

Factors facilitating pest infestation in two low-income urban areas of Cape Town, South Africa: an urban health observation study

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PART 0: PREAMBLE

ABSTRACT

High pest burdens in low-income urban areas pose a significant public health threat to residents due to pest-induced diseases and other negative health consequences. Furthermore, pests can also be a source of nuisance and social stigma. To ward off pests and the problems they are associated with, many residents of socioeconomically disadvantaged urban areas frequently use pesticides, including highly toxic illegal pesticides. Inappropriate and indiscriminate use of pesticide is a concern since pesticide exposures can put residents, especially children, at risk for negative health effects. While pesticide use and exposures are common in many low socioeconomic urban areas globally, pesticide-induced adverse health effects are of particular concern in developing countries, such as South Africa, where pesticide regulations and enforcement thereof is often lacking.

Following the alarming rise in number of children hospitalized with pesticide poisoning in the Cape Town surrounds, researchers at the University of Cape Town conducted a study whose aim was to identify common in-home pests, pesticide use and exposure patterns, and pesticide risk perceptions in Khayelitsha and Philippi, two low socioeconomic communities of Cape Town. This study was part of the larger project and was focused on investigating factors that contribute to pest infestation in low socioeconomic urban areas.

An analysis of qualitative data that examined factors in housing, environment and practices and pest control behaviours of poor urban residents that facilitate pest infestation is presented in this mini-dissertation. The protocol (Part A) describes the study population and the methods used to collect and analyse the data. The structured literature review (Part B) describes the double health burden from pests and pesticide exposure faced by low-income urban residents. It also discusses the poverty-related factors that contribute to pest infestations in impoverished urban areas. Lastly, it critically evaluates research on alternative non-toxic pest control methods relevant for low socioeconomic urban communities.

The article (Part C) presents an analysis of the findings of the study. The findings showed that low-income urban areas had a high pest burden and that residents commonly used highly toxic illegal street pesticides for pest control. Pest infestation was found to be facilitated by closely linked poverty-related factors pertaining to deteriorated housing, unsanitary environments, and lack of water and sanitation. The findings also suggested that pest infestations significantly diminished residents' locus of control, and were also a cause for significant economic burdens and mental distress. The article ends by making intervention and policy recommendations on how pests and pesticide exposures can be reduced in order to lower the health risks they pose.

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PART A: PROTOCOL

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1. INTRODUCTION

Pests pose an increasingly significant threat to public and environmental health, particularly for residents in low-income communities (Bonney et al., 2008). Pest infestations increase the potential to be exposed to vector-borne diseases and pesticides, both of which can negatively impact on health. A devastating effect of pesticide used in homes to control pests is the increase in the number of poisonings of children, as witnessed in a tertiary paediatric hospital in Cape Town (Balme et al., 2010). A majority of these cases of childhood poisonings were from Khayelitsha and Philippi, areas where data for this study was collected from. In developing countries, highly toxic pesticides are widely available, producing higher accidental poisoning and death rates compared to developed countries (Konradsen et al., 2003). As the presence and availability of pesticides in the home most likely indicates the presence of pests, it is important to understand the factors that lead to infestation, with the goal to reduce pests. Pest reduction would by extension also reduce the double burden of disease caused by pests and pesticides.

Some of the factors for pest infestation in low socioeconomic urban communities are linked to rapid urbanisation and low-cost housing which provide favourable conditions for the proliferation of pests and pest-borne diseases (Bonney et al., 2008). Favourable conditions for pest infestations include stagnant water, dilapidated housing and accumulating garbage (de Masi et al., 2009; Jassat et al., 2013; Kelly et al., 2013; Rauh et al., 2002). Such problems are more prominent in low socioeconomic areas and the problem posed by pests can only be expected to worsen as it is estimated that two-thirds of the world's population will be living in cities by 2050 (United Nations 2014). Recommendations arising from studying the factors of pest infestations can have wide reaching effects if municipalities or countries adopt them and include them in their urban health and poverty alleviation policies. However, before such recommendations can be made, it is crucial to understand the extent of problems that can be caused by pests.

1.1 Problems caused by pests

Pests in low-income urban areas are a cause for concern for three major reasons: 1) their potential as disease vectors, 2) the stigma associated with them, and 3) the nuisance they cause to residents. Common synanthropic urban pests include cockroaches, bed bugs, mosquitoes, fleas, lice, rodents, flies and ants (Bonney et al., 2008). These urban pests can cause a range of health problems, from gastrointestinal diseases transmitted by flies (Getachew et al., 2007; Nmorsi et

al., 2006) to asthma triggered by cockroach allergens (Perzanowski et al., 2008) to dermatological lesions caused by bed bugs (Bonney et al., 2008). However, pests cause much more than just physiological health problems, some pests such as bed bugs are associated with social stigma, which can negatively affect the mental health of affected people (Dogget et al., 2012; Eddy & Jones, 2011). The presence of pests that are not known to transmit diseases to humans, such as bed bugs (Delaunay et al., 2011) can be a nuisance to residents. To understand the extent of the problems caused by pests, pests common in low socioeconomic areas of Cape Town are discussed next. Cockroaches, rats, fleas, flies and bed bugs have been identified to be the most common pests and of most concern to residents of impoverished areas of Cape Town (Govender et al., 2011a; Tolosana et al., 2009). These poverty-related pests (Rother, 2008) are of public health concern due to the health problems they are associated with.

Cockroaches

Cockroaches are hardy and common insect pests, and are a cause of significant health consequences for residents, particularly in poor urban settings (Arruda et al., 2001; Nicholas et al., 2005; Wang et al., 2008). Surveys conducted in households in low socioeconomic communities in both high- and low-income countries have found high prevalence of cockroaches: 69% (N=100) in Uganda (Nalwanga & Ssempebwa, 2011), 72% (N=1,151) in Lebanon (Habib et al., 2011), 51% (N=740) in South Africa (Tolosana et al., 2009), and 83% (N=103) in the United States of America (USA) (Wang et al., 2008). What these surveys show is that households in low-income communities, whether they are located in a low income country (Uganda), upper-middle income country (Lebanon and South Africa) or high income country (USA) (World Bank, 2015), are likely to have a high prevalence of cockroaches. Such findings are a cause for concern to low socioeconomic communities because of the potential disease risk posed by cockroaches.

The presence of cockroaches in households can be a potential cause for a number of ill-health effects. Cockroach allergens have been identified as one of the allergens that cause asthma and increase morbidity among asthmatic children (Arruda et al., 2001). While mortality from asthma is low (Perzanowski et al., 2008) the burden of disease and economic costs are significant. In a systematic review, Bahadori et al. (2009) found that the majority of direct costs of asthma were from hospitalisations and medication costs. Indirect costs were from days missed at work for

adults and parents, and days missed at school for children. It is worthy to note that people of low socioeconomic status predominantly bear the brunt of health and economic costs associated with asthma and cockroach allergen sensitisation as cockroaches thrive in the overcrowded, unhygienic and poor quality housing they live in (Arruda et al., 2001; Kitch et al., 2000; Sarpong et al., 1996). In addition to their implication in asthma and asthma morbidity, cockroaches are also vectors of intestinal parasites of concern to humans. In a study to isolate intestinal parasites carried by German cockroaches in Ethiopia, Hamu et al. (2014) found that 77% of the 210 batches (N=2,010) of cockroaches collected harboured at least one intestinal parasite in their gut. Parasites were also identified on the external body of cockroaches in 11% of the batches. Identified intestinal parasites with potential health effects included *Ascaris lumbricoides*, *Trichuris trichiura*, *Taenia species*, *Strongyloides*-like parasite, *Entamoeba histolytica/dispar/moshkovski*, *Giardia duodenalis* and *Balantidium coli*. Other studies have also corroborated the evidence of cockroaches as parasite transmitters (El-Sherbini & El-Sherbini 2011; Pai et al., 2003). Not only do cockroaches act as vectors for parasites, they can also transmit other pathogens such as bacteria, fungi and viruses via food contamination (Baumholtz et al., 1997).

Rodents

Rodents are also commonly prevalent in low-income communities resulting in urban nuisances, as well as posing a threat to public health and causing damage to property. The three commensal rodent species considered to be more serious pests in the urban environment are the brown rat (*Rattus norvegicus*), the roof rat (*Rattus rattus*) and the house mouse (*Mus musculus*) (Battersby et al., 2008). These three species have a worldwide distribution (Global Invasive Species Database, 2015). Similar to cockroaches, rodents in urban areas are highly prevalent in impoverished communities. A survey conducted in impoverished urban communities of Johannesburg, South Africa, found that the average prevalence of rats in households (N=419) in the study sites was 54%, with a higher prevalence of 69% in an informal settlement on the outskirts of the city (Jassat et al., 2013). In São Paulo, Brazil, in an investigation of rodent infestation in 1,529 households, the rate of building infestation was 40% (de Masi et al., 2009). Even self-reported prevalence of rodent infestation is similarly high, with 79% of respondents (N=740) residents in a rural area, an urban township and an informal settlement in South Africa citing rats as the most problematic indoor pest (Tolosana et al., 2009). Problems caused by

rodents include negative health effects, food losses and damage to infrastructure (Battersby et al., 2008).

Perhaps the most well-known disease indirectly transmitted by rodents is bubonic plague. Though not much of a problem now as it was in the Middle Ages, the World Health Organization (WHO) reported that in 2013 there were 783 cases of bubonic plague reported worldwide (WHO, 2014). Recent outbreaks have been reported in Madagascar (CNN, 2015), USA and China (NPR 2014). Plague is transmitted to humans by bites from rodent fleas infected with *Yersinia pestis* (Battersby et al., 2008). Rodents are also implicated in many other health conditions.

Rodents have been found to trigger asthma, a health condition disproportionately affecting children in low-income urban communities, via allergens found in mouse urine, hair and dander (Perzanowski et al., 2008; Phipatanakul, 2002). Other rodent-borne diseases include haemorrhagic fever, Hantavirus pulmonary syndrome, Lyme disease, Lassa fever, schistosomiasis and salmonellosis (Amatre et al., 2009; Battersby et al., 2008; Bonner et al., 2007; Graves & Janda, 2001; Matuschka et al., 1996; Meerburg et al., 2009). Rodents transmit these and other diseases directly through bites, consumption of food and water contaminated with rodent faeces and urine, and inhaling pathogens present in rodent faeces. In the Cape Flats, an impoverished suburb of Cape Town, South Africa, there have been disconcerting reports of large rats biting children and bed-ridden individuals (Schronen, 2003). Such occurrences are of concern as bites by rats infected with *Streptobacillus moniliformis* can transmit rat-bite fever (Graves & Janda, 2001). Rodents can also transmit disease indirectly via rodent ectoparasites such as fleas and ticks (Meerburg et al., 2009). In addition to transmitting disease and causing physical harm through bite sites, rat bites like other mammalian bites may potentially cause psychological trauma to victims (Dendle & Looke, 2009).

In addition to their potential as disease-vectors, rodents can also cause significant economic losses to already impoverished urban households by damaging property and spoilage of stored foodstuffs (Battersby et al., 2008). With their gnawing and burrowing habits, rodents can damage infrastructure such as wood and plastic and can bite through food storage receptacles. For example, in a study to explore the perceptions of urban residents (N=170) towards rodent

infestation in Niamey, Niger, damages to food stock and to houses were cited by 63% and 47% interviewees respectively as the two main problems caused by rodents (Garba et al., 2014). Rodents are a nuisance and health hazard in and of themselves, but they are also associated with fleas, another pest of health concern in urban areas.

Fleas

The two groups of fleas with the most potential for negative health effects on humans are rodent fleas and fleas found on domestic animals (Hinkle, 2008). Naturally, the prevalence of rodent fleas which are rodent ectoparasites is dependent on the prevalence of rodents, which has been found to be high in low-income areas across the globe (de Masi et al., 2009; Jassat et al., 2013; Tolosana et al., 2009). As blood-feeders, fleas can transmit blood-borne diseases from host animals to humans via two common ways: by regurgitation of blood meals, or by contaminated faecal pellets (Bitam et al., 2010). Rodent fleas can transmit *Yersinia pestis*, the pathogen that causes bubonic plague from infected rodents to humans (Battersby 2008; Hinkle 2008). While rat fleas are the main vector for *Y. pestis*, cat fleas (*Ctenocephalides felis*) have also been found to be competent vectors for *Y. pestis* in plague-endemic regions in Uganda (Eisen et al., 2008). This is a cause for concern as cat fleas are the most common fleas in human habitats in Uganda (Eisen et al., 2008). Additionally, both cat and rodent fleas can transmit *Rickettsia* spp. that cause murine typhus (Hinkle 2008; Raoult 2001). Cat fleas can also transmit *Bartonella* spp., bacteria that can cause endocarditis in immunocompromised people or those with pre-existing valvular disease (Avidor 2004; Chomel, 2006). In addition to fleas being a vector of human pathogens, flea bites can cause itchy skin lesions and discomfort.

Flies

Many species of synanthropic flies are known to transmit disease to humans. Species capable of transmitting disease to humans are known as “filth flies” because they feed and breed on human and animal excrement, animal carcasses, waste and decaying material (Graczyk et al., 2001). By flying from contaminated matter to uncontaminated matter, filth flies can easily transmit pathogens on their bodies (Graczyk et al., 2001). In addition to mechanical transmission of pathogens through direct contact with a fly’s body, some flies can also transmit pathogens through regurgitation of digestive juices thus spreading pathogens ingested with previous feedings, and also through defecating on the surface they rest and feed on (Hogsette & Amendt,

2008; De Jesús et al., 2004). The housefly (*Musca domestica*), a major urban pest fly, is a significant vector of foodborne pathogens with the most common ones being disease-causing *Escherichia coli*, *Shigella* and *Salmonella* (Hogsette & Amendt, 2008; Olsen et al., 2001). While the morbidity risk from foodborne pathogens transmitted by flies is usually low, there are some fly species that can occasionally transmit foodborne gastrointestinal diseases on a large scale (Olsen, 1998) such as the enterohemorrhagic colitis outbreak caused by *E.coli* in a nursery school in Japan (Kobayashi et al., 1999).

There are many other disease pathogens transmitted by flies. For example, in studies to assess the role of different fly species as pathogen vectors in Addis Ababa, Ethiopia (Getachew et al., 2007) and in Ekpoma, Nigeria (Nmorsi et al., 2006), both helminth and protozoan parasites were detected from external surfaces and internal gut contents of flies collected. Flies were collected in open defecating grounds, garbage heaps, butcheries near human dwellings (Getachew et al., 2007), an abattoir, market shops, pit latrines and kitchens (Nmorsi et al., 2006). Most of these collection sites can be highly unsanitary and therefore are a cause for concern for urban health as they harbour potentially disease causing microorganisms. Helminth parasite eggs detected included *A. lumbricoides*, hookworms, *T. trichiura*, *Taenia species*, *Strongyloides stercoralis*, and *H.nana*. Protozoan parasite cysts detected included *E. histolytica*, *E.coli*, and *G. lamblia*. Flies are therefore a public health concern as the parasites they carry can cause gastroenteric diseases in humans. The transmission of these parasites by flies is associated with unsanitary conditions; conditions that are common in highly populated, low-income urban areas.

Bed bugs

Bed bugs are increasing globally and are becoming a major public health concern (Davies et al., 2012) especially in urban areas where they are predominantly found (Eddy & Jones, 2011). For example, Gbakima et al., (2002) found that 98% of 233 surveyed rooms in camps for internally displaced people in Freetown, Sierra Leone were infested with bed bugs. Similarly, in a survey of bed bugs in five areas of Lagos State, Nigeria, bed bug infestations were found in the two areas whose sanitary conditions and standards of living were relatively low compared to those of other areas surveyed (Okwa & Omoniyi, 2010). While bed bugs can occur in housing of all socioeconomic groups (Bonney et al., 2008; Harlan et al., 2008), socioeconomically disadvantaged individuals suffer the most as they usually cannot afford to pay for effective

control and often live in deteriorating dwellings that have numerous places for bed bugs to hide in (Dogget et al., 2012; Eddy and Jones, 2011). Even though bed bugs have been found to carry over 40 pathogens (Delaunay et al., 2011), little evidence exists to suggest these pests act as disease vectors of pathogens that cause disease in humans either biologically or mechanically (Delaunay et al., 2011; Dogget et al., 2012; Harlan et al., 2008).

