equipment must be done regularly (eg. weekly) to ensure that adequate quantities are available at all times.

2.3 Area depots

Area depots are to be provided where workers can shower, use the toilet, change, clean and store their equipment and street clothes. Workers must be given sufficient opportunity to use these facilities at the beginning and end of each work day so as to prevent contaminated work wear and equipment from being taken home. The area depot must be equipped as follows:

Table 4: AREA DEPOT FACILITIES
• Shower
• Toilet
• Facilities for washing boots and tools (contained area with running water and drain)
• Facilities for washing and drying clothes (basins, covered washing line and clothes pegs)
• Facilities for separate storage of each workers' street clothing and PPE (eg. bins or plastic bags on hooks) and for team's tools
• Facilities for cleaning vehicle (eg. paved area with drain that can be washed down)
• Hazardous waste disposal container for equipment that is damaged or discarded
• Facilities for storage of equipment

The following supplies must be inventoried regularly and kept stocked at the area depot:

Table 5: SUPPLIES NEEDED FOR AREA DEPOTS	
Lathering liquid soap	For handwashing and showering at welfare facility
Toilet paper	
Disinfected cloths	(Eg. Soaked in bleach solution) for wiping boots, masks, gloves, etc.

Box of disposable gloves	For cleaning tools and vehicles.
Scrub brushes, buckets and basins	For cleaning boots, tools and vehicles.
Laundry soap, washbasin, washline and pegs	For washing clothes at welfare facility.
Disinfectant	Bleach for cleaning boots, masks, tools and vehicle at welfare facility.

When use of a particular site is discontinued, the site must be disinfected after all equipment has been removed using lime and/or hypochlorite solution.

3. HEALTH CARE

3.1 Workers' health

All workers are to be given tetanus and hepatitis immunisation injections before commencement of employment (unless they are in possession of a vaccination card indicating that these are up to date). Booster hepatitis injections must be given as required.

Deworming tablets must be given to workers and their families both prior to the commencement of employment and after every six months of employment.

Protocols to be followed by workers who experience an accident or a work-related illness are to be provided to workers in writing (eg. posted on wall at welfare facility).

3.2 Householder health

Because the level of understanding of health issues, disease transmission, and appropriate hygiene practices to prevent infection is variable in the population whose sanitation systems are being serviced, educational material addressing health and hygiene will be provided to all households after their UD systems are serviced (the information will be provided by the employer, but issued by the contractor). Because of the possibility that a householder's home environment has become contaminated with helminth eggs from their own or others' vaults during the servicing of their UD toilet, and because of the prevalence of helminthic infections in the eThekwini Metro, the opportunity should be taken to provide deworming medicine to householders after servicing their UDs. Deworming medicine should be provided along with the advice that anyone who is or may be pregnant or is breastfeeding and children under the age of two should not take the medication.

Where sludge is buried on site, clear instructions must be given to the householder that the disposal site should not be disturbed through digging or planting for a minimum of three years to prevent contact with buried pathogens which may still be viable. The employer will assist with any educational material required in this regard.

4. SAFE WORK PRACTICES

This section details safe work practices for the different activities required for desludging on-site systems.

4.1 Tools and protective wear

Workers must wear protective clothing (overalls, gloves and boots) at all times while handling sludge and masks while emptying the vault or emptying bins. During their training workers will be shown how to remove protective equipment without contaminating the inside surfaces of that equipment.

Workwear and tools must be regarded as contaminated at all times and may not touch household surfaces (ie. Tools may not be laid on the ground, workers may not lean on walls or touch taps/handles with their work gloves). Tools must be transported and stored during work in a dedicated bag or bin to avoid sludge dripping off or brushing off tools as they are carried.

In no cases may workers use tools or objects (eg. shovels, pieces of wire, sticks, etc) belonging to the household to handle sludge. They may also not use the household tap to wash tools or personal equipment.

4.2 Preparing the site

The work areas should be prepared as follows:

- The householder must be asked to remove any washing, children's toys or other objects from the path/s that will be used by workers to avoid these becoming contaminated, and to keep children away from the work area.
- A tarpaulin / plastic sheet must be placed in front of the vault with the edge of the tarpaulin covering the base of the vault to prevent any spilled sludge from falling off the tarpaulin on to the ground. The bin that is to be filled and all tools for sludge removal must be placed on this tarpaulin, taking care that tools do not touch the ground.

