GEOHELMINTH TRANSMISSION AMONG SLUM-DWELLING CHILDREN IN DURBAN, SOUTH AFRICA

By

THABANG INNOCENTIA MOSALA

Submitted in fulfilment of the academic requirements for the degree of DOCTOR OF PHILOSOPHY

in the

Faculty of Science
School of Life and Environmental Sciences
University of Natal
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ACKNOWLEDGEMENTS

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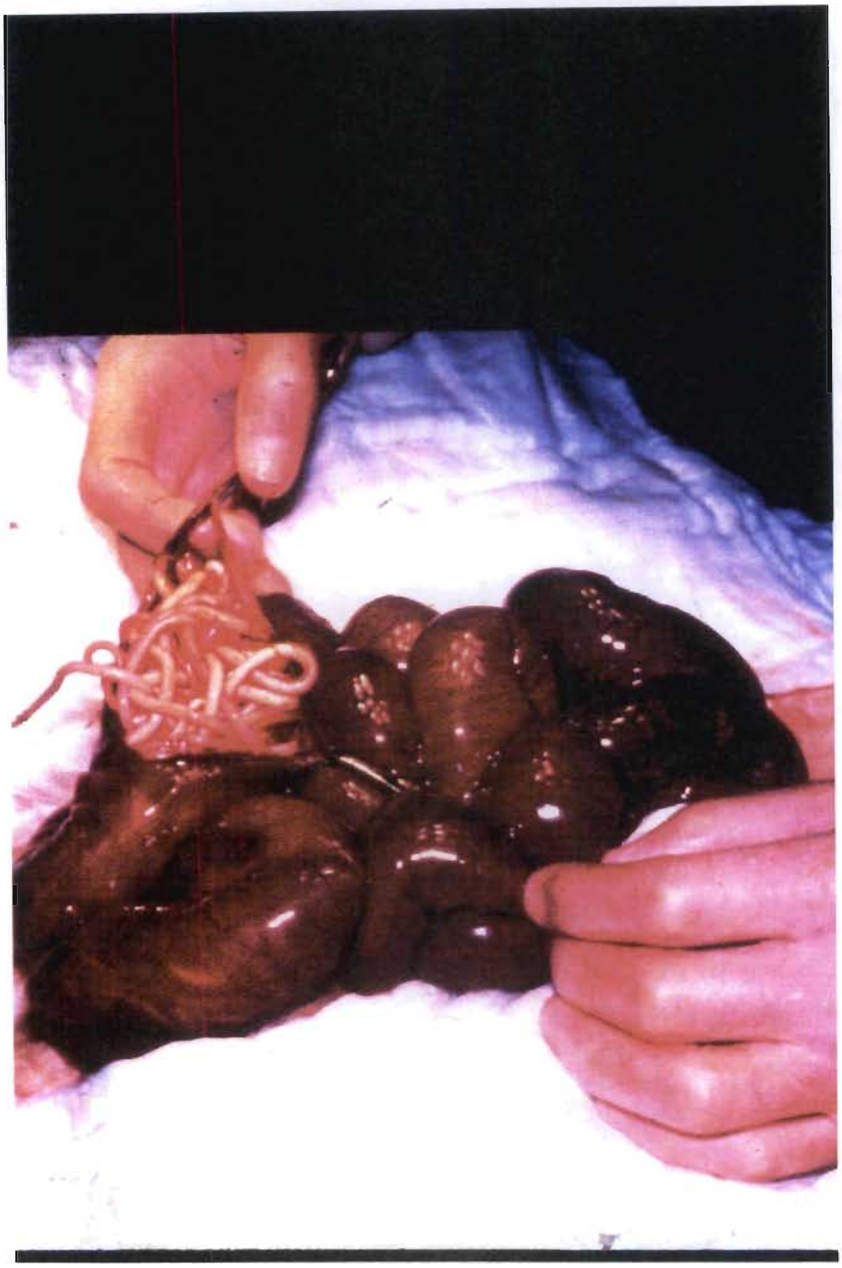
CHAPTER 1



Impacted mass of adult *Ascaris lumbricoides*: in small intestine causing intestinal obstruction leading to distention, gangrene and death. (Courtesy Prof. G.P. Hadley - Department of Paediatric Surgery, Nelson R. Mandela School of Medicine).

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FRONTISPIECE

Slum environment in which this study was carried out: (a) rooftop view of densely crowded shacks in Quarry Road West, **(b)** rubbish hips in Canaan, **(c)** author with her subjects, **(d)** flood damage in Quarry Road West and **(e)** inside shack.

"...But worms are very unglamorous things, you talk of faeces and you talk of latrines and there's no fashionable side to worms. You can always find politicians and policy makers who will love to come to open a brand new cardiac unit. Everybody's very willing to have a paediatric wing named after them or a special renal unit named after them. Just find someone who wants to have a toilet named after them, then you will control ascariasis"

Kan, 1989 in Crompton *et al.*, 1989

ABSTRACT

Geohelminthiasis is a serious problem in city slums and despite being easily treatable in the short term, its elimination enjoys a low priority by parents, teachers and public health authorities. This is partly due to the greater emphasis given to the AIDS and TB programmes.

This study of the prevalence, intensity, and reinfection rates of single and multiple geohelminth (*Ascaris lumbricoides, Trichuris trichiura* and *Necator americanus*) infections in young children living in slums (informal settlements) in the Durban Unicity is a first for an African city and one of few similar studies anywhere in the world.

The geohelminth status was assessed by means of a baseline survey of ten different slums, followed by two further surveys, one after 4½ - 6 months and another after 12 months. Infections were measured by microscopic examination of faeces before and after chemotherapy, and risk factors within and between slums were identified by means of a quantifiable questionnaire.

The study showed that:

1. The slums have a high endemicity and transmission rate of geohelminth infections.
2. The sub-tropical climate and environment ensured a high survival rate of infective stages.
3. *A. lumbricoides* had a high prevalence and intensity, followed by *T. trichiura* with a moderately high prevalence and light intensity. A small proportion of children had intensities of these helminths an order of magnitude higher than previously recorded from rural areas of South Africa. *N. americanus* had a very low prevalence and a very light intensity.
4. Egg output from follow-up 1 to follow-up 2 increased 4.6 fold for *A. lumbricoides* and 9.4 fold for *T. trichiura*.
5. Albendazole proved to be a very effective drug against *A. lumbricoides* and *N. americanus* but not as effective against *T. trichiura*.
6. The infection and reinfection rates of *A. lumbricoides* and *T. trichiura* proved to be influenced by different risk factors.
7. The most important risk factors included topographical position of the slum, quality of the dwelling, number of inhabitants, geophagy and source of fruit and vegetables.

Whereas the ideal solution to the geohelminth problem in the slums would be to upgrade the slum and its inhabitants, this is not an immediately viable option. The challenge of geohelminth control in these slums must be to determine the degree of environmental contamination by human faeces containing infective eggs, to ascertain the survival rate of the eggs and larvae and to implement a control programme together with suitable education of the inhabitants. The Parasite Control Programme should take into consideration that many slum-dwelling children do not go to school and need to be treated at home. A further factor that will have to be taken into account is that lack of influx control to urban areas will mean the continual reinfection of slum-dwellers by the movement from the rural areas.

PREFACE

The research work described in this thesis was carried out in the Diagnostic Laboratory, Centre for Integrated Health Research, School of Life and Environmental Sciences, University of Natal, Durban, from August 1998 to March 2001, under the supervision of Professor C. C. Appleton (University of Natal) and Dr. A. Olsen (Danish Bilharziasis Laboratory, Copenhagen).

These studies represent original work by author and have not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others it has been duly acknowledged in the text.

Thabang Innocentia Mosala

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MATERIALS AND METHODS

2

LITERATURE REVIEW

2.1 GENERAL CONSIDERATIONS ON URBAN SLUMS

This chapter will focus first on a review of published studies on geohelminth endemicity in urban slums nationally and internationally. It will then review the literature on transmission patterns and reinfection rates of these parasites in the slum environment. The literature on geohelminth transmission in urban slums is sparse, and despite high prevalences and intensities of ascariasis, trichuriasis and hookworm in the rural areas of KwaZulu-Natal province, little is known about the occurrence, reinfection rates, transmission patterns and epidemiology of these parasites in the ±500 urban slums in and around the Durban Unicity, so that this review will necessarily be brief.

There is no doubt that rapid urbanization in developing countries has created conditions favourable for the transmission of geohelminths. This is due to widespread overcrowding, indiscriminate faecal contamination of the soil and environmental degradation (WHO, 1995). A significant proportion of parasite-related deaths occurs in these countries and the individuals at greatest risk are children living in rural areas and in urban slums (informal settlements / squatter areas). Such people are usually poor and lack proper housing, safe water supplies and functional waste and excreta disposal systems (Rosenfield *et al.*, 1984).

The large-scale movement of people is a fundamental feature of slum development around the world. The work of Bruce-Chwatt (1970), Prothero (1977, 1983), Räisänen *et al.*, (1985), Gyorkos *et al.*, (1989), Satterthwaite (1993), Tshikuka *et al.* (1995) and Wilson (1995) has helped to raise the awareness of the role of human migrations in increasing levels of parasite transmission in endemic areas, and in introducing diseases to the new areas. These authors have also shown that disease itself may be responsible for the migration, thus resulting in the geographic spread of infection. A further effect of population mobility may also be to hamper the development of intervention programmes aimed at controlling diseases. It is therefore the duty of governments to ensure that safeguards are set up so that diseases imported by migrants and immigrants have little opportunity to become established in these slums.

The movement of refugees, the mass migration of rural people into urban areas, and high rates of urban growth without a complimentary expansion of urban services, have collectively resulted in the creation of overcrowded temporary settlements in cities throughout the world (Bundy *et al.,* 1985; Savioli *et al.*, 1992). As a result, 45% of the world's population now lives in cities and diseases that were traditionally 'rural' have spread into these cities, usually affecting the most deprived sections of the population there. Prothero (1977) emphasized that epidemiologists need to pay attention to the nature and variety of these population movements and to their differing impacts upon disease and human health.

2.2 URBAN SLUMS – THE GLOBAL SITUTATION

Many studies have demonstrated that urban slums are areas of high geohelminth endemicity and transmission, and that children have been found to be the most vulnerable group for these parasites (e.g. WHO, 1995). It has been suggested that for children living in such heavily infested areas, i.e. where the environment is heavily seeded with infective eggs and larvae, infection is a routine occurrence. Hence, those children with moderate or heavy intensity infections should be treated frequently, and additional measures such as health education and environmental modification should be implemented together as a longer term measure (Monzon, 1991).

2.2.1 Urban slums in Africa

In South Africa after the end of *apartheid* in 1994, there was a large influx of migrants and immigrants into cities, both from the former homelands and from beyond the country's borders. Studies on geohelminths in KwaZulu-Natal date back to 1952 when Elsdon-Dew & Freedman found that the prevalence of ascariasis and trichuriasis among black migrant labourers from rural areas coming to work in Durban, and who were living in overcrowded slum areas (e.g. Cato-Crest, the first and largest slum in Durban) doubled to 50.8% and 61.9% respectively within two years. The only other recent urban slum survey was conducted at Besters (second largest slum in Durban) with a population of 16000 where Coutsoudis *et al.* (1994) highlighted the levels of protein energy malnutrition, vitamin A and low iron status. In their study, *A. lumbricoides* and *T, trichiura* prevalences were 59.0% and 61.0% respectively. Hookworm was not found. The intensity of infection and epidemiology of these parasites investigated or correlated to the findings on malnutrition, low vitamin A or low iron status. There is no available information on parasite endemicity and transmission patterns in urban slums in any other South African cities.

A study on excreta disposal facilities and intestinal parasitism in urban slum dwellers in Botswana, Zambia and Ghana, concluded that the provision and use of piped water and sanitation facilities may not protect families from infection if the overall level of faecal contamination of the environment remains high (Feachem *et al.,* 1983). Transmission of geohelminth infections in these poor communities is also exacerbated by overcrowded conditions. Children living in these areas are surrounded by illness at birth and remain at risk for the rest of their lives.

In a study in Nigeria, Holland *et al.* (1989) showed that children aged 5-16 years remained predisposed to *A. lumbricoides* over 2 reinfection periods. The study did not examine predisposition to other infections or in children below 5 years.

2.2.2 Urban slums in Asia

In Malaysia the prevalences of geohelminth infections in 4-13 year old children living in urban slums were found to be 50% - 90% (Kan, 1982, 1984, 1985a, 1985b; Bundy *et al.*, 1988; Kan *et al.*, 1989; Rajeswari *et al.*, 1994). These studies have shown that children of both sexes living in urban slum areas have high levels of infection with *A. lumbricoides* and *T. trichiura*. The rate of acquisition of infections appeared to be low in 1-3 year olds but reached stable, higher levels in the 6-10 years old age class which has the highest intensity of infection and the highest rates of associated morbidity (Cooper & Bundy 1986; Thein-Hlaing, 1987). Chan (1991) showed that children with above-average intensities of ascariasis and trichuriasis were likely to be reinfected with high intensities of both parasites and that the 2-12 year olds were the most predisposed to reinfection and had the highest intensities. Other studies in slums in Kuala Lumpur have indicated that there was a persistent predisposition to helminthic infections at the family level, and thus recommended familial treatment as the most appropriate intervention against geohelminths (Cooper & Bundy, 1986; Chan *et al.*, 1994).

The degree of protein energy malnutrition in a sample of 131 children less than 10 years old from the Indira colony in Delhi, India, was found to be significantly associated with their history of passing adult *A. lumbricoides* in their stools (Gupta, 1985). Another study in Kuala Lumpur showed that anthelmintic treatment of *A. lumbricoides*-infected children was followed by their gaining more weight than uninfected children. A study in a fishing community (population 460 in 70 households) following an 11-month reinfection period has shown that children harboured predominantly smaller worms before treatment, while adults expelled mainly large worms. In contrast, worms expelled by both children and adults after reinfection were larger and more homogenous in size, particularly within the relatively heavily infected groups. An understanding of these phenomena is important to assess the merits of providing treatment without reducing exposure to infection with sanitation or other risk factors (Haswell-Elkins & Anderson, 1987; Elkins & Haswell-Elkins, 1989).

A study in Bangkok, Thailand, that sought to rank urban environmental problems based on their risk level suggested that biological pathogens such as intestinal worms were amongst the most serious (Ittiravivongs *et al.*, 1992).

Ascaris lumbricoides is one of the most common intestinal parasites of man in the Philippines. A study by Monzon (1991) among children aged <1-14 years found a prevalence of 84.4% and correlated it with an "over-crowding effect" amongst the worms. They found that this effect was most noticeable among the heavily infected children. Another study in Manila revealed reinfection rates of 68.6%, 4½ months post-treatment, 85.8% after 6½ months and 89.5% after 8½ months (Garcia *et al.*, 1961). These rapid reinfection rates were attributed to poor environmental sanitation and a lack of personal hygiene (Cabrera *et al.*, 1975).

Similar urban slum conditions have been reported from Bangladesh (Tanner *et al.*, 1986; Holland *et al.*, 1988; Henry *et al.*, 1990; Hall *et al.*, 1992; Hall & Nahar, 1994). Children living in houses made of wood or bamboo had high prevalences of *A. lumbricoides*, but this occurred more frequently in children from relatively crowded areas and where mothers had minimal education.

2.2.3 Urban slums in Central, South America and the Caribbean

Studies undertaken in a shanty town in Coatzacoalcos, Mexico, also showed that clustering of heavily infected individuals in households may prove to be an important consideration in developing rational, community-based control programmes for *A. lumbricoides* and *T. trichiura.* This was a slum where 70.0% of households practice open air defaecation, where children became infected with *A. lumbricoides* between 1 and 2 years of age and the intensity of infection peaked in 5-6 year olds. High intensities of *T. trichiura* were observed in children between 3 and 10 years old (Forrester *et al.*, 1988).

A longitudinal study in the Caribbean on the trichuriasis intensity and prevalence in Jamaica, has suggested that *T. trichiura* is more difficult to control by traditional mass chemotherapy than *A. lumbricoides*, but that the former may be more amenable to control by selective chemotherapy (Bundy *et al.*, 1985).

2.3 FUTURE REFLECTIONS ON URBAN SLUMS

Rapid urbanization is a phenomenon found mostly in the third world, i.e. in large parts of Africa, Latin America and Asia. Cities and towns receiving this influx are often administratively, economically and socially incapable of coping with the increased population due to low standards of housing, inadequate water supply, sewage and waste disposal. These are factors that increase the risk of imported diseases becoming established and there are numerous examples where migrants have introduced diseases into previously unexposed communities (e.g. Prothero, 1977; Prost, 1987; Appleton *et al.*, 1996; Katz, 1998).

Geohelminth control can be successful. Yokogawa (1983) has recounted the remarkably successful campaign that took place in Japan after World War II, where the overall prevalence of ascariasis was reduced from 61.3% in 1927 to 0.05% in 1982. Although ascariasis was virtually eliminated from the country, the reduction took 55 years! Geohelminth control programmes also have a beneficial psychological impact on children and improve compliance with other aspects of health care (Boivin & Giordani, 1982; Watkins *et al.*, 1992; Appleton & Kvalsvig, 1994; Simeon *et al.*, 1995; Fincham *et al.*, 1996; Kruger *et al.*, 1996).

3

THE STUDY AREA AND POPULATION

3.1 INTRODUCTION

This was a prospective cohort community-based study conducted in 10 urban slums in Durban, in the province of KwaZulu-Natal, South Africa. Durban is situated at 31°00'E: 29°50'S. Figure 3.0 shows the location of the selected study slums as well as others within the Durban Metropolitan Area (in the year 2000 this was changed to Durban Unicity).

What is an urban 'slum'?

It is difficult to define a **'slum'** in the present context. Slums are very variable but seem to be characterised by a number of features which apply to most though not all of the study slums, viz.:-

1. They are overcrowded, both in terms of number of houses erected per unit area, and the number of people occupying each house.
2. The houses are usually erected illegally on council, state or privately-owned land.
3. Slums have very poor sanitation facilities (or none at all), and inadequate water availability, both in terms of quality and quantity. This leads to very poor general hygiene and high endemicity for infectious diseases.
4. These communities are often highly mobile and people circulate between the cities and their rural homes (Prothero, 1977).
5. Crime levels are often high, because they tend to be inaccessible to law enforcement agencies and serve as hideouts for criminals.

One third of the African population in Durban, i.e. 180 000 families, live in urban slums. These slums were first established in 1948 and by 1999 had increased to 102, of which 49 were stable and 53 were unstable. Currently (2001) it is estimated that about 500 urban slums exist in the Durban Unicity (Figure 3.0). The 10 study slums are numbered as follows: 1. Bottlebrush, 2. Kennedy Lower, 3. Lusaka, 4. Pemary Ridge, 5. Quarry Road West, 6. Simplace, 7. Briardene, 8. Smithfield, 9. Park Station and 10. Canaan (75% of the families moved to Quarry Heights during the study period).

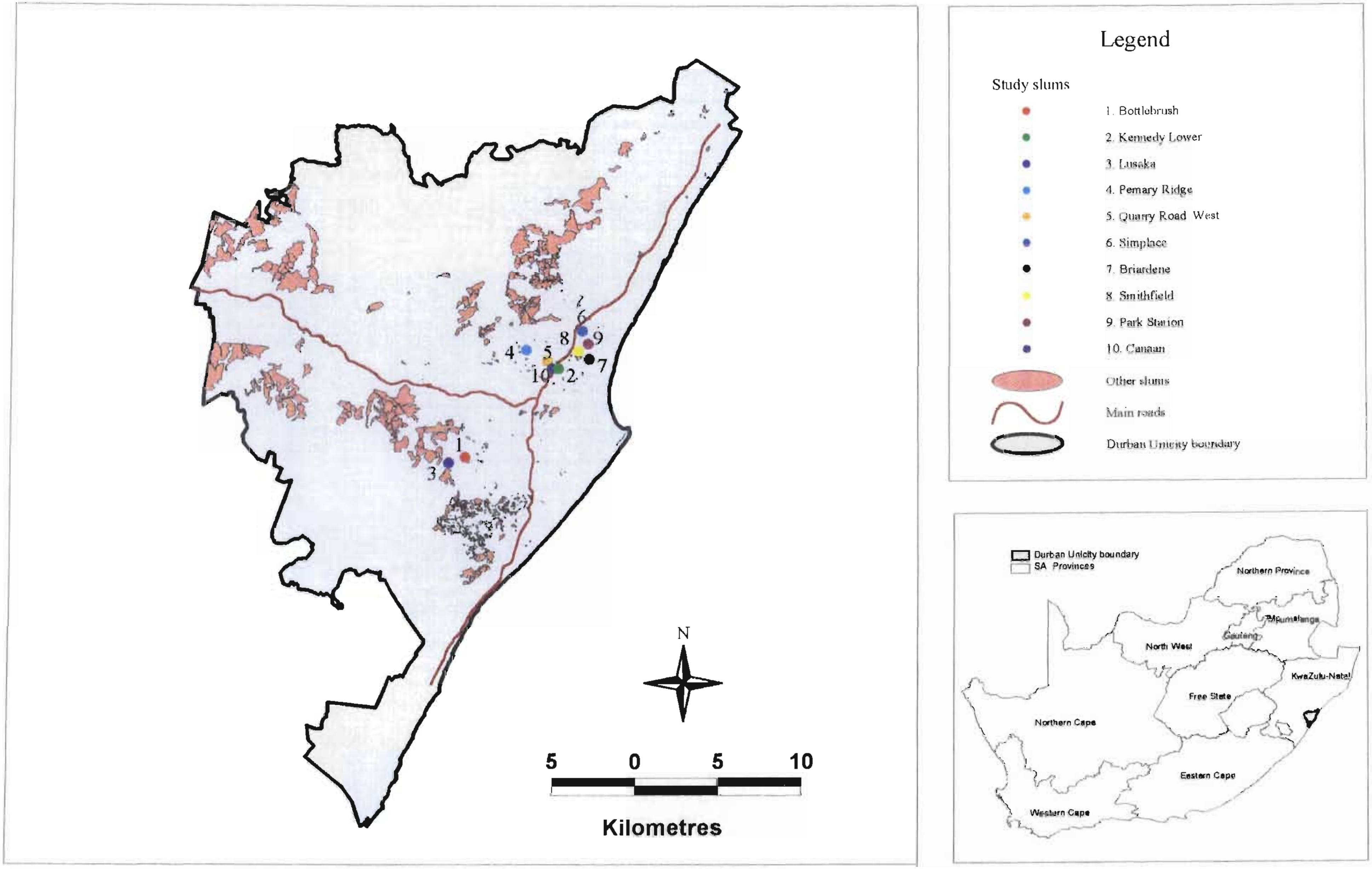


Figure 3.0 . Map showing the location of study slums in relation to other slums within the Durban Unicity boundary.

3.2 ENVIRONMENTAL FACTORS

Certain infective stages of geohelminths such as eggs and larvae survive for a long time outside their hosts and are therefore subject to climatic stress. In order to discuss meaningfully the transmission of these parasites, it is therefore necessary to have a knowledge of the environmental factors that such free-living stages are subject to. These factors include: topography, rainfall, environmental temperature and soil conditions.

Topography:

Durban is situated on a coastal plain and is fairly hilly with altitudes ranging from 0 - 290 metres above sea level (m.a.s.l). Figures 3.1 - 3.9 (p19 - 27) show the altitudinal and slope gradients of nine slums. The Quarry Road West area was small and on level ground, therefore it was not possible to digitize the altitudinal bands using the Geographical Information System (GIS).

Rainfall:

Durban has a mean annual rainfall of 1000mm, mostly in summer. The monthly rainfall from January 1997 to September 2000, the period during which the study was conducted, is summarised in Table 3.1 (p28).

Environmental temperature:

Average daily temperatures during mid-winter (July) range from 9.7°C to 24.3 °C with an absolute minimum and maximum of 4°C and 26°C respectively. Mid-summer (January) average temperatures range from 19.5°C to 29°C with the minimum being 19°C and the maximum being 39°C. There is no frost since temperatures never go below 4°C.

Soil conditions:

The distributions of different soil types and their properties in each study slum are explained in Table 3.2 (p29). The slums investigated lie in two categories of soil types, viz.:

1. Those with high clay content (± 38%) and low sand content (± 18%), poor drainage and a soil thickness of 0.6 - 0.9m (Cartref and Milkwood types) (Macvicar *et. al.*, 1991).