As obligate blood feeders, the main health concern caused by bed bugs is skin lesions accompanied by intense itching (Bonney et al., 2008; Harlan et al., 2008). Additionally, bed bugs, like cockroaches, also produce allergens that may trigger asthma attacks (Dogget et al., 2012). If large numbers of bed bugs are present, anaemia and iron deficiency may occur (Dogget et al., 2012; Pritchard & Hwang, 2009). In addition to these physical and biological discomforts, bed bugs may also cause psychological distress due to the social stigma associated with them. It is widely believed, incorrectly, that bed bug presence signifies poor hygiene and unsanitary living conditions (Dogget et al., 2012). However, bed bugs can be found around where people sleep, regardless of the cleanliness conditions. Such stigma resulting from having a bed bug infestation can lead to social isolation and shame of individuals affected, while disfigurement caused by bite marks can impact on self-esteem (Dogget et al., 2012).

Mosquitoes

Although mosquitoes are not disease-causing in the present study areas, in a study conducted in a rural Eastern Cape village, an urban township and two informal settlements in the Western Cape, 32% of respondents (N=740) identified mosquitoes as problematic household pests (Tolosana et al., 2009). It is plausible to assume that the reason for this finding is similar to that found in other urban areas of sub-Saharan Africa where mosquitoes are not disease vectors. For instance, in resource-limited urban areas of Burkina Faso, residents found mosquitoes to be a nuisance due to the bites they inflict and the resultant itchiness and rash, and their buzzing noise which disturbed sleep (Samuelsen et al., 2004). Stephens et al., (1995) also reported similar findings from two cities in Tanzania. Therefore, while mosquitoes are not disease causing in the current study areas of Khayelitsha and Philippi, they are an identified nuisance which can impact on residents' well-being due to itchy skin and disturbed sleep.

Overall, household pests present three key problems for residents in low-income urban areas. Firstly, a number of urban pests are potential disease-vectors that can negatively affect human health. Secondly, some pests are associated with social stigma and shame, with assumptions of poor housekeeping and hygiene habits. Such stigma and shame can cause mental anguish and psychological distress for those affected (Dogget et al., 2012). Lastly, whether disease-causing or stigma-inducing, pests can be a great source of nuisance. They can worry residents endlessly and disturb their normal daily routines and/or sleep (Samuelsen et al., 2004; Stephens et al., 1995). While understanding the problems caused by urban pests is important, it is also crucial to examine the factors present in these poor urban areas that contribute to pest infestations in order to make recommendations to reduce pests and the problems they cause.

2. FACTORS PROMOTING PEST INFESTATION

Pest infestations in homes are facilitated by multiple factors that allow access and proliferation of pests. These factors mainly have to do with 1) the physical structure of housing, 2) the immediate environment surrounding the dwelling unit, as well as 3) personal and behavioural factors of residents. Substandard housing and unhygienic environment, factors common in low-income urban communities are recognized as having a negative effect on health (Bashir 2002; Harpham 2009) and can be facilitators for pest infestations. Looking at each of these three factors in turn, links to larger societal concepts of social and environmental justice and personal agency are drawn that show the complex interplay of pest promoting factors low socioeconomic urban areas.

2.1 Role of housing

The rapid urbanization in developing countries has led to a rapid rise in the number and size of informal settlements (Vlahov et al., 2007) which are characterized by poor housing conditions. In these communities, housing is characterised by low quality building materials and deteriorating structures (Tshikotshi 2009), making it easy for pests to gain entry into the home. Several studies conducted in developing countries have found that poor housing quality promotes home pest infestations. For example, in Sierra Leone, Kelly et al., (2013) and Bonner et al., (2007) report that the risk of contracting Lassa fever, a disease transmitted by rats, is directly linked to poor quality housing factors. Studies done in Sao Paulo, Brazil (de Masi et al., 2009) and Johannesburg, South Africa (Jassat et al., 2013) also found that rodent infestation was linked to poor housing quality such as cracks in the walls and ceilings.

The relationship between housing deterioration and pest infestation is not only limited to developing countries, but includes poor urban communities in developed countries as well. For example, in New York City deteriorated housing conditions such as holes in the walls and ceiling were found to be directly linked to the presence of cockroach allergens in inner-city households (Rauh et al., 2002), while in Boston the presence of cockroach allergens in public housing was linked to poor housekeeping, holes in the walls and ceiling and longer occupancy of buildings (Peters et al., 2007). Peeling paint, mould and water damage were also found to increase the odds of rodent and cockroach infestations, with high building occupancy increasing the odds of cockroach infestation (Bradman et al., 2005). Most of these studies looking at housing conditions related to pest infestation, explored the presence of one type of pest in the home, not taking into account that pests do not usually occur in isolation (Norris & Schroeder, 2005). Moreover, it is not only the physical structure of housing that is a factor in pest infestation, but also the conditions of sanitation amenities, which overlap with conditions of housing surroundings.

2.2 Impact of surrounding environment

Low socioeconomic urban areas in developing countries are characterized by inadequate environmental sanitation such as poor drainage of surface and household wastewater, indiscriminate garbage dumping and inadequate refuse collection, which provide breeding grounds, easy access to food and shelter for rodent and insect pests (Jassat et al., 2013; Nalwanga & Ssempebwa, 2011). Furthermore, poor sanitation such as having pit latrines instead of flush toilets and lack of functional draining systems have also been identified as risk factors for rodent infestation (de Masi et al., 2009; Jassat et al., 2013). Other environmental variables that favour rodent infestation include the presence of accessible garbage which provides food and shelter, access points such as cracks and holes in the housing structure, and thick vegetation next to houses (de Masi et al., 2009; Kelly et al., 2013). These pest-favouring conditions are common in many poor urban areas in developing countries, from Johannesburg (Jassat et al., 2013) and Rustenburg, South Africa (Tshikotshi, 2009), Sao Paulo, Brazil (de Masi et al., 2009) to Kampala, Uganda (Nalwanga & Ssempebwa, 2011). With these conditions prevailing in many low socioeconomic urban areas of developing countries, it is plausible to expect that the current study areas, Khayelitsha and Philippi are also plagued with the similar conditions.

Khayelitsha and Philippi are low-income residential areas with a mix of formal and informal housing. Informal housing or shacks in South Africa are often built of poor quality and salvaged materials such as wood and corrugated iron sheets (Tshikotshi, 2009) which as shown above can provide easy access for pests. Formal houses are permanent houses that are solidly built, usually with concrete blocks. In urban areas, shacks are usually found in the backyards of formal housing, most notably in the backyards of government subsidized Reconstruction and Development Program (RDP) housing (Lemanski, 2009). These provide a source of income for the owners of the main, permanent house, but are often not included in city and country-wide statistics (Govender et al., 2011b; Housing Development Agency, 2012). Both backyard shacks and other informal dwellings often lack indoor plumbing, sanitation, drainage, proper road access and waste disposal services (Housing Development Agency 2012; Tshikotshi 2009). In five low socioeconomic areas of Cape Town, for example, Govender et al., (2011b) found that backyard shack residents shared garbage bins provided by the municipality with the main houses, leading to pile up of garbage between collection days. Backyard shack dwellers also had no formal facilities for disposal of waste water, sometimes resorting to using the main house toilet to dispose of wastewater. Lacking proper planning, dwellings in these areas are often overcrowded and the surroundings littered with environmental hazards. With these conditions, these areas provide shelter and promote proliferation of pests. However, the state of housing and the surrounding environment in low socioeconomic urban areas is not only determined by the residents themselves, but by much broader societal issues that need to be understood and taken into consideration as part of reducing the problem of pest infestation.

2.3 Environmental and social justice

Environmental and social justice are two closely linked issues that are increasingly recognized as being important factors impacting the health of urban low-income populations (Kubanza & Simatele, 2015; Onstad, 1997). The concept of environmental justice comprises three notions: equity in distribution of environmental risks, recognition of social differences of participants, and political participation in creation and management of environmental policies (Čapek, 1993; Schlosberg, 2004). The environmental justice movement arose in the USA in the 1980s as an extension of the civil rights movement where black communities protested the disproportionately high dumping of toxic waste and environmental pollution of their communities (Munnik, 2007). Similarly, environmental justice in South Africa was embraced as an extension of the anti-

apartheid struggle (Munnik, 2007). Just how important environmental justice is to health is seen in Section 24 of the South African constitution which proclaims that “everyone has the right to an environment that is not harmful to their health or wellbeing.” While the notion of environmental justice is multi-dimensional, (Čapek, 1993; Kubanza & Simatele, 2015; McDonald 2002; Schlosberg, 2004), when applied to low socioeconomic urban areas in this study, it will be used to describe the disproportionate exposure of socioeconomically disadvantaged residents to an unhealthy and toxic environment (Kubanza & Simatele, 2015; Rauh et al., 2008). The urban poor in sub-Saharan African countries are subjected to environmental injustices, such as inequities in solid waste management (Govender et al., 2011b; Kubanza & Simatele, 2015), which can negatively impact on pest infestation. Moreover, inequities in distribution of environmental risks closely reflect inequities in socioeconomic status.

Poor urban residents are largely affected by inequitable distribution of material resources, subjecting them to substandard housing and unsanitary environments (Krieger & Higgins 2002; Rauh et al., 2008), factors that increase the risk of pest infestation. These social disparities experienced by residents of low socioeconomic urban areas are a form of social injustice (Bashir, 2002; Eddy & Jones, 2011). The concept of social justice has been in existence for millennia, but pre-eminent contemporary proponents include philosophers John Rawls and David Miller (Jackson, 2005). Broadly, the concept of social justice has a focus on the equitable distribution of material resources through poverty alleviation and reduction of inequity (Jackson, 2005; Jost & Kay, 2010). As discussed above, living in substandard housing and in environmentally polluted areas is linked to poverty and provides favourable conditions for pest infestations, thus placing urban residents of low socioeconomic status at increased risk for pest-associated health problems. For example, both rodents (Jassat et al., 2013; de Masi et al., 2009; Kelly et al 2013) and cockroaches (Habib et al., 2011; Nalwanga & Ssempebwa, 2011; Tolosana et al., 2009) are associated with housing of low quality. However, social injustice extends beyond housing quality and environmental pollution. Another notion included in the concept of social justice is procedural justice, which is the preservation of basic human rights of groups and individuals in decision-making processes (Jost & Kay, 2010). Residents in low-income areas are, unsurprisingly, often left out of policy and decision-making processes (Housing Development

Agency, 2012); processes that are important if discussions and decisions are to be made on how to reduce pest infestation problems.

Both concepts of environmental and social justice are applicable in the context of the present study as South Africa has a history of social and environmental injustices, legacies from the apartheid regime which are still in the process of being redressed. When coming into power, the ruling African National Congress (ANC) aptly noted that “poverty and environmental degradation have been closely linked” (McDonald, 2002), thus acknowledging that socioeconomic status should be considered when redressing environmental injustices and inequities. It is after all the socioeconomically disadvantaged who disproportionately live in dilapidated housing and environmental health risks, factors that have been identified as contributing to pest infestation in homes. Environmental and social justice issues are thus the channels by which pest infestations in poor urban communities can be addressed in a broader socio-political context. Stakeholders involved in this discourse include residents themselves, municipal service providers, urban planners and policy makers. Approaching pest infestation through environmental and social justice will therefore ensure that ultimately, recommendations made on the basis of this study and the larger study it is a part of, take into account the collaborative effort required from all concerned stakeholders. Having discussed housing and environmental conditions, which are pest infestation promoting factors linked to issues of social and environmental justice, another factor facilitating pest infestation is discussed next.

2.4 Residents’ behaviours and practices

In addition to housing and the immediate home environment, behaviours and practices of residents are another important factor that impacts on pest infestation. Keeping domestic animals in and around homes, poor household hygiene, and utilization of ineffective pest control measures are some practices that can negatively impact on pest infestation. Animals kept in homes can harbour varied pest types that can potentially pose a risk to human health. For example, in 396 dogs examined for ectoparasites in poor areas in urban and rural Nigeria, 39% were infested with fleas, 24% with ticks and 11% with lice (Ugbomoiko et al., 2008). These ectoparasites are of health concern to humans as they can potentially transmit diseases and cause skin irritations. Free-range chickens kept around the home have also been found to be hosts to fleas, ticks, lice and mites, all pests with potentially negative health consequences for humans

(Mukaratirwa & Hove, 2009; Mungube et al., 2008). Since pets and animals such as chickens live in or in close proximity to houses in poor urban areas, ectoparasites harboured by these animals can be a source of infestation in homes. A combination of limited knowledge about the importance of treating pets for ectoparasites and the lack of resources to buy treatment or to send animals to a veterinarian may mean that pet owners of low socioeconomic status treat pets for parasites, if at all, at advanced stages of disease (Ugbomoiko et al., 2008), thus increasing the likelihood that ectoparasites harboured will negatively affect the health of residents.

Another way in which residents' behaviour may facilitate pest infestation is through their housekeeping practices. It is important to note though that behaviour as a factor for pest infestation is not exclusive of the housing conditions and surrounding environment. For instance, even though poor housekeeping has been associated with the presence of cockroaches in homes (Peters et al., 2007), the dilapidated state of housing in socioeconomically disadvantaged urban communities may mean that proper cleaning and hygiene practices may not be effective in keeping pests out (Eddy & Jones, 2011; Srinivasan et al., 2003). Residents respond by adopting varied ways of responding to the seemingly ever-present threat of pests in the home. As reported by Tolosana et al. (2009), some low-income residents plagued with rats have become apathetic to their presence, seeing their presence as inevitable. In one urban area in Uganda, some residents were reported to contribute to pest infestation by leaving dirty dishes unwashed overnight, thus providing a food source for pests such as cockroaches and rats (Nalwanga & Sseempebwa, 2011). However, the study does not report on the reasons why the residents left dishes unwashed. It could be because residents had become indifferent to pests as previously reported (Tolosana et al., 2009) or that as is common in low socioeconomic urban areas (Tshikotshi, 2009), they may not have had access to appropriate facilities within their housing units which would be an even bigger problem at night, if for example, residents only had access to an outside communal tap or disposed of wastewater outside. While some residents in low socioeconomic urban areas have chosen to accept or ignore the scourge of pests, many practice a variety of pest control methods. How residents choose to manage pests in their homes can be determined by the level of control that residents feel they have over pest problems.

The locus of control theory (Rotter, 1966) can be used as a lens through which to analyse how members of households, through their practices and behaviour, perceive their ability to control

pest infestation. The locus of control theory, which arose from the social learning theory developed by Julian Rotter, posits that individuals perceive events as either being internally controlled through their actions and beliefs, or externally controlled via circumstances over which they have no control (Rotter, 1966). For example, a dirty and poorly kept house and piles of garbage outside the home both contribute to pest infestation. However, the cleanliness of a house may be perceived as internally controlled whereas garbage outside the home may be seen as lying outside the control of household members.