4.3 Pit emptying

The following procedure must be followed:

- The vault is opened and the lid is placed inner side up on a tarpaulin, taking care not to contaminate the ground with gloves.
- The bin used to collect sludge is placed on the tarpaulin.
- Sludge is then transferred from the vault to the bin, taking care to not drop sludge during the transfer. The bin should not be filled beyond a weight that two people can carry comfortably.

Once the bin is filled it is covered with the bin lid and moved to one side (still on the tarpaulin). If the outside of the bin has been soiled with sludge this must be cleaned using a disinfectant solution.

- The bin is then carried or wheeled to the transport vehicle or disposal pit and the next bin is placed on the tarpaulin.
- After the vault is empty the cover is replaced, taking care not to contaminate the earth or surfaces.
- The tarpaulin is then folded up taking care not to contaminate the surrounds.

- If any sludge is spilled on the surrounding surface the spill area will be scraped as clean as possible, with contaminated soil discarded in the pit, and then disinfected with an appropriate disinfectant solution (lime or sodium hypochlorite).

4.4 Burial of sludge on site

If there is any doubt regarding the suitability of the site for on-site burial of sludge this must be discussed with the engineer.

A hole or trench should be prepared of adequate proportions to contain the sludge while also allowing for 300mm of soil backfill on top of the sludge surface to provide an adequate barrier between sludge and the surface.

Digging of holes must be done with clean tools, not the tools used for pit emptying.

A tarpaulin must be placed on the lip of the disposal pit/trench to protect the ground in the event that sludge is spilled during transfer. Tools and bins must also be placed on the tarpaulin. After sludge is placed in the hole, the top 300mm of the hole is to be backfilled with soil using a clean spade and the remainder of the soil that has been removed is to be heaped over the burial site. Workers must test the burial site for stability; if there is any indication that a person or animal could sink into the buried sludge the burial site must be cordoned off with stakes and danger tape and the householder must be made aware of the risk and advised to keep children away from the site for a month.

4.5 Welfare breaks on site

Workers may not enter homes because of the risk of pathogens on their protective clothing transferring to surfaces inside the house. Workers may not use cups or jugs of water, basins or buckets from the householder because of the risk of contaminating them. Drinking water is to be carried to site with workers and protected (i.e. placed inside a closed bag) to prevent accidental contamination. Food brought to the site must similarly be kept in closed bags / containers to prevent accidental contamination.

Gloves must be removed and hands thoroughly sprayed with ethanol before a worker engages in drinking, eating, smoking, talking on the telephone or other activities where pathogens on his/her hands could be transferred to the mouth or to other objects.

If at all possible use of outdoor household facilities such as the toilet or tap should be avoided. Should it be unavoidable workers should follow the following protocols:

- Spray bottoms of boots with disinfectant and wipe with newspaper/papertowel before entering the toilet (contaminated newspaper/papertowel must be discarded in a removal bin or rubbish bag that is removed from the site by the team)

- Spray hands with disinfectant before touching toilet door handle or tap handle or alternately disinfect handle after use.

4.6 Remediating contamination

Accidental contamination of the site is to be remediated as follows:

- If sludge is spilled at any point it must be picked up with a spade used for emptying the pit, discarded into the pit, and then the area must be doused with disinfectant solution.
- If household surfaces are touched by gloves, bins, etc. they must be sprayed with ethanol or doused with bleach solution. If sludge is visible it must first be wiped off with a paper towel that is then disposed of in the bin for sludge or the workers' rubbish bag.
- If a worker steps in sludge the boots must be wiped clean with a paper towel which is then disposed of in a bin for sludge and then sprayed with ethanol.
- If a significant spill occurs (eg. the contents of a bin spill out on the ground) the sludge must be removed with a contaminated spade and then the area must be soaked with a disinfectant solution and covered with 2cm of clean soil (using a clean spade).

The household tap may be used to prepare a bleach solution in a dedicated bucket brought on to site by the team. The worker who collects water must remove his/her work gloves and disinfect his/her hands thoroughly using an ethanol spray before touching the tap.