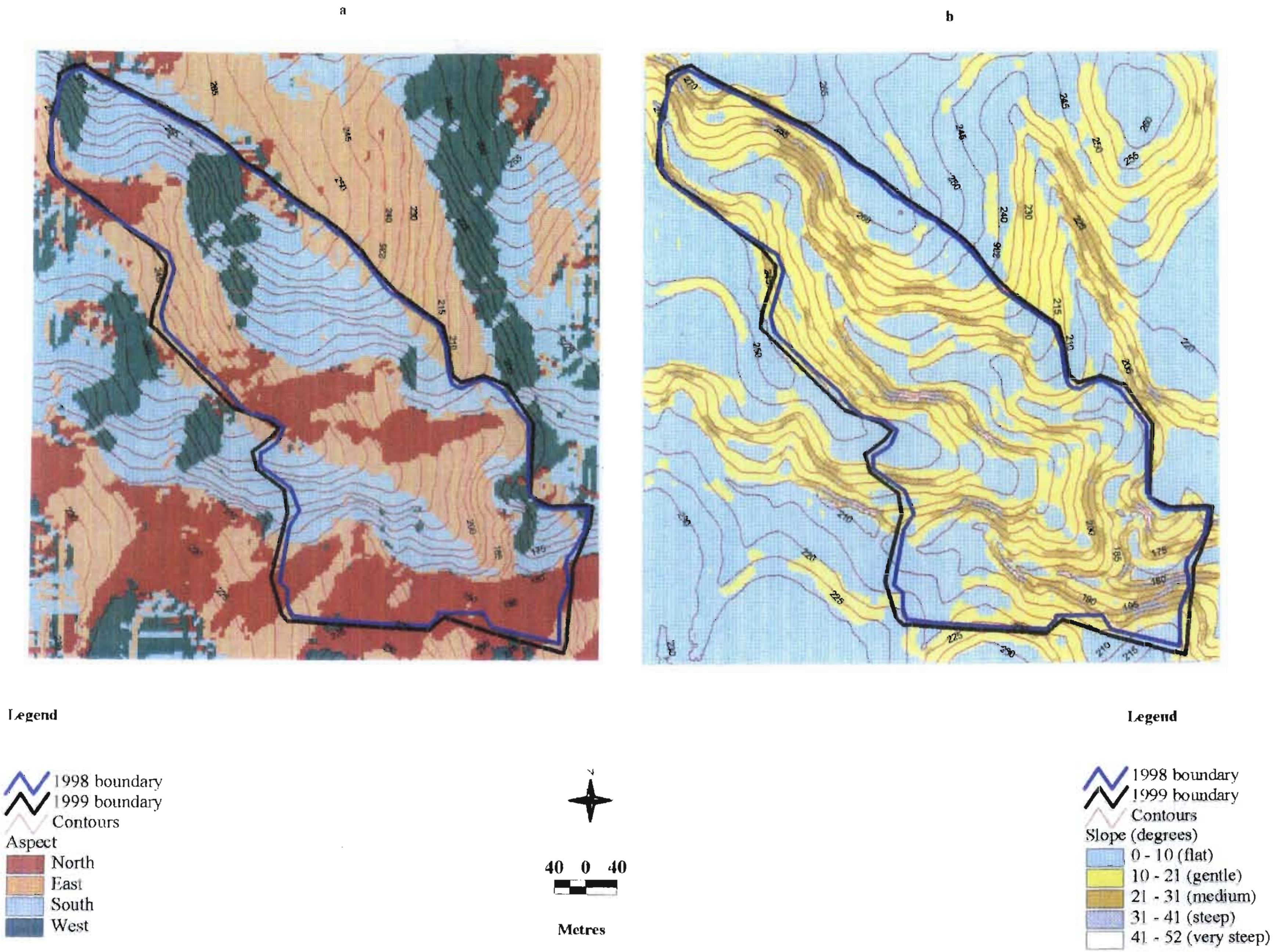


Figure 3.1 GIS map of Bottlebrush showing 1998 and 1999 boundaries, altitudinal contours and (a) aspect and (b) slope gradients.

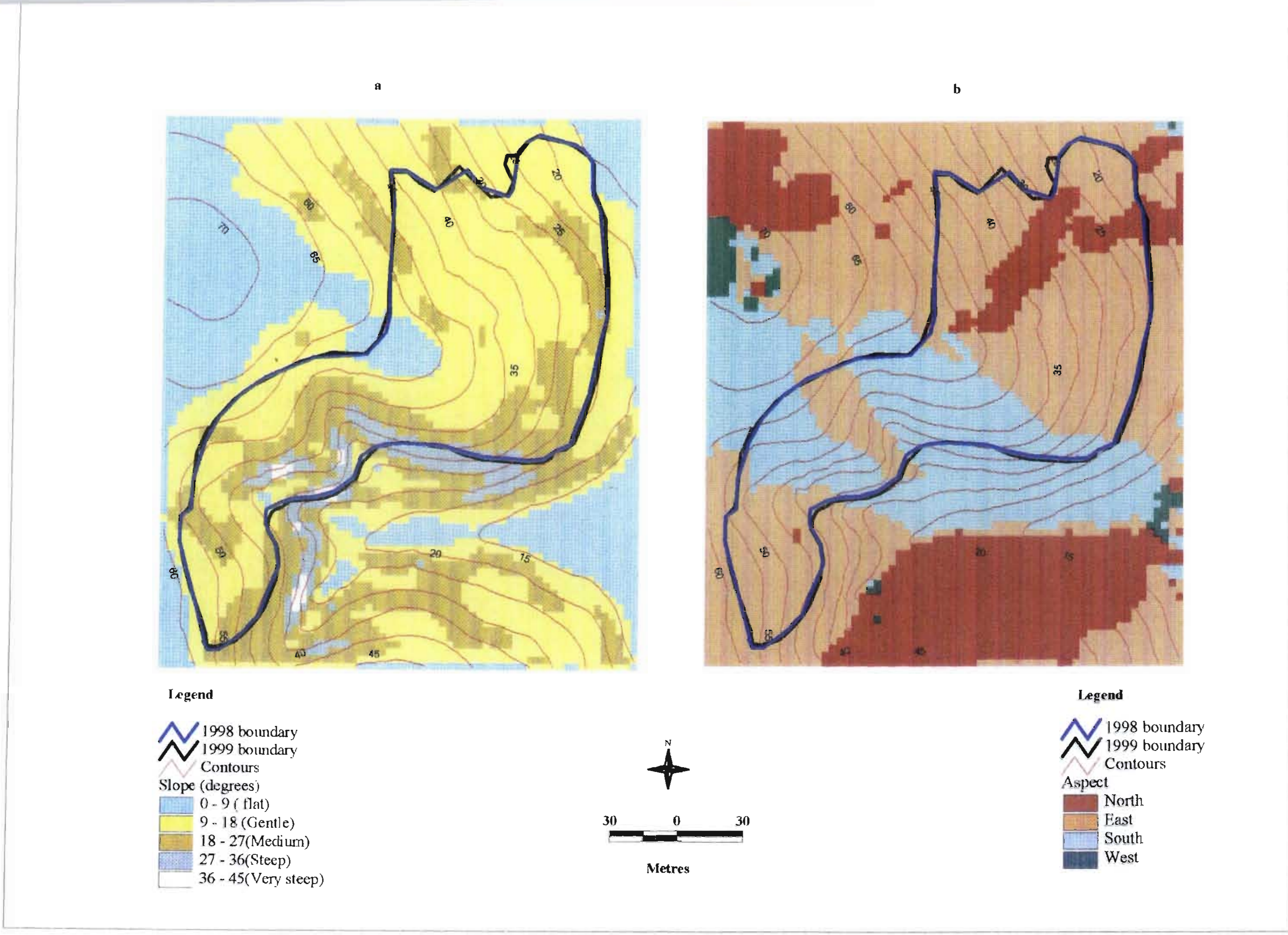


Figure 3.2 GIS map of Kennedy Lower showing 1998 and 1999 boundaries, altitudinal contours and (a) slope gradients and (b) aspect.

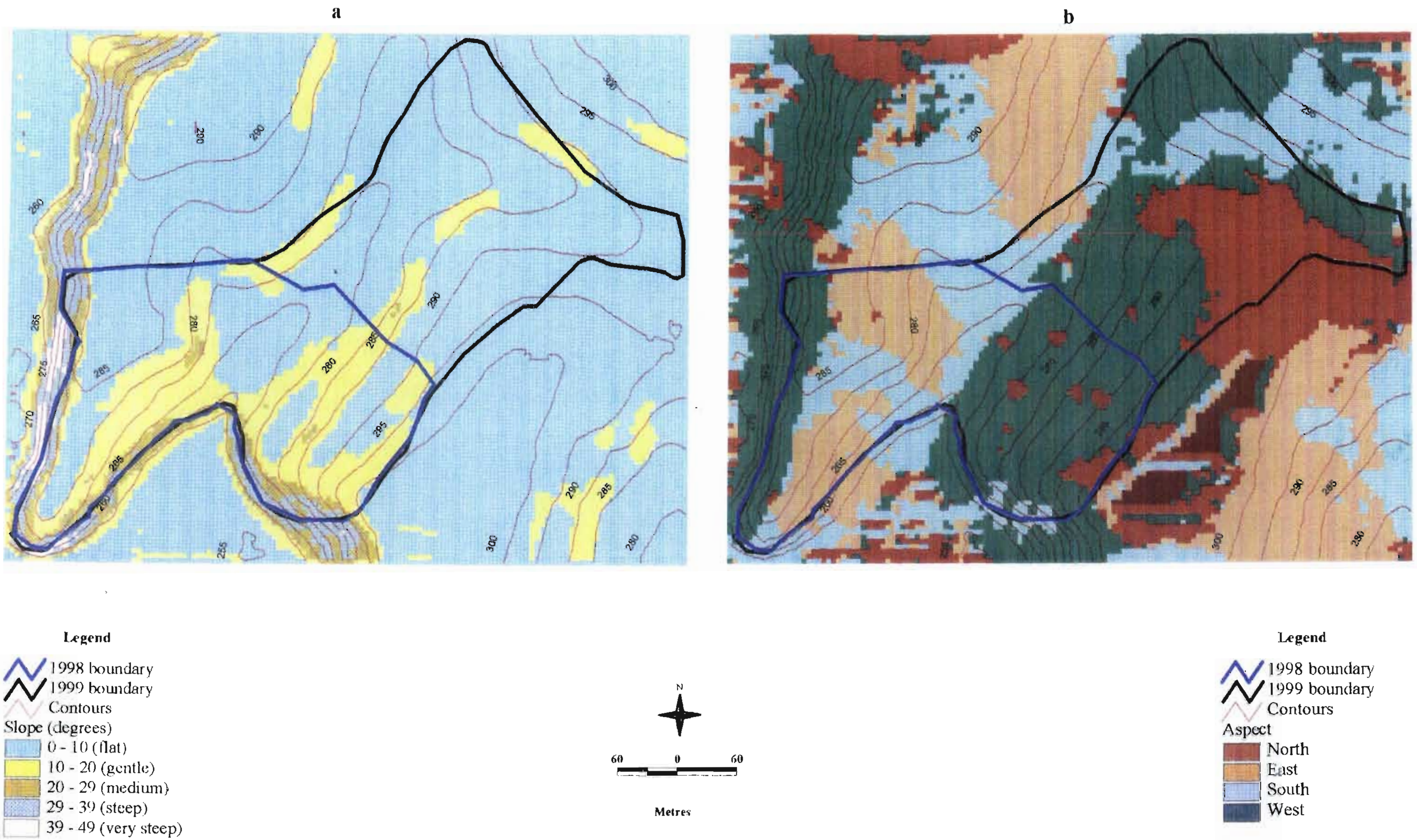


Figure 3.3 GIS map of Lusaka showing 1998 and 1999 boundaries, altitudinal contours and (a) slope gradients and (b) aspect.

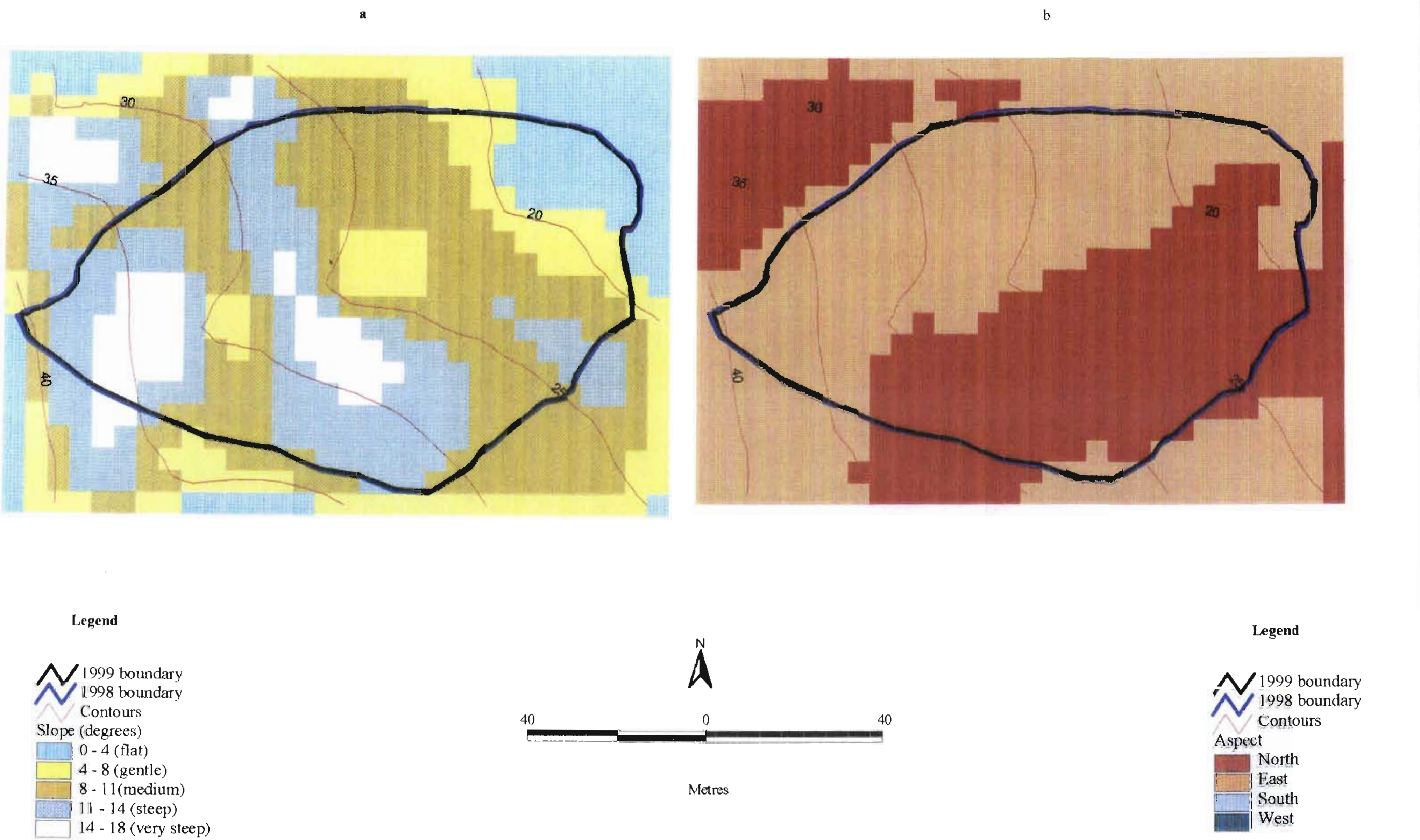


Figure3.4 GIS map of Pemary Ridge showing 1998 and1999 boundaries, altitudinal contours and (a) slope gradients and (b) aspect.

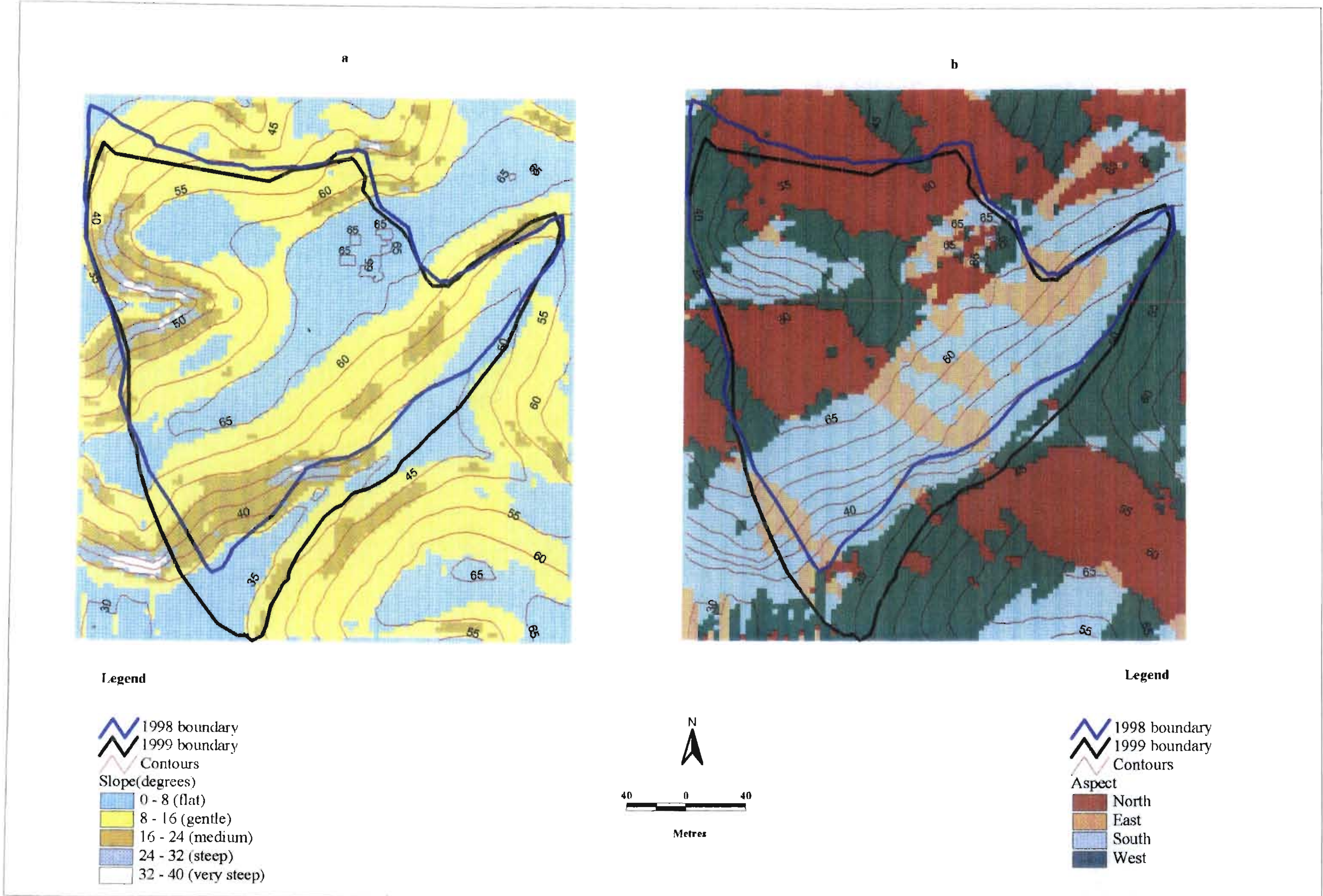


Figure3.5 GIS map of Simplace showing 1998 and 1999 boundaries, altitudinal contours and (a) slope gradients and (b) aspect.

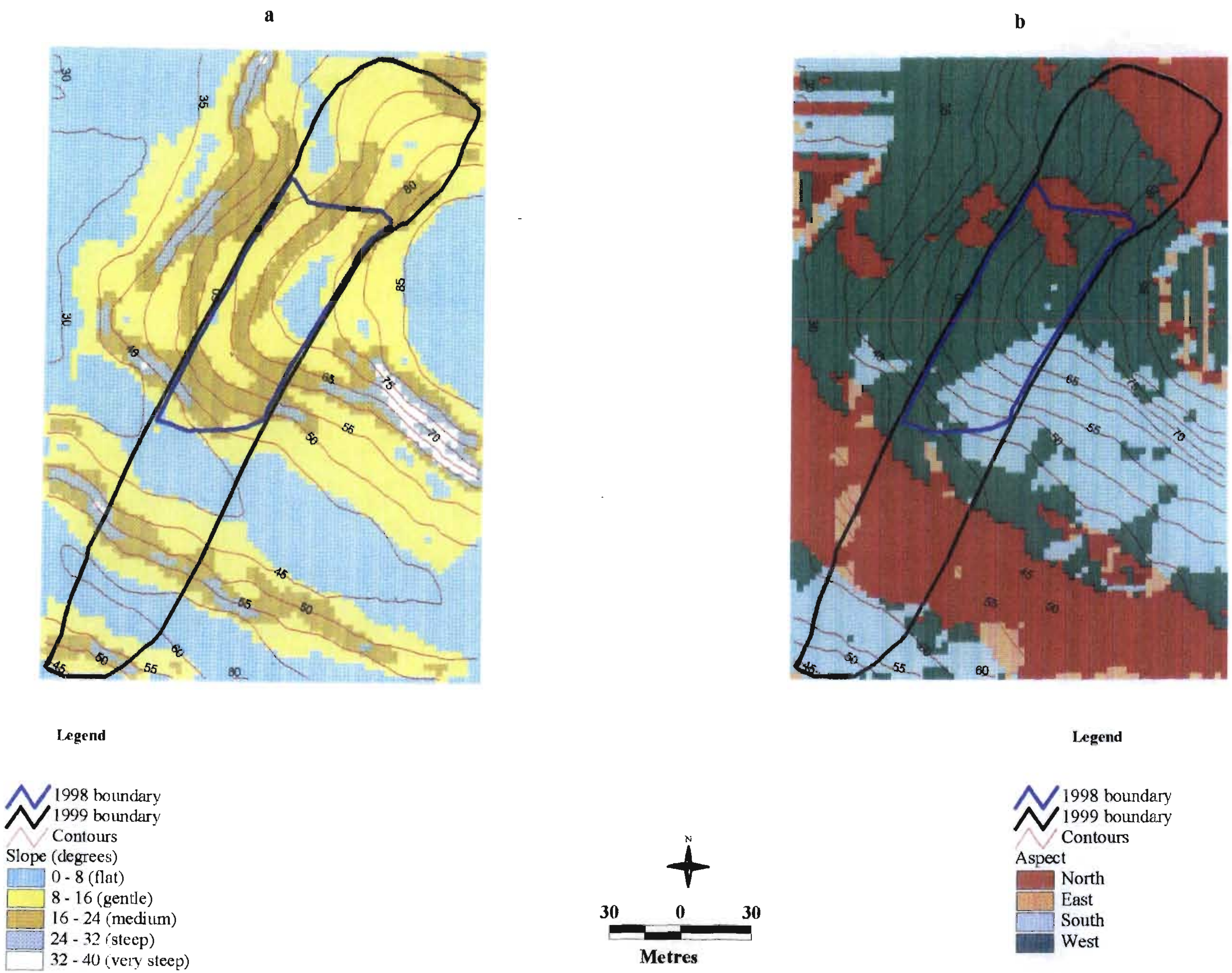


Figure 3.6 GIS map of Briardene showing 1998 and 1999 boundaries, altitudinal contours and (a) slope gradients and (b) aspect.