When applied to health and health behaviour, the health locus of control is termed the health locus of control (HLC) (Lau, 1982) and is often used in studies of health related behaviour such as diet, exercise and smoking (Norman, 1995). A number of factors have been found to determine whether people have high internal or external beliefs regarding their health and health behaviours. Previous levels of success, higher level of education and higher income have been found to be associated with high internal beliefs (Gaber & Abdel-Latif, 2012; Heimlich & Ardoin, 2008). Furthermore, higher internal control beliefs are associated with higher value being placed on a health outcome or event (Norman, 1995). While some studies were found that examined health locus of control as it relates to environmental health risks (Gaber & Abdel-Latif 2012; Riechard & Peterson, 1998), none could be located that specifically examined health locus of control as it relates to practices for controlling pests in the home. Nonetheless, the concepts are still applicable to pest infestation and control in homes. What the theory means therefore is that if individuals do not see the health value in performing pest control measures, are less educated or are socioeconomically disadvantaged, they are likely to perceive the presence of pests in their home as outside of their control. On the other hand, if individuals have had previous success in getting rid of pests, are better educated, are of higher socioeconomic status, or place higher health value in getting rid of pests, they are more likely perceive pest control as internally controlled. As data are analysed in this study, these two domains, internal and external control, will be identified and linked to their role on pest infestation in the study areas.

3. IN-HOME PESTICIDE USE: EXPOSURE AND HEALTH CONCERNS

With urban pests a common problem in low-income residential areas, pesticides are often used as a control method. However, the heavy use of pesticides exposes residents to a wide range of potential negative health effects. For example, pesticide exposure has been linked to leukaemia,

non-Hodgkin lymphoma, and other solid tumours such as brain, breast, prostate and colon cancers (Turner et al., 2010). Also, *in utero* exposure may affect the development of the reproductive system (Landrigan, 2001). Pesticide exposure is furthermore associated with neurological diseases such as Parkinson's disease, chromosome mutations, low birth weight and increased infertility in women (Sanborn et al., 2007). Exposure to pesticides and the negative health effects they cause are of special concern to children.

Children's immature physiology and hand-to-mouth behaviour are some of the factors that make them particularly vulnerable to negative health consequences caused by pests (Tolosana et al., 2009). Additionally, children eat more food for their size compared to adults, which increases their vulnerability if food has been exposed to pesticides. They also have larger body surface area than adults, making them more vulnerable to dermal absorption of pesticides. Children also have immature metabolic pathways that are less able to detoxify and excrete certain toxins. They also have more time in which to develop chronic ill-health effects caused by early exposures to pesticides. Lastly, children tend to play on the ground where they may ingest or inhale pesticide residue in dust or low-lying air layers (Landrigan, 2001; Tolosana et al. 2009). To illustrate the vulnerability of children to pesticide exposure, in a retrospective study of child pesticide poisoning in a tertiary paediatric hospital in Cape Town, Balme et al. (2010) found that in the six year period between 2003 and 2008, exposure by oral ingestion accounted for 75% of the cases (N= 306), with 5% exposed from home pesticide spraying and the remainder with unknown exposure route. Of the total number of cases seen during this period, 29% of cases were from Khayelitsha and 10% were from Philippi, areas where data of the current study were collected from. While ingestion is the most common way for accidental exposure, some pesticides persist in the indoor environment and are present in the air and dust in homes (Lu et al., 2013). Therefore even if pesticides are stored safely away from children, uninformed and indiscriminate application of pesticides can still put occupants' health, especially that of children (Tolosana et al., 2009), at risk. Troubling reports of child pesticide poisonings in low-income urban areas point to the high pest burden faced by residents, and perhaps the lack of knowledge on the appropriate use and storage of pesticides (Nalwanga & Sseempebwa, 2011) and the potential negative health effects they can cause. It is thus important to identify the ways in which homes in poor urban areas become pest-infested if the health problems, including poisonings, caused by pesticides are to be reduced.

In countries lacking tight regulation of pesticide sale and use, such as South Africa, there are additional worries about illegal pesticides available from unlicensed vendors (Rother, 2008). Illegal or street pesticides are easily available from informal markets and are sold in unlabelled packaging that lacks usage instruction and health and safety warnings (Rother, 2008). With up to 80% of poor urban households in South Africa using pesticides to control cockroaches and rats, using illegal pesticides is an attractive option due to their low cost compared to commercially available pesticides, their easy accessibility and their effectiveness due their high toxicity (Rother, 2008). What this review of the literature has revealed is that the deprived conditions under which poor urban residents live exposes them to pests and the health problems they cause, and that poverty-related factors are what facilitate pest infestations in low-socioeconomic urban areas.

4. GAPS IN LITERATURE

It is important that pest-reduction recommendations made for possible incorporation into poverty alleviation and urban health policies take into account the local context of the areas in which they are to be applied. However, many studies identifying on pest promoting factors low-income urban areas have been conducted in developed countries (Bradman et al., 2005; Wang et al., 2008; Pai et al., 2003; Peters et al., 2007; Rauh et al., 2002), with fewer conducted in developing countries (de Masi et al., 2009; Costa et al., 2014) and even fewer in sub-Saharan African context (Jassat et al., 2014; Kelly et al., 2013). Taking the local context into consideration is crucial since housing and environmental conditions in developed and developing countries differ in important ways. For example, while low-cost housing in in developed countries has indoor plumbing and sanitation, these amenities are often lacking in low-cost housing of developing countries (Govender et al., 2011b; Tshikotshi, 2009). Furthermore, most studies investigating housing conditions that facilitate pest infestation focused on the presence of one pest type in the home, disregarding that it is more common to find multiple types of pest in homes (Norris & Schroeder, 2005).

5. STUDY BACKGROUND, AIM, PURPOSE AND RESEARCH QUESTIONS

The observation data used in this study were part of a larger study (described in section 6). Survey observations were carried out concurrently with surveys (part of parent study) in selected households when the research team consisted of at least one research assistant trained in

Anthropology or Public Health qualitative research methods. Observations were conducted to identify and record home and environmental factors that could lead to pests gaining entry into the home. A copy of the Observation Guidelines can be found in Part D (Appendix A). This mini-thesis will present the analysis the observation data.

5.1 Aim

The aim of this study is to investigate the housing and environmental conditions, as well as residents' practices and behaviours that contribute to pest infestation in low-income urban communities.

5.2 Purpose

Findings from this study and the larger study it is a part of (described in Section 6) will be used to make recommendations on how pest infestation and its associated health problems, including child pesticide poisonings, can be reduced.

5.3 Research questions

5.3.1 Primary research question

What household and proximal environmental factors contribute to indoor pest infestations in two low socioeconomic urban residential areas in Cape Town?

5.3.2 Sub-questions

- 1) What housing factors lead to indoor pest infestation?
- 2) What observed practices and behaviours of household members contribute to pest infestation?
- 3) What environmental factors around the home are associated with pest infestation?
- 4) From informal conversations with household members, what economic impacts and health effects result from pest infestation?
- 5) What are the observable predictors and patterns of pesticide use within poor urban housing leading to increased exposure risks for household members, particularly children?

6. METHODS

6.1 Study design

The observation data used in this study were recorded during data collection of the larger study lead by Assoc. Prof. H-A. Rother in the School of Public Health and Family Medicine at the University of Cape Town. The study was conducted in 2009 in Khayelitsha and Philippi, two low socioeconomic urban communities of Cape Town. The study's aim was to identify common in-home pests, pesticide use and exposure patterns, and pesticide risk perceptions. A survey questionnaire was administered to households (N=199) by trained fieldworkers. The methods of the larger study included collection of hospital data from a tertiary children's hospital (Balme et al., 2010), interviews with street pesticide sellers (Rother, 2010), a rat trap intervention (Roomaney et al., 2012), and concurrent cross-sectional surveys and observations.

6.2 Study population and sampling

6.2.1 Study location

The study population consists of households in Philippi and Khayelitsha, large impoverished townships in the Cape Flats area of Cape Town. These townships were chosen for the study because many cases of childhood pesticide poisonings seen at the local tertiary children's hospital were from these areas (Balme et al., 2010). Both townships consist of both formal and informal housing. The following descriptions of the two areas are derived from the 2011 census.

Khayelitsha

The estimated population of Khayelitsha is about 391 749 (City of Cape Town 2011). The area is typical of low socioeconomic status (SES) areas with 36% of the population aged 20 or older with grade 12 education or higher, and an unemployment rate of 38 % in the working age group (15-64 years) (City of Cape Town 2011). Of those employed, 74% of households have a monthly income of R3 200 or less. Sixty-four percent of households have piped water in their dwelling or inside their yard, and 81% of households use electricity for lighting. Rubbish is collected at least once a week in 81% of households (City of Cape Town 2011).

Philippi

The estimated population of Philippi is about 191 025 (City of Cape Town 2011). Only 32% of those aged 20 or older have completed grade 12 or higher (City of Cape Town 2011). The unemployment rate in the 15-64 year age group, at 38% is similar to that of Khayelitsha (City of Cape Town 2011). Of those employed, 78% of households have a monthly income of R3 200 or less (City of Cape Town 2011). In this suburb 67% of households have access to piped water in their dwelling or inside their yard and 86% of households use electricity for lighting (City of Cape Town 2011). Eighty-four percent of households have rubbish removed at least once a week (City of Cape Town 2011).

6.2.2 Sampling Strategy

A sample size of 199 households, 100 in Philippi and 99 in Khayelitsha, was selected as a practical sample size without a formal sample size calculation. A systematic random sampling method was used for selecting households to include in the larger study including surveys. Every tenth house, for a total of 199 households, starting from community centres was included in the survey sample. There was no difference in the proportion of informal to formal house in two study areas: 55% and 56% of households in Khayelitsha and Philippi respectively live in informal dwellings (City of Cape Town 2011). A total of 50 household observations were conducted in households in Philippi (n=21) and Khayelitsha (n=29) when the fieldwork team consisted of at least one member trained in qualitative research methods. While systematic random sampling is better suited for the survey component of the study, having purposively selected Philippi and Khayelitsha for the high number of child pesticide poisonings from these areas, it is not expected that the sampling strategy will negatively affect findings from the observations. A sample of ten of the most comprehensive and detailed household observations were used to validate survey data. Such validation was useful if survey responses were not congruent with observable or objective occurrences. An example of this incongruence would be if rat droppings were visible in the house but a participant reported having no rat problem.

6.3 Data collection

Observations were conducted by research assistants trained in qualitative research methods who were either Anthropology or Public Health Master's students and fluent in one of the commonly spoken languages in the study areas: isiXhosa, Afrikaans or English. Research assistants worked

in pairs; one collected survey data while the other recorded observations using the Observation Guidelines (Part D). Research assistants were trained on how to follow and administer the Observation Guidelines, what things to look for and on drawing pictures to represent observations. Data was collected in the presence of the head of the household or any adult (18 years and older) who was present at the home. Informal conversations pertinent to the aims of the study held by the research team with household members were also documented. Although not set out as a data collection method in the Observation Guidelines, some fieldworkers took the initiative to include hand drawn schematics illustrating the layout of houses in plots. Handwritten observations were later transcribed to Microsoft Word documents. Research assistants were provided with pesticide charts for identification of pesticides that household members used. Observations were made of factors that could influence pests entering the home, places where pesticides were used and kept and potential exposures. The proximity of neighbouring houses and factors about the surrounding environment that might influence pests entering the home were also documented. The proximity refuse disposal sites, both formal (landfills) and informal were documented as well.

6.4 Potential limitations

The study is limited in that it uses data from an already completed study, and may leave out observations that were documented but are no longer available. The guidelines for the observations were also set before the proposal of the mini-thesis. The household observations were handwritten, and some of the writing was illegible so the typed out transcriptions may miss out some information. The observation transcripts identify cases where the observations were not fully legible. However, it is not expected that a few missing words will affect the analysis and findings, since it is still possible to make out the meaning of the data. Although fieldworkers were trained in the use of the Observations Guidelines, different fieldworkers had different styles of documenting with some observations being detailed and comprehensive while others are cursory.

6.5 Data management and analysis

Qualitative analysis will be used to analyse the data collected for this study. Since the study is context specific, the goal is to describe rather than to quantify phenomena or make universal generalizations (Schutt, 2012). Qualitative data analysis is suitable for this study since it allows

for a holistic analysis of a broad-spectrum of non-quantitative data. By using thematic analysis, the “method for identifying, analysing, and reporting patterns (themes) within data” (Braun & Clarke, 2006) broad patterns or themes inherent in the data will be identified and this will help in answering the study questions.

6.5.1 Data management

Anonymised observation data, saved into Microsoft Word documents were obtained from the Principal Investigator, A/Prof H-A. Rother. Data from the two sites, Philippi and Khayelitsha were saved separately into different folders. Observation data will be imported into QSR International’s (2012) NVivo 10 qualitative data analysis computer software. Observations were documented in English, with translations noted where participants used Xhosa or Afrikaans words in informal conversations.

6.5.2 Data analysis

The study’s aim and literature provided broad conceptual frameworks within which the data will be nested. However, to develop the themes of study sub-questions (section 5.3.2), initial analytical categories will be drawn from the observation data and preliminary literature review. Since familiarisation with data is an important first step in any qualitative data analysis (Ritchie & Lewis, 2003), all the observation data will be read in order to engage with them and to start to recognize patterns and recurrence of concepts and themes. In this preliminary stage, inductive coding, that is, using codes that emerge from the data rather than from conceptual frameworks will be used (Miles et al., 2014). During the familiarisation stage data will be read for content, quality and pattern recognition (Ulin et al., 2005). Similar data will be grouped into parent nodes in NVivo. Parent nodes will be further split into child nodes (subnodes) if there are hierarchical or interrelationships within categories. Simultaneous coding or coding single qualitative datum into different codes (Miles et al., 2014) will be applied as necessary. Analysis of data not included in preliminary stage of analysis will be carried out after initial code development has been done. As coding and analysis are iterative in nature, the coding scheme evolves over time (Miles et al., 2014; Ulin et al., 2005) and therefore coding will be revised as necessary. Some codes may be added, discarded or reworded or redefined as new data is read.

Once all data has been coded, similar codes will be grouped together into what will become themes. Grouping similar codes in this manner to form themes will be useful in identifying

recurrent concepts and making links between these concepts. Themes developed from collation of codes will then be analysed in context of the data and in relation to existing literature. Emerging themes will be compared to those identified in the literature and to concepts of social and environmental justice theories as well as to the health locus of control theory. The questions in the Observation Guidelines did not set out to identify data relating to the locus of control theory, but its importance emerged from the literature review and informal conversations had with participants. Negative or atypical cases will be identified by applying constant comparative analysis. This will help in identification and interrogation of data that deviates from emerging themes and commonalities. Identifying negative cases may also provide new avenues for analysis or may be a trigger for new research enquiry. Just like the coding process, the thematic analysis process too will be refined over time as the author immerses herself deeper into the data. Analysis will be refined by moving cyclically from data description to data explanations, and back to data descriptions to validate the data explanations (Hennink et al., 2011). Following this iterative process will not only refine the analysis, but will also be also useful in identifying and filling in gaps.

7. ETHICAL CONSIDERATIONS

All study participants were informed of the study purposes in one of three languages: isiXhosa, Afrikaans or English. Fieldworkers who conducted the observations were conversant in the language(s) spoken by study participants. Study participants were informed of the voluntary nature of participation and were given consent forms to sign (Part D). They were also informed that they were free to withdraw their consent at any time for any reason. Participants were further informed that all data collected would be kept confidential and that individual participants would not be identifiable from any published work. While the consent forms given to participants stated that no harm was expected to arise from participating in the study, it is possible that some participants could have felt ashamed and embarrassed by the presence of pests and pest facilitating conditions in their homes.

As part of the larger study, participants received some benefit as they received training on pesticides safety and two rat traps per household. The rat traps given were part of a rat trap acceptability study, a study separate from the current one, and is discussed elsewhere (Roomaney

et al., 2012). In the long-term it is expected that lessons learnt and findings from the study will be used to make recommendations to urban planners and policy makers as well as municipal service providers in Khayelitsha and Philippi. These recommendations would help guide these stakeholders on how to design or improve existing programs and services in order to reduce the problem of pest infestation and their associated problems.

The study was granted ethics approval by the University of Cape Town Human Research Ethics Committee (REC REF: 222/2007) on May 7, 2007. The ethics approval letter can be found in Part D, Appendix C. All information that can be used to identify participants, such as household addresses, will be removed from the data and will not form part of analysis.