All road accidents where significant amounts of sludge are spilled must be reported to the Department of Water and Sanitation and to the Health and Safety Officer and steps must be taken to minimize the impact of any contamination on public health and the environment.

4.7 Responding to personal exposure

If the skin comes into contact with sludge, visible sludge must be wiped off with a paper towel and the area must then be sprayed with an ethanol solution. If contaminated material has entered the eyes, nose, or mouth, they should be flushed well with water. In this case water can be taken from the household tap after gloves have been removed and hands have been thoroughly sanitised with ethanol. In the event of a cut or puncture wound from a contaminated object, the person should immediately expose the wound, allow it to bleed, and then spray the area with ethanol and wash the area thoroughly with soap and water at the welfare facility. If a person suffers a significant exposure to sewage or sludge, the person should shower as soon as possible.

4.8 Transporting sludge and tools

Bins containing sludge must be covered with lids and secured in the truck for transport. Tools should be transported in a dedicated bin or bag. Due to the likelihood of viable pathogens in sludge it should be handled as a hazardous waste (containing infectious substances) during transportation. Transporters must be informed of the nature and risks of the load and carry accurate documentation. Hazchem placards must be fitted to the vehicles. Empty bins may not be stacked inside each other during transport as this will contaminate the outside of the bins.

4.9 Cleaning protective equipment, tools and vehicles

Under no circumstances may protective equipment, tools or vehicles be cleaned on site (at homes where UDs are serviced) or at workers' homes. All cleaning must be done at the area depots.

Many disinfectant agents are neutralised by the presence of organic matter (eg. sludge). It is therefore important to remove all visible soiling with running water and a scrub brush before soaking them with a disinfectant solution.

Cleaning must be done as indicated in Table 6 below.

Table 6: CLEANING CONTAMINATED EQUIPMENT	
Clothing	Clothing should be washed with sodium hypochlorite added to the water, or alternately with water hot enough to kill pathogens (over 60 degrees C).
Masks (non-disposable type)	After rinsing with running water masks can be placed in a basin with a bleach solution for half an hour then rinsed and hung up to dry.
Gloves	Gloves must be rinsed with running water, wiped with a cloth soaked in a bleach solution, rinsed, and hung up to dry.
Boots	Boots must be soaked in a basin of warm water to loosen soil if needed, then scrubbed with a bleach solution, rinsed with running water and left to dry.
Tarpaulins	Tarpaulins must be sprayed with a disinfectant and wiped and allowed to dry, ensuring that the same side is always reserved for contact with the ground.
Tools	Tools must be soaked in a bucket to remove soiling and then scrubbed with a brush. Handles should be wiped with a bleach solution.
Vehicles	The bed, handles (gate and doors, inside and out), steering wheel, gear lever, hand brake, seats (back and front) and floors of vehicles should be washed down thoroughly with a cloth and a disinfectant solution before being used for any other purpose. Surfaces that are likely to be touched with hands (steering wheel, handles, gear lever, hand brake, etc) should be sprayed with ethanol frequently and wiped down with a disinfectant solution at the end of the day.

5. Supervision and compliance

A clear chain of supervision and reporting must be established by the contractor and posted in the welfare depot. This must provide for how, and to whom, workers and supervisors report the following:

- lost or damaged equipment
- significant personal exposure to sludge (eg. puncture, immersion of an unprotected body part, splashes to the eyes, nose or mouth)
- spills on site or in transit which they could not completely remediate
- safety violations by other workers

Annex 2 provides examples of situations for which the contractor must have clear reporting systems in place.

While thorough training of workers and provision of the necessary equipment to follow procedures may go a long way toward ensuring that workers comply with health and safety requirements, it can be assumed that a system of incentives and penalties will also be required to curb and control violations. This system should be clearly explained during training, posted in the welfare depot, and enforced.