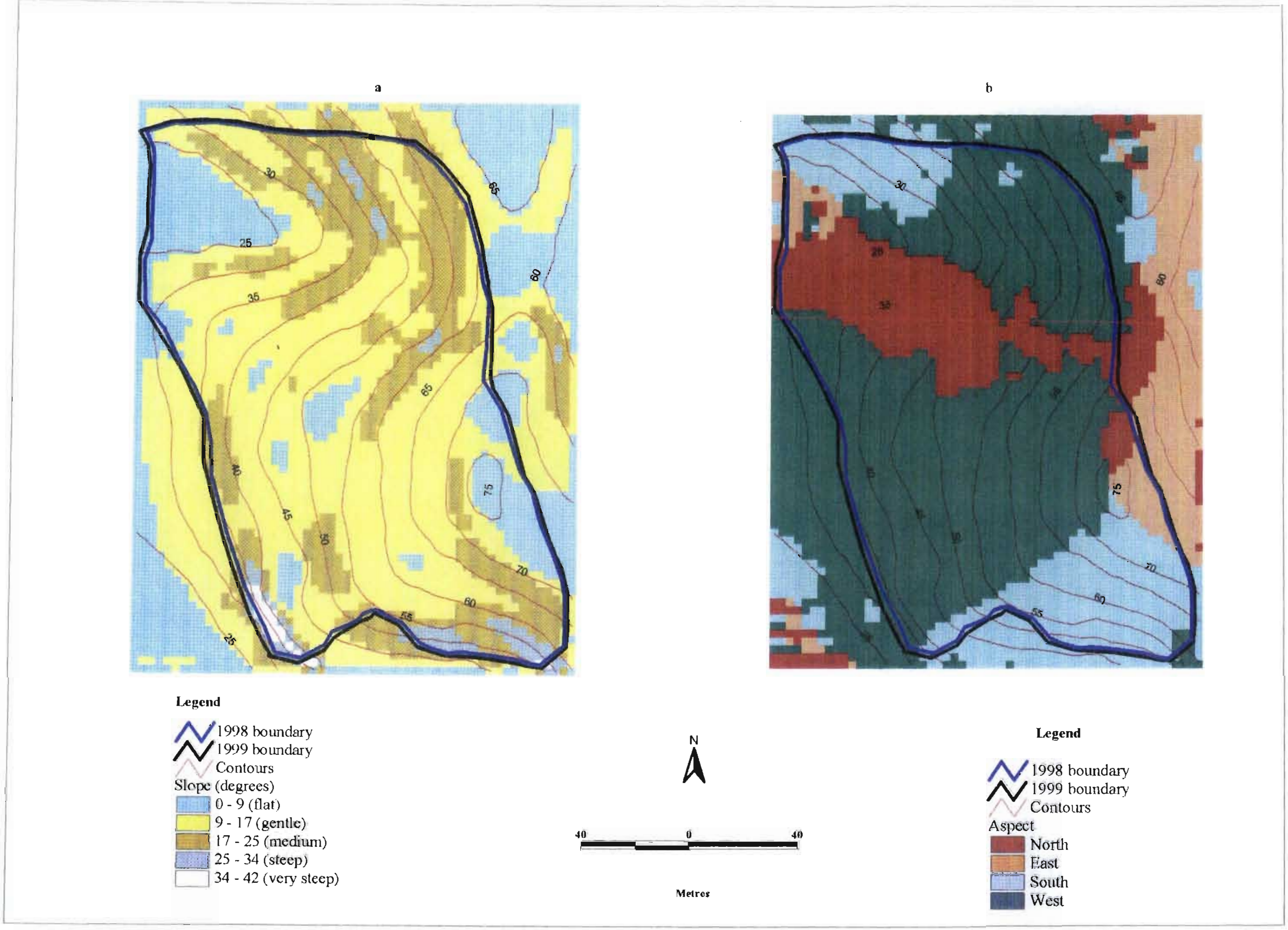


Figure3.7 GIS map of Smithfield showing 1998 and1999 boundaries, altitudinal contours and (a) slope gradients and (b) aspect.

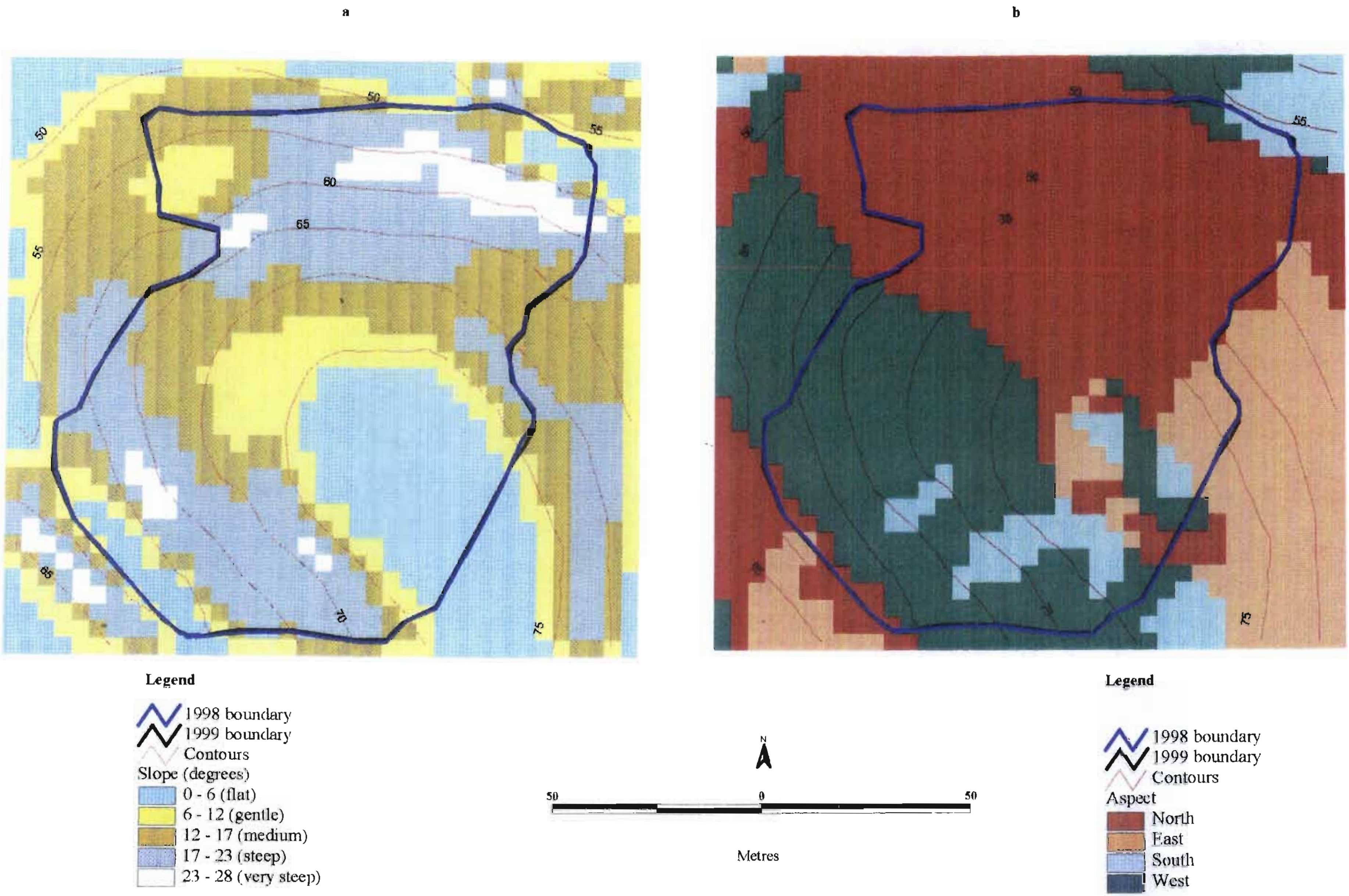


Figure 3.8 GIS map of Parkstation showing 1998 and 1999 boundaries, altitudinal contours and (a) slope gradients and (b) aspect.

2. Those with low clay content (± 3%) and high sand content (± 94%), very good drainage and a soil thickness of >1m (Fernwood & Dundee types) (Macvicar *et al.*, 1991).

Floodplains:

Quarry Road West and Pemary Ridge are built along rivers and fall within the 1:50 year floodplain. These slums lie along the Umgeni River and one of its tributaries respectively. They experience considerable flood damage during heavy rains, Figure 3.10 (p30).

3.3 GENERAL DESCRIPTION OF THE URBAN SLUMS

For the purpose of this study urban slums can be described as illegal settlements constructed on either council, state or privately owned land. They are generally overcrowded and overpopulated, without any kind of permanent shelter, and without basic amenities such as clean potable water, lighting, sanitation or waste disposal. The infra-structure in these slums in respect of their size, housing density (Plate I – p32), sanitation coverage and type (Plate II – p33), aspect, slope, altitude (Figure 3.1 - 3.9), soil structure and shade provided by trees (Plate III – p34) and water availability.

Instability within the slums:

Since 1949 new slums have been built enlarged but existing ones have rather and become denser. Figure 3.11 (p35) shows an example of such a slum. During the study there was a continual change in the infrastructure of these slums leading to instability in some cases. Most of the slums are associated with a certain risk to the inhabitant's safety. Some are built on unstable sloping ground, others on a floodplain, next to quarries and dumping sites (see Chapter 3 title-page). Most are densely populated with houses built close together and with flammable material (see Frontispiece -a). Thus the models that will be developed for geohelminth transmission patterns will be in relation to this inherent instability in the study population.

Upgrading of slums by Durban Metro Housing Development :

Several interventions were implemented within the study slums during the study period. According to Mr. M.S. Makhathini, acting executive director, Durban Metro Housing, (Pers. comm.) the aims of these interventions were:

1. to install essential services, e.g. lighting, sanitation, water, roads and clinics;
2. to improve quality of life and

Table 3.1 Monthly average rainfall (mm) in Durban (Station number: 0240808A2). Data from Weather Bureau, Pretoria.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec
1997	187.1	99.5	59.6	167.9	40.5	89.4	159.2	16.6	71.2	151.3	277.2	71.3
1998	93.3	158.3	83.6	237.4	52.2	0.0	22.9	69.4	25.5	64.5	106.4	182.6
1999	94.0	239.3	44.2	36.7	36.5	74.4	3.5	12.2	74.1	195.9	59.1	291.8
2000	181.7	157.3	148.8	63.2	167.5	3.8	20.2	17.1	62.8			

Table 3.2 Description of soil types at the individual study slums (provided by Dr. T.E Francis, City Engineers Unit: Geotechnical Section)

Slum	Geological formation	Parent rock	Soil type	Soil series	Thickness	Sand (%)	Silt (%)	Clay (%)	Drainage	Porosity (%)
1. Bottlebrush	Natal Group	Sandstone	Pale gray fine sand	Cartref	0.6 - 0.9m	80	3	3	Good	42
2. Kennedy Lower	Pietermaritzburg	Shale	Dark gray clay	Milkwood	0.6 - 0.9m	18	31	38	Very poor	51
3. Lusaka	Natal Group	Sandstone	Pale gray fine sand	Cartref	0.6 - 0.9m	80	3	3	Good	42
4. Pemary Ridge	Recent alluvium	Alluvial river deposits	Sand layered with sandy clay and clay	Fernwood & Dundee	>1m	94	2	5	Very good	53
5. Quarry Road West	Recent alluvium	Alluvial river deposits	Sand layered with sandy clay and clay	Fernwood & Dundee	>1m	94	2	5	Very good	53
6. Simplace	Pietermaritzburg	Shale	Dark gray clay	Milkwood	0.6 - 0.9m	18	31	38	Very poor	51
7. Briardene	Pietermaritzburg	Shale	Dark gray clay	Milkwood	0.6 - 0.9m	18	31	38	Very poor	51
8. Smithfield	Pietermaritzburg	Shale	Dark gray clay	Milkwood	0.6 - 0.9m	18	31	38	Very poor	51
9. Park Station	Pietermaritzburg	Shale	Dark gray clay	Milkwood	0.6 - 0.9m	18	31	38	Very poor	51
10. Canaan	Pietermaritzburg	Shale	Dark gray clay	Milkwood	0.6 - 0.9m	18	31	38	Very poor	51

Figure 3.12 Illustration of flood damage to shacks in Quarry Road West: The stream has washed between the dwellings, removing topsoil and toilets. This is typical example of a slum built on a river's flood plain.

3. to improve the slum if it was economically worthwhile for the slum communities.

The changes/instabilities occurred in three ways, viz.:-

1. ***In-situ* upgrading,** where the area was developed without relocating the inhabitants. This was because the ground was suitable for upgrading and the slum was located close to employment e.g. Briardene and Lusaka (Figure 3.12).

2. **Relocation,** where families were relocated to an undeveloped area e.g. Quarry Heights (see Plate I – f). Reasons for the relocation included:- the area being geologically unsuitable for development and the risk to people's safety was unacceptably unsafe to the community. In some cases, the area was too small and overcrowded to expand, e.g. Quarry Road West (see Frontispiece - a).

3. **Partial relocation,** where a slum was built on a floodplain, on land that could be developed or on state or privately owned land, e.g. Briardene and Canaan.

Six of the slums in this study underwent some of the above-mentioned changes during the study period, and similar changes are on schedule for others in the near future.

Each study slum has its own characteristic features as well as a committee which has to be consulted each time a survey is conducted. The City Health Department provided the following infrastructure in the urban slums, viz.:- sanitation, piped water, refuse skips and bags, health education and cleaning campaigns. This study used the City Health Department's infrastructure to be able to conduct research. The summary of conditions inside the individual slums at the start and at the end of the study is given in Table 3.3 (p38).

3.4 DESCRIPTIONS OF THE INDIVIDUAL STUDY SLUMS

The characteristic of each study slum is described in detail below. These descriptions will be used in the analysis (see section 6.4) as a risk factor called simply "slum".

Bottlebrush (no. 1) (30°88'E : 29°90'S):

This slum is built on a very steep slope (Figure 3.1). Housing density is mixed, with some parts being more dense than others. It has the highest sanitation coverage of well maintained Ventilated Improved Pit-latrines (V.I.P.) (Plate II), a community hall, a crèche and a well-

PLATE I

Levels of crowding in the study slums

High housing density: **(a)** Pemary Ridge with surrounding partial shading from trees, **(b)** Park Station with little shading from surrounding trees and steep slope, **(c)** Canaan before (relocation).

Low housing density: **(d)** Bottlebrush **(e)** Smithfield and **(f)** Relocated slum (Canaan) – now called Quarry Heights.

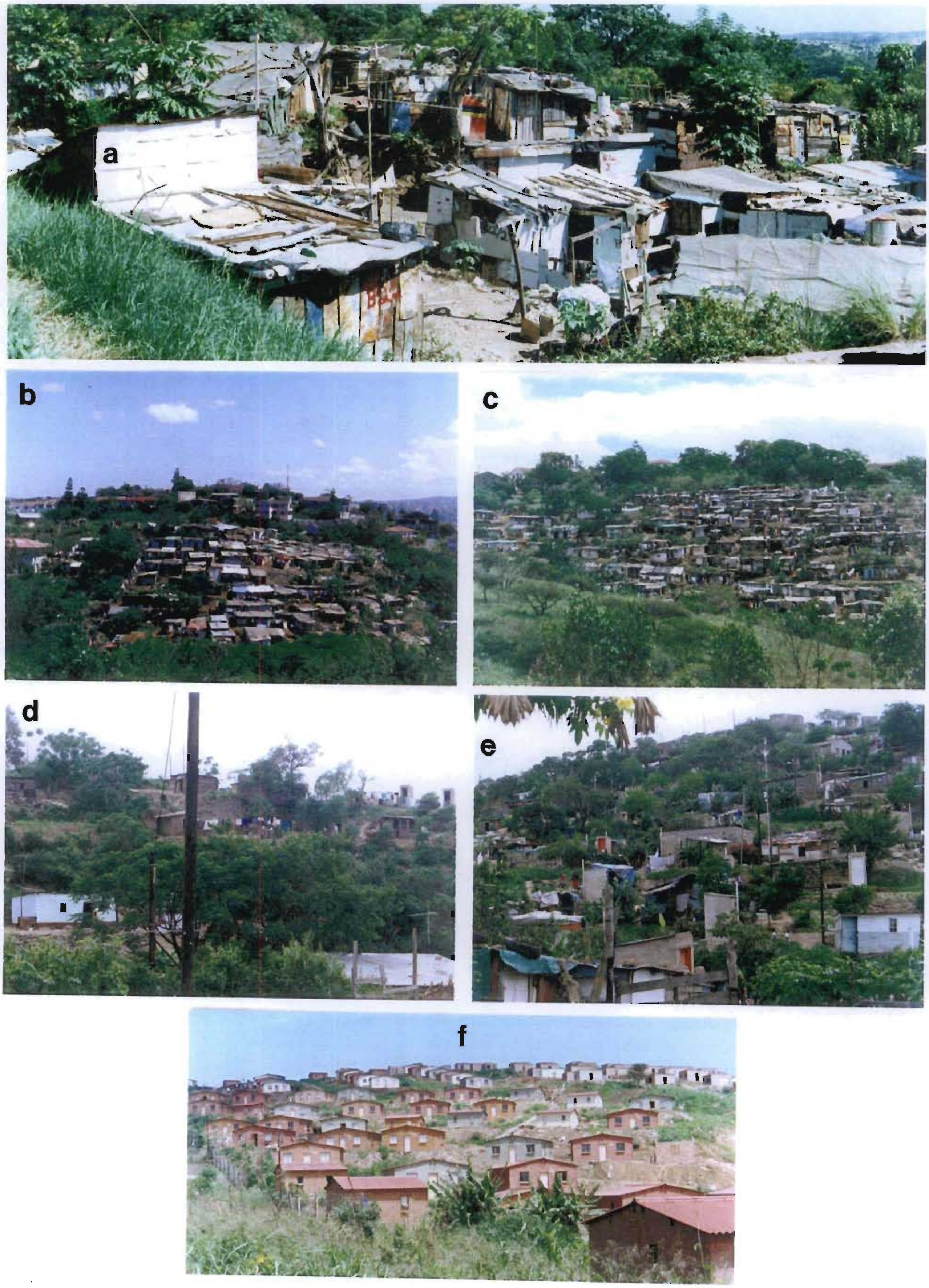


PLATE II

a

b

c

d

e

f

Five types of toilets found in the study slums: **(a)** flush toilet **(b)** chemical toilet **(c)** V.I.P latrine **(d)** pit-latrine **(e & f)** "*Stamkoko*" toilet which passes into a hole made into a sewage pipe (↑) serving the nearby residential suburb.

PLATE III

Pemary Ridge: Showing the secluded and heavily shaded environment of the slum. This slum gave the highest baseline levels of *Ascaris lumbricoides* and *Trichuris trichiura* infections and the most rapid reinfection rate for both parasites (see Figure 5.3d, Chapter 5).

Simplace 1998

Simplace 1999

Figure 3.10 Simplace: the aerial photographs (1:11 000) show how the slum increased in area by 11 415 m² between 1998 and 1999. The number of shacks increased by 505.

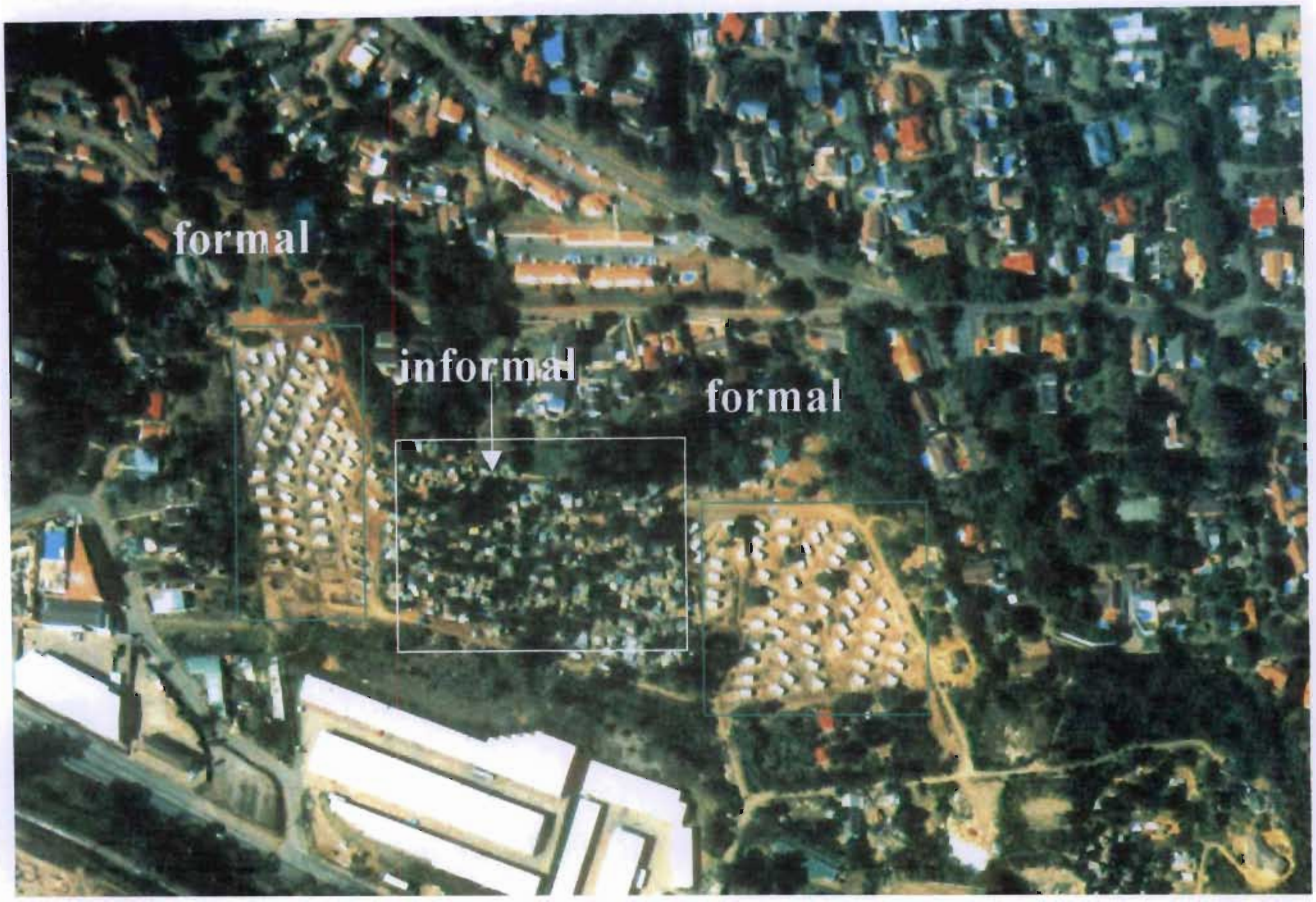


Figure 3.12 ***In-situ* up-grading:** at Briardene with the formal part of the slum provided with flush toilets and chemical toilets for the informal part.

equipped clinic. It is the largest slum in the study. Despite being the largest study area, compliance was 83 – 100% throughout the study.

Kennedy Lower (no. 2) (30°98'E : 29°81'S):

This slum is built next to a dumping site on a potentially unstable landfill site (see Chapter 3 title page). Some households earn up to R600 per month selling goods retrieved from the dump and most families live on the food from the dumping site. Several shacks were recently gutted by fire and the affected families currently reside in the nearby community hall awaiting relocation. Because of the hazardous nature of the chemicals used by the authorities to treat organic waste in the dump, there is debate over whether the people should be relocated or not. The dilemma is that most people scavenge on the dump, which is therefore a source of income and food for them. Slum development is subsidised by government. There is a good sanitation coverage by V.I.P. toilets but these are poorly maintained and 70% are full.

Lusaka (no. 3) (30°86'E : 29°91'S):

This slum has undergone partial *in-situ* upgrading. In 1998, at the beginning of the study, there were large spaces between houses and the one standpipe was provided next to the municipal hall. Part has been upgraded, and those who cannot afford to buy the new low-cost houses, remain in the informal part of the slum. Two roomed houses with flush toilets (Plate II - p33) have now been built and electricity has also been installed. 12.3% of the children who participated in the study remain in the informal part of the slum while 87.7% moved to the upgraded homes.

Pemary Ridge (no. 4) (30°94'E : 29°79'S):

This slum is built on a 1:50 year floodplain (once in 50 years it will be flooded) in a forest next to the Umgeni River (Plate III – p34). In 1998 there was no standpipe and people got piped water from the nearby residential community or collected it from the river. There were two pit latrines and 1 *stamkoko*. The *stamkoko* was destroyed during the January 2000 floods (see Plate II). In 1999 a school was built nearby and a standpipe has been installed.

Quarry Road West (no. 5) (30°97'E : 29°80'S):

This slum is the most crowded of all the slums studied, with very narrow spaces between the dwellings (see Frontispiece - a). Floods constantly affect this area because it is built on the

1:50yr floodplain. Since the recent flooding (January 1999) (Figure 3.10 - p30), the affected families are living in the nearby Kennedy Lower community hall. The number of shacks has tripled within a two-year period from 200 in 1998 to 600 in 2000. Ten chemical toilets were installed between January and April 1999 and they were meant to be used by individual families at R40.00 per week. However, the families could not afford to pay for the toilets' maintenance, and they were removed after four months.

Simplace (no. 6) (31°06'E : 29°77'S):

This slum has spread and housing density has increased (Figure 3.11 p35). The number of shacks has doubled and the area has increased by 11 415 m². The area is earmarked for the *in-situ* upgrading of 600 sites and the remaining households will be relocated to another site. Conducting research here was difficult because there are political conflicts between supporters of the Inkatha Freedom Party and the African National Congress. Thus there are effectively two committees, and both had to be consulted. There is a well-equipped crèche where working parents/guardians leave their children during the day.