8. TIME SCHEDULE

Tasks	2015									
	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	
Planning										
Literature review										
Protocol development										
Submit protocol to supervisor and Ethics Review Committee										
Extended literature review										
Analysis and Write up										
Data analysis										
Write up, submit sections to supervisor										
Submit thesis to UCT										
Final submission deadline if August deadline not met										

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PART B: LITERATURE REVIEW

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1. INTRODUCTION AND OBJECTIVES OF LITERATURE REVIEW

Urban pests pose an increasing public health problem, particularly for low-income communities (Bonney et al., 2008). The presence of pests in homes poses significant health risks as many pests can directly or indirectly transmit diseases (Adamkiewicz et al., 2011; Bonney et al., 2008). In addition to transmitting disease, pest infestations can also negatively impact on the mental health of affected residents (Susser et al., 2012). Some factors identified in the literature that facilitate pest infestation and proliferation in homes include housing structure, the surrounding environment, as well as residents' hygiene and cleanliness behaviour (de Masi et al., 2009; Rauh et al., 2002). To control pests, residents in low-socioeconomic urban areas commonly use pesticides, both commercially available (Kibuule & Kagoya, 2015; Nalwanga & Ssempebwa, 2011; Tolosana et al., 2009) and illegal pesticides (Rother, 2010b; Saller et al., 2007). The concern is that exposure to pesticides poses potential acute and chronic health risks for residents (Balme et al., 2010; De Silva et al., 2006; Konradsen et al., 2003; Sengupta & Banerjee, 2014). Poor urban residents are thus faced with the threat of a double health burden from pests and pesticide exposure. In order to reduce this double health burden, the factors promoting pest infestation and pesticide use first need to be understood.

Poverty, coupled with rapid urbanization in developing countries creates conditions for sub-standard housing and surrounding environments that are conducive for pest infestation (Roomaney et al., 2012; Rother, 2008; Rother, 2010a). Like many developing countries, South Africa is also experiencing rapid urbanization. However, many conditions that favour pest infestation in low-income urban areas in South Africa were fuelled by apartheid policies (Lemanski, 2009). This mini-thesis investigated the housing and environmental factors, as well as residents' practices and behaviours, which contribute to pest infestation in two low-income urban communities of South Africa in order to make recommendations for urban health policies with a focus on reducing pests and pesticide use. The following literature review provides the contextual issues for understanding the complexity of issues linked to pest infestation, including the physical and mental health impacts of pest infestation. Alternative non-toxic pest control measures are critically evaluated to assess their potential applicability and effectiveness in low-income settings in developing countries. The literature review ends with identifying gaps in research on pest infestation in impoverished urban areas. The objectives of the literature review were:

- to identify poverty-related factors that facilitate pest infestation in urban areas;
- to identify the physical and mental health effects of living with pests;
- to examine the extent of pesticide use in low-income urban areas, particularly in sub-Saharan Africa and to document their associated health effects; and
- to critically evaluate current research on alternative non-toxic pest control methods relevant for low-socioeconomic urban communities

2. SEARCH STRATEGY

The following search strategy was used to inform this literature review:

Strategy: Relevant search engines were used to search for terms relating to the topic. The reference lists of identified articles were scanned and manually searched to look for relevant articles and reports with related subject matter. Both qualitative and quantitative studies were included in the review. Relevant reports and publications from organizations such as the World Health Organization and the Housing Development Agency, and informal material, such as newspaper articles, were also considered.

Search engines:

EBSCOhost (including Africa-Wide Information), Science Direct, PubMed, JSTOR and Google Scholar

Inclusion criteria: Studies conducted on pesticide use in low-income areas; studies on health effects of pesticides; studies on non-toxic pest control methods; housing; housing conditions; and studies on pest control interventions focused on housing, environment and behaviour;

Exclusion criteria: Studies on agricultural pests; studies on lab testing of pesticides; and articles not in English.

Search terms included:

- **Pests and health:** pest infestation, disease-vector, cockroaches, rats, mice, fleas, bed bugs, flies, stigma, mental/psychological health, disease, health effects

- **Poverty:** low-income, poor, socioeconomically disadvantaged, inner-city, slums, developing countries, African countries; low and middle income countries, informal housing
- **Pesticides and health:** hazardous pesticides, exposure, domestic use, health, illegal street pesticides, acute toxicity, chronic toxicity, poisoning, persistent pesticides, commercial pesticides
- **Pest reduction interventions:** pest control, interventions, integrated pest management, housing improvement, environmental management, community participation

3. SUMMARY OF THE LITERATURE REVIEW

3.1 Poverty-related factors facilitating pest infestation

3.1.1 Substandard housing

Structural defects in housing such as cracks in walls and ceilings, poor quality building material, damp and mould, have been found to be associated with the likelihood of cockroach and rodent infestations in impoverished urban areas both developed and developing countries of developed countries (Adamkiewicz et al., 2011; Jassat et al., 2013; Pai et al., 2003; Rauh et al., 2002; Srinivasan et al., 2003). The extent of pest infestation appears to be directly related to the extent of dilapidation in the structure of the dwelling as suggested by a study by Narsai et al., (2013). The study identified housing problems and investigated perceived housing satisfaction among residents (N=300) of four low socioeconomic status (SES) housing typologies in Durban, South Africa. It was found that dissatisfaction with pest infestation was greater among dwellers of informal settlements (96%, n=75) compared to residents of government subsidised housing (84%, n=75), traditional rural housing (84%, n=75) and inner-city apartments (81%, n=75). This finding suggests that structural defects in shacks, the predominant housing type informal settlements, make them more prone to pest infestation than do structural defects in other housing types. These conditions are favourable to pests as they provide access to shelter, food and nesting places.

Pests common in poor urban areas include rats, mice, flies, cockroaches, fleas, mosquitoes, bed bugs and ants (Bonney et al., 2008; Tolosana et al., 2009). These pests, prevalent in many

deprived urban areas partly as a consequence of dilapidated housing, pose a potential risk to health due to the adverse health effects that cause (Adamkiewicz et al., 2011). While the state of housing disrepair common in poverty stricken urban areas has long been recognized to negatively affect the health outcomes of residents (Arku et al., 2011; Herrin et al., 2013; Montgomery & Hewett 2005; Narsai et al., 2013), the impact that exposures to urban pests have on health has been a missing component in health research in developing countries.

3.1.2 Unsanitary environments

Environmental factors such as piles of solid waste, poor drainage, and lack of basic services (e.g. water and toilets), common in poor urban areas of developing countries, are conducive to harbourage of pests (Costa et al., 2014; Muoki et al., 2008; Kelly et al., 2013).

Many cities in developing countries have poor waste disposal services and dumping in open spaces is common (Govender et al., 2011; Jassat et al., 2013; Tadesse et al., 2008). For example, Tadesse et al. (2008) found that in Mekelle, Ethiopia, a city with 47, 000 households, there were only 58 municipality-supplied waste disposal containers, which were often overflowing with rubbish as they were not regularly collected. In a study of 419 households in five low SES neighbourhoods of Johannesburg, South Africa, Jassat et al. (2013) found that houses that did not have a waste container inside the house had a significantly higher prevalence of rats (67%) compared to houses with waste containers inside the house (50%). Furthermore, the lowest income levels were found to be significantly associated with an increased rodent infestation. While the study analysed numerous socioeconomic and environmental factors, the authors did not consider potential confounders that could affect the results such as proximity of homes to open-air food vendors.

Similarly, a survey by Govender et al. (2011) found that 68% of subsidised houses (N=336) in a Cape Town neighbourhood did not have waste containers inside the house, with up to 18% of respondents in these households reporting disposing of excreta and soiled diapers on the streets and in storm drains. While Govender et al. (2011) did not report on pest infestation, the environmental conditions that they found in the areas surveyed are favourable for pest infestation. Inappropriate disposal of waste in open space or waterways or storing in the home not only increased the frequency of pests, it also increased the risk of pest borne diseases. Boadi

and Kuitunen (2005), for example, found that keeping waste in the home or disposing of it in open space was associated with the presence of flies in the homes, which in turn put children at increased risk of diarrhoeal disease.

3.1.3 Poverty as a barrier to pest control

The socioeconomic status of residents of low-income areas limits their pest control options. For one, residents are not likely to be able to afford the high costs of professional pest extermination (Chaudhuri 2004; Eddy & Jones 2011; German & Latkin, 2014). Furthermore, for the 35% of residents in urban South Africa who are tenants rather than owners of the houses they occupy (Rust, 2006), their agency in what they can do to control pests may be diminished. For example, if landlords are not responsive to complaints and requests for pest control or to fix structural defects that provide access to pests, residents are forced to live in homes overrun with pests running a high risk of exposures to negative pest-related health impacts. A further 12% of urban South African residents who are squatters in informal settlements (Rust, 2006) also face harsh living conditions in squalid housing and degraded environments. These conditions combined with poverty and lack of tenure security experienced by residents in informal settlements (Narsai et al., 2013) greatly reduces the agency of informal settlement residents in what they are able to do to control pests. Faced with poverty, residents of informal settlements may be struggling with much more pressing issues such as ensuring adequate food, shelter, water and fuel such that pest control is low on their priority lists. Such lack of control over one's living environment can in itself negatively affect the health of residents (Evans et al., 2003; Suglia et al., 2011).

3.2 Health effects of pests

3.2.1 Physical health effects

The presence of pests in homes is a cause for concern since they can directly or indirectly transmit diseases, can be a source of annoyance, as well as lead to social stigma. Health problems caused by pests can be due to pathogens they transmit or skin lesions caused by bites. Flies and cockroaches carry numerous pathogens both internally and on their external body surfaces (Tatfeng et al., 2005; Förster et al., 2007). In Accra, Ghana, Boadi and Kuitunen (2005) found a positive correlation between the presence of flies in homes and incidences of diarrhoea in children less than six years of age. Furthermore, cockroach and mouse allergens found in excreta and external surfaces of these pests have been implicated in asthma, which

disproportionately affects residents of lower-income communities, where conditions that promote pest infestation are prevalent (Chew et al., 2006; Peters et al., 2007; Wang et al., 2008).

Rodents are known to be direct vectors for a range of diseases including leptospirosis, Lassa fever, haemorrhagic fever and rat bite fever (Begon 2003; Costa et al., 2014; Elliott, 2007; Goeijenbier et al., 2013). Bites from fleas that parasitize rodents can transmit bubonic plague and murine typhus (Amatre et al., 2009; Civen & Ngo, 2008; Stenseth et al., 2008). Bed bugs also carry health risks as their bites can cause systemic allergic reactions, as well as cutaneous lesions that may become secondarily infected by bacteria (Goddard & de Shazo, 2012; Fletcher et al., 2002; Leaderer et al., 2002; Thomas et al., 2004). For a long time, bed bugs were known to become infected with various pathogens including hepatitis B virus, acquired in laboratory settings, but they had never been shown to be disease vectors (Delaunay et al., 2011; Goddard & de Shazo, 2012; Jupp et al., 1991) until recently in a study where Salazar et al. (2015) showed that bed bugs experimentally infected with *Trypanosoma cruzi*, the Chagas disease-causing parasite, could transmit the parasite to uninfected mice. This new finding suggests that bed bugs may potentially be competent disease vectors. While urban pests are known to transmit diseases of human importance or cause other ill-health effects, there is a lack of rigorous epidemiological studies for urban pests not considered a public health priority.

3.2.2 Mental health effects

In addition to risks of physical ill-health effects, some pests can potentially have an adverse effect on mental health. For example, in a longitudinal study on the impact of infestation on well-being in low-income residents in Waterbury, Connecticut, USA Zahner et al. (1985) found that respondents whose homes were infested with one or more type of pest (i.e. mice, rats or cockroaches) reported experiencing anxiety-provoked psychophysiological symptoms such as dizziness, sweaty palms and headaches. Strikingly, over the three years the study was conducted, respondents who reported decreasing levels of infestation in their homes also reported experiencing fewer psychophysiological symptoms. Similar to the study by Zahner et al. (1985), German and Latkin (2014) found that even after controlling for confounding factors, residents in a low-income area of Baltimore City, USA with high rat prevalence were 63% more likely to report high depressive symptoms compared to residents in neighbourhoods with a lower rat prevalence. While these studies do not report on or account for possibly pre-existing

psychological disorders among participants, there exists extensive evidence that suggests that pest infestation can contribute to mental distress.

Perhaps the pest known to elicit the most severe forms of psychological effects is the bed bug (Burrows et al., 2013; Goddard & de Shazo, 2012; Rieder et al., 2012; Susser et al., 2012). With the global resurgence of bed bugs (Potter et al., 2010), there is increasing evidence of the mental health effects of these infestations. To start off with, bed bugs have been erroneously associated with poor housekeeping and hygiene habits, a perception that has been disproved but still persists (Doggett et al., 2012). Residents of low-income urban areas, whose houses are commonly small in size and in a dilapidated state, two conditions that have been reported to make thorough cleaning difficult (Govender et al., 2011; Srinivasan et al., 2003), are likely to be affected by this misconception. The fear of social stigmatisation may lead to affected residents isolating themselves, in order to avoid ridicule and/or spreading the infestation to others (Doggett et al., 2012; Rieder et al., 2012).

Additionally, the nocturnal feeding activity of bed bugs can result in hypervigilance leading to insomnia, anxiety, nightmares, and possibly depression (Goddard & de Shazo, 2012; Susser et al., 2012). Goddard and de Shazo (2012) concluded that in some individuals, symptoms caused by bed bugs which may also include flashbacks of infestation and personal dysfunction can resemble those of posttraumatic stress disorder. Gbakima et al. (2002) also concluded that rampant bed bug infestations in camps for internally displaced people in Freetown, Sierra Leone, were compounding the stress experienced by residents due to trauma of the civil war. The housing conditions in the camps built with sticks and tarpaulin, with an average of six family members per four square metre room (Gbakima et al., 2002), are comparable to housing conditions found in low-income housing and informal settlements in other sub-Saharan African cities where overcrowding and poor quality building materials are common (Govender et al., 2011; Kibuule & Kagoya, 2015; Yakubu et al., 2014). Psychological effects resulting from bed bug infestation are heightened in people who are predisposed or have existing mental disorders (Burrows et al., 2013; Rieder et al., 2012) and can have disastrous consequences (Burrows et al., 2013).

The literature reviewed in this section does not show the true extent of the association of bed bug infestation and mental health problems as there is little empirical evidence. The papers by

Burrows et al. (2013) and Rieder et al. (2012) are case reports and therefore exclude people who may have experienced bed bug induced mental health problems but did not seek medical attention. Furthermore, only few original research studies have been conducted on the topic and all of them are relatively recent (Gbakima et al., 2002; Goddard & de Shazo, 2012; Susser et al., 2012). More research is needed to investigate the impact of bed bugs on mental health.

3.3 Pesticide use in low-income urban areas

With pest infestation being a pervasive problem in poor urban areas, residents usually rely on pesticides, which are easily accessible, for pest control and elimination. The use of pesticides, both observed and reported, as well as exposure to hazardous pesticides in low-income urban areas is well documented. In a study on household pesticide exposures in children in South Africa, Tolosana et al. (2009) found that 89% (n=61) of children from informal settlements were exposed to pesticides. This is a much higher exposure rate compared to 78% in children from urban areas (n=292) and 63% in children from rural areas (n=387). Similarly, a study on pesticide use and storage patterns in households with children in Minnesota, USA found that 88% (N=308) of households with varied income levels reported using pesticides (Adgate et al., 2000). Another study in Iran found that 97% (N= 482) of urban respondents used pesticides (Dehghani et al., 2013). With the combination of poverty-related factors such as dilapidated housing and inadequate sanitation that impact on pest infestation and the wide availability pesticides, it is unsurprising that residents in low socioeconomic urban communities often use more and spend more on pest control than households in higher socioeconomic communities (Thomas et al., 2001).