In addition, contractors must document and report the following to the employer's Health and Safety Officer:

- significant personal exposure to sludge (eg. puncture, immersion of an unprotected body part, splashes to the eyes, nose or mouth)
- spills on site or in transit which they could not completely remediate
- other incidents of contamination of the environment or exposures of workers or the public to sludge
- monthly report of violations and associated penalties and exemplary practice and associated incentives

Appendix 1: Indicative Scope for Workers' Environmental / Health Training

TRAINING PROGRAMME FOR SLUDGE HANDLERS	
1. Purpose of sanitation: to reduce transmission of disease	Emptying must complete the lifecycle of onsite sanitation without compromising its main objective
Hazards of handling sludge	Infection: epidemiology of important pathogens Non-biological hazards: chemicals, gases, sharp objects Routes of transmission Contamination of the environment during sludge removal Contamination of the environment by buried sludge Contamination of the environment by stockpiled sludge Skills for identifying new hazards in a new situation
2. Protecting yourself	Principles of hygiene at home and at work Correct use of tools and equipment Importance of each item of PPE When and how to don and remove PPE Sanitising hands on the job and showering before going home Handling accidental exposure (first aid and reporting) How to report lost or damaged equipment Preventing storage/use of protective equipment at home Sterilisation or disposal of PPE when contract has ended Deworming treatment Accessing healthcare
3. Protecting others	Preparing the site to prevent contamination Preventing contact between tools or PPE and household surfaces Preventing spills during transfer of sludge Handling accidental spills or contact of tools/PPE with surfaces Meeting personal needs (toilet, drinking water) while on the job Loading and transporting sludge Handling spills in public areas/on roadways Cleaning vehicles Providing the householder with information about health and hygiene Informing the householder of spills and giving instructions Providing deworming medication and instructions for safe use to householders
4. Administration	Reporting lost or damaged equipment Reporting violations Reporting spills that could not be adequately remediated Reporting illnesses or accidents that may be work related
5. Incentives and enforcement	Penalties for noncompliance Incentives for compliance

Appendix 2: Developing systems for reporting

SITUATIONS FOR WHICH REPORTING SYSTEMS MUST BE PUT IN PLACE				
Situation	**Example**	**Action**	**Time frame**	**Report to whom**
Protective wear lost or damaged	Glove is torn	Use alternative (eg. double disposable gloves) for remainder of shift. If no alternative, do not continue work until protective wear is replaced.	Find alternative/stop work immediately; report before end of shift	Team leader
Significant personal exposure to sludge	Puncture wound from sharp in sludge	Refer for medical care	Immediate	Team leader - Health/safety officer
Significant environmental exposure to sludge	Sludge bin falls off vehicle and spills sludge on roadway	If on site, follow protocol, if on public roadway restrict the site, wait for assistance	Immediate	Team leader – Health/safety officer - traffic dept if needed.
Violations by team members	Worker climbs into pit	Fellow worker reports violation	Immediate	Team leader - contactor

Appendix 3: Violations for which contractors will be fined

VIOLATIONS FOR WHICH THE CONTRACTOR WILL BE FINED	
Worker	Working without a required item of PPE (masks required while removing sludge) Household environment not prepared (eg. householder instructed to remove washing) Area between pit and bin not protected Tarpaulin placed with the contaminated side down Climbing into the pit Handling sludge directly with gloves Contaminated tools placed directly on the ground Transporting bins containing sludge without lids Carrying bins without gloves Bins stacked inside each other Using contaminated tools to remove sludge from the soil or prepare disposal pit Using householders' tools, buckets, jugs, etc. Spilling a visible amount of sludge on the ground Touching household surfaces (taps, handles) with work gloves or unsanitized hands Stepping knowingly into sludge (stepping on spilled sludge, placing boot inside of bin or stepping into the pit) Eating/drinking/smoking etc without removing gloves and disinfecting hands Entering home in PPE Leaving rubbish on site Not reporting a significant spill/accident resulting in contamination Failing to remediate a spill or contamination of a surface Not reporting significant personal exposure to sludge Not reporting lost/forgotten/damaged protective wear Leaving unstable disposal area unmarked Householders not informed of spills, risks or health information Taking PPE home
Team leader	Committing any of the violations listed for workers Failing to replace damaged PPE Failing to address or report violations Failing to initiate remediation of contamination in the case of an incident/accident
Contractor	Committing any of the violations listed for workers Welfare depot not properly stocked with cleaning/welfare supplies Required safety supplies not available on site Failing to address, document and report violations Failing to initiate remediation of contamination in the case of an incident/accident