Briardene (no. 7) (31°01'E : 29°80'S):

This slum is undergoing *in-situ* upgrading. By June 1999 *in-situ* upgrading had started and some families were moved from the old part of the slum to the developed part (Figure. 3.12 – p36). This has led to the problem that a previous shack owner leaves behind relatives who become the new owner, and who now refuse to be moved because they claim they did not ask to be relocated. The slum has poor leadership and committees change frequently. It was not easy to conduct surveys here, because at each visit I had to meet the new leaders to seek their support. The soil conditions (mainly clay) made it difficult to collect samples after rain because the ground became slippery - the slum is built on a steep slope (Figure 3.5 - p23).

Smithfield (no. 8) (31°00'E : 29°79'S):

This slum has large spaces between houses, maintaining a rural character (see chapter 7 title-page). Before the study began (1997), the owner of the land on which the slum is built, won a court order to demolish the shacks. After all the shacks had been demolished, the communities rebuilt them within a matter of days. In November 1999, sixteen shacks were burnt down as a result of witchcraft accusations. The situation became very tense because the field assistant I had appointed was the one accused of practicing witchcraft. Each family has a new large space and they tend to dig a trench around the house so that they can extend the house when they are able to. It is generally a very clean slum and refuse is collected weekly. Sanitation coverage is also good, i.e. 70% coverage.

Park Station (no. 9) (31°01'E : 29°79'S):

This slum is built on a very steep north facing slope (Plate I b - p32). There is a narrow path leading into the slum, the path is surrounded by a thick bush, which was used as a toilet in 1998. The same area has now been converted to a vegetable garden. There is a crèche where the teacher usually brings soil from the market to share with the children as a snack (see geophagy). The area lies on a North-facing slope (Figure 3.8 - p26). It is not shaded. There is a small stream in the valley nearby.

Canaan (no. 10) (30°97'E : 29°81'S):

In 1998 there were 5008 families here. In 1999, because of the unstable ground which lies next to a quarry (Chapter 3 title-page), 75.0% of these families were relocated to a new area called Quarry Heights built for low-income communities (Plate I f). Although the houses at Quarry Heights have flush toilets, no water is provided. Because water has to be bought separately, it is limited to cooking, bathing and toilets, leaving the children to use the bush for defaecation. There are no trees and therefore no shade (Plate 1f).

Lacey Road (pilot area – no. 11):

This slum is built on Department of Education land. There were 158 shacks in 1998, 46 pit latrines and 10 chemical toilets. The number of shacks has increased to only 164 in 1999 so that this is a relatively stable slum. It also has the best-organised committee. It was used as a pilot study only because of poor participation by children during the initial phase of the study. This poor compliance was a result of high mobility - the children went to their grandmothers in the rural areas during weekends, and this made it difficult to collect samples and treat them. They were taken to rural areas for several reasons: (i) high levels of sexual abuse by HIV positive men who think they will be cured by sleeping with virgins, (ii) too much traffic on the nearby road leading to many accidents, (iii) absence of recreational facilities and (iv) no crèche.

3.5 SELECTION CRITERIA FOR STUDY SLUMS

Eleven established slums were selected for the study. Selection of these was based on: (i) safety for the researcher (PI), (ii) accessibility (iii) co-operation from the leaders and communities.

They were stratified according to sanitation coverage (Table 3.4) such that at the beginning of the study (1998) five slums had good sanitation coverage while the other five had poor sanitation coverage. The 11th slum, Lacey Road, was used as a pilot survey and is not included in the analysis.

Inclusion and exclusion criteria:

Established slums, defined as those which have existed for more than five years, were included for selection. However, since some were characterised by endemic violence, they were excluded for the safety of the researcher.

Stratification of slums:

Stratification of slums was done on the basis of toilet coverage (i.e. number of dwellings with toilets) in 1998. There are five types of toilets/sanitation facilities, (Plate II a - e):-

a) Flush toilets - Lusaka (water available), Canaan and part of Briardene (no water).
b) Chemical toilets - remaining part of Briardene.
c) Ventilated Improved Pit latrine (V.I.P.) - Bottlebrush and Kennedy Lower.
d) Pit-latrine - Park Station, Smithfield, Simplace, Briardene, Canaan, Pemary Ridge and Lusaka.
e) Water-pipe toilet (*stamkoko)* - Pemary Ridge and Park Station

and those who used bush (open defaecation) – Quarry Road West, Pemary Ridge, Simplace, Briardene, Canaan, Kennedy Lower and Park Station and Lusaka.

The sanitation categories are shown in Table 3.4.

Table 3.4 List of slums with good sanitation coverage (1,2,3,8) and with poor sanitation coverage, (4,5,6,7,9,10) at the beginning of the study (1998).

Good Sanitation Coverage

Name of slum	No. of dwellings	Water supply	Sanitation type	Sanitation coverage	Refuse removal
1. Bottlebrush	800	DC stand pipe	836 V.I.P	100%	Refuse skips
2. Kennedy Lower	290	DC stand pipe	170 V.I.P	59%	Refuse skips
3. Lusaka	722	Standpipe and river	400 pit latrines	55%	Burnt
8. Smithfield	65	Purchase from neighbouring residence	50 pit latrines	77%	Burnt & buried

Poor Sanitation Coverage

Name of slum	No. of dwellings	Water supply	Sanitation type	Sanitation coverage	Refuse removal
4. Pemary Ridge	56	Purchased from neighbours, river used for bathing	3 latrines	6 %	Burnt & buried
5. Quarry Road West	220	DC standpipe installed on the road, river used for bathing	27 latrines	11 %	Burnt & buried
6. Simplace	420	DC standpipe, water purchased by slum community	20 latrines	5 %	Burnt & dumped
7. Briardene	216	DC standpipe, water purchased by slum community	22 chemical toilets	10 %	Refuse skip
9. Park Station	147	DC standpipe, water purchased by slum community	10 latrines	7 %	Burnt & buried
10. Canaan	2500	DC standpipe, water purchased by slum community	200 latrines	8 %	Burnt & buried

3.6 THE STUDY POPULATION

The results of a structured quantifiable questionnaire (Appendix B) describing the biological, environmental, socio-cultural and socio-economic characteristics of the study population is summarized in Table 3.5 (p42 – 54). This table is very comprehensive and provides the database with which the parasitological results were tested. In addition it provides proper description of the study population.

'able. 3.5 Percentages (n) of selected characteristics indicating demographic, biological, environmental, socio-economic, socio-cultural and environmental household conditions in the 10 slums studied within the Durban Unicity.

'actor	*Level*	**Bottlebrush**	**Kennedy Lower**	**Lusaka**	**Pemary Ridge**	**Quarry Road West**	**Simplace**	**Briardene**	**Smithfield**	**Park Station**	**Canaan**	Total
;lum soil type		Cartref	Milkwood	Cartref	Fernwood & Dundee	Fernwood & Dundee	Milkwood	Milkwood	Milkwood	Milkwood	Milkwood	
nterviewee	*Parent*	78.2 (140)	63.6 (68)	87.5 (56)	79.7 (51)	85.7 (60)	79.7 (98)	87.6 (92)	78.6 (22)	79.4 (50)	79.8 (95)	79.4 (732)
	Guardian	21.8 (39)	36.4 (39)	12.5 (8)	20.3 (13)	14.3 (10)	20.3 (25)	12.4 (13)	21.4 (6)	20.6 (13)	20.2 (24)	20.6 (190)
;ex of child	*Females*	46.5 (93)	45.1 (55)	41.4 (29)	52.3 (34)	47.6 (39)	41.5 (51)	49.1 (55)	51.7 (15)	53.5 (38)	57.4 (70)	48.1 (479)
	Males	53.5 (107)	54.9 (67)	58.6 (41)	47.7 (31)	52.4 (43)	58.5 (72)	50.9 (57)	48.3 (14)	46.5 (33)	42.6 (52)	51.9 (517)
\ge of child (years)	*2*	12.5 (25)	16.4 (20)	15.7 (11)	21.5 (14)	11.0 (9)	22.4 (25)	21.4 (24)	10.3 (3)	19.7 (14)	16.4 (20)	16.6 (165)
	3	13.0 (26)	16.4 (20)	17.1 (12)	4.6 (3)	11.0 (9)	19.5 (24)	9.8 (11)	0.0 (0)	12.7 (9)	17.2 (21)	13.6 (135)
	4	16.0 (32)	10.7 (13)	15.7 (11)	15.4 (10)	18.3 (15)	10.6 (13)	15.2 (17)	13.8 (4)	11.3 (8)	11.5 (14)	13.8 (137)
	5	12.0 (24)	12.3 (15)	5.7 (4)	9.2 (6)	18.3 (15)	8.9 (11)	9.8 (11)	3.4 (1)	12.7 (9)	14.8 (18)	11.4 (114)
	6	12.0 (24)	13.1 (16)	10.0 (7)	9.2 (6)	13.4 (11)	12.2 (15)	4.5 (5)	13.8 (4)	7.0 (5)	14.8 (18)	11.1 (111)
	7	7.5 (15)	9.8 (12)	8.6 (6)	10.8 (7)	7.3 (6)	9.8 (12)	10.7 (12)	0.0 (0)	11.3 (8)	8.2 (10)	8.8 (88)
	8	10.0 (20)	6.6 (8)	10.0 (7)	15.4 (10)	7.3 (6)	4.9 (6)	8.9 (10)	34.5 (10)	11.3 (8)	4.9 (6)	9.1 (91)
	9	8.0 (16)	4.1 (5)	5.7 (4)	6.2 (4)	2.4 (2)	6.5 (8)	11.6 (13)	10.3 (3)	9.9 (7)	2.5 (3)	6.5 (65)
	10	9.0 (18)	10.7 (13)	11.4 (8)	7.7 (5)	4.9 (4)	11.4 (14)	8.0 (9)	13.8 (4)	4.2 (3)	9.8 (12)	9.0 (90)
'opographical osition of dwelling	*Crest*	30.2 (54)	49.5 (53)	7.8 (5)	1.6 (1)	2.9 (2)	13.0 (16)	34.3 (36)	39.3 (11)	11.1 (7)	7.6 (9)	21.0 (194)
	Mid- or foot-slope	19.6 (35)	21.5 (23)	20.3 (13)	45.3 (29)	30.0 (21)	39.0 (48)	7.6 (8)	17.9 (5)	30.2 (19)	35.3 (42)	26.4 (243)
	Valley bottom	22.3 (40)	17.8 (19)	3.1 (2)	28.1 (18)	25.7 (18)	29.3 (36)	6.7 (7)	39.3 (11)	41.3 (26)	5.9 (7)	20.0 (184)
	Flat	27.9 (50)	11.2 (12)	68.8 (44)	25.0 (16)	41.4 (29)	18.7 (23)	51.4 (54)	3.6 (1)	17.5 (11)	51.3 (61)	32.6 (301)

Factor	*Level*	Bottlebrush	Kennedy Lower	Lusaka	Pemary Ridge	Quarry Road West	Simplace	Briardene	Smithfield	Park Station	Canaan	Total
Quality of dwelling	*Corrugated iron*	8.4 (15)	15.0 (16)	3.1 (2)	18.8 (12)	12.9 (9)	24.4 (30)	8.6 (9)	14.3 (4)	14.3 (9)	5.0 (6)	12.1 (112)
	Cardboard	10.6 (19)	0.9 (1)	12.5 (8)	10.9 (7)	10.0 (7)	7.3 (9)	1.0 (1)	10.7 (3)	11.1 (7)	4.2 (5)	7.3 (67)
	Asbestos	0.6 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.8 (1)	13.3 (14)	0.0 (0)	9.5 (6)	0.0 (0)	2.4 (22)
	Brick	17.9 (32)	14.0 (15)	71.9 (46)	0.0 (0)	0.0 (0)	3.3 (4)	61.9 (65)	0.0 (0)	0.0 (0)	52.9 (63)	24.4 (225)
	Mud	20.7 (37)	14.0 (15)	1.6 (1)	4.7 (3)	0.0 (0)	12.2 (15)	1.9 (2)	35.7 (10)	4.8 (3)	0.8 (1)	9.4 (87)
	Wooden planks	14.5 (26)	13.1 (14)	7.8 (5)	17.2 (11)	20.0 (14)	5.7 (7)	12.4 (13)	17.9 (5)	14.3 (9)	10.1 (12)	12.6 (116)
	Mixed materials	27.4 (49)	43.0 (46)	3.1 (2)	48.4 (31)	57.1 (40)	46.3 (57)	1.0 (1)	21.4 (6)	46.0 (29)	26.9 (32)	31.8 (293)
Child's origin	*Rural*	45.3 (81)	24.3 (26)	18.8 (12)	39.1 (25)	41.4 (29)	26.0 (32)	31.4 (33)	17.9 (5)	42.9 (27)	12.6 (15)	30.9 (285)
	Township	50.3 (90)	52.3 (56)	56.3 (36)	42.2 (27)	20.0 (14)	37.4 (46)	54.3 (57)	78.6 (22)	49.2 (31)	16.8 (20)	43.3 (399)
	Another slum	2.8 (5)	14.0 (15)	21.9 (14)	7.8 (5)	22.9 (16)	28.5 (35)	12.4 (13)	0.0 (0)	3.2 (2)	68.9 (82)	20.3 (187)
	Urban	1.7 (3)	9.3 (10)	3.1 (2)	10.9 (7)	15.7 (11)	8.1 (10)	1.9 (2)	3.6 (1)	4.8 (3)	1.7 (2)	5.5 (51)
Number of rooms per dwelling	1	15.6 (28)	4.7 (5)	1.6 (1)	26.6 (7)	20.0 (14)	30.1 (37)	12.4 (13)	10.7 (3)	20.6 (13)	13.4 (16)	15.9 (147)
	2	31.8 (57)	31.8 (34)	95.3 (61)	60.9 (39)	60.0 (42)	45.5 (56)	82.9 (87)	42.9 (12)	66.7 (42)	84.0 (100)	57.5 (530)
	3	31.8 (57)	25.2 (27)	1.6 (1)	9.4 (6)	20.0 (14)	8.9 (11)	4.8 (5)	28.6 (8)	7.9 (5)	0.8 (1)	14.6 (135)
	4	19.0 (34)	30.8 (33)	0.0 (0)	3.1 (2)	0.0 (0)	11.4 (14)	0.0 (0)	17.9 (5)	4.8 (1)	0.0 (0)	9.9 (91)
	4 or more	1.7 (3)	7.5 (8)	1.6 (1)	0.0 (0)	0.0 (0)	4.1 (5)	0.0 (0)	0.0 (0)	0.0 (0)	1.7 (2)	2.1 (19)
Number of inhabitants per dwelling	*(mean) range*	(7) 2 – 19	(7) 3 – 14	(7) 2 - 11	(4) 2 – 8	(5) 2 –8	(7) 2 – 12	(6) 2 – 11	(6) 3 – 9	(6) 2 – 11	(7) 2 - 11	(6) 2 – 19
Care-giver	*Mother*	30.4 (55)	75.7 (81)	60.9 (39)	96.7 (58)	97.1 (68)	87.9 (104)	50.5 (53)	21.4 (6)	88.9 (56)	58.0 (69)	64.0 (589)
	Father	1.1 (2)	0.0 (0)	4.7 (3)	0.0 (0)	0.0 (0)	0.8 (1)	0.0 (0)	3.8 (4)	0.0 (0)	8.4 (10)	26.9 (32)

actor	*Level*	**Bottlebrush**	**Kennedy Lower**	**Lusaka**	**Pemary Ridge**	**Quarry Road West**	**Simplace**	**Briardene**	**Smithfield**	**Park Station**	**Canaan**	**Total**
	Granny	18.8 (34)	20.6 (22)	25.4 (15)	3.3 (2)	1.4 (1)	9.8 (12)	33.3 (35)	17.9 (5)	3.2 (2)	26.9 (32)	17.4 (160)
	Crèche	49.8 (90)	3.7 (4)	10.9 (7)	0.0 (0)	1.4 (1)	1.6 (2)	12.4 (13)	60.7 (17)	7.9 (5)	6.7 (8)	15.4 (142)
eophageous parent	*Yes*	16.1 (29)	33.6 (36)	26.6 (17)	23.8 (15)	30.4 (21)	23.6 (29)	25.7 (27)	25.0 (7)	31.7 (20)	18.2 (22)	24.2 (223)
	No	83.9 (151)	66.4 (71)	73.4 (47)	76.2 (48)	69.6 (48)	76.4 (94)	74.3 (78)	75.0 (21)	68.3 (43)	81.8 (99)	75.8 (700)
arent get soil from	*Ground*	79.3 (23)	55.6 (20)	88.2 (15)	60.0 (9)	95.2 (20)	48.2 (14)	80.8 (21)	85.7 (6)	42.9 (9)	59.1 (13)	65.9 (147)
	House walls	13.3 (4)	5.6 (2)	0.0 (0)	6.7 (1)	0.0 (0)	27.5 (8)	0.0 (0)	14.3 (1)	19.1 (4)	0.0 (0)	8.9 (20)
	Market	6.8 (2)	38.9 (14)	11.8 (2)	33.3 (5)	4.8 (1)	24.1 (7)	19.2 (5)	0.0 (0)	38.1 (8)	40.9 (9)	22.9 (51)
nprovement llowing treatment	*Yes*	86.1 (118)	82.7 (86)	95.2 (60)	82.5 (52)	88.4 (61)	85.4 (105)	100 (102)	89.3 (25)	76.2 (48)	82.2 (97)	86.7 (754)
cording to arents/guardian.	*No*	13.9 (19)	17.3 (18)	4.8 (3)	17.5 (11)	11.6 (8)	14.6 (18)	0.0 (0)	10.7 (3)	23.5 (15)	17.8 (21)	13.3 (116)
ppetite improved ter treatment	*Yes*	89.1 (148)	56.7 (68)	89.2 (58)	83.7 (41)	70.7 (58)	70.0 (84)	99.0 (99)	88.0 (22)	61.9 (39)	70.5 (86)	74.2 (703)
ooks healthy	*Yes*	68.7 (114)	58.3 (70)	86.2 (56)	67.3 (33)	62.2 (51)	60.0 (72)	87.0 (87)	72.0 (18)	36.5 (23)	64.7 (79)	63.7 (603)
ow plays with her children	*Yes*	25.9 (43)	55.0 (66)	55.4 (36)	24.5 (12)	15.8 (13)	40.0 (48)	60.0 (60)	0.0 (0)	6.3 (4)	40.9 (50)	35.1 (332)
rforms better in hool	*Yes*	22.2 (37)	25.8 (31)	0.0 (0)	18.4 (9)	11.1 (9)	10.0 (10)	0.0 (0)	28.0 (7)	12.7 (8)	4.9 (6)	12.4 (117)
opped coughing	*Yes*	20.5 (34)	23.3 (28)	1.5 (1)	0.0 (0)	0.0 (0)	4.2 (5)	2.0 (2)	20.0 (5)	0.0 (0)	1.6 (2)	8.1 (77)
ained weight	*Yes*	56.6 (94)	60.0 (72)	56.6 (30)	65.3 (32)	65.8 (54)	71.7 (86)	61.0 (61)	48.0 (12)	49.2 (31)	41.8 (51)	55.2 (523)
hen did the worms me out after	*After a day*	34.5 (50)	4.0 (4)	59.0 (36)	18.8 (12)	10.0 (7)	29.5 (36)	72.1 (75)	34.6 (9)	38.1 (24)	44.3 (51)	34.9 (304)
atment	*After a week*	25.5 (37)	19.0 (19)	34.4 (21)	25.0 (16)	34.3 (24)	25.4 (31)	21.2 (22)	34.6 (9)	38.1 (12)	44.3 (29)	34.9 (220)
	Did not see	40.0 (58)	77.0 (77)	6.6 (4)	56.3 (36)	55.7 (39)	45.1 (55)	6.7 (7)	30.8 (8)	42.9 (27)	30.4 (35)	39.8 (346)
other's level of ucation	*None*	2.4 (4)	0.0 (0)	6.3 (4)	1.6 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	1.7 (2)	1.2 (11)

Factor	LEVEL	Bottlebrush	Kennedy Lower	Lusaka	Pemary Ridge	Quarry Road West	Simplace	Briardene	Smithfield	Park Station	Canaan	Total
	Primary	45.3 (77)	55.1 (59)	56.3 (36)	54.7 (35)	54.3 (38)	61.8 (76)	51.0 (53)	46.4 (13)	69.4 (43)	44.1 (52)	53.0 (482)
	Secondary	52.4 (89)	43.9 (47)	37.5 (24)	43.8 (28)	45.7 (32)	38.2 (47)	49.0 (51)	53.6 (15)	30.6 (19)	54.2 (64)	45.7(416)
	Tertiary	0.0 (0)	0.9 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.1 (1)
Father's level of education	*None*	10.9 (16)	6.7 (6)	12.5 (7)	11.5 (7)	4.3 (3)	5.4 (6)	9.0 (8)	18.5 (5)	9.7 (6)	11.1 (12)	9.3 (76)
	Primary	27.9 (41)	68.5 (61)	53.6 (30)	62.3 (38)	61.4 (36)	70.5 (79)	68.5 (61)	25.9 (7)	72.6 (45)	66.7 (72)	58.1 (477)
	Secondary	61.2 (90)	24.7 (22)	33.9 (19)	26.2 (16)	32.9 (30)	24.1 (27)	22.5 (20)	55.6 (15)	17.7 (11)	22.2 (24)	32.5 (267)
	Tertiary	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	1.4 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	1.0 (0.1)
Mother's level of employment	*Not employed*	34.1 (58)	14.0 (15)	17.2 (11)	68.8 (44)	87.1 (61)	43.0 (52)	21.2 (22)	46.4 (13)	56.5 (35)	31.4(23)	38.3 (348)
	Formal	5.9 (10)	14.0 (15)	1.6 (1)	1.6 (1)	4.3 (3)	2.5 (3)	2.9 (3)	0.0 (0)	0.0 (0)	1.7(1)	42.0 (38)
	Informal	60.0 (102)	72.0 (77)	81.3 (52)	29.7 (19)	8.6 (6)	54.5 (66)	76.0 (79)	53.6 (15)	43.5 (27)	66.9 (30)	57.5 (522)
Father's level of employment	*Not employed*	14.5 (20)	39.8 (35)	44.6 (25)	11.5 (7)	4.3 (3)	18.8 (21)	35.2 (32)	18.5 (5)	6.5 (4)	27.8 (23)	22.4 (182)
	Formal	10.1 (14)	4.5 (4)	0.0 (0)	8.2 (5)	20.0 (14)	5.4 (6)	3.3 (3)	0.0 (0)	6.5 (4)	1.9 (1)	6.4 (52)
	Informal	75.4 (104)	55.7 (49)	55.4 (31)	80.3 (49)	75.7 (53)	75.9 (85)	61.5 (56)	81.5 (22)	87.1 (54)	70.4 (43)	71.2 (579)
Guardian's level of employment	*Not employed*	50.0 (5)	100.0 (11)	100.0 (18)	0.0 (0)	100.0 (8)	100.0 (8)	100.0 (8)	0.0 (0)	100.0 (8)	88.9 (60)	91.8 (67)
	Formal	20.0 (2)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	2.7 (2)
	Informal	30.0 (3)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	11.1 (1)	5.5 (4)
Mother's income per month	*Low- < R200*	54.2 (64)	75.0 (72)	92.3 (48)	30.0 (6)	87.5 (7)	73.5 (50)	84.5 (71)	60.0 (9)	40.7 (11)	90.1 (73)	72.2 (411)
	Middle - R300 – R1 000	36.4 (43)	25.0 (24)	5.8 (3)	70.0 (14)	12.5 (1)	26.5 (18)	13.1 (11)	40.0 (6)	59.3 (11)	8.6 (6)	25.1 (16)
	High - R1 000	9.3 (11)	0.0 (0)	1.9 (1)	0.0 (0)	0.0 (0)	0.0 (0)	2.4 (2)	0.0 (0)	0.0 (0)	1.2 (1)	2.6 (15)