In many developing countries with poor or no pesticide regulation and enforcement, highly toxic pesticides that have been banned or severely restricted in developed countries are available for household use (World Health Organization, 2010a). South Africa, for example, is still using the outdated and poorly enforced Fertilisers, Farm Feeds, Agricultural Remedies and Stock Remedies Act of 1947 (Rother, 2010a), but is currently in the process of formulating new pesticide regulation legislation following the adoption of the Pesticide Management Policy in 2010. The lack adequate enforcement of pesticide control laws adversely affects low-income urban residents, as is the case in South Africa where informal markets are awash with illegal

street pesticides (highly hazardous pesticides that are only registered for agricultural use but are informally sold for household use) (Rother, 2010a).

Illegal street pesticides, which are decanted and repackaged into unlabelled containers and sold in informal markets for in-home use (Kibuule & Kagoya, 2015; Rother, 2008; Rother, 2010b) are often highly toxic, hence their effectiveness in killing pests (Rother, 2010b). For instance, in South Africa commonly available illegal street pesticides include the organophosphates chlorpyrifos (class II) and methamidophos (class Ib), as well as aldicarb, a highly toxic WHO class Ia carbamate (Rother, 2010a). However, illegal street pesticides are not unique to developing countries. Even in countries with stringent pesticide regulations such as the USA, low-income urban residents can still have access to highly hazardous and banned pesticides (Saller et al., 2007; Vates & Osterhoudt, 2008). Indoor use of highly hazardous illegal street pesticides is a serious health concern. When used indoors they degrade much more slowly than when used outdoors where physicochemical reactions occur to facilitate degradation (Dehghani et al., 2013; Saller et al., 2007). The availability of highly hazardous pesticide is not restricted to the black market. In South Africa, for instance, Tolosana et al. (2009) found that informal urban settlements had higher use of the commercially available rodenticide *Rattex* (difethialone), which is classified by WHO as an extremely hazardous pesticide (class Ia) (World Health Organization, 2010b) compared to rural and formal urban settlements.

Other commonly used pesticides in low-income urban areas are classified as moderately hazardous. In poor urban areas of Uganda, for example, diazinon, a moderately hazardous organophosphate (class II) (World Health Organization, 2010b) banned in many developed countries, was found to be a commonly used for insect control (Kibuule & Kagoya, 2015; Nalwanga & Ssempebwa, 2011). Many commonly used commercially available pesticides such as *Doom* (Tolosana et al., 2009), *Raid* and *Combat* (Saller et al., 2007) which contain pyrethroid as the active ingredient are also classified as moderately hazardous or class II (World Health Organization, 2010b). However, with prolonged and concurrent exposures, even moderately hazardous pesticides can have additive or synergistic effects that are harmful to health (Das et al., 2007; Belden & Lydy, 2000; Hernández et al., 2013; Zeliger, 2008). With many low-income urban residents in developing countries reporting using multiple pesticides (Dehghani et al.,

2013; Loroño-Pino et al., 2014; Nalwanga & Ssempebwa, 2011; Tolosana et al., 2009), awareness of the possible of amplified health effects of pesticides is important.

3.4 Pesticides and health

Exposures to pesticides place residents at risk of a number of adverse health effects, both acute toxicity and chronic health effects. The manifestations of symptoms following pesticide exposure can vary in severity and onset depending on the exposure route, mode of action, class and physicochemical properties of the pesticide (Kwong, 2002; Leibson & Lifshitz, 2008). Symptoms of acute pesticide poisoning occur within 24 hours of exposure and can include dizziness, vomiting, blurred vision and wheezing (Alarcon et al., 2005; Balme et al., 2010; Konradsen et al., 2003). Chronic toxicity can be manifested months or even years after an episode of acute pesticide exposure or as a result of chronic low-dose exposure (De Silva et al., 2006). Health effects associated with chronic pesticide exposure include various types of cancers (Bassil et al., 2007; Rudant et al., 2007), neurological impairments and diseases (Kofman et al., 2006; Peiris-John et al., 2002; Sanborn et al., 2007), low birth weight and preterm births (Sanborn et al., 2007; Whyatt et al., 2003). While most studies on the health effects of chronic pesticide poisoning come from agricultural and occupational exposures (De Silva et al., 2006; Ecobichon, 2001; Kesavachandran et al., 2009), they are relevant to urban residents because of the availability of illegal street pesticides and low-level chronic exposure which results from the longer persistence of pesticide residues when used indoors (Dehghani et al., 2013; Saller et al., 2007).

Children are at a particularly higher risk of adverse health effects resulting from pesticide exposure. Their immature physiology, hand-to-mouth behaviour, and larger skin surface areas compared to adults, make them more vulnerable than adults to the harmful health effects of pesticides (Garry, 2004; Tolosana et al., 2009). A meta-analysis by Chen et al. (2015) found that low-level chronic exposure to residential pesticides increases the likelihood of childhood hematopoietic and lymphoid cancers. Children with chronic pesticide exposure also have an increased risk of cognitive and neurodevelopmental impairments and impairments in reproductive development and physiology (Bretveld et al., 2006; English et al., 2012; Kofman et al., 2006; Sanborn et al., 2007). The increased vulnerability of children, coupled with the ease of availability of illegal street pesticides in impoverished urban areas, may explain the high

numbers of acute pesticide poisoning cases seen at a tertiary paediatric hospital in Cape Town (Balme et al., 2010).

The risk of chronic and life-threatening diseases due to pesticide exposure should be of concern to governments and health departments of sub-Saharan African countries. With many health systems in the region already struggling to cope with an increase in non-communicable diseases due to changes in lifestyles and epidemiologic transitions (Baingana & Bos, 2006; Dalal et al., 2011), pesticide-induced adverse health effects may intensify this burden. With the varied health risks posed by both pests and pesticide exposures, alternative pest control methods are desirable in low-income communities in order to reduce the impact of this double health burden.

3.5 Alternative pest control methods

With the known health risks, environmental persistence and resistance of pesticides, alternative pest control measures such as rat traps (Roomaney et al., 2012) are increasingly being advocated as more suitable and effective means for pest control. Perhaps the most well-known environmentally friendly and sustainable method for pest control is integrated pest management (IPM), a holistic approach that uses biologic, chemical, environmental and behavioural-cultural methods to control pests (Ehler, 2006; Sandler, 2010). IPM also uses a combination of knowledge about the pest's life cycle, sanitation, education in nontoxic pest control methods, structural repairs and maintenance, and sparing application of the least-toxic pesticides as a last resort measure (Brenner et al., 2003; Krieger et al., 2010). It is a strategy most widely used to control agricultural pests and reduce pesticide poisoning of agricultural workers (Mancini et al., 2009), but because of its adaptability and effectiveness (Sandler, 2010), it has been adopted as a public health measure to control vector-borne diseases and urban pests (Kass et al., 2009; Okech et al., 2008).

Studies that have evaluated the effectiveness of IPM, mostly conducted in developed countries, have found it to be an effective, environmentally sound and sustainable method for pest control in low-income urban areas (Kass et al., 2009; Krieger et al., 2010; McConnell et al., 2005; Wang & Bennett, 2006; Williams et al., 2006). For example, in an intervention trial in New York City, Brenner et al. (2003) compared the levels of cockroach infestation in intervention and control households. Intervention households received tailored IPM programs from researchers, community health centres and health educators consisting of instruction on non-chemical

approaches to pest control, better housekeeping and sanitation, and repair services to housing structure. At six month follow up, 40% fewer intervention households had cockroach infestations while there was no change in the rate of infestation in control households. Studies have also found that even though IPM and other alternative pest control methods can have high initial costs, in the long-term they can be more cost-effective compared to traditional pesticide application-based control methods (Brenner et al., 2003; Roomaney et al., 2012; Wang & Bennett, 2006). By reducing pesticide use, alternative pest control methods can also potentially reduce residents' exposure to pesticides (Kass et al., 2009).

Even though IPM has been found to be successful in low-income urban areas of developed countries, follow-up has been limited and has not continued beyond the study period, usually six months and therefore no knowledge exists on whether IPM benefits persist long-term. Additionally, most of these studies only delivered IPM in selected apartments, ignoring adjacent or neighbouring apartments. Such an oversight may mean that environments were not modified as well as they could have been, and thus the results are not a true reflection of what basing the intervention at building or at community level could achieve. The study by Kass et al., (2009) was an exception to this shortcoming as it adopted a different approach by delivering IPM to whole apartment buildings, which is integral to environmental modification as an IPM method, regardless of participating households. As with all IPM strategies such a large scale approach requires community buy-in and participation (Brenner et al., 2003; Scammell et al., 2011). With lack of collective participation being cited as one of the hindrances to adoption of IPM in agriculture in developing countries, a sector where it is most popularly used (Parsa et al., 2014), it is of little wonder then that no studies could be found on the application of IPM in low-income urban areas of developing countries. Alternative pest control methods, including IPM, need community participation and the participation of various stakeholders including non-governmental organizations and national and local government departments, requirements also pointed out by Roomaney et al. (2012) as necessary for the successful implementation of a rat trap intervention to reduce the use of highly toxic illegal street pesticides.

While IPM has had limited application in low-income urban areas of developing countries, integrated vector management (IVM), a strategy aimed at the control of disease vectors, has been

successfully used especially in malaria endemic areas (Chanda et al., 2008; Okech et al., 2008). The successful implementation of IVM in developing countries can be linked to IVM being targeted at notifiable vector-borne diseases that are considered emergencies (Ehrenberg & Ault, 2005), thereby garnering concerted control efforts from governments and non-governmental organizations alike. However, with many developing countries facing much more pressing health issues, such as the quadruple burden of disease that South Africa is facing due to communicable, non-communicable, perinatal and maternal, and injury-related disorders (Mayosi et al., 2009), control efforts of urban pests not linked to epidemiological emergencies are not a priority for the health sector (Ehrenberg & Ault, 2005). Furthermore, as Biehler and Simon (2010) argued, the indoor environment is not taken seriously as a space for political engagement, but is rather perceived as the private responsibility of inhabitants. With indoor residential environments thus neglected by health and housing authorities, low-income urban residents, who are likely to be powerless and marginalised, are left to fend off pest infestations on their own. Therefore, unless a major shift in political will and public health prioritisation occurs, IPM and IVM are unlikely to be given priority as pest control measures in low-socioeconomic urban areas of developing countries.

4. GAPS IN LITERATURE

Several studies have examined housing, environmental and socioeconomic conditions that promote pest infestation in low-income urban areas (Costa et al., 2014; de Masi et al., 2009; Jassat et al., 2013; Pai et al., 2003; Rauh et al., 2002). Many such studies have been conducted in developed countries (Bradman et al., 2005; Chew et al., 2006; Childs et al., 1998; Pai et al., 2003; Peters et al., 2007; Wang et al., 2008), with fewer studies conducted in developing countries (de Masi et al., 2009; Costa et al., 2014) and particularly in South Africa (Jassat et al., 2013; Rother, 2008). Most of these studies have focused on one pest type, with rodents being the most studied in poor urban areas of both developed (Childs et al., 1998; Pai et al., 2003) and developing countries (Costa et al., 2014; de Masi et al., 2009; Jassat et al., 2013). Focus on one pest type does not present the full extent of the health burden that pests are to urban residents of low SES since in practice pests do not usually occur in isolation (Norris & Schroeder, 2005). The few studies that have identified factors that promote infestation by multiple pest types have been conducted in developed countries (Bradman et al., 2005; Chew et al., 2006; Wang et al., 2008). Similar studies are lacking in developing countries. The lack of studies may indicate that pest

infestations in poor urban areas of developing countries are of low priority for governments and health departments. This neglect may be because the negative health consequences of urban pests in low-socioeconomic areas that are not vectors for notifiable diseases are not considered emergencies, important or documented (Ehrenberg & Ault, 2005). Thus, it follows that with urban pests being low on the agenda of health departments and governments of developing countries, there is also lack of studies on the health impact that exposure to urban pests has on low-income urban residents in these countries.

While some of the conditions found to be factors in promoting pest infestation in low-income urban areas of developed countries, such as deteriorated housing (Bradman et al., 2005; Pai et al., 2003; Rauh et al., 2002) may occur in developing countries as well, conditions in developed and developing countries are not comparable. To highlight differences, low-cost urban housing in developed countries has indoor plumbing and sanitation while such facilities are often times lacking in impoverished urban communities in developing countries (Govender et al., 2011; Lemanski, 2009; Narsai et al., 2013).

The findings of this study will contribute to the literature on pest infestation risk factors that are unique to low-income urban areas of developing countries. Furthermore, this study, aims to add knowledge to the field of urban and environmental health research by using qualitative research methods to examine factors in the home, environment and residents' behaviour that might influence not just one or two pest types, but all pest types found in homes in low-socioeconomic urban communities in a sub-Saharan African context. Having this knowledge will be crucial in formulating suitable and context-specific recommendations on how to tackle the problem of pest infestations and thus the health problems associated with pesticide exposure in low-income urban areas of South Africa and other sub-Saharan African countries.

5. NEEDS FOR FURTHER RESEARCH

In developing countries, particularly in sub-Saharan Africa, there are limited studies on the health problems caused by pesticide residue in homes. Many studies on pesticide use have been conducted in agricultural and occupational settings in both developing and developed countries. However, studies on home pesticide use and residue presence have mostly been conducted in

developed countries. There is therefore a need to study the health impacts of pests and pesticide residue presence in low-socioeconomic urban areas of developing countries.

There have also been few studies conducted in impoverished urban areas of developing countries looking at the association of urban pests with physical health problems (Boadi & Kuitunen 2005; Rother 2008). For example, studies in the USA have shown an association between exposure to cockroach allergens and high prevalence of childhood asthma and allergies in low-income urban communities (Chew et al., 2006; Wang et al., 2008). While identified health risks such as asthma may hold true for developing countries, the different stages of health transitions, for example the quadruple burden of disease in South Africa (Mayosi et al., 2009), may change the trajectory of health outcomes due to pests and pesticides. This calls for context-specific studies that will investigate the link between urban pests and health problems in sub-Saharan Africa.

There is also lack of studies on the mental health problems caused by pests in low-socioeconomic urban communities of developing countries. Pest infestations, particularly bed bug infestations, have been shown to be a cause for mental distress in low-income urban residents in developed countries (German & Latkin, 2014; Susser et al., 2012). However, to the knowledge of the author there have been no studies on the association of mental health problems with pest infestations in poor urban areas of sub-Saharan Africa. Since mental health has a low public health priority in many developing countries, it would be important to examine if pest infestations have any effect on mental health of poor urban residents in developing countries. Differences in cultural beliefs and knowledge, which may impact on mental health differently between developed and developing countries, also warrant studies examining this topic.

Lastly, while IPM has been shown to be a promising alternative to pest control in urban areas of developed countries (Brenner et al., 2003; Kass et al., 2009), it has not been given much consideration in poor urban areas of developing countries. With the potential to lower pest infestation and pesticide exposure, there is great need for research studies to investigate whether IPM can be a viable pest control alternative in urban areas of developing countries.

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PART C: JOURNAL ARTICLE

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Pest infestation in two low-income urban communities of Cape Town, South Africa: an observational study¹

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Abstract

Background: Pest infestation and their associated health problems disproportionately impact on the well-being of residents of low-income urban areas. The relatively high use of pesticides to control these pests also negatively affects health, especially that of children. Exposure to pesticides can cause acute health problems such as headaches and blurred vision, as well as chronic health problems such as cancers and reproductive disorders. The aim of this study was to identify factors that are likely to facilitate pest infestation and residents' practices regarding pesticide use in low-income urban areas in order to make recommendations for urban health policies that will reduce pests and pesticide use.

Methods: Household observations (N=50) and informal conversations with household members were conducted in Khayelitsha (n=29) and Philippi (n=21), two low-income communities in Cape Town, South Africa. An observation guide was developed to investigate factors in the housing infrastructure, and environment, as well as to document pesticide use patterns and exposure to toxic pesticides. Data were analysed using a thematic analysis approach.