	LEVEL	Bottlebrush	Kennedy Lower	Lusaka	Pemary Ridge	Quarry Road West	Simplace	Briardene	Smithfield	Park Station	Canaan	Total
ather's income per ıonth	*Low- < R200*	12.8 (15)	62.5 (35)	40.5 (15)	60.7 (34)	47.1 (33)	66.3 (63)	38.6 (22)	34.8 (8)	57.6 (34)	54.4 (43)	46.5 (15)
	Middle - R300– R1 000	78.6 (92)	37.5 (21)	59.5 (22)	39.3 (22)	51.4 (36)	33.7 (32)	61.4 (35)	65.2 (15)	42.4 (25)	45.6 (36)	51.8 (302)
	High - >R1 000	8.5 (10)	0.0 (0)	0.0 (0)	0.0(0)	1.4 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	1.7 (11)
iuardian's income er month	*Low- < R200*	29.6 (81)	22.2 (2)	85.7 (6)	0.0(0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	100.0 (1)	10.0 (1)	26.9 (18)
	Middle - R300 – R1 000	70.4 (19)	77.8 (7)	14.3 (1)	100.0 (20)	100.0 (20)	100.0 (4)	100.0 (7)	0.0 (0)	0.0 (0)	90.0 (5)	73.1 (49)
	High - R1 000	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
Vater source	*Tap in the house (1999)*	0.0 (0)	0.0 (0)	89.1 (57	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	73.1 (87	15.4 (144)
	Purchase from standpipe	44.8 (81)	99.1 (108)	10.9 (7)	100.0 (65)	98.6 (121)	100.0 (105)	100.0 (29)	100.0 (29)	100.0 (63)	0.0 (0)	69.9 (649)
	River	0.0 (0)	0.9 (1)	0.0 (0)	0.0 (0)	1.4 (1)	1.6 (2)	0.0 (0)	0.0 (0)	0.0 (0)	26.9 (32)	3.9 (36)
	Rain-tank	0.6 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.1 (1)
	Tap in the yard	54.7 (99)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	10.7 (99)
/ater transport to ome	*Head*	56.7 (102)	39.4(43)	10.9 (7)	100.0 (65)	100.0 (71)	100.0 (123)	100.0 (105)	100.0 (29)	100.0 (63)	25.4 (30)	68.8 (638)
	Wheel-barrow	43.3 (78)	60.6 (66)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	15.5 (144)
	Not transported	0.0 (0)	0.0 (0)	89.1 (57)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	74.6 (88)	15.6 (145)
/ater storage at ome	*Plastic container*	98.9 (180)	100.0 (109)	100.0 (64)	100.0 (65)	100.0 (71)	100.0 (123)	100.0 (105)	100.0 (29)	100.0 (63)	100.0 (121)	99.8 (930)
	Metal container	1.0 (2)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.2 (2)
	Do not store water	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
ow long is water ored ?	*A day*	100.0 (183)	100.0 (109)	100.0 (64)	100.0 (65)	100.0 (71)	100.0 (123)	100.0 (105)	100.0 (29)	100.0 (63)	100.0 (12)	100.0 (933)
	A week	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)

	A month	0.0 (0)	0.0 (0)	0.0 (0)	0.0(0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
	More than a month	0.0 (0)	0.0 (0)	0.0 (0)	0.0(0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)

Factor	*LEVEL*	**Bottlebrush**	**Kennedy Lower**	**Lusaka**	**Pemary Ridge**	**Quarry Road West**	**Simplace**	**Briardene**	**Smithfield**	**Park Station**	**Canaan**	**Total**
Who collects water?	*Mother & children*	98.8 (181)	99.0 (108)	10.9 (7)	100.0 (65)	100.0 (81)	100.0 (122)	97.1 (102)	100.0 (29)	100.0 (63)	33.3 (38)	84.9 (791)
	Father	1.1 (2)	0.9 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	2.9 (3)	0.0 (0)	0.0 (0)	0.0 (0)	0.6 (6)
	nobody	0.0 (0)	0.0 (0)	89.1 (57)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	66.7 (76)	14.4 (133)
	Guardian	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
How often is water collected?	*Daily*	38.8 (71)	31.2 (34)	6.3 (4)	100.0 (65)	70.0 (49)	53.3 (65)	72.4 (76)	72.4 (21)	73.0 (46)	20.2 (23)	49.1 (454)
	Several times a day	60.7 (111)	68.8 (75)	4.7 (3)	0.0 (0)	30.0 (21)	46.7 (57)	27.6 (29)	27.6 (8)	27.0 (17)	13.2 (15)	36.4 (336)
	Weekly	0.5 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.1 (1)
	Tap in the house	0.0 (0)	0.0 (0)	89.1 (57)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	66.7 (76)	14.4 (133)
Cooking facility	*Paraffin*	76.1 (140)	74.3 (81)	15.7 (10)	100.0 (65)	100.0 (81)	93.5 (115)	40.9 (43)	100.0 (28)	100.0 (63)	31.7 (38)	70.2 (655)
	Gas	23.9 (44)	25.7 (28)	9.4 (6)	0.0 (0)	0.0 (0)	6.5 (8)	28.6 (30)	0.0 (0)	0.0 (0)	23.3 (28)	23.3 (144)
	Electricity	0.0 (0)	0.0 (0)	75.0 (48)	0.0 (0)	0.0 (0)	0.0(0)	30.5(32)	0.0(0)	0.0(0)	43.3(52)	14.1(132)
Use of household bleach	*Yes*	2.7 (5)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0(0)	0.0(0)	0.0(0)	0.0(0)	0.0(0)	0.5(5)
	No	97.3 (179)	100.0 (109)	100.0 (64)	100.0 (64)	100.0 (82)	100.0 (123)	100.0 (110)	100.0 (28)	100.0 (65)	100.0 (122)	99.5(928)
Is water boiled before use?	*Yes*	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0(0)	0.0(0)	0.0(0)	0.0(0)	0.0(0)	0.0(0)
	No	100.0 (183)	100.0 (109)	100.0 (64)	100.0 (65)	100.0 (71)	100.0 (123)	100.0 (105)	100.0 (29)	100.0 (63)	100.0 (121)	100.0 (933)

;anitation

;anitation habits for nen during the day.	*Safe*	98.8(174)	100.0 (109)	90.6 (58)	12.3 (8)	4.2 (3)	61.8 (76)	53.3 (56)	93.1 (27)	17.7 (11)	77.5 (93)	66.6 (615)
	Unsafe	1.1(2)	0.0 (0)	9.4 (56)	87.7 (57)	95.8 (68)	38.2 (47)	46.7 (49)	6.9 (2)	82.3 (51)	22.5 (27)	33.4 (309)

'actor	*LEVEL*	Bottlebrush	Kennedy Lower	Lusaka	Pemary Ridge	Quarry Road West	Simplace	Briardene	Smithfield	Park Station	Canaan	Total
;anitation habits for vomen during the lay	*Safe*	98.4 (181)	100.0 (109)	90.6 (58)	12.3 (8)	4.2 (3)	61.8 (76)	52.4 (55)	51.7 (15)	17.5 (11)	77.5 (93)	65.3 (609)
	Unsafe	1.6 (3)	0.0 (0)	9.4 (8)	87.7 (57)	95.8 (68)	38.2 (47)	47.6 (50)	48.3 (14)	82.5 (52)	22.5 (27)	34.7 (324)
;anitation habits for nen at night	*Safe*	99.4 (175)	100.0 (109)	87.5 (56)	12.3 (8)	4.2 (3)	54.5 (67)	39.0 (41)	37.9 (11)	9.7 (6)	77.5 (93)	61.6 (569)
	Unsafe	0.6 (1)	0.0 (0)	12.5 (8)	87.7 (57)	95.8 (68)	45.5 (56)	61.0 (64)	62.1 (18)	90.3 (56)	22.5 (27)	38.4 (355)
;anitation habits for vomen at night	*Safe*	83.2 (153)	95.4 (104)	87.5 (56)	7.7 (5)	4.2 (3)	37.4 (46)	33.3 (35)	6.9 (2)	4.8 (3)	77.5 (93)	53.6 (500)
	Unsafe	16.8 (31)	4.6 (5)	12.5 (8)	92.3 (60)	95.8 (68)	62.6 (77)	66.7 (70)	93.1 (27)	95.2 (60)	22.5 (27)	46.4 (433)
anitation habits for irls during the day	*Safe*	81.8 (148)	100.0 (105)	90.6 (58)	1.5 (1)	0.0 (0)	35.0 (43)	35.2 (37)	51.7 (15)	9.7 (6)	75.0 (90)	54.6 (422)
	Unsafe	18.2 (33)	0.0 (0)	9.4 (6)	98.5 (64)	100.0 (71)	65.0 (80)	64.8 (68)	48.3 (14)	90.3 (56)	25.0 (30)	45.4 (496)
anitation habits for oys during the day	*Safe*	81.5 (150)	98.1 (105)	90.6 (58)	1.5 (1)	0.0 (0)	34.1 (42)	35.2 (37)	24.1 (7)	9.5 (6)	75.0 (90)	53.3 (435)
	Unsafe	18.5 (34)	1.9 (2)	9.4 (6)	98.5 (64)	100.0 (71)	65.9 (81)	64.8 (68)	75.9 (22)	90.5 (57)	25.0 (30)	46.7 (388)
anitation habits for irls at night	*Safe*	51.1 (94)	95.3 (102)	87.5 (56)	1.5 (1)	0.0 (0)	15.4(19)	35.2(37)	0.0(0)	1.6(1)	75.0(90)	41.7(543)
	Unsafe	48.9 (90)	4.7 (5)	12.5 (8)	98.5 (64)	100.0 (71)	84.6 (104)	64.8 (68)	100.0 (29)	98.4 (62)	25.0 (30)	58.3 (389)
anitation habits for oys at night	*Safe*	51.1 (93)	95.4 (104)	87.5 (56)	1.5 (1)	0.0 (0)	15.4 (19)	23.8 (25)	0.0 (0)	1.6 (1)	75.0 (90)	41.8 (389)
	Unsafe	48.9 (89)	4.6 (5)	12.5 (8)	98.5 (64)	100.0 (71)	84.6 (104)	76.2 (80)	100.0 (29)	98.4 (62)	25.0 (30)	58.2 (541)
t what age are iildren taught to	3	38.9 (70)	23.9 (26)	36.9 (24)	7.9 (5)	4.2 (3)	20.8 (25)	30.5 (25)	55.2 (16)	12.7 (8)	35.8 (43)	27.2 (252)

hildren taught to se toilet(years)?	*4*	42.2 (76)	33.9 (37)	50.8 (33)	46.0 (29)	40.8 (29)	34.2 (41)	32.4 (34)	27.6 (8)	39.7 (25)	33.3 (40)	38.1 (352)
	5	18.9 (34)	42.2 (46)	12.3 (8)	46.0 (29)	54.9 (39)	42.5 (51)	28.6 (30)	17.2 (5)	47.6 (30)	30.8 (37)	33.4 (309)
	6	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	2.5 (3)	8.6 (9)	0.0 (0)	0.0 (0)	0.0 (0)	1.3 (12)
'resence of toilet	*Yes*	97.2 (180)	100.0 (109)	92.3 (60)	11.1 (7)	7.0 (5)	53.7 (66)	83.8 (88)	79.3 (23)	82.5 (52)	74.2 (89)	66.4 (616)
	No	2.8 (5)	0.0 (0)	7.7 (5)	88.9 (56)	93.0 (66)	46.3 (57)	16.2 (17)	20.7 (6)	82.5 (52)	25.8 (31)	33.6 (312)
'actor	***Level***	**Bottlebrush**	**Kennedy Lower**	**Lusaka**	**Pemary Ridge**	**Quarry Road West**	**Simplace**	**Briardene**	**Smithfield**	**Park Station**	**Canaan**	**Total**
Iow often is toilet :leaned?	*Daily*	33.9 (61)	38.5 (42)	32.3 (21)	0.0 (0)	0.0 (0)	0.0 (0)	12.5 (13.)	13.8 (4)	4.8 (3)	15.0 (18)	17.5 (162)
	Weekly	57.2 (103)	56.9 (58)	56.9 (37)	3.2 (2)	2.8 (2)	26.7 (32)	44.2 (46)	34.5 (10)	0.0 (0)	49.2 (59)	37.8 (349)
	When its dirty	0.0 (0)	6.2 (2)	6.2 (4)	88.9 (56)	93.0 (66)	40.8 (49)	16.3 (17)	44.8 (13)	82.5 (52)	25.8 (31)	31.4 (290)
Iow are nappies lisposed off?	*Safe*	95.6 (173)	98.9 (93)	92.3 (60)	6.3 (4)	2.8 (2)	31.4 (33)	81.0 (85)	20.7 (6)	4.9 (3)	73.3 (88)	61.2 (547)
	Unsafe	4.4 (8)	1.1 (1)	7.7 (5)	93.7 (59)	97.2 (69)	68.6 (72)	19.0 (20)	79.3 (23)	95.1 (58)	26.7 (32)	38.8 (347)
'oilet condition	*Good*	0.0 (0)	0.0 (0)	1.6 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	3.4 (4)	0.5 (5)
	Satisfactory	65.7 (119)	38.3 (41)	59.4 (38)	0.0 (0)	0.0 (0)	1.6 (2)	5.7 (6)	0.0 (0)	0.0 (0)	54.6 (65)	29.3 (271)
	Functional	16.6 (31)	27.1 (29)	23.4(15)	0.0 (0)	0.0 (0)	33.3 (41)	46.7 (49)	51.7 (15)	27.0 (17)	1.7 (2)	21.4 (198)
	Bad	17.1 (31)	18.7 (20)	1.6(1)	9.2 (6)	7.1 (5)	26.0 (32)	28.6 (30)	41.4 (12)	34.9 (22)	7.6 (9)	18.1 (168)
	Full	0.6 (1)	15.9 (17)	14.1(9)	1.5 (1)	0.0 (0)	36.6 (6)	19.0 (20)	6.9 (2)	38.1 (24)	32.8 (39)	17.1 (158)
hild risk behaviour (children wash hands...												
Vith soap and water	*Never*	49.7 (85)	74.3 (78)	88.9 (56)	76.6 (49)	63.8 (44)	81.3 (100)	89.4 (93)	10.7 (3)	79.4 (50)	79.7 (94)	71.8 (652)
	Occasionally	46.8 (80)	17.1 (18)	11.1 (7)	9.4 (6)	21.7 (15)	11.4 (19)	7.7 (8)	89.3 (25)	9.5 (6)	8.5 (10)	20.8 (189)
	Always	3.5 (6)	8.6 (9)	0.0 (0)	14.1 (9)	14.5 (10)	7.3 (9)	2.9 (3)	0.0 (0)	11.1 (7)	11.9 (14)	7.4 (67)

Factor	Level	Bottlebrush	Kennedy Lower	Lusaka	Pemary Ridge	Quarry Road West	Simplace	Briardene	Smithfield	Park Station	Canaan	Total
Vith water only	*Never*	4.1 (7)	73.3 (77)	7.9 (5)	19.0 (12)	21.7 (15)	20.5 (25)	11.7 (12)	0.0 (0)	19.0 (12)	12.6 (15)	19.8 (180)
	Always	89.5 (159)	24.8 (26)	90.5 (57)	62.8 (36)	49.3 (34)	68.9 (84)	86.4 (89)	96.4 (27)	54.0 (34)	82.4 (98)	70.5 (639)
	Occasionally	6.4 (11)	1.9 (2)	1.6 (1)	23.8 (15)	29.0 (20)	10.7 (13)	1.9 (2)	3.6 (1)	27.0 (17)	5.0 (6)	9.7 (88)
After playing	*Never*	74.4 (128)	88.6 (93)	82.5(52)	89.1 (57)	82.9 (58)	89.4 (110)	80.8 (84)	82.1 (23)	92.1 (58)	84.0 (100)	83.8 (763)
	Occasionally	1.2 (2)	8.6 (9)	1.6 (1)	3.1 (2)	7.1 (5)	0.8 (1)	1.0 (1)	0.0 (0)	0.0 (0)	1.7 (2)	2.5 (23)
	Always	24.4 (42)	2.9 (3)	15.9 (10)	7.8 (5)	10.0 (7)	9.8 (12)	18.3 (19)	17.9 (5)	7.9 (5)	14.3 (17)	13.7 (125)
Before eating	*Never*	51.2 (87)	65.7 (69)	49.2 (31)	71.9 (46)	68.6 (48)	69.1 (49)	51.9 (54)	21.4 (6)	76.2 (48)	61.3 (73)	60.2 (547)
	Occasionally	32.9 (56)	15.2 (16)	27.0 (17)	9.4 (6)	7.1 (5)	10.6 (13)	22.1 (23)	67.9 (19)	9.5 (6)	16.8 (20)	19.9 (181)
	Always	15.9 (27)	19.0 (20)	23.8 (15)	18.8 (12)	24.3 (17)	20.3 (19)	26.0 (27)	10.7 (3)	14.3 (9)	21.8 (26)	19.9 (181)
After defecation	*Never*	51.2 (88)	60.0 (63)	49.2 (31)	70.3 (8)	68.6 (48)	72.4 (70)	51.0 (53)	21.4 (6)	77.8 (49)	63.9 (76)	60.2 (548)
	Occasionally	42.4 (73)	21.9 (23)	25.4 (16)	12.5 (11)	18.6 (13)	13.0 (11)	26.0 (27)	10.7 (22)	14.3 (7)	21.8 (23)	19.9 (228)
	Always	6.4 (11)	18.1 (19)	25.4 (16)	17.2 (27)	12.9 (9)	14.6 (12)	23.1 (24)	0.0 (0)	11.1 (7)	16.8 (20)	14.8 (135)
Before going to bed	*Never*	38.4 (66)	28.6 (30)	93.7 (59)	42.2 (31)	28.6 (20)	46.3 (44)	88.5 (92)	60.7 (17)	50.8 (32)	68.1 (81)	52.8 (481)
	Occasionally	23.8 (41)	44.8 (47)	4.8 (3)	48.4 (6)	62.9 (44)	47.2 (45)	7.7 (8)	0.0 (0)	38.1 (24)	28.6 (34)	31.8 (290)
	Always	37.8 (65)	26.7 (28)	1.6 (1)	9.4 (8)	8.6 (6)	6.5 (6)	3.8 (4)	39.8 (11)	11.1 (7)	3.4 (4)	15.4 (140)
In the morning when he wakes up	*Never*	19.8 (34)	14.3 (15)	54.0 (34)	43.8 (28)	25.7 (18)	30.1 (37)	52.9 (55)	10.7 (3)	50.8 (32)	60.5 (72)	36.0 (328)
	Occasionally	19.8 (34)	50.5 (33)	4.8 (3)	10.9 (7)	34.3 (24)	22.0 (27)	26.9 (28)	0.0 (0)	15.9 (10)	7.6 (9)	21.4 (195)
	Always	60.5 (104)	35.2 (57)	41.3 (26)	45.3 (29)	40.0 (28)	48.0 (59)	20.2 (21)	89.3 (25)	33.3 (21)	31.9 (38)	42.6 (388)
Use hands when eating	*Never*	19.2 (33)	18.1 (19)	6.3 (4)	14.1 (9)	10.0 (7)	15.4 (19)	7.7 (8)	10.7 (3)	17.5 (11)	14.3 (17)	14.3 (130)

	Occasionally	48.8 (84)	62.9 (66)	50.8 (32)	65.6 (42)	60.0 (42)	67.5 (83)	46.2 (48)	21.4 (6)	63.5 (40)	53.8 (64)	55.7 (507)
	Always	32.0 (55)	19.0 (20)	42.9 (27)	20.3 (13)	30.0 (21)	17.1 (21)	46.2 (48)	67.9 (19)	19.0 (12)	31.9 (38)	30.1 (274)
Cutting of nails by mother	*Never*	72.1 (124)	89.5 (94)	25.4 (16)	85.9 (55)	81.4 (57)	61.8 (76)	33.7 (35)	67.9 (19)	74.6 (47)	43.7 (52)	63.1 (575)
	Occasionally	1.2 (2)	2.9 (3)	15.9 (10)	7.8 (5)	4.3 (3)	8.1 (10)	5.8 (6)	0.0 (0)	11.1 (7)	21.0 (25)	7.8 (71)
	Always	26.7 (46)	7.6 (8)	58.7 (34)	6.3 (4)	14.3 (10)	30.1 (37)	60.6 (63)	32.1 (9)	14.3 (9)	35.3 (42)	29.1 (265) 29.2

ADULT RISK BEHAVIOUR (WASH HANDS WITH....)

Fact6r	*LEVEL*	**Bottlebrush**	**Kennedy Lower**	**Lusaka**	**Pemary Ridge**	**Quarry Road West**	**Simplace**	**Briardene**	**Smithfield**	**Park Station**	**Canaan**	**Total**
With soap and water	*Never*	5.2 (9)	1.9 (2)	7.9 (5)	7.8 (5)	1.4 (1)	4.9 (6)	6.7 (7)	3.6 (1)	9.5 (6)	6.7 (8)	5.5 (50)
	Occasionally	76.2 (131)	87.6 (92)	41.3 (26)	68.8 (44)	87.1 (61)	53.7 (66)	26.0 (27)	64.3 (18)	50.8 (32)	56.3 (67)	61.9 (564)
	Always	18.6 (32)	10.5 (11)	50.8 (32)	23.4 (15)	11.4 (8)	41.5 (51)	67.3 (70)	32.1 (9)	39.7 (25)	37.0 (44)	32.6 (297)
With water only	*Never*	1.2 (2)	76.2 (80)	3.2 (2)	33.3 (21)	29.0 (20)	30.3 (37)	4.8 (5)	0.0 (0)	27.0 (17)	22.7 (27)	23.2 (211)
	Occasionally	22.1 (38)	21.9 (23)	27.0 (17)	28.6 (18)	36.2 (25)	18.9 (23)	28.9 (31)	14.3 (4)	36.5 (23)	26.9 (32)	25.8 (234)
	Always	76.7 (132)	1.9 (2)	69.8 (44)	38.1 (24)	34.8 (24)	50.8 (62)	65.4 (68)	85.7 (24)	36.5 (23)	50.4 (60)	51.0 (463)
Before preparing meals	*Never*	2.3 (4)	6.7 (7)	4.8 (3)	3.1 (2)	4.3 (3)	10.6 (2)	10.6 (11)	0.0 (0)	3.2 (2)	6.7 (8)	4.6 (42)
	Occasionally	51.2 (88)	77.1 (81)	55.6 (35)	57.8 (37)	38.6 (27)	71.5 (88)	41.3 (43)	64.3 (18)	52.4 (33)	63.0 (75)	57.6 (525)
	Always	46.5 (80)	16.2 (17)	39.7 (25)	39.1 (25)	57.1 (40)	26.8 (33)	48.1 (50)	35.7 (10)	44.4 (48)	30.3 (36)	37.8 (344)
Before eating	*Never*	1.2 (2)	1.9 (2)	0.0 (0)	7.8 (5)	2.9 (2)	4.1 (5)	0.0 (0)	0.0 (0)	7.9 (5)	0.0 (0)	2.3 (21)
	Occasionally	68.0 (117)	94.3 (99)	76.2 (48)	53.1 (34)	32.9 (23)	65.9 (81)	71.2 (74)	92.9 (26)	55.6 (35)	75.6 (90)	68.8 (627)
	Always	30.8 (53)	3.8 (4)	23.8 (15)	39.1 (25)	64.3 (45)	30.1 (37)	28.8 (30)	7.1 (2)	36.5 (23)	24.4 (29)	28.9 (263)

After defecation	*Never*	1.7 (3)	1.0 (1)	0.0 (0)	1.6 (1)	2.9 (2)	0.8 (1)	1.0 (1)	0.0 (0)	1.6 (1)	1.7 (2)	1.3 (12)
	Occasionally	83.1 (143)	95.2 (100)	74.6 (47)	64.1 (41)	62.9 (44)	69.9 (86)	76.0 (79)	100.0 (28)	60.3 (38)	73.9 (88)	76.2 (694)
	Always	15.1 (26)	3.8 (4)	25.4 (16)	34.4 (22)	34.3 (24)	29.3 (36)	23.1 (24)	0.0 (0)	38.1 (24)	24.4 (29)	22.5 (209)
n the morning when /he wakes up	*Never*	5.2 (9)	12.4 (13)	17.5 (11)	52.4 (33)	20.3 (14)	35.2 (43)	12.5 (13)	7.1 (2)	66.7 (42)	34.5 (41)	24.3 (221)
	Occasionally	38.4 (66)	68.6 (72)	25.4 (16)	17.5 (11)	42.0 (29)	33.6 (41)	33.7 (35)	0.0 (0)	6.3 (4)	22.7 (27)	33.1 (301)
	Always	56.4 (97)	19.0 (20)	57.1 (36)	30.2 (19)	37.7 (26)	31.1 (38)	53.8 (56)	92.9 (26)	27.0 (17)	42.9 (57)	42.5 (386)