Results: Households in the study areas were found to have a high pest burden from multiple pests. Participants indicated health problems and material losses caused by pests as factors that negatively impacted on their lives. Many participants used toxic pesticides bought in informal markets to control pests in their homes. The main factors identified as potential facilitators of pest infestation were housing disrepair, an unsanitary environment, and lack of water and

¹ For submission to BMC Public Health- see Appendix D for instructions for authors. For readability, lines have not been numbered, the text has been justified and figures and tables have been embedded within the text.

sanitation. Pest infestations were found to be stress inducing and also negatively impacted on residents' locus of control.

Conclusion: This study found multiple poverty-related factors that facilitate pest infestation in the selected low-income urban communities of Cape Town. Gaps in residents' perceptions of pests and pest control practices also negatively impacted on pest infestation. Collaborative, intersectoral interventions focusing on increasing residents' knowledge about appropriate use of pesticides are needed. Furthermore, non-toxic pest control measures should also be promoted as effective and safe alternatives. It is vital that relevant urban planning and health policies focused on reducing the double health burden from exposure to pest infestation and pesticides faced by low-income communities are considered.

Key words: Pest infestation, Exposure, Health effects, Low-income housing, Urban health, Pesticides, South Africa

Background

Pest infestation, associated diseases and pesticide exposures pose a significant public health problem that is largely neglected by researchers and health policy-makers and left to be dealt with by individuals as a private responsibility. Low-income urban residents therefore bear the brunt of pest-induced problems as infestations by rodents, cockroaches, flies and bed bugs are common in poor communities. These pests can transmit numerous diseases. Rats are known to transmit leptospirosis, bubonic plague, and Lassa fever [1–3], while flies and cockroaches can transmit foodborne gastrointestinal diseases [4, 5]. Cockroach and mouse allergens, are known to cause or trigger asthma, especially in children [6, 7]. Bed bugs on the other hand can lead to severe mental distress [8, 9]. There is, however, limited knowledge on urban pest infestations in developing countries, knowledge that could be helpful in formulating poverty reduction and urban planning and health policies aimed at combating the public health threat posed by pests.

Low-income urban areas of both developed and developing countries have a high pest burden [10, 11] due to the presence of factors that facilitate infestation. Residents of poor urban areas thus face a high risk of diseases transmitted by pests. Factors that promote pest infestation have been well investigated in impoverished urban areas of developed countries and include

structurally defective housing, unhygienic indoor conditions, overcrowding and unsanitary environmental conditions [6, 10, 12–14]. While rapid urbanisation in developing countries has led to sub-standard housing and services as demand far exceeds the supply of quality housing and services that governments can provide [15], there have been few studies conducted to identify context-specific factors that promote pest infestation in developing countries [2, 16, 17]. While South Africa is also undergoing rapid urbanisation, sub-standard housing and service provision in poor urban areas in the country are predominantly a result of the legacy of apartheid policies [18].

Studies on pest promoting factors that have been done in both developed and developing countries have mostly focused on the presence of one pest type, with rodents being the most studied [14, 16, 17]. However, such studies do not represent the true extent of pest infestation in urban areas since in practice pests do not usually occur in isolation [19]. The few studies that have investigated infestation by multiple pest types have been conducted in low-income urban areas of developed countries [7, 10, 12] and are lacking in developing countries. The paucity of research studies investigating pest promoting factors in urban areas of developing countries may indicate the low priority of urban pests on the public health agenda, due to the non-emergency state of many health problems caused by urban pests [20]. While they may not be considered a public health emergency, individuals still have to contend with the nuisance of pests.

There is evidence that many poor residents of urban areas often rely on pesticides for pest control [21–23]. The concern with pesticides, however, is that long-term exposure can cause chronic health effects such as cancer, birth defects, neurological disorders and reproductive defects [24–27]. There is also the risk of acute poisoning, particularly unintentional poisoning of children, an occurrence on the increase in the Western Cape Province in South Africa [28, 29]. Many such cases of child pesticide poisoning are attributable to highly hazardous illegal “street pesticides,” which are pesticides registered for agricultural use but sold in informal markets for domestic use [30, 31]. Residents of impoverished urban areas are thus faced with a double health burden from pests and pesticide exposures. However, there is limited knowledge about residents’ knowledge of the health effects of pesticides, their knowledge about pest infestation and prevention, how their lives are impacted by pests, and their attitude towards pest control practices.

Examining the perceptions of residents towards pests and pest control can be an important first step towards designing information and awareness campaigns, and formulating pest and pesticide use reduction strategies. As demonstrated by studies on rodent perceptions in low-income urban areas by German and Latkin in Baltimore, USA [32], and Garba et al. in Niamey, Niger [33], people have varying perceptions on pests which may affect their pest control practices. The locus of control theory [34] can be used as a lens through which to analyse how members of households, through their practices and behaviour, perceive their ability to control pest infestation. The locus of control theory, which arose from the social learning theory developed by Julian Rotter, posits that individuals perceive events as either being internally controlled through their actions and beliefs, or externally controlled via circumstances over which they have no control [34]. Assessing the local perceptions will therefore help in tailoring awareness programs to the prevailing perceptions, knowledge and practices. In addition to identifying pest promoting factors and examining pest perceptions, knowing the types of pests and pest control methods used is also important in devising context-specific health promotion activities as well as recommending effective, sustainable and safe pest control methods.

Research literature on factors that facilitate infestation by multiple pest types in urban areas of developing countries is limited, as is knowledge about low-income urban residents' knowledge, perceptions, and attitudes towards pests, pesticide exposure and pest control methods. This study aimed to fill these gaps in knowledge by using qualitative data collection and analysis methods to identify the factors that promote pest infestation by multiple pest types in low-income urban areas in a developing country. This article presents findings from this investigation as well as findings on residents' perceptions of pests, pesticide use and exposure patterns. This study was part of a larger study whose aim was to investigate the link between illegal street pesticides and child poisonings in two poor urban areas in Cape Town [28]. The larger study also included interviews with sellers of street pesticides [31] and a rat trap acceptability study [11].

Methods

This study used household observation data collected in 2009 from 50 households in Khayelitsha (n=29) and Philippi (n=21), which are two low-income communities in Cape Town, South Africa. Philippi and Khayelitsha were chosen as the study sites since many cases of child

pesticide poisonings seen at the local tertiary paediatric hospital were from these areas [28]. Both communities are typical of low socioeconomic status areas in South Africa with a mix of formal and informal housing. Formal housing refers to solidly built permanent houses, while informal housing refers to houses made of makeshift building materials. Informal houses are commonly known as shacks. Informal housing accounts for 56% and 55% of households in Philippi and Khayelitsha respectively [35]. In both communities, about 65% of houses have access to piped water either indoors or in the yard and above 80% of household use electricity for lighting [35]. Furthermore, there is a high unemployment rate (38%) in the 15-64 years age group in both areas [35].

For the parent study surveys, a sample of 199 households was selected as a practical sample size without conducting a formal sample size. A systematic random sampling strategy was used where every tenth house starting from the community centres of Khayelitsha and Philippi was included. Household observations, conducted concurrently with household surveys, were conducted in homes when there was a household member 18 years or older present. Written consent was obtained from each participant.

Observations presented in this study were conducted in selected households when the data collection team consisted of at least one research assistant that was a Master's student in either Anthropology or Public Health and trained in qualitative research methods. Observation data were therefore not collected from all households in the larger study. All fieldworkers were fluent in one of the local languages (i.e. IsiXhosa, Afrikaans or English). Observation data were collected following the Observation Guideline developed by the primary investigator of the study (Table 1). Research assistants were trained on how to administer the Observation Guidelines in identifying key factors in the home and the external environment that might facilitate pest infestation (Table 1), and on drawing pictures to represent observations.

Direct observations were conducted as per recommendations by Ulin et al. [36] that is, following predetermined criteria pertinent to the aims of the study. A fieldworker conducted the household survey interviews (not part of this study); while a research assistant with training in qualitative research methods transcribed observations and informal conversations. Combinations of verbatim statements and/or key words or ideas in line with the aims of this study expressed by

participants during informal conversations with fieldworkers were written down. Observations and informal conversations were recorded on the same sheet of paper. Quotation marks were used for verbatim statements. Key ideas or words from informal conversations jotted down were preceded by phrases such as: he/she complained/claimed/said etc. While not set out as a data collection method in the Observation Guidelines, some fieldworkers took the initiative to include hand drawn schematics illustrating the layout of houses in plots to assess overcrowding inside houses and housing densities in the built environment. Although research assistants were trained in the use of the Observations Guidelines, different research assistants had different styles of documenting with some observations being detailed and comprehensive while others are cursory. Therefore not all observation data from each household included all factors about the household boundaries and external environmental factors that could facilitate pest infestation as laid out in the Observation Guidelines.

Table 1: Key areas in the observation guide used in Khayelitsha and Philippi

Area of observation	Factors observed
Immediate home and household boundaries	(i) Factors that could influence pest entry into the home (ii) Number of children observed in the household (iii) Places where pesticides are kept and exposure routes
Environment beyond household boundaries	(i) Proximity of neighbouring houses (ii) Factors about neighbouring houses that might influence pest entry (iii) Location and proximity of landfills (iv) Presence and location of street sellers of pesticides

The observation data were handwritten in English and later transcribed into Microsoft Word documents which were then imported into NVivo 10 [37]. Inductive coding, that is using codes arising from the data rather than from conceptual frameworks or theory, as described by Miles et al. [38] was used. Coding began with repeated reading of transcripts to start recognising recurring patterns in data. An initial coding framework was created from eight detailed transcripts. This initial coding framework was refined as data coding continued with codes being merged, discarded or with new codes being identified. After the seventeenth transcript was

coded, no new unique codes emerged, but rather variations of those already in the coding framework. This point signified data saturation [39]. Table 2 shows a list of coding categories identified from the data. Coding categories represent the reduction and merging of similar codes. After all transcripts were coded, the coding categories were further refined and grouped into themes following the process of thematic analysis [40].

Table 2: Coding categories and definitions derived from the data

Coding categories	Definition
Pests present	Pests present in home talked about by participants and pests observed by fieldworkers
Pest control methods	Descriptions of different methods participants reported using for pest control
Causes of pests	Descriptions by participants of the causes of pests
Pesticides used	Pesticides observed in the home and pesticides participants reported using
Dirtiness - interior	Observations of state of cleanliness/uncleanliness of houses
Dirtiness - exterior	Observations of state of uncleanliness of external environment
Pest problems	Damages and health problems participants reported as being caused by pests
Pesticide problems	Difficulties in using pesticides reported by participants
Housing conditions	Observations of housing quality, size and proximity of houses to each other
Environmental conditions	Observation on of stagnant water, sanitation, presence of external toilets houses to dumping sites, proximity of houses to dumping sites.

The Human Research Ethics Committee at the University of Cape Town granted ethics approval for this study (HREC REF: 609/2015 in Appendix C).

Results

Findings from the household observations (N=50) and informal discussions with study participants are presented in this section, starting with most common pests identified in the study areas of Khayelitsha and Philippi. Factors facilitating pest infestation are presented next and are grouped under the key identified themes of housing, environmental and behavioural factors impacting on pest infestation. Impacts of pest infestation on pest control practices are presented last. Table 3 shows key findings from the study. Similar codes were grouped to form sub-themes, which were further grouped into major themes.

Table 3: Key findings from the three data collection methods

Key Findings	Overarching theme	Sub-themes	Data Source
Common pests and pest problems	Pests and pest problems	<ul style="list-style-type: none"> • Pest prevalence • Health consequences • Non-health related consequences 	<ul style="list-style-type: none"> • HO, IC • IC • HO, IC
Factors promoting pest infestation	Housing quality and location	<ul style="list-style-type: none"> • Structural defects • Construction material • House size and indoor overcrowding • Proximity to other houses 	<ul style="list-style-type: none"> • HO • HO • HO • HO, HS
	Condition of surrounding environment	<ul style="list-style-type: none"> • External hygiene • Proximity of refuse containers to houses • External toilets 	<ul style="list-style-type: none"> • HO, IC • HO, HS • HO, HS
	Individual and group facilitators	<ul style="list-style-type: none"> • Housekeeping habits • Lack of community participation 	<ul style="list-style-type: none"> • HO, IC • IC
Impacts of pest infestation	Pest control practices and behaviour	<ul style="list-style-type: none"> • Pest control methods used • Reasons for chosen pest control methods • Perceptions about different pest control methods 	<ul style="list-style-type: none"> • IC, HO • IC • IC
	Loss of control and hopelessness	<ul style="list-style-type: none"> • Past attempts of pest control • Acceptance • Gaps in pest perceptions 	<ul style="list-style-type: none"> • IC • IC • IC
Household observations (HO), Hand-drawn schematics (HS), Informal conversations (IC)			

Common pests and pest problems

Flies, cockroaches, mice, rats, mosquitoes, ants, bed bugs and fleas were common pests identified in most homes in Khayelitsha and Philippi. Observations and informal conversations showed that 28 (97%) households in Khayelitsha, and at least 16 (76%) households in Philippi had a pest infestation. There was no information on pest presence in four households in Philippi. Of all the study households with pests, 30 were plagued by more than one pest type while 14

mentioned only one pest type present. Only two households, one in each area, were reported to have no pests present.

Participants had varying perceptions of the ways in which pests can adversely affect health and impact on their lives in general. For example, with flies being the pest observed in nearly every household, some participants expressed disgust at their presence since they said flies carried germs and could contaminate uncovered food. Overall, rats were reported to be the pests causing the most problems for participants. Three of the 50 participants reported that someone in their household had been bitten by rats. Rats were also cited by participants as causing the most damage to material possessions in homes such as eating food and chewing through television cables, clothes and furniture. A total of 12 participants (24%) cited rats as causing financial losses as well. Participants who bought food in bulk and stored it in plastic containers for their own use or for small enterprises they ran from their homes, complained that rats chewed through the containers and ate the food. Even though cockroaches were present in 14 (28%) of homes visited, only one participant expressed the belief that they carried germs. Cockroaches were mainly perceived to be damaging to electrical appliances as they left stains on televisions and microwaves. The presence of bed bugs which were said to cause skin irritations and leave stains on mattresses was reported by some participants. Bed bugs were seen by participants as a seasonal pest, with some claiming they were more common in summer while others said they were more common in winter. In addition to specific problems identified for each pest, all pests were perceived by participants as a nuisance.

Factors promoting pest infestation

Three key factors were identified as potentially facilitating pest infestation in homes in Khayelitsha and Philippi (Table 4). These are further elaborated on below.

Table 4: Key factors identified facilitating pest infestation in Khayelitsha and Philippi

Key factors	Details of key factors facilitating pest infestation
Housing quality and location	(i) Housing structural defects allowed for pest entry (ii) Small size of and overcrowded houses made cleaning difficult (iii) Proximity of houses to dumping sites and refuse bins facilitated pest infestation (iv) High housing density facilitated movement of pests between houses
Environment, waste disposal and sanitation	(i) Building materials discarded in backyards provided shelter for pests (ii) Dumping in open spaces provided food for pests (iii) Inadequate drainage and blockages provided breeding grounds and water for pests
Individual and community level facilitators	(i) Poor housekeeping habits favoured pest proliferation (ii) Lack of community participation and coordinated efforts in pest control undermined individual pest control efforts

Housing quality and location

Substandard structural and design conditions

Of the 50 households where observations were conducted, 32 (64%) were informal houses (shacks), with the remainder of houses classified as formal or permanent. Shacks were built haphazardly and were characterized by poor building materials such as wooden boards and corrugated iron sheets for walls. Most shacks had holes or gaps in the walls, between doors and the floor and between walls and ceilings. Pests entered homes and lived in these spaces as illustrated by a shack occupant who referred to the gap between the roof and the ceiling where rodents nested as the “house of masters” (Participant K0033). Permanent houses, built of concrete blocks were an improvement with solid walls with no holes or gaps. However, some of them, even though occupied, were still under construction lacking ceilings and having gaps between the walls and the roof. Many permanent houses also had gaps between doors and the floors. Some permanent houses had add-on rooms, which were built of the same poor quality materials as shacks. Seventeen houses (34%) were observed to have floors in poor condition, with concrete floors having holes and cracks while vinyl and linoleum floor coverings were torn or peeling off.

There were 14 (28%) explicit records of houses in the study, both shacks and permanent houses, whose sizes were very small for the number of occupants and furniture in them. Many shacks consisted of a single room, with furniture used to divide the space into different ‘rooms.’ The result was that the houses were tightly packed with furniture and other household materials and appliances were stacked on top of each other (Figure 1). Due to lack of space, some kitchens had utensils and appliances placed on the floor. While there were some clean and well-kept houses, both shacks and permanent houses, there were more dirty and unkempt houses due to how cluttered and cramped they were. The dirtiness of houses was determined based on observations of stains on floors and carpets, crumbs and unwiped spills on floors and counter tops, and unwashed dishes and pots in the kitchen areas. With the lack of space, many households did not have enough cupboard space and stored food in plastic containers on table tops and on floors, placing food within easy access of pests.



Figure 1. Overcrowding in kitchen areas in homes in Khayelitsha (photo courtesy of H-A. Rother, Environmental Health Division, School of Public Health & Family Medicine, University of Cape Town)

Housing densities and proximity to other houses and dumping sites

Observation data showed that effective urban planning and planning regulation was greatly lacking in Khayelitsha and Philippi, as there is extensive overcrowding in the built environment. Shacks tended to be in very close proximity to one another, with some shacks separated by just a narrow footpath. However, even when the main house was a permanent structure, such close housing proximity was evident. Figure 2 shows schematics (drawn by fieldworkers) showing the layout of buildings in residential plots in Khayelitsha. It illustrates the high dwelling density present in the areas, with plots having numerous buildings, and shacks and permanent buildings in different stages of completion. Such overcrowding in the built environment facilitated the movement of pests from one house to another directly and indirectly. A flea-ridden cat, which facilitated indirect movement, was observed entering the house of a participant, who identified it as a neighbour's cat. Moreover, direct movement of pests was facilitated by the close proximity of houses to one another and to refuse collection points, and by the habit of residents to leave front doors open when someone was at home, as observed by the fieldworkers.

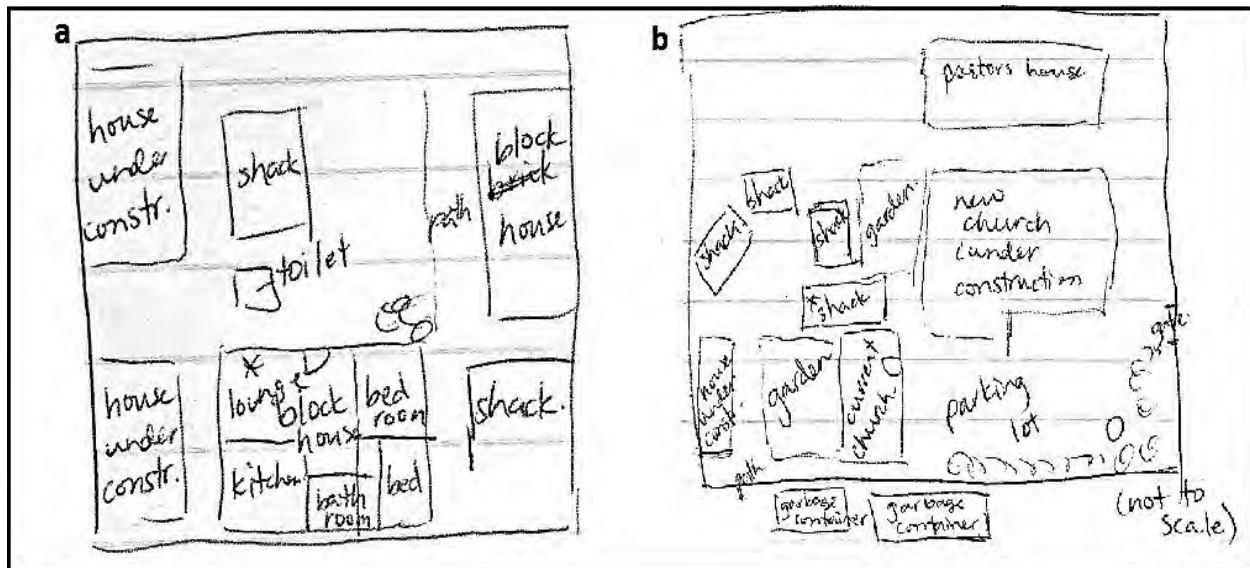


Figure 2. Schematics illustrating layout of plots and housing densities in Khayelitsha. Not to scale.

Environment and waste disposal

Rubble and waste

The environment surrounding homes in Khayelitsha and Philippi was observed to be littered with waste and piles of building material including concrete blocks and wooden boards (Figure 3). There was extensive on-going construction in these areas during the research period as new shacks were being built or more rooms were being added to main houses. One participant referred to the piles of neighbour's building materials next to her shack where rats lived and bred as a "rats' paradise." While there were refuse bins provided by the municipality in nearly all plots, much waste remained on the streets and in areas surrounding houses. Flies were the most commonly observed pests around these dumping sites. Dumping site is used here to refer to illegal refuse dumping areas as opposed to landfills which are planned areas for organized refuse disposal. The observation data do not refer to the presence of landfills in the study areas. With houses being so close, in some instances even when refuse bins or other piles of rubbish were placed far from the house they belonged to, they were still in close proximity to neighbouring houses. Some participants, whose houses were observed to be kept clean and neat, complained that the reason why their homes were infested with pests was because of the environment which acted as a pest attractant.



Figure 3. External housing environmental in Khayelitsha (photo courtesy of H-A. Rother, Environmental Health Division, School of Public Health & Family Medicine, University of Cape Town)

Water and sewage

All shacks visited, as well as some permanent houses, lacked indoor plumbing and toilets, but shared communal taps and toilets external to the home instead. The schematic in Figure 3 typifies the extent of toilet sharing. The drains under communal taps not only served their drainage purpose but it was observed that they were also used as a dumping area to throw away food, soiled diapers and other waste. It was observed that houses close to these communal taps were impacted by the consequences of overflow from the drains which contained bits of food and emitted a stench that attracted flies and other pests. Residents who lacked indoor plumbing were also observed throwing out dirty water on the narrow paths that separate houses. Standing water resulting from this practice or from clogged drains therefore provided much needed water and breeding grounds for pests.

Individual and collective facilitators

Through informal conversations, many participants made a link between a dirty home and the presence of pests. To counteract this unwelcome combination, a few participants reported that they used household cleaning products or cleaning products mixed with pesticides to keep their homes clean and to get rid of pests. Household cleaning products were also touted for “making the place smell nice,” which was in contrast with the foul smells coming from outside toilets, stagnant water and rubbish collecting outside. One participant said in his household they used *Madubula* (a household disinfectant similar to *Jeyes Fluid*, containing 13% carbolic acid) for bathing to protect themselves from ectoparasites, while another said she and her household used *Lux* bath soap to prevent lice infestation. While some participants made an effort to keep their houses clean, even these houses were not spared from pest infestation, a consequence blamed on the unclean environment. There were also houses, mostly shacks, which were visibly dirty with spilled food, crumbs, and unwashed dishes.

There was also a sense that without collective effort from the community, applying pest control measures limited to one’s own home was a futile exercise.

“There is no need to use pesticides to kill rodents in your household because if the neighbour does not, it’s of no use to you to attempt” (Participant K0053).

Impacts of pest infestation

Pest control methods

Given the high pest problems listed, many participants reported using pesticides to rid pests from their homes. They used both commercially available pesticides and illegal street pesticides available in informal markets [31]. For insect pests, commercially available aerosol insecticide sprays including *Doom*, *Fastkill*, *Kombat* (pyrethroids) and *Baygon* (chlorpyrifos) were commonly used. Insecticide chalk (pyrethroid), an illegal pesticide that participants bought from the taxi rank, train station or door-to-door vendors was also popular for control of insect pests. For mosquito control, mosquito coils were also used. For rodents, aldicarb, a highly acutely toxic carbamate which was previously legally registered as a nematicide in agriculture, was used illegally as a street pesticide, and commercially available *Rattex* (difethialone) were most commonly used. One participant had a plastic Coke bottle filled with a clear liquid pesticide, most likely an organophosphate solution, bought from the train station which she feared could be mistaken for water.^a Another illegal pesticide that was used by participants, *Green Leaf* (organophosphate acetate) powder from China, had packaging and contents that resembled those of baking yeast. Some participants who used pesticides could hardly afford them as unemployment is high in the study areas, with some participants reporting that child support grants were their only source of income. Few participants reported using pesticide-free control measures. Rat traps and fly tape were each mentioned once, each by a different participant. Two other participants stated that the reason that available rat traps were ineffective was because they were “old models” and not strong enough for rats the size of cats.

While many participants stated that they stored pesticides where children could not reach them such as in the top cupboard or shelf; some placed them in places where they were easily accessible to children, such as under the bed. Awareness of health risks posed by pesticides, especially to children was mixed. For example, one participant who used an organophosphate solution for insect control said children must be outside when the pesticide was being applied; while another said she had stopped using aerosol insecticides for fear that they might cause her toddler to have asthma. In contrast, one participant whose wife had been bitten by rats, said he used to keep pesticides safely away from children but since the rats had gotten “out of control”, he instructed his children to apply and place pesticides everywhere around the house.

Keeping cats for rodent control was rarely stated as a pest control measure practised by participants. However, for some, keeping cats was an effective rodent control method.

“We have a cat, the attacker. We have no rats at all. I think the cat also eats cockroaches. I think the cat is the best weapon for pests” (Participant K090).

However, the majority of participants who discussed the effectiveness of cats for rodent control were less enthusiastic. At least two participants said they did not keep cats because they or someone in their household disliked or were scared of them. One participant said even though she would prefer cats over using rodenticides, she could not because she was allergic to cats. Superstitious beliefs regarding cats were also prevalent. Two participants said cats were associated with evil spirits, and could bring these into the home. Cats were also seen to be associated with witchcraft.

“I love cats but I can’t [have one] because if you have a cat people tend to think that you do witchcraft. Especially the black cat” (Participant K0056).

Loss of control, hopelessness and stress

Many participants reported to be actively involved in pest control measures, with many using pesticides and a few keeping cats for rodent control. Others, however, admitted that they had used pesticides in the past with little success, hence they had given up. Some participants had become so accustomed to having pests in their homes that they appeared oblivious to their presence or did not view them as problem. Such acceptance and despondency was common with flies, which were present in the majority of households. Participants expressed that pests were an inevitable part of life in the townships and there was nothing they could do

A few participants perceived pests to have a supernatural cause. One participant attributed the presence of insect pests in homes as a punishment from God, while two others said pests were the works of witchcraft. One of the participants who perceived pests as being caused by witchcraft went on to disclose that he used *muti* (traditional medicine) for rat control since he said claimed that rats were “sent” by jealous community members.

A sense of loss of control, whereby pests were dictating residents' behaviours and choices was also expressed by some participants. While rodents were reported to damage belongings by many participants, at least two participants explicitly said the reason why they no longer owned or no longer wanted to acquire new televisions was because of the damage caused by rodents. One woman, who lived in a shack, had to change her living arrangements at times because of the rats in her home:

“The rats can be scary at times. Sometimes I even go to my friend’s house which is a permanent house. She only has mice” (Participant K0049).

Some participants also expressed a constant fear and worry about germs carried by flies and cockroaches. These participants felt that these pests were dictating on their lives since the participants could not use any dishes or utensils without washing them first as a precaution against germs, even if they had been washed before. A further two participants said they could not sleep soundly at night due to the sound of mosquitoes and flies.

Discussion

Facilitators of pest infestation

Household observations and informal conversations with household members confirmed that these areas had a high pest burden, as has been noted in other low-income urban areas globally [10, 12, 13, 17, 22, 41]. Residents found pests to be a nuisance and were also aware of the health hazards of pests. The three key factors, all closely linked to poverty, that were identified as promoting pest infestation in the study areas were sub-standard housing, unsanitary environment and ineffective pest control measures at the individual and at the community level. Studies conducted in urban areas in the USA, a country where many studies on determinants of pest infestation have been conducted, have found that low-income urban residents are disproportionately affected by pest infestation compared to high-income urban residents [42, 43].

The findings of this study show that housing in low-income urban areas is in a state of disrepair and greatly favours pest infestation. Structural defects, which were most common in shacks,

provided entry points for pests. Shacks in South Africa have been consistently shown to be poorly constructed and with poor quality building materials [18, 44]. However, even permanently built houses, with fewer structural defects and thus fewer pest entry points were not entirely free of pest promoting factors. Some permanent houses, even though occupied were still under construction. These findings are supported by Govender et al. [45] who found permanent government-subsidised houses, known as Reconstruction and Development Programme (RDP) houses, to be poorly constructed and incomplete upon occupation. Not only does deteriorated and incomplete housing provide entry points for pests, it also makes cleaning, an important step in pest control, difficult [10, 45–47]. While substandard housing in low-income urban areas of developing countries is attributable to the pressures of rapid urbanisation [15], in South Africa the problem is compounded by the legacy of apartheid housing policies [18]. Even though permanent houses are soundly constructed for the most part, with fewer pest entry points, extensive overcrowding, which impedes cleaning and is associated with pest infestation [17], could override this relative advantage. Pest infestation resulting from poor quality housing should be a cause for concern for public health policy makers as a clear correlation between housing quality and health status of residents has long been established [48–51]. While keeping one's own house clean may to an extent deter pest infestation, community participation, the lack of which was lamented by one participant in the study, has been found to have a significant effect in reducing rodent infestation [14].

Faced with housing related problems such as pest infestation, overcrowding, poor indoor air quality, and mould and dampness, low-income urban residents have to contend with a variety of health problems such as asthma, allergies, and skin ailments [48]. While this study did not set out to examine health problems caused by pests in low-income urban areas, there were complaints of skin irritations caused by insect pests, rodent bites and fear of germs carried by pests. Future studies are needed to assess physical health problems caused by pests in low-income urban areas of developing countries.

The external environment in Khayelitsha and Philippi was also identified as favourable for pest invasion due to inadequate sanitation and sewerage, open-space dumping and uncollected waste. Piles of waste discarded in the open, putrid stagnant water and drains blocked by food waste and other waste matter were some of the environmental conditions that were observed to cause pest

infestations in people's homes. Lack of proper sanitation and waste disposal have been observed in other low-income urban areas as well, leading to environmental conditions that favour pest infestation [52, 53]. Socioeconomically disadvantaged urban residents are faced with environmental injustices as they are disproportionately exposed to unhealthy and toxic environments [50, 54], which puts them at risk for negative health outcomes. Whereas the City of Cape Town has contracted waste collection services in Khayelitsha to several companies, a social audit conducted by the Social Justice Coalition found that waste collection and cleaning services in informal areas of Khayelitsha were sorely lacking [55]. The release of the social audit report swiftly brought about changes, as one of the waste removal contractors was replaced [56]. Whether the change will have long-lasting positive effects in pest infestation and environmental sanitation is yet to be seen. Other researchers who have found similar deficiencies in other low-income urban areas of developing countries recommended that municipal authorities should implement efficacious waste management systems [53, 57, 58]. Implementing such changes would potentially decrease pest infestation as the environment would be less favourable for pest harbourage and proliferation. Urban planning policies should also

Impacts of pest infestation on control measures

Pest infestation was found to have a significant impact on pest control behaviour and practices of residents. Many participants used pesticides, both commercial and highly hazardous illegal street pesticides. The most commonly used pesticides were aerosolised synthetic pyrethroids, mosquito coils, aldicarb and organophosphate solutions, with the last two being illegal street pesticides. Illegal street pesticides are sold in unlabelled packaging therefore residents do not have access to information about health hazards, and safe handling and storage instructions [31]. While there was some awareness on the danger of pesticides, especially to children, in some households pesticides were stored within easy reach of children. This finding partly explains the high number of childhood pesticide poisoning cases from Khayelitsha and Philippi seen at the local paediatric hospital [28]. More importantly, this finding highlights the lack of knowledge on safe use and storage of pesticides which has also been reported in low-income urban areas of Uganda and Thailand [21, 41, 59]. While the use of household cleaning products as pesticides may be well intentioned, mixing cleaning products with pesticides for a "super strength, multi-purpose" cleaning product may have severe unintended health consequences for example if such mixtures spontaneously combust, result in more toxic mixtures or give off toxic vapours.