Factor	*Level*	Bottlebrush	Kennedy Lower	Lusaka	Pemary Ridge	Quarry Road West	Simplace	Briardene	Smithfield	Park Station	Canaan	Total
Before going to bed	*Never*	4.1 (7)	2.9 (3)	33.3 (21)	27.0 (17)	18.6 (13)	39.3 (48)	32.7 (34)	0.0 (0)	38.1 (24)	42.0 (50)	23.9 (217)
	Occasionally	74.4 (128)	92.4 (97)	46.0 (29)	54.0 (34)	64.3 (45)	33.6 (41)	37.5 (39)	82.1 (23)	33.3 (21)	40.3 (48)	55.6 (505)
	Always	21.5 (37)	4.8 (5)	20.6 (13)	19.0 (12)	17.1 (12)	27.0 (33)	29.8 (31)	17.9 (5)	28.6 (18)	17.6 (21)	20.6 (187)
After changing nappies	*Never*	3.5 (6)	29.8 (31)	9.5 (6)	22.2 (14)	11.6 (8)	17.2 (21)	15.4 (16)	3.6 (1)	33.3 (21)	10.1 (12)	15.0 (136)
	Occasionally	57.9 (99)	54.8 (57)	50.8 (32)	50.8 (32)	37.7 (26)	46.7 (57)	38.5 (40)	60.7 (17)	44.4 (28)	60.5 (72)	60.5 (460)
	Always	38.0 (65)	15.4 (16)	39.7 (25)	27.0 (17)	50.7 (35)	36.1 (44)	46.2 (48)	35.7 (10)	22.2 (14)	29.4 (32)	29.4 (309)
Where are fruit & vegetables obtained from?	*Street vendors*	7.0 (12)	33.3 (35)	0.0 (0)	17.2 (11)	20.2 (14)	12.2 (15)	1.0 (1)	0.0 (0)	0.0 (0)	0.0 (0)	9.5 (87)
	Supermarket or shops	0.0 (0)	1.0 (1)	1.5 (1)	0.0 (0)	0.0 (0)	2.4 (3)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.5 (5)
	Rubbish dump	55.8 (96)	16.2 (17)	0.0 (0)	65.6 (42)	1.4 (1)	59.3 (73)	0.0 (0)	0.0 (0)	0.0 (0)	8.4 (10)	26.2 (239)
	Garden	0.6 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.8 (1)	0.2 (2)
Are your children fed leftovers?	*Yes*	100.0 (171)	99.0 (104)	92.2 (59)	100.0 (64)	100.0 (70)	97.6 (120)	92.3 (96)	100.0 (27)	100.0 (64)	94.1 (112)	97.4 (887)
	No	0.0 (0)	1.0 (1)	7.8 (5)	0.0 (0)	0.0 (0)	2.4 (3)	7.7 (8)	0.0 (0)	0.0 (0)	5.9 (7)	2.6 (24)
Where is food stored?	*Bucket*	95.3 (164)	100.0 (105)	100.0 (64)	100.0 (64)	100.0 (71)	100.0 (123)	98.1 (103)	96.4 (27)	100.0 (63)	100.0 (119)	97.4 (887)

	Cupboard	95.9 (165)	87.6 (92)	95.3 (61)	100.0 (64)	88.6 (62)	88.6 (109)	91.3 (95)	96.4 (27)	98.4 (62)	95.0 (113)	98.8 (903)
	Fridge	4.1 (7)	12.4 (13)	0.0 (0)	0.0 (0)	11.4 (8)	2.4 (3)	7.7 (8)	3.6 (1)	1.6 (1)	5.0 (6)	1.1 (10)
Where are your meals taken?	*Indoors*	0.0 (0)	0.0 (0)	4.7 (3)	0.0 (0)	0.0 (0)	8.9 (11)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	10.4 (14)
	Outdoors	37.2 (64)	33.3 (35)	50.0 (32)	48.4 (31)	45.7 (32)	42.3 (52)	35.6 (37)	42.9 (12)	38.1 (24)	42.9 (51)	40.6 (370)
	Both indoors and outdoors	2.9 (5)	21.0 (22)	14.1 (9)	1.6 (1)	54.3 (38)	4.0 (5)	8.7 (9)	57.1 (16)	0.0 (0)	10.1 (12)	7.5 (68)
Food preparation	*Fry*	58.9 (100)	45.7 (47)	35.9 (23)	48.4 (31)	54.3 (38)	53.7 (66)	55.8 (58)	57.1 (16)	58.7 (37)	45.4 (54)	51.5 (470)
	Boil	75.5 (139)	63.3 (69)	46.2 (30)	47.7 (31)	54.9 (39)	57.7 (71)	62.9 (66)	72.4 (21)	65.1 (41)	73.6 (89)	63.7 (596)

Factor	***Level***	**Bottlebrush**	**Kennedy Lower**	**Lusaka**	**Pemary Ridge**	**Quarry Road West**	**Simplace**	**Briardene**	**Smithfield**	**Park Station**	**Canaan**	**Total**
Geophageous child	*No*	75.5 (139)	63.3 (69)	46.2 (30)	47.7 (31)	54.9 (39)	57.7 (71)	62.9 (66)	72.4 (21)	65.1 (41)	73.6 (89)	63.7 (596)
	Yes	24.5 (45)	36.7 (40)	53.8 (35)	52.3 (34)	45.1 (32)	42.3 (52)	37.1 (39)	27.6 (8)	34.9 (22)	26.4 (32)	36.3 (339)
Source of soil for geophageous children	*From the ground*	29.5 (13)	30.0 (12)	16.7 (6)	20.6 (7)	17.9 (5)	26.9 (14)	48.7 (19)	12.5 (1)	36.4 (8)	65.6 (21)	31.6 (106)
	From walls of the house	25.0 (11)	10.0 (4)	13.9 (5)	8.8 (3)	7.1 (2)	11.5 (6)	7.7 (3)	37.5 (3)	4.5 (1)	31.3 (10)	11.3 (38)
	Market	45.5 (20)	35.0 (14)	38.9 (14)	50.0 (17)	71.4 (20)	38.5 (20)	25.6 (10)	50.0 (4)	50.0 (11)	3.1 (1)	418 (140)
	From friends	0.0 (0)	10.0 (4)	13.9 (5)	17.6 (6)	3.6 (1)	15.4 (8)	7.7 (3)	10.3 (4)	9.1 (2)	0.0 (0)	6.3 (33)
	From mother	0.0 (0)	15.0 (6)	5.6 (2)	17.6 (6)	0.0 (0)	7.6 (4)	10.3 (4)	0.0 (0)	9.1 (2)	0.0 (0)	5.4 (18)
requency of child eophagy	*Daily*	56.8 (25)	47.5 (19)	50.0 (18)	67.6 (23)	53.6 (15)	71.2 (37)	43.6 (17)	75.0 (6)	81.8 (18)	81.3 (26)	60.3 (202)
	Weekly	43.2 (19)	52.5 (21)	47.2 (17)	32.4 (11)	46.4 (13)	28.8 (15)	56.4 (22)	25.0 (2)	18.2 (4)	15.6 (5)	38.5 (129)
	Monthly	0.0 (0)	0.0 (0)	2.8 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	3.1 (1)	0.6 (2)
/hy does the child it soil?	*Its nice*	47.7 (21)	50.0 (20)	41.7 (15)	20.6 (7)	32.1 (9)	42.3 (22)	53.8 (21)	75.0 (6)	36.4 (8)	53.1 (17)	43.6 (146)
	Imitates friends	13.6 (6)	15.0 (6)	8.3 (3)	11.8 (4)	14.3 (4)	21.2 (11)	20.5 (8)	12.5 (1)	45.5 (10)	3.1 (1)	16.1 (54)

	Imitates mother	13.6 (6)	22.5 (9)	5.6 (2)	26.4 (8)	0.0 (0)	17.3 (9)	5.2 (2)	0.0 (0)	0.0 (0)	6.3 (2)	11.6 (39)
	Suppresses hunger	15.9 (7)	7.5 (3)	8.3 (3)	20.6 (7)	39.3 (11)	13.5 (7)	7.7 (3)	0.0 (0)	9.1 (2)	25.0 (8)	15.2 (51)
oil preference	*Clay*	75.0 (33)	75.0 (30)	72.2 (26)	67.6 (23)	75.0 (21)	78.8 (42)	92.7 (38)	100.0 (8)	86.4 (19)	84.4 (27)	78.3 (264)
	Sandy	25.0 (11)	12.5 (5)	25.0 (9)	32.4 (11)	3.6 (1)	5.8 (3)	7.3 (3)	0.0 (0)	13.6 (3)	6.3 (2)	14.2 (48)
	Loamy	0.0 (0)	12.5 (5)	2.8 (1)	0.0 (0)	21.4 (6)	13.5 (7)	0.0 (0)	0.0 (0)	0.0 (0)	6.3 (2)	6.2 (21)
istance between welling and water urce	*<500 metres*	100.0 (181)	99.1 (106)	89.2 (58)	20.0 (13)	18.3 (13)	50.4 (62)	51.4 (54)	89.7 (26)	9.5 (6)	78.6 (81)	65.8 (600)
	>500 metres	0.0 (0)	0.9 (1)	10.8 (7)	80.0 (52)	81.7 (58)	49.6 (61)	48.6 (51)	10.3 (3)	90.5 (57)	21.4 (22)	34.2 (312)

actor	*Level*	**Bottlebrush**	**Kennedy Lower**	**Lusaka**	**Pemary Ridge**	**Quarry Road West**	**Simplace**	**Briardene**	**Smithfield**	**Park Station**	**Canaan**	**Total**
	Minimum distance (metres)	2	17	0	56	230	15.00	33.00	70.00	1.00	0.00	0.00
	Maximum distance metres)	420	900	1640	1450	2400	1500	1390.00	690.00	1890.00	1400.00	2400.00
istance between velling and nitation facility	*<500 metres*	100.0 (181)	100.0 (107)	92.5 (62)	12.3 (8)	0.0 (0)	89.9 (107)	71.4 (75)	100.0 (29)	100.0 (63)	39.2 (20)	76.0 (652)
	>500 metres	0.0 (0)	0.0 (0)	7.5 (5)	87.7 (57)	100.0 (71)	10.1 (12)	28.6 (30)	0.0 (0)	0.0 (0)	60.8 (31)	24.0 (206)
	Minimum	2	17	25.00	20.00	400.00	2.00	54.00	12.00	2.00	1.00	1.00
	Maximum	250	109	1800	830.00	940.00	900.00	1200.00	109.00	333.00	880.00	1800.00
	<4 metres	1.6 (3)	0.0 (0)	0.0 (0)	60.0 (39)	95.7 (67)	43.1 (53)	4.8 (5)	0.0 (0)	40.3 (25)	35.3 (42)	25.3 (234)
erage distance ween dwelling	*4 – 20 metres*	18.1 (33)	37.4 (40)	89.1 (57)	38.5 (25)	4.3 (3)	56.9 (70)	82.9 (87)	20.7 (6)	51.6 (32)	22.7 (27)	41.0 (380)
	> 20 metres	80.2 (146)	62.6 (67)	10.9 (7)	1.5 (1)	0.0 (0)	0.0 (0)	12.4 (13)	79.3 (23)	8.1 (5)	42.0 (50)	33.7 (312)

4

MATERIALS AND METHODS

4.1 INTRODUCTION

This prospective cohort study investigated geohelminth transmission among children aged 2 to 10 years living in some of the slums in and around Durban, South Africa. An interdisciplinary perspective was adopted using methods from parasitology, epidemiology and social science.

4.2 PREPARATORY PHASE

Procedural considerations:
Before work started, 10 selected slums and 1 pilot slum were visited. During these visits meetings were held with slum leaders, their communities and the Environmental Health Officers (EHOs) allocated to the areas, in order to explain the purposes of the proposed study. Permission was also sought from parents for their children to be included in the research. Their general approval of the study was obtained to ensure full cooperation. Parents and guardians were assured of the confidentiality of results with regards to individual children and each parent/guardian signed a written consent form (Appendix A) agreeing to treatment for their children. The study was approved by the ethics committee of the Nelson R. Mandela Medical School, University of Natal and the Central Medical Ethics Committee in Denmark.

The criteria for selecting slums were based on accessibility, safety and levels of violence and disputes between the land-owners and slum communities. It took six months of contact to develop a rapport with the slum communities. This is regardless as a relatively short time and was promoted by the following:

1. The gender and small stature of the Principal Investigator (PI), which meant that she did not pose any threat to the community leaders. A down-to-earth approach by the PI, coupled with patience and a friendly personality, also provided useful in this regard;
2. Fluency in local languages (*isiZulu, isiXhosa* and *Sesotho*) was an obvious advantage;

3. Providing temporary employment to 12 laboratory assistants who were subsequently trained in routine parasite diagnosis by the Centre for Integrated Health Research (University of Natal). Twenty four field assistants were also hired from the communities for collecting urine and stool samples from the participants' homes. These laboratory and field assistants were all appointed from the study slums to ensure that compliance was high and that problems arising from the work were dealt with easily;
4. The communities appreciated that their children would be treated free-of-charge which should ensure compliance throughout the study period.

Research team :

The team comprised 1 team leader (PI), 12 laboratory assistants within a minimum of matriculation (grade 12) qualification, 24 field assistants, 4 nurses, 1 data entry clerk and a statistician.

The team leader (PI) was responsible for:

- training the team and explaining the study objectives to slum communities and local health facilities;
- organising the practical procedures for data collection;
- financial management of the project;
- quality control of the work of laboratory assistants;
- preparing progress reports for the funding institution;
- organizing and delivering treatment for the communities being investigated;
- organizing admissions and transporting children who needed to be treated under medical supervision

The laboratory assistants were responsible for:

- labeling the stool/urine containers;
- preparing and reading the slides;
- recording the results;
- conducting questionnaire surveys;
- cleaning the working environment.

The field assistants were responsible for:

- collecting stool/urine samples;
- introducing questionnaire interviewers to parents during household surveys and during treatment.

4.3 THE WORKSHOP

It is now generally accepted within public health circles that community participation is an essential aspect of health delivery within the Primary Health Care system in less developed countries. At the beginning of the study, a workshop was held with key persons representing the Durban's North-and-South-Central Metropolitan Councils (in whose areas the study slums were situated), Departments of Environmental Health and Nursing, leaders of each of the 10 study slums, non-governmental organizations, social workers, supervisors, laboratory and field assistants. The workshop was held at the Department of City Health in Durban.

The aim of the workshop was to discuss the main objectives of the proposed study and to get a general opinion on it from participants. At the same time, community support was sought in order to design sustainable strategies for subsequent data collection. Another objective was to emphasize that I wanted to listen to the people of the slums in order to assess their needs for the development of appropriate control programmes. Since this was a community-based study, intervention was tailored to conform to prevailing climatic, social, political, cultural and economic conditions. I wanted to demonstrate the value of community participation in dealing with disease transmission, prevention and control.

The aims of the workshop were:

1. to make sure that things run smoothly;
2. to make sure everyone knows his/her role and that all are involved;
3. to build confidence in the project team;
4. to check the team's ability to perform the tasks;
5. to make sure that health professionals are not insecure and do not feel threatened, a situation which may lead to their jeopardising the study by open rejection of the method;
6. to ensure the safety of the PI when working in the slums.

The (PI) was the main facilitator.

4.4 FOCUS-GROUP DISCUSSIONS

Focus-group discussions with persons of homogenous age and sex composition, i.e.12 mothers, were conducted in each of the four slums to elicit the following preliminary information on specific topics:

1. To get ideas about what the community sees as important issues in the study so that a questionnaire could be formulated.
2. To become acquainted with key local words related to the study, e.g. slums were called "*Mjondolo*", faeces were called "*Boshy*" and worms were called "*Isikelemu*" etc.

4.5 STUDY DESIGN

A schematic representation of the study design is shown in Figure 4.1. This study consisted of five parts namely:

1. **Baseline survey** - cross-sectional survey of all registered children. Outcome variables were prevalence and intensity of geohelminth infections before treatment.
2. **Post-treatment survey** - cross-sectional survey after first treatment.
3. **Re-treatment survey** - cross-sectional survey of those who were still positive for *A. lumbricoides* in the post treatment survey.

The longitudinal study consisted of two baseline surveys viz.:

4. **Follow-up 1 survey** - cross-sectional survey in all slums at 4½ to 6 months post-treatment to establish if reinfection prevalence has reached baseline level.
5. **Follow-up 2 survey** - cross-sectional survey in all slums after 12 months post-treatment. This was done in conjunction with last treatment and questionnaire survey.

These surveys are described separately as each of them is related to the specific objectives and activities given in Chapter 1 (p9 & 10).

4.5.1 Baseline survey

During the baseline survey the whole study sample was investigated. This provided a sound basis for estimating the geohelminth status and the need for intervention in the population. It involved screening of children 2-10 year old for *A. lumbricoides, T. trichiura* and hookworm infection or multiple infections of these selected geohelminths. The plan was then to mass-treat all the positive and negative children living in slums where the prevalence was above 50% following WHO (1998). Since all slums were above this level, the target group was mass treated in September and October 1998 and at the end of field surveys (Figure 4.1). The post-treatment stool examination was done 30 days after 1st and 2nd chemotherapy. The cohort consisted of those children found negative after

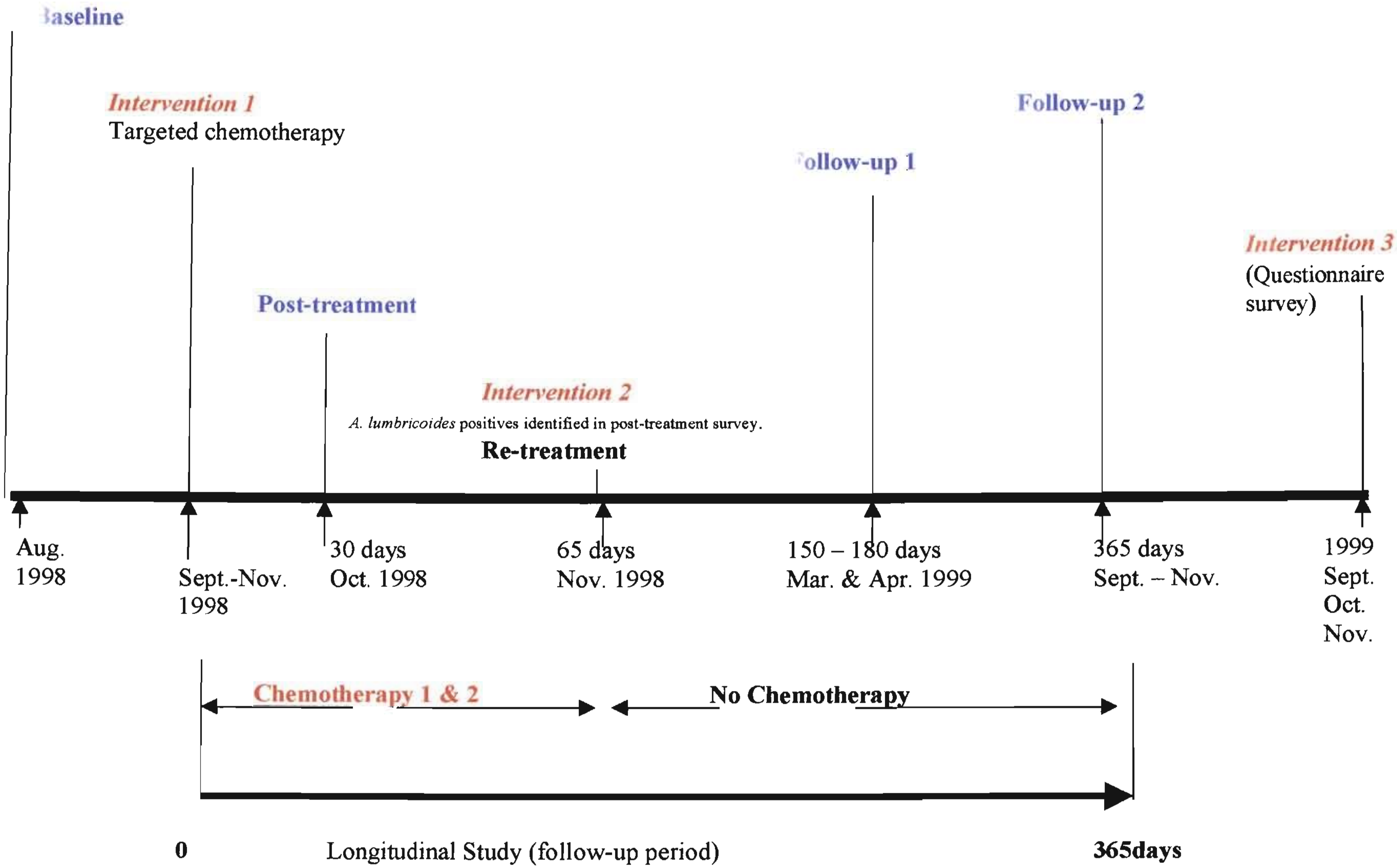


Figure 4.1 Summary of the study design.

first treatment, and re-examined for the study on reinfection rates that followed, while those still positive for *A. lumbricoides* at post-treatment (re-treatment), after the same period, were re-treated until negative and included in the cohort. Those who were found positive for *T. trichiura* after retreatment were included in the follow-up surveys but excluded in the analysis.

4.5.2 **The longitudinal study** (follow-up 1 and 2 surveys)

Follow-up surveys monitored changes in the geohelminth population as a result of treatment; reinfection and impact of the control programme. A cohort of 947 children aged 2-10 years was followed for one year in order to investigate risk factors influencing infection by *A. lumbricoides* and *T. trichiura*. Reinfection surveys were carried out at intervals of 4½ to 6 months (150-180 days) **(follow-up 1:** March & April 1999), and 12 months (365 days) **(follow-up 2:** October to December 1999). The questionnaire survey was conducted during follow-up 2, which was conducted simultaneously with the last chemotherapy (intervention 3) for ethical reasons and also to ensure compliance. One slum i.e. Lacey Road was chosen, for conducting a **pilot survey,** and was then excluded from the analysis.

4.6 SOCIO-ECONOMIC FACTORS

One of the specific aims of the study was to identify socio-economic, socio-cultural and hygiene-related factors which could be associated with geohelminth infections. The challenge in the identification of these indicators was two-fold:

1. quantification of these kinds of variables is difficult (Maier *et al.*, 1994);
2. they were essential for a valid and meaningful reflection of key issues affecting transmission of geohelminth infections in the lives of communities living in slums.

In order to develop appropriate tools for data collection, a module of social science was included in the first phase of the project, i.e. a workshop based on the input of an experienced social scientist. Initially, four open-ended data collection sessions (group discussions and in-depth interviews) was carried out with influential groups in the slums, e.g. mothers, women's league members, Environmental Health Officers (EHOs), laboratory and field assistants, to try to answer the key questions on knowledge, attitudes, perceptions and beliefs about intestinal parasites in general.

Based on the purely qualitative data collected from these discussions and interviews, it was possible to identify key factors which could be singled out as culturally appropriate indicators of the research issues in question. Two hypothetical examples of such indicators are (i) a particular style of house construction as an indicator of wealth, and (ii) proximity of a house to a particular water source as a sign of access to safe water. An effort was made to formulate closed, quantifiable questions regarding these key factors. After thorough pre-testing, this questionnaire (Appendix B) was piloted using laboratory assistants in the pilot slum. It was conducted in *isiZulu* (local language) and allowed the collection of data on the risk factors being investigated. These included: biological (i.e. sex and age); environmental (i.e. soil type, topographical position of dwelling, origin of child, child care-giver, sanitation, water source, food hygiene, child and adult personal hygiene); socio-cultural (geophageous behavior of parent/guardian and child); socio-economic (house-crowding effect, distance between houses, household income, employment and education, food source, storage, preparation and hygiene). The community's thoughts about the study, how it could be improved and whether it was necessary, were also gauged during the general meeting with the slum community and household questionnaire survey.

4.7 SAMPLING TECHNIQUE

4.7.1 Sample size calculation

The number of slums to be included in the study was calculated following the method described by Hayes & Bennett (1995). This method was developed for (Acquired Immuno Deficiency Syndrome - AIDS) intervention studies but is suitable for other types of epidemiological research.