With pesticides being the method of choice for pest control for many residents, the use of non-toxic pest control methods such as rat traps and fly tape was rarely mentioned. This may point to the lack of knowledge or appreciation of the effectiveness and safety of other pest control methods, a state of affairs common in other low-income urban areas [30, 41]. Biological control of rodents using cats, was lauded by a few participants as being effective, but was avoided by many participants due to superstitious beliefs that perceived cats to be evil and associated with witchcraft. Such beliefs are unfortunate since keeping cats for rodent control was found to be effective, leading to a 60% lower chance of reporting the presence of rats in low-income housing in Johannesburg, South Africa [17]. Such beliefs have to be taken into consideration when conducting awareness campaigns and educating residents on less toxic pest control measures.

Economic and mental-health impacts of living with pests

Although the study did not explicitly assess the extent of economic burden caused by pests, informal conversations with participants suggested that the damages and loss of material possessions caused by pests, especially by rodents, were potentially a significant source of economic burden to residents. Such losses potentially perpetuated the economic vulnerability of residents, the majority of whom were of low-socioeconomic status. While most studies on economic damages caused by rodents in Africa have been conducted in agricultural regions [60, 61], at least one other study has reported on the material damage and economic losses experienced by urban residents in Niger due to rodents [33]. Furthermore, pesticides, the pest control method of choice for some study participants, proved costly and unaffordable. Affordability is one of the reasons that has been found to entice residents of low-income urban areas to purchase highly toxic illegal pesticides from informal markets rather than purchase commercially available pesticides [30, 31]. When it comes to pests and pesticides, low-income urban residents are caught in the vicious cycle of poverty. On one hand, living in poverty means living in housing and environments that facilitate pest infestation; on the other hand living with pests can cause financial burdens. This is a significant problem for many low-income urban residents in sub-Saharan Africa.

While this study did not seek to assess the mental well-being of residents affected by pests, which was not realized to be a significant problem prior to the research, informal conversations with participants suggested that pest infestation caused residents significant mental stress. There

is undisputed evidence that pest infestation can cause severe mental distress [32, 62] or worsen psychological symptoms in people who are pre-disposed or have existing mental disorders [8, 63]. Some residents expressed a constant worry about pests, with some changing their daily routines -staying at a friend's house or washing dishes repeatedly- in order to accommodate pests. Informal conversations with participants also showed that some residents had grown despondent, and were lacking confidence in their ability to successfully control pests.

Rotter's locus of control theory [34] is useful in explaining the effects that pests potentially had on residents' agency in controlling pests. The locus of control theory refers to the degree to which individuals believe that their own actions (internal locus of control) or the actions of external forces, over which they have no control (external locus of control), are responsible for certain outcomes [34]. People with strong internal locus of control have high self-efficacy, believing in their ability to accomplish goals or in their ability to control outcomes (e.g. in this study, pest infestation). Those with strong external locus of control are often helpless, believing there is nothing they can do to control outcomes [64]. Findings from this study suggest that many participants in this study had a weak internal locus of control. They perceived external forces to be responsible for high pest infestation. The external factors perceived to determine pest infestation included the unsanitary external environment which was blamed for attracting pests, lack of community participation or neighbours who did not practice pest control in their own homes, and supernatural causes of pest infestation. Several studies have shown that having a weak internal locus of control has a negative impact on mental health [65, 66], such as the distress experienced by some residents who did not believe in their ability to successfully control pests. Such mental stress arising from pest infestation can amplify the health problems and financial burden caused by pests. However, pest control in low-income urban areas should not be seen as the sole responsibility of residents.

While residents would be expected to keep their homes clean and free of conditions that may attract pests, municipal authorities also have a responsibility to keep the external environment sanitary through regular refuse removal and providing extermination services. The City of Cape Town, under whose jurisdiction the areas of Khayelitsha and Philippi fall, has been providing rat control services using live catching and bait blocking, as well as door-to-door awareness raising campaigns [67]. These efforts alone, however, do not seem to be very effective due to lack of

effective waste management, dilapidated housing conditions, and ineffective pest control practices by residents. Ultimately, it is policies that aim to reduce poverty, the main cause of the factors identified as promoting pest infestation, that can be counted on to lead to a drastic reduction in pest infestation in low-income urban areas.

Study limitations

Not having been involved in the study design or data collection process proved to be a challenge in analysing the data since there was lack of consistency between fieldworkers in collecting data using the Observation Guidelines (Appendix A). Some of the observation data were content rich and followed the guidelines closely, while other data were superficial and did not address all the questions outlined in the guide. There is a possibility that fieldworkers' conceptions and biases might have influenced the kinds of data that were recorded. In some instances there was lack of clear delineation between what content was strictly from observations and what was derived from informal conversations with participants. Despite these limitations, available data were still sufficient to achieve the research aims, as data saturation or the point where no more new insights emerged [39], was reached.

Conclusion and recommendations

The study presents findings on an urban environmental health topic that is under researched in many developing countries. It supported findings from other low-income urban areas of developing countries that housing disrepair, environmental waste and inadequacy of water and sanitation services all contribute to pest infestation. The study also presents unexpected findings that some residents perceive pests as having supernatural causes and that some use pesticides mixed with cleaning products for pest control. Furthermore, findings from the study also suggest that living with pests can be a cause of significant mental distress, a phenomenon that has been reported in other studies. These findings have implications for pest reduction and pest control interventions.

The study areas are unique in that they consisted of a combination of formal and informal housing with informal houses, or shacks located in the back yards of formal houses. This arrangement exerts pressure on the services provided in already impoverished communities. With a high pest burden, residents in the study areas face a constant threat from pesticide

exposure and poisoning, as well as exposure to vector borne diseases. If no interventions are undertaken to curtail the problem, high rates of pesticide poisoning, especially that of children, can be expected to stay the same or even increase. Vector borne diseases may also be expected to increase the burden of disease faced by low-income urban residents.

It is imperative that steps that address environmental injustices that have led to low-income urban areas being disproportionately affected by pests be taken. Both the indoor and the external residential environmental quality have to be taken into consideration. Historically, the indoor environment of poor urban areas, where residents are likely to be powerless and marginalised, has not been taken seriously as a space for political engagement [68], but has rather been seen as the sole responsibility of residents. Furthermore, disparities present in indoor environments have been underappreciated as an environmental justice issue [51]. Such political and policy shortsightedness in providing and maintaining healthy indoor environments can potentially negatively impact on pest infestation. However, with firmly established associations between poor indoor environment quality and poor health outcomes, it is recommended that health-related policies pay close attention to indoor residential environments.

In the short-term, health departments could run radio shows, distribute leaflets and put up posters in bus and train stations informing residents of the dangers of using illegal street pesticides and the precautions to take when using legally registered pesticides. Use of alternative non-toxic pest control methods, such as rat traps, should also be promoted. It is important that these educational and awareness raising interventions address gaps in local perceptions about pests and pest control methods. Health practitioners serving low-income urban areas could also be encouraged to not only focus on the biological aspects of their clients' health, but to also routinely assess their psychosocial well-being, as pest exposures can affect both physical and mental health. Long-term solutions would require the collaboration of other sectors such as housing and urban planning departments, water and sanitation departments, and municipal authorities, which have an impact on health of residents.

Piloting of programs that explore the effectiveness, acceptability and long-term sustainability of pest control methods aimed at improving housing quality and environmental sanitation are needed in order to make evidence-based recommendations to urban health planners and policy makers, municipal authorities and civil based organizations. Such programs should aim to

include and give a voice to residents of low-income urban areas, who are often left out of decision-making processes. The author envisions that these recommendations would be applicable in similar contexts in sub-Saharan Africa, with perhaps tailored modifications for areas where notifiable vector-borne diseases such as malaria are endemic. Implementing these recommendations would not only help reduce the double health burden caused by exposure to pests and pesticides, but would also fulfil the rights to dignity, a healthy environment and access to adequate water and sanitation that are enshrined in South Africa's constitution.

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ENDNOTES

^a Active ingredient of clear liquid inferred from pesticide point chart created Rother, H-A. Available at: https://open.uct.ac.za/bitstream/item/2265/OC_Lecturenotes_Pesticide_Poisoning.pdf?sequence=1 [Accessed May 30, 2016]

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Figure legends

Figure 1. Overcrowding in kitchen areas in homes in Khayelitsha. Photos show cramped kitchen spaces with appliances stacked on top of each other in 1a, and dishes placed on top of cement sacks in 1b.

Figure 2. Schematics illustrating layout of plots and housing densities in Khayelitsha. Schematics show a mix of shacks and permanent houses. Multiple buildings in various stages of completion are shown in 2a. An external shared toilet is shown towards the centre of the plot. Figure 2b illustrates the of houses to refuse containers.

Figure 3. External housing environmental in Khayelitsha. Photo shows external environments littered with rubble. A permanent house and shacks are in the background in 3a.

PART D: APPENDICES

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Appendix A: Household Survey Observation Notes Guideline

Survey Number:

Date:

Observer's Name:

Interviewer's Name:

Time Started:

Time Finished:

Location of Interview:

Type of House of Person Interviewed:

Household Address:

Immediate Home and Household Boundaries

- Describe the setting briefly and what factors you see that could influence pests entering this home
- How many children do you see in this household?
- If you go in the home, describe where pesticides are used, kept and potential exposures.

Environment Beyond Household Boundaries

- How close is the next neighbour? What about the neighbours homestead could affect pests in this one?
- Where is the nearest land fill?
- Can you see any street sellers of pesticides? How close to this home?

Observations

Appendix B: Consent Form

“Street Pesticides”: Households in Informal Settlements and Urban Townships - 2009 Introduction and Informed Consent

Read to respondent:

Hello, my name is..... and I am from the University of Cape Town. I am involved in a project on the methods for controlling pests.

I would like to ask your permission to interview you for a research study. The purpose of this interview is to find out about the use of chemicals to control pests and your understanding of health & safety issues related to these chemicals.

Your participation in this study is very important to us and will assist us in understanding better about pesticides that are sold on the streets of Cape Town. Your answers will help us to improve your own health and safety and your children's.

This interview is confidential. I will not write your name down. Only the researchers will see your answers. Your participation is voluntary, which means that you can refuse to participate and you can stop the interview at any time.

This is not a test and there are no right and wrong answers. Please try to answer these questions as truthfully as possible for us to better understand the use of pesticides. If you do not understand a question, please ask me to repeat it or explain it. The interview should take 20-30 minutes.

This study will not involve any harm or discomfort to you. After answering the questions, you will receive a rat trap, as well as training on pesticides health and safety. May I interview you? May I start the interview now? **(If yes, please sign below.)**

If you have any questions or want further information about the study, please contact:

Study Principal Investigator:

Dr. Andrea Rother
School of Public Health and Primary Health Care
University of Cape Town
Anzio Rd., Observatory 7925 South Africa
T: (021) 4066300; F: (021) 4066163; e-mail: andrea@cormack.uct.ac.za

_____	_____	_____
Name of Participant (print)	Signature	Date
_____	_____	_____
Interviewer's name (print)	Signature	Date
_____	_____	_____
Witness's name (print)	Signature	Date

Appendix C: Letter of Approval from Research Ethics Committee for Current Study



UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee



Room E52-24 Old Main Building
Groote Schuur Hospital
Observatory 7925

Telephone [021] 406 6338 • Facsimile [021] 406 6411

Email: ncsl.tsama@uct.ac.za

Website: www.health.uct.ac.za/fhs/research/humanethics/forms

16 September 2015

HREC REF: 609/2015

A/Prof A Rother
Environmental Health Division
Public Health & Family Medicine

Dear A/Prof Rother

PROJECT TITLE: FACTORS FACILITATING PEST INFESTATION IN TWO LOW-INCOME URBAN AREAS OF CAPE TOWN, SOUTH AFRICA: AN URBAN HEALTH OBSERVATION STUDY (MPH-candidate N Mngadi) sub-study-linked to 222/2007

Thank you for your response to the Faculty of Health Sciences Human Research Ethics Committee dated 28 August 2015.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

- Please add the UCT FHS HREC contact details to the Informed Consent Document

Approval is granted for one year until the 30th September 2016.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.

(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

We acknowledge that the MPH student Nontoko Mngadi will also be involved in this study.

Please quote the HREC REF in all your correspondence.


Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Yours sincerely

Signed

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE

Appendix D: Letter of Approval from Research Ethics Committee for Parent Study

 UNIVERSITY OF CAPE TOWN

Health Sciences Faculty
Research Ethics Committee
Room E52-24 Groote Schuur Hospital Old Main Building
Observatory 7925
Telephone [021] 406 6338 • Facsimile [021] 406 6411
e-mail: presward@curie.uct.ac.za

07 May 2007

RBC REF: 222/2007

Dr A Roether
Public Health & Family Medicine

Dear Dr Roether

**PROJECT TITLE: CONSEQUENCES OF THE USE OF "STREET PESTICIDES" AND
COMMERCIAL PESTICIDES FOR PEST CONTROL IN SOUTH AFRICA'S PERI-URBAN
AREAS ON CHILDREN'S HEALTH AND HEALTH POLICY**

Thank you for submitting your study to the Research Ethics Committee for review.

It is a pleasure to inform you that the Ethics Committee has formally approved the above-mentioned study.

As we discussed on the telephone, please could you let us have copies of new informed consent forms and questionnaires or information regarding other study methods which you intend using as the research develops.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the REC. REF in all your correspondence.

Yours sincerely

Signed

**A/PROF. M. BLOCKMAN
CHAIRPERSON, HSE HUMAN ETHICS**

Appendix E: Instructions for Authors (BMC Public Health)

Source

<https://www.biomedcentral.com/bmcpublichealth/authors/instructions/researcharticle>

[2015, December 8]

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Research articles should report on original primary research, but may report on systematic reviews of published research provided they adhere to the appropriate reporting guidelines which are detailed in our [Editorial Policies](#). Please note that non-commissioned pooled analyses of selected published research will not be considered.

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- [List of abbreviations used](#) (if any)
- [Competing interests](#)
- [Authors' contributions](#)
- [Authors' information](#)
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Article within a journal supplement

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Online document

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Online database

Healthwise Knowledgebase. US Pharmacopeia, Rockville. 1998. <http://www.healthwise.org>. Accessed 21 Sept 1998.

Supplementary material/private homepage

Doe J. Title of supplementary material. 2000. <http://www.privatehomepage.com>. Accessed 22 Feb 2000.

University site

Doe, J: Title of preprint. <http://www.uni-heidelberg.de/mydata.html> (1999). Accessed 25 Dec 1999.

FTP site

Doe, J: Trivial HTTP, RFC2169. <ftp://ftp.isi.edu/in-notes/rfc2169.txt> (1999). Accessed 12 Nov 1999.

Organization site

ISSN International Centre: The ISSN register. <http://www.issn.org> (2006). Accessed 20 Feb 2007.

Dataset with persistent identifier

Zheng L-Y, Guo X-S, He B, Sun L-J, Peng Y, Dong S-S, et al. Genome data from sweet and grain sorghum (*Sorghum bicolor*). GigaScience Database. 2011. <http://dx.doi.org/10.5524/100012>.

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