The general formula for sample size (n) calculation is:

n	=	$1 + f\,8\,[(i_0 + i_1)/p + k^2(i_0^2 + i_1^2)]/(i_0 - i_1)^2$ where:
n	=	number of slums in each group
f	=	is dependent on the power. For $p<0.05$ two sided test and 80% power, f = 7.85).
i_0	=	reinfection without intervention (low/poor sanitation coverage – group 1) (12 months)
i_1	=	reinfection with intervention (high/good sanitation coverage- group 2) (12 months)
p	=	number of subjects selected in each slum

k	=	the coefficient of variation (mean/SD) of the true reinfection rates
For $\mathbf{i_0}$ and $\mathbf{i_1}$	=	60% and 40%, respectively.
Power	=	80%, $P<0.05$, k =10% and p = 75,
n	=	$1 + 7.85 [(0.6 + 0.4)/75 + 0.01 (0.36 + 0.16)]/0.04 = 4.64$

4.7.2 Targeted population

All children aged between 6 months and 12 years in these slums participated, but only those between the ages of 2 - 10 years were included in the analysis. For ethical reasons and at their parent's request, and also to ensure high compliance, those younger than a year or older than 10 years were tested and, if infected, treated as well. The cohorts of children investigated in individual slums thus ranged from 29 to 200, depending on the size of the slum. This particular age-group (2-10 yrs) was ideal because:

1. It constitutes the section of the population at greatest risk of geohelminth infection in terms of both prevalence, intensity and transmission potential;
2. Children of this age group are the most co-operative and easily accessible;
3. This group achieves maximum return in terms of reduction of morbidity and effect on their educability;
4. It serves as a reference for evaluating the need for community intervention (Crompton *et al.*, 1989; Bundy & Cooper, 1989; WHO, 1995; Mosala, 1996; Anderson & May, 1992).

4.8 DATA COLLECTION

4.8.1 Field methods

Because people themselves are more aware of their problems than outsiders, the project was dependent on the **communities' acceptance** and **commitment** to it. Thus when parents and guardians advised us that it would be best to sample and treat only when they are at home, this was done for the duration of the study. We were advised by parents to sample and treat on Saturdays and Sundays only, a time when they would be at home. Any outstanding stool samples were collected during the course of the week.

4.8.2 Laboratory methods

4.8.2.1 Stool collection and examination

Basic demographic data which included the name, age, sex and physical address of each child were collected from mothers or guardians at recruitment into the study. Field assistants living in specific slums were appointed and trained to collect stool specimens from each child's home. Each child was provided with two sample bottles with his or her identity number, day of collection, sample number and name on them. For each participant, single samples were collected twice during the week. In 1998 laboratory examinations were done at the Centre for Integrated Health Research, University of Natal. In 1999 however, the samples were examined by the same laboratory assistants using the pathology laboratory at Prince Mshiyeni Hospital in Umlazi, Durban. Each stool sample was examined in duplicate using a modified 50mg Kato-Katz thick smear (Katz *et al.*, 1972; WHO, 1998; Archer *et al.*, 1997). This gave a useful indirect measure of worm burden. The Kato-Katz method has the following advantages over the formal-ether concentration technique (Allen & Ridley, 1970).

1. Smears can be prepared anywhere in the field because no electricity or specialized equipment is needed - the only requirements being the Kato-Katz kit and a microscope.
2. Plastic templates and spatulas and glass microscopic slides used for the preparation may be re-used after thorough washing. The remainder of the materials can be easily disposed of.
3. The preparation of slides can start immediately after stool collection.
4. Slides are quick and easy to prepare.
5. It is more sensitive than other techniques (e.g. Stoll or Beaver thick smear techniques) when measuring the intensity of infection, i.e. the number of eggs per gram (e.p.g.) of stool. It can detect very light intensities and was found to predict worm loads better than the direct thick smear and the formal-ether concentration technique methods (Sinniah & Subramaniam, 1991).

The smears were read for hookworm eggs within one hour of preparation before they became invisible due to the glycerol treatment of the specimen, and again 24 hours later for *T. trichiura* and *A. lumbricoides* eggs. A total of 15 104 samples were examined as listed in Table 4.1.

Table 4.1 The number of children diagnosed in the different compartments of the study.

Survey	N	Stools collected	Slides examined
Baseline	996	1 992	3 984
Post-treatment	996	1 992	3 984
Re-treatment	56	112	224
Follow-up 1	781	1562	3 124
Follow-up 2	947	1894	3 788
Total	996	7 552	15 104

4.8.2.2 Intensity of geohelminth infection

The intensity of infection was measured indirectly by counting the number of eggs per 50mg Kato-Katz preparation and classified following Renganathan *et al.* (1995) (Table 4.2). As that classification did not provide for infections above 100 000 e.p.g. for *A. lumbricoides* and over 20 000 e.p.g. for *T. trichuris*, a category 'very heavy' was added for very heavy infections of *A. lumbricoides* and *T. trichiura* that were found, i.e. above 100 000 and 20 000 (e.p.g.) respectively. This creation of an additional category is, as will become apparent later, testimony to the very high levels of transmission in these slums.

Table 4.2 Egg counts classification for *A. lumbricoides, T. trichiura* and hookworm (intensity of infection - e.p.g.) used during the study (Renganathan *et al.*, 1995), with the 4th category added in this study .

Parasite species	Light	Moderate	Heavy	Very heavy
A. lumbricoides	1 - 4 999	5 000 - 49 999	50 000 - 100 000	> 100 000
T. trichiura	1 - 999	1 000 - 9 999	10 000 - 20 000	> 20 000
Hookworm	1 - 99	100 - 399	> 400	

'Cure' rates following drug treatment were estimated as the proportion of children excreting eggs of any particular geohelminth before treatment who had a zero count after treatment or retreatment. Proportions were compared using standard chi-square tests. **Geometric Mean (GM)** egg counts were estimated as exponent $[(\Sigma \log_e (c + 1) / n] - 1$, where c was the egg count (e.p.g.) for a particular individual and n the number of samples. Geometric means were compared using analysis of variance (ANOVA) (Albonico *et al.*, 1994).

4.8.2.3 Urine collection, preservation and examination

During the baseline survey, urines of children aged above three years were also collected for *Schistosoma haematobium* examination. A large specimen bottle was given to the child with the same identification number as the stool sample bottle. The parents were asked to collect urine samples between 10H00 and 14H00. After return to the laboratory, they were prepared, preserved and examined following Archer, *et al.* (1997).

4.8.2.4 Geophagy

The amount of soil in a stool sample was estimated qualitatively by means of silica counts following the method of Geissler *et al.* (1997), i.e. the number of silica crystals visible (Figure 4.2) per microscope field at 100X magnification. These counts were scored as shown in (Table 4.3).

Table 4.3 Qualitative assessment of geophagy by scoring the number of silica crystals per microscopic field at 100X Archer, *et al.*, (1997).

Category	**Number of silica crystals per field of vision**
Occasional	1 crystal every second field
Scanty	2 crystals every second field
+	3 crystals per field
+ +	4 - 5 crystals per field
+ + +	6 - 8 crystals per field

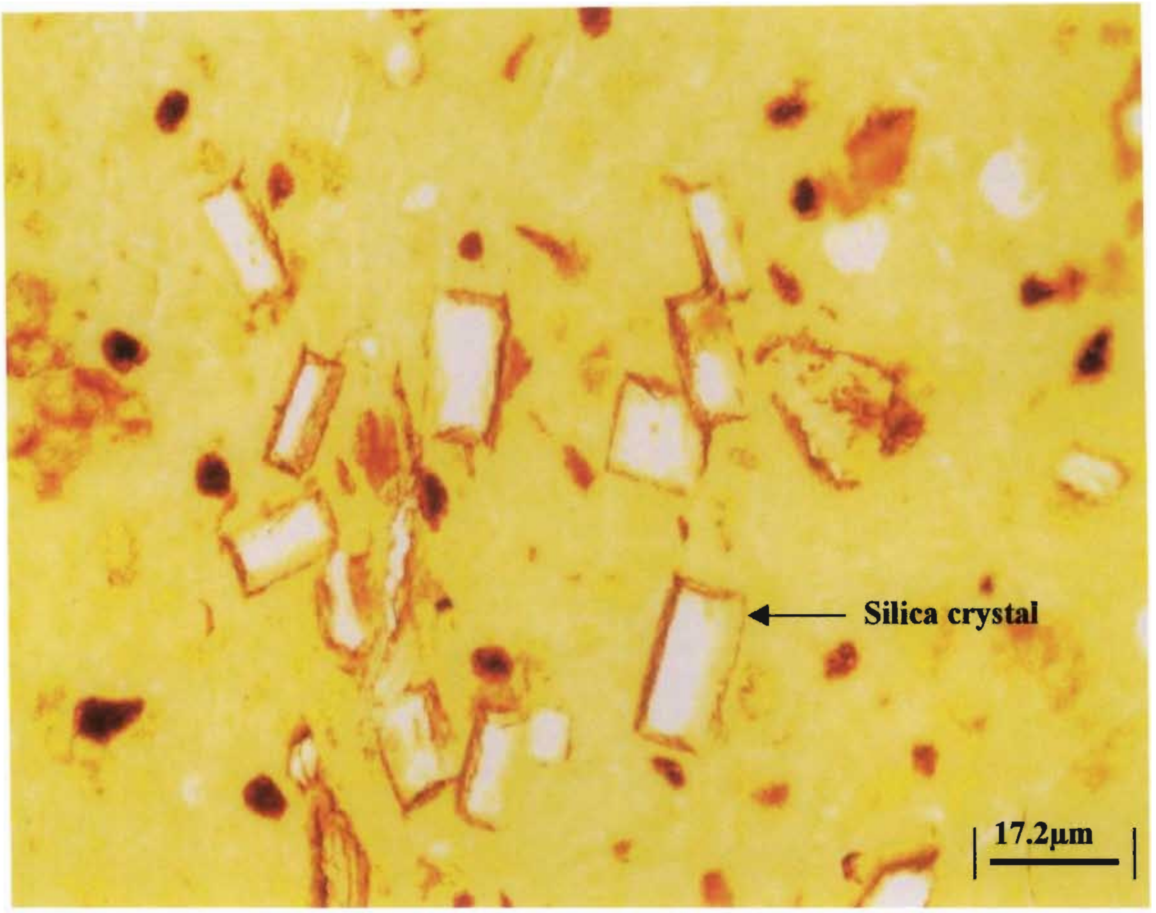


Figure 4.2 Silica crystals (◄—) seen in a Kato-Katz stool preparation (400x) indicating that a child has ingested soil-contaminated food or water.

At the end of each household questionnaire interview, those children older than three years who said that they were geophageous would show the interviewer the precise sites where they collected the soil they ate. They were then given a plastic bag and asked to put into it the amount of soil they would eat each day or week, whichever was appropriate. The soil was then dried and weighed to give a crude estimate of the child's daily or weekly intake of soil.

4.8.2.5 Quality control

Two different laboratory assistants read the duplicate Kato-Katz samples from the same individual and the average of the two was taken as the result. Accuracy was maintained through the re-examination of 10% of slides, or all slides if the cohort was small, by the PI.

4.9 GEOHELMINTH TREATMENT

4.9.1 Targeted chemotherapy

Because prevalence rates in all slums were high (>60% for *A. lumbricoides* and *T. trichiura*), targeted mass anthelminthic treatment of all children, both infected and uninfected, was administered with the assistance of four nurses from the City Health Department. Albendazole 400mg (Zentel®) tablets were given as a single dose to children above two years of age whose parents had signed consent forms beforehand (Appendix A). Children below 2 years of age were given the initial dose of Zentel® suspension (400mg/20ml for 3 days) and their parents/guardians were asked to supervise the remaining doses at home. During the first treatment programme, children who had hookworm infection, heavy intensities of ascariasis and trichuriasis, those found to have signs and symptoms of anaemia, 2nd or 3rd degree malnutrition, kwashiorkor, scabies, low haemoglobin levels (see Chapters 4 title page) and/or distended abdomen (see Chapters 5 title page), were given a referral letter (Appendix A) to the nearest clinic for medical attention.

Finger-prick blood was obtained using Brand Safety Flow Lancets (Microtainer ™) for haemoglobin determination in the field using a portable battery-operated BMS 10-101 Hemoglobinometer. WHO's definition of anaemia in childhood is a haemoglobin concentration below 11 g/dl (WHO, 1964). Haemoglobin levels of these same children were measured again 12 months later during the third intervention and compared with the pre-treatment (baseline) readings.

4.9.2 Hospital treatment of heavily infected children

Following in-depth interviews held at the beginning of the study with 12 mothers in four slums, it was learnt that when their children took anthelmintics (Piperazine), worms sometimes escaped via orifices such as the mouth and/or nose. *A. lumbricoides* boluses could be felt as a sausage-shaped mass in the right lower abdominal quadrant. Frequently this mass can be visualized by x-rays, which also show scattered worms characterised by groups of worms lying parallel to each other, and filling the host intestinal lumen, producing an x-ray shadow of parallel lines. These were presumably heavily infected individuals and because of the potential danger of such situations, I arranged that they be treated under medical supervision. Clinic physicians co-operated by referring them to the Paediatric Out-patient Departments (P.O.P.D.) of several local hospitals (King Edward VIII, R.K. Khan and Addington) where they were admitted and then treated. They were also given the taxi-fare to get home. This enhanced the community's support for the project, helped maintain the sample size and increased compliance. Adults wanted to be treated as well, but accepted that children were at a far greater risk.

King Edward VIII Hospital was the most frequently used, and a notice was sent to every doctor working in the P.O.P.D. explaining the study. This included a form, which the doctor was asked to complete for every such child examined, summarizing his/her diagnosis and the action he/she took.

Paediatricians at local hospitals and the Nelson R. Mandela Medical School (University of Natal), supported this approach, fearing that such heavy infections might lead to gastro-intestinal complications such as *A. lumbricoides* boluses.

Children admitted to the P.O.P.D. of King Edward VIII Hospital presented with two categories of symptoms, viz. **A** and **B** as discussed below:

A. those suspected/found to have sub-acute obstructions:

- colicky abdominal pain;
- vomit (not bile-stained);
- worm boluses palpable in the abdomen;
- no abdominal distension;
- vomiting worms/ passing worms per rectum.

Before treatment these children would be starved for 24 - 36 hours, given intravenous fluids and an anti-spasmodic. Following this the worms (*A. lumbricoides*) would start moving out of the bolus in search for food, allowing the bolus to loosen. The child could then take liquids again followed by solid food and finally treatment with Albendazole® and an anti-spasmodic.

B. those suspected or found to have an acute obstruction:

- bile stained vomit;
- constant abdominal pain;
- constipation;
- abdominal distension;
- bolus palpable in abdomen,

In this second group complications may occur i.e. possible ischaemic bowel (intestines not receiving an adequate blood supply), gangrene of bowel – see Chapter 1 title-page (death of tissue in intestine wall, the affected section may need to be removed), peritonitis (inflammation of the peritoneum). If the bolus and signs of obstruction persist in spite of these above measures in Group B, laparotomy is indicated (Dr. Ramjii pers. comm).

4.9.3 Drug efficacy

Evaluation of the efficacy of Albendazole against *A. lumbricoides* and hookworm was based on cure rates, i.e. no of eggs found in post-treatment stool samples. A post-treatment examination was carried out after 30 days, and all children who were still positive for ascariasis, were retreated after another ±30 days until all were negative. Children who were hospital-treated were checked. It was not expected that trichuriasis infection levels would be significantly reduced (Appendix C, Table 2). Reinfection rates were measured after 4½ - 6 and 12 months in all slums. The same procedures for stool examination, drug administration and post-treatment assessment were followed as for the one year-long reinfection study.

4.10 STATISTICAL ANALYSIS

Data analysis was carried out using SPSS™ (Statistical Package for Social Science, 1999). First, the infection rates (both prevalences and intensities) were compared between slums using Chi-square (χ^2) tests while the Mann-Whitney *U* test was used to assess differences in intensity of infection (Holt, *et al.*, 1980). A significance level of 0.05 was used for all tests. Second, multivariate techniques were used, (a) to identify key risk factors using variable reduction techniques such as factor analysis, (b) to assess similarity and differences in slums using canonical variate analysis and cluster analysis, (c) to see which factors were potential confounders.

The infection rates were described for key risk factors as follows:

1. for categorical risk factors (e.g. sex, silica in stool, age group, parent education, income level, employment level) the percentage infected is given for each level of the factor (e.g. males and females) and,
2. for continuous risk factors (e.g. age, amount of soil eaten per time), the mean and the standard deviation are given separately for those children who are infected, and those who are not.

This was done separately for each parasite and each study stage. Finally, at each stage of the study a multiple logistic regression using prevalence as an independent variable, and multiple linear regression using intensity as a dependent variable, were fitted in order to find which were the most important risk factors for infection/reinfection for each parasite, and to control for baseline differences (Breslow & Clayton, 1993 and Holt & Scott, 1982). This analysis also examined the extent to which between-slum differences could be explained by the effect of risk factors.

5

RESULTS – I

PARASITOLOGY

5.1 INTRODUCTION

This chapter presents the prevalences, intensities and reinfection rates of single and multiple infections of *Ascaris lumbricoides*, *Trichuris trichiura* and hookworm, infecting slum-dwelling children aged 2-10 years as outlined in the first two specific objectives in Chapter 1 (p10). The differences in prevalences and intensities between the study slums are presented first, followed by data on the efficacy of Albendazole (400mg) and on haemoglobin levels before and after treatment. Then, morbidity associated with *A. lumbricoides, T. trichiura* and hookworm infections is also reported. The overall prevalences and intensities of the pooled data are considered and finally the results of the urine examinations for *Schistosoma haematobium* are presented.

5.2 PREVALENCE OF GEOHELMINTH INFECTIONS

5.2.1 Baseline prevalences of *A. lumbricoides*, *T. trichiura* and hookworm infection amongst the 10 study slums

Prevalences of *A. lumbricoides* and *T. trichiura* were high but that of hookworm was low. There are significant differences in *A. lumbricoides* prevalence at baseline between slums (χ^2 = 24.81 on 9 d.f.; p = 0.003), with prevalences ranging from 96.3% (Park Station) to 81.7% (Quarry Road West). There was strong evidence that the *T. trichiura* prevalence at baseline also differed significantly between slums (χ^2 = 27.94 on 9 d.f.; p = 0.001). The overall prevalence of *T. trichiura* ranged from 54.5% (Kennedy Lower) to 86.2% (Smithfield). The overall prevalence of hookworm was 4.7%. It was absent at Bottlebrush and Briardene, but there were highly significant differences between the slums (χ^2 = 79.97 on 9 d.f.; $p < 0.0001$) (Figure 5.1 a-j). The actual prevalences (raw data) of geohelminth infections in all surveys in all 10 study areas are summarised in Table 1, Appendix C.

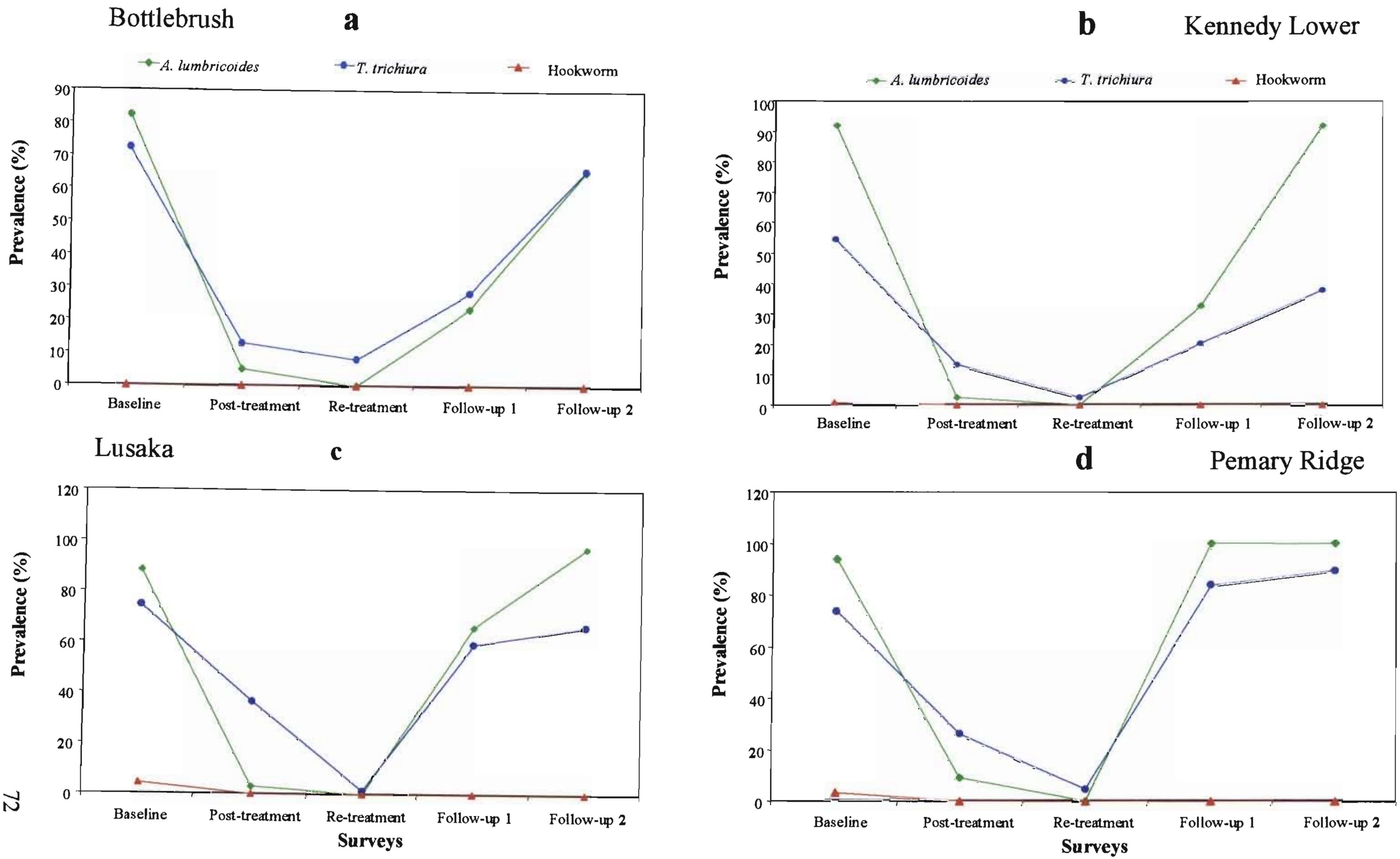


Figure 5.1 (a-d): Changes in prevalence of *Ascaris lumbricoides, Trichuris trichiura* and hookworm infections in individual slums during the study period.

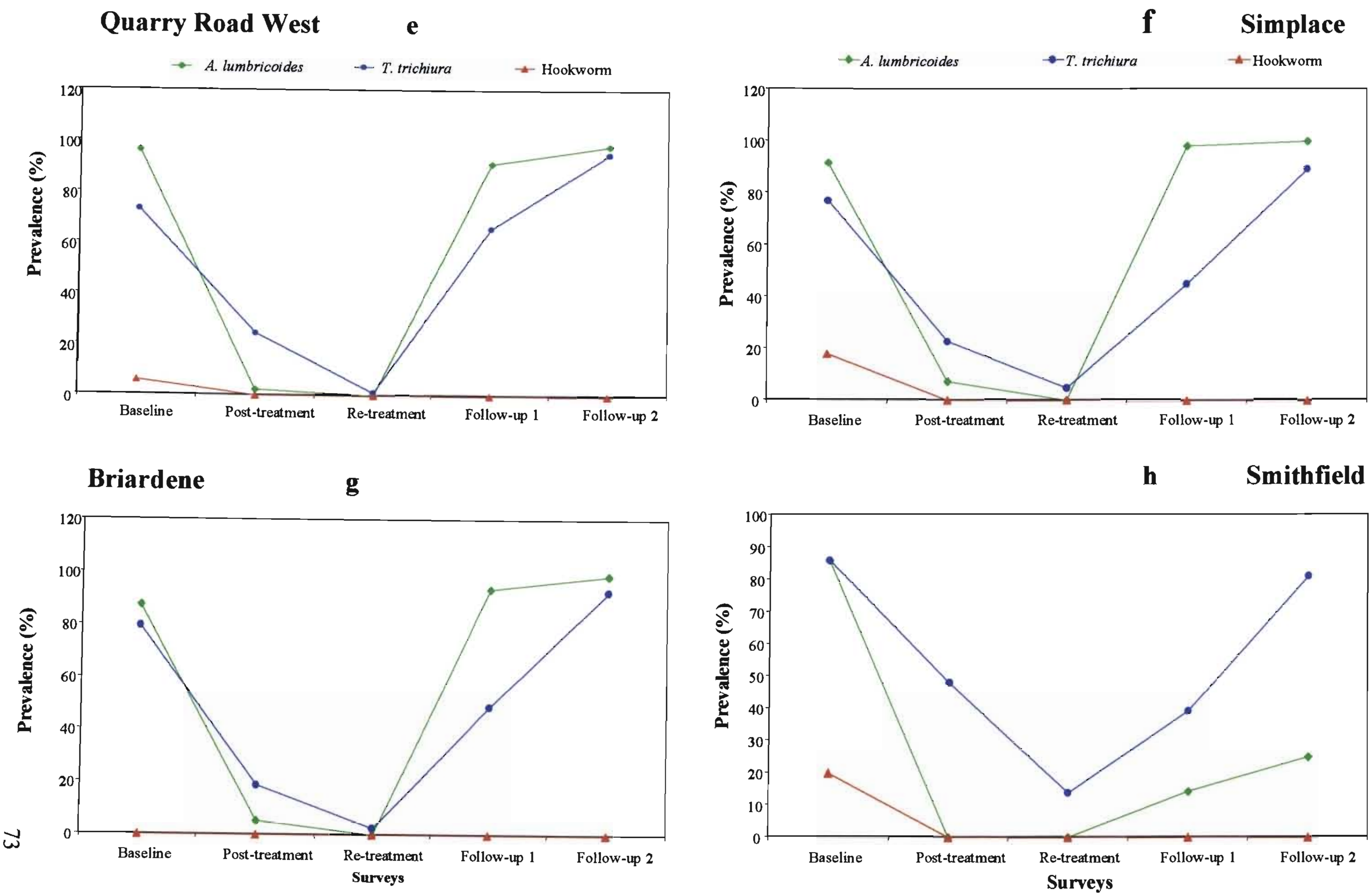


Figure 5.1 (e-h): Changes in prevalence of *Ascaris lumbricoides*, *Trichuris trichiura* and hookworm infections in individual slums in all surveys during the study period.

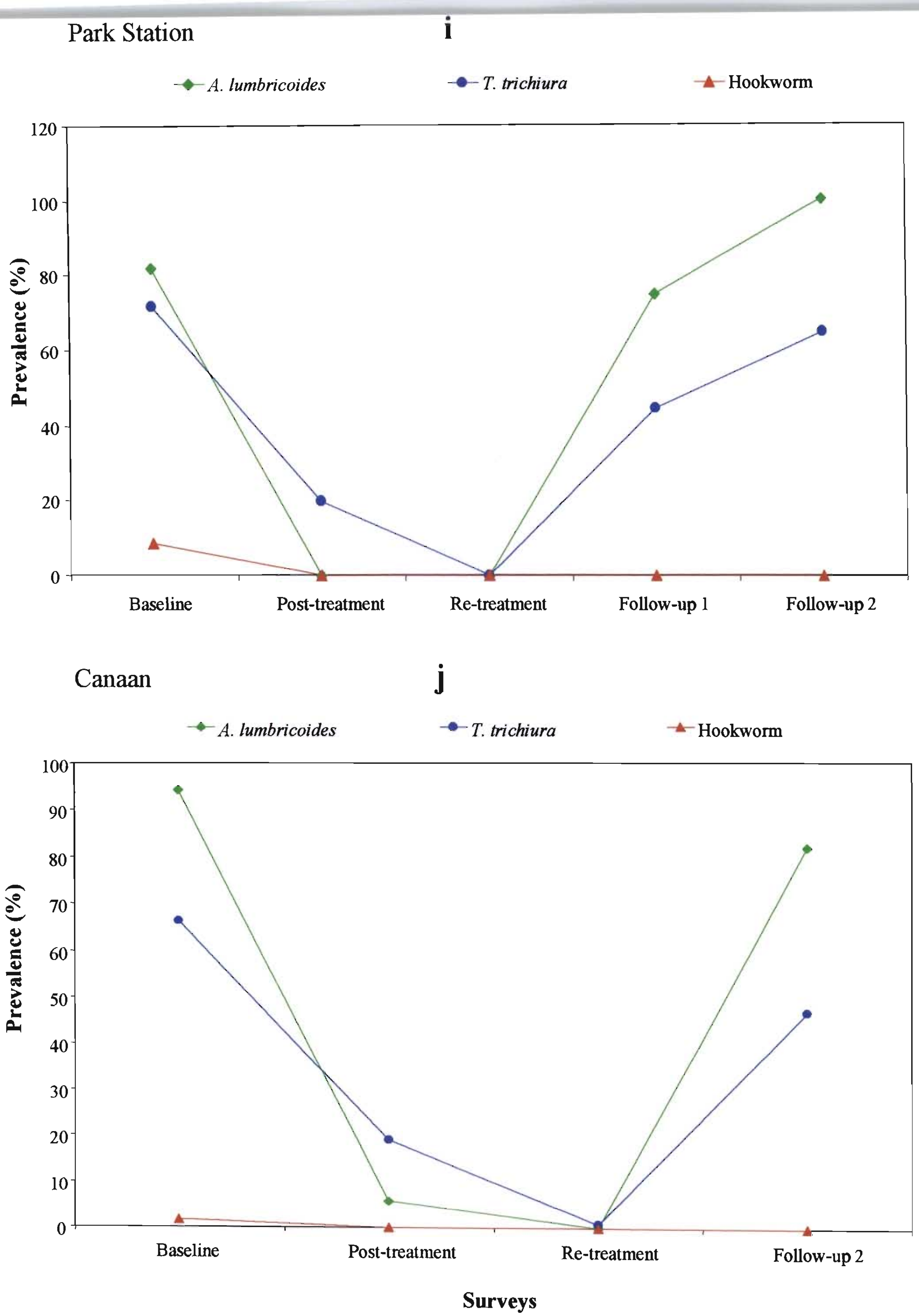


Figure 5.1 (i-j): Changes in prevalence of *Ascaris lumbricoides*, *Trichuris trichiura* and hookworm infections in individual slums in all surveys during the study period.

5.2.2 Post-treatment prevalences of *A. lumbricoides*, *T. trichiura* and hookworm amongst the 10 study slums

Post-treatment prevalences are given in (Table 2, Appendix C). The efficacy of Albendazole 400mg (Zentel®) against *A. lumbricoides* was from 95.5-100% with only 4.5 % of the children not cured after first treatment. Two slums, Smithfield and Park Station, showed cure rates of 100% after just a single dose. There was evidence of differences among slums in terms of ascariasis cure rates (χ^2 = 17.83 on 9 d.f.; $p = 0.043$) (Figures 5.1 a-j).

Cure rates for trichuriasis after the first treatment were between 51.7% and 87.0%. Albendazole was only moderately effective as 20.6% of the children remained infected compared to ascariasis, where 4.5% were not cured. However, after this first treatment, the prevalence had been reduced considerably except at Smithfield where it was 50.0%. The *T. trichiura* cure rate thus shows strong evidence of a difference in efficacy between slums (χ^2 = 36.66 on 9 d.f.; $p<0.0001$) (Figure 5.1h).

Albendazole was 100% effective in treating hookworm infections.

5.2.3 Follow-up 1 prevalences of *A. lumbricoides* and *T. trichiura* amongst the 10 study slums

After four to six months post-treatment the overall prevalence of *A. lumbricoides* was 64.0%, which was lower than at baseline. There was very strong evidence of differences between slums (χ^2 = 412.25 on 8 d.f.; $p < 0.0001$) and these differences were far more marked than at baseline (Figure 5.1 a-j). Smithfield had the lowest reinfection rate with only 14.3% of children reinfected; Bottlebrush had 23.5%, Kennedy Lower 32.5%, Lusaka 66.0%, Park Station 74.6%, Quarry Road West 91.5%, Briardene 94.0%, Simplace 98.3% and Pemary Ridge the highest at 100.0%. The differences in reinfection prevalence amongst the 9 slums after four to six months and after 12 months are given (Table 3, Appendix C).

5.2.4 Follow-up 2 prevalences of *A. lumbricoides* and *T. trichiura* amongst the 10 study slums

After 12 months post-treatment the prevalence of *A. lumbricoides* in Smithfield was still very low (25.0%). Bottlebrush had risen to 65.6% and Kennedy Lower had reached the baseline level of 91.7%, whereas Lusaka, Briardene and Canaan reinfection rates were 96.9%, 99.1% and 82.0% respectively. Pemary Ridge, Quarry Road West, Simplace and Park Station had prevalences that exceeded the baseline level after only 12 months (Table 3, Appendix C). Pemary Ridge actually exceeded the baseline level after only 4½ months (Figure 5.1d) (χ^2 = 249.07 on 9 d.f.; $p < 0.0001$).

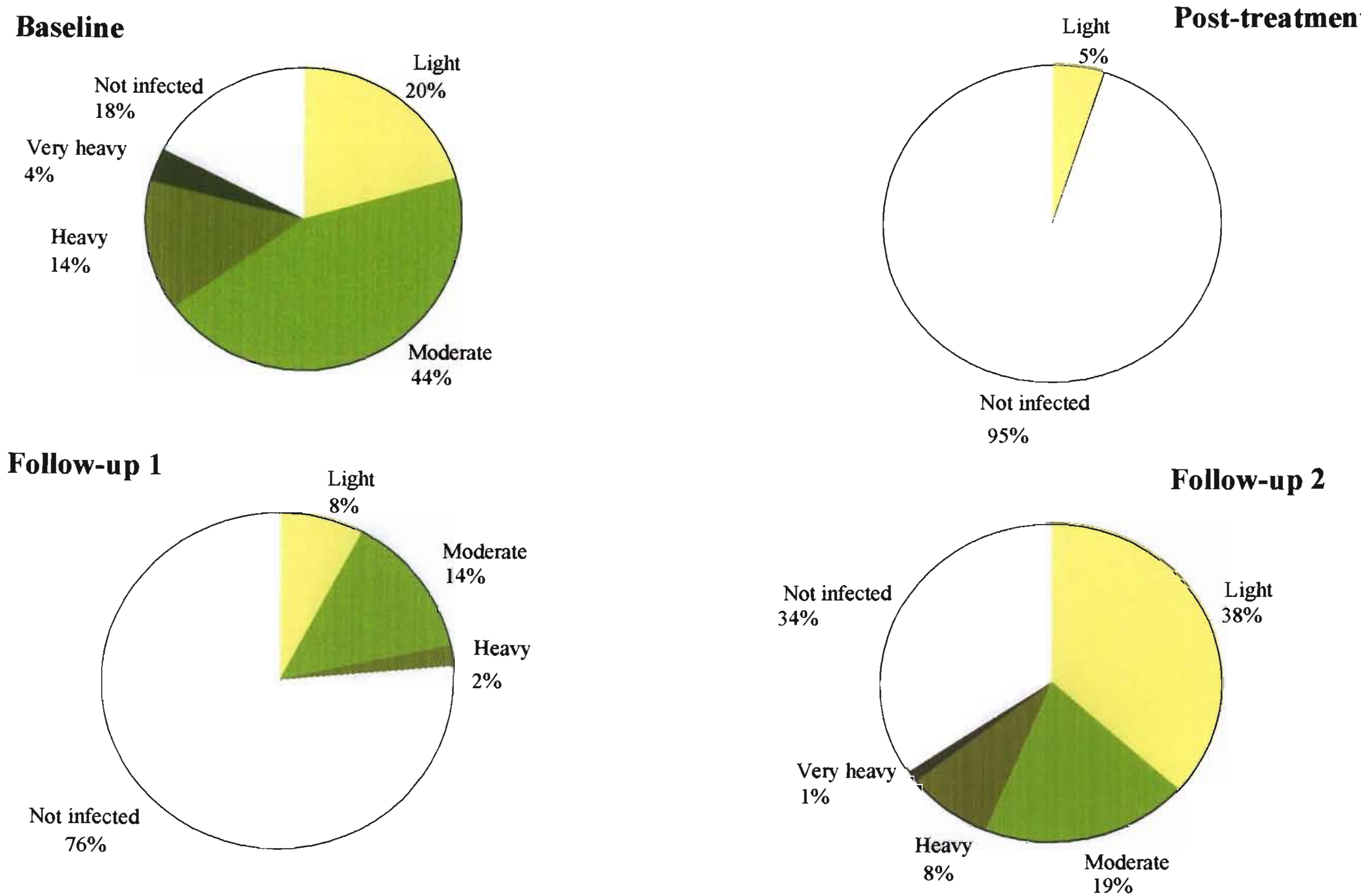


Figure 5.2a Bottlebrush (no.1) *A. lumbricoides* intensities of infection (e.p.g.) in 4 surveys during the study period. Light = 1- 4 999; moderate = 5 000 - 49 999; heavy = 50 000 - 100 000; very heavy = > 100 000 e.p.g.

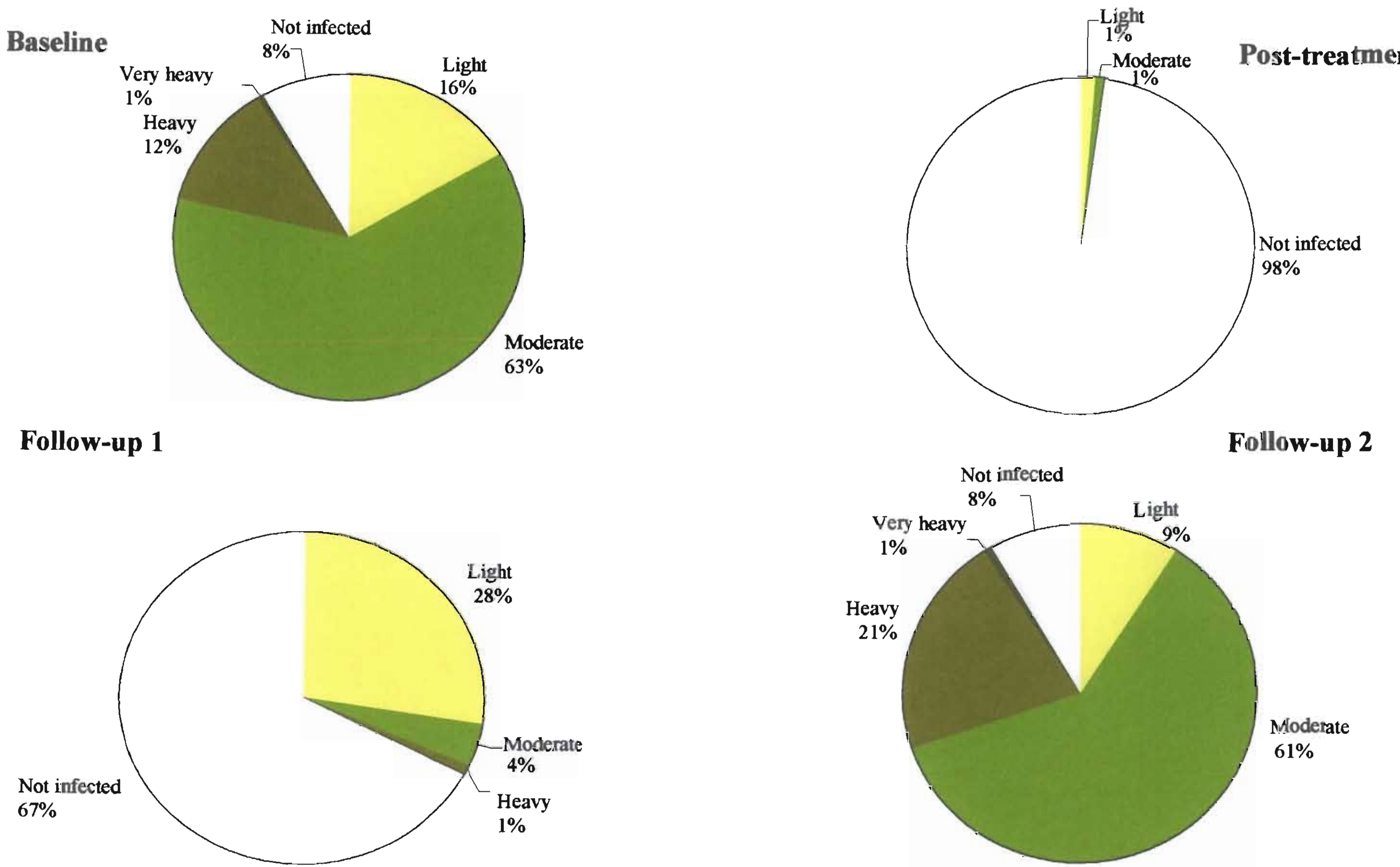


Figure 5.2 b Kennedy Lower (no.2) *A. lumbricoides* intensities of infection (e.p.g.) in 4 surveys during the study period. Light = 1- 4 moderate = 5 000 - 49 999; heavy = 50 000 - 100 000; very heavy = > 100 000 e.p.g.

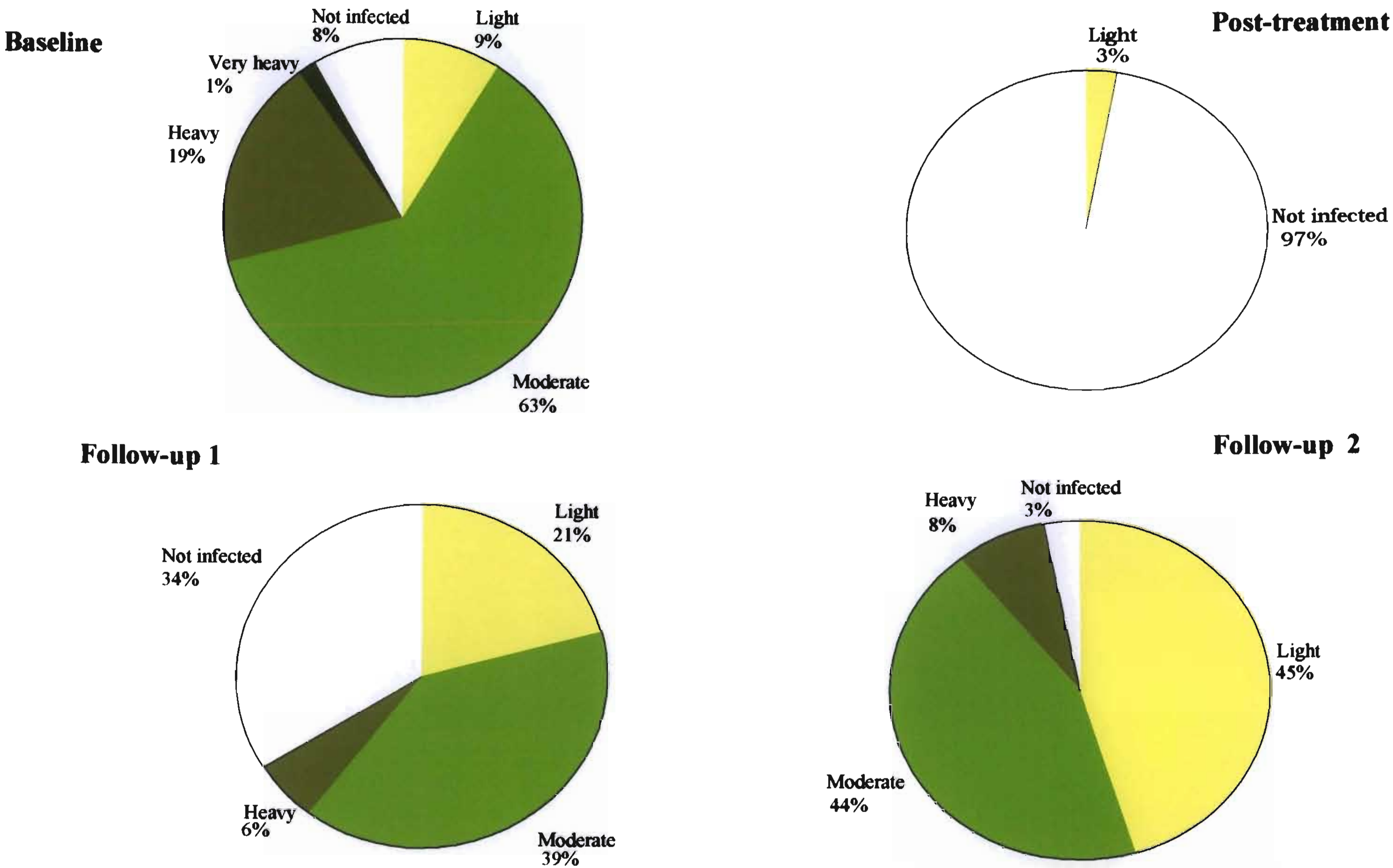


Figure 5.2c Lusaka (no.3) *A. lumbricoides* intensities of infection (e.p.g.) in 4 surveys during the study period. Light = 1- 4 999; moderate = 5 000 - 49 999; heavy = 50 000 - 100 000; very heavy = > 100 000 e.p.g.

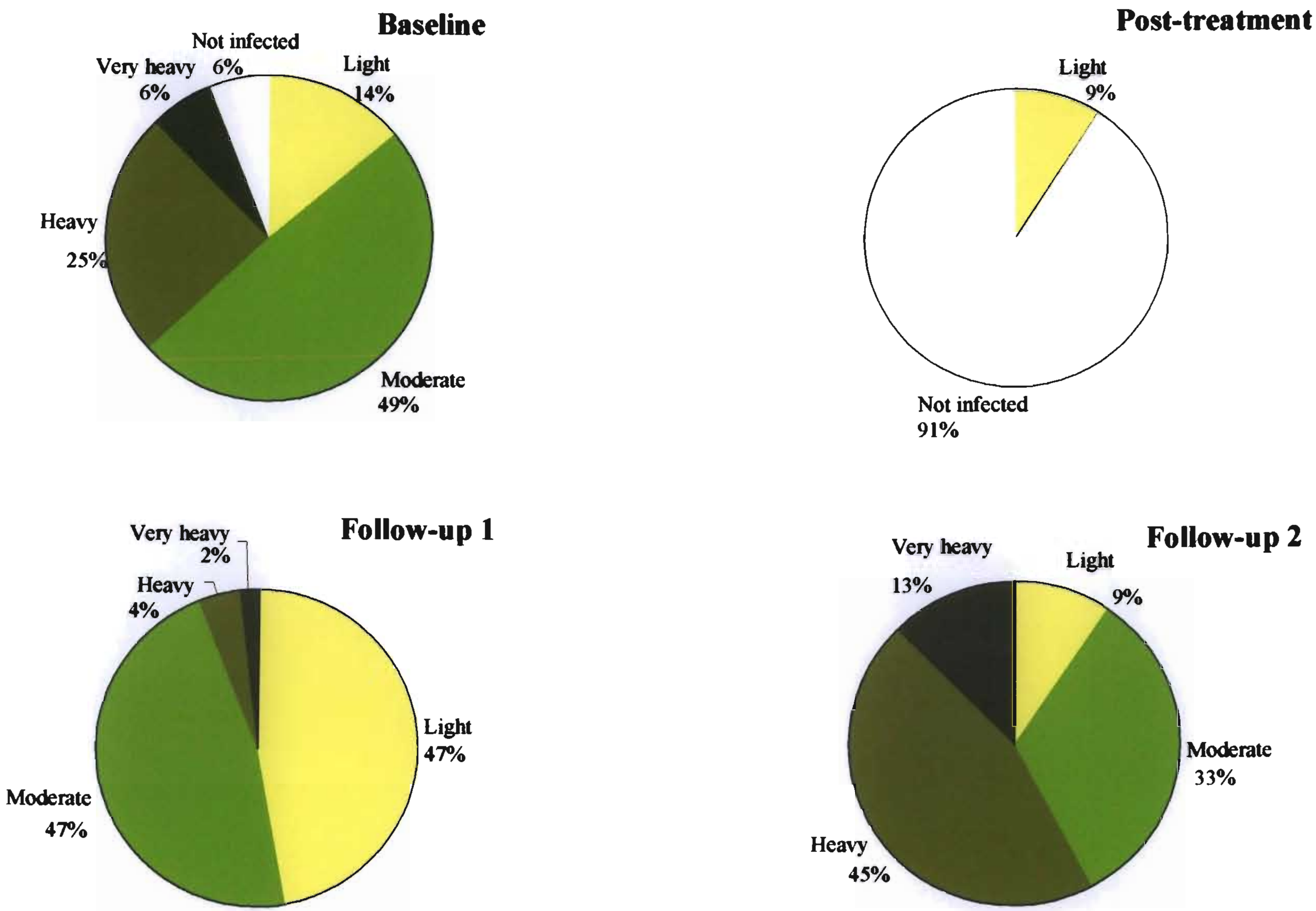


Figure 5.2d Pemary Ridge (no.4) *A. lumbricoides* intensities of infection (e.p.g.) in 4 surveys during the study period. Light = 1- 4 999; modera = 5 000 - 49 999; heavy = 50 000 - 100 000; very heavy = > 100 000 e.p.g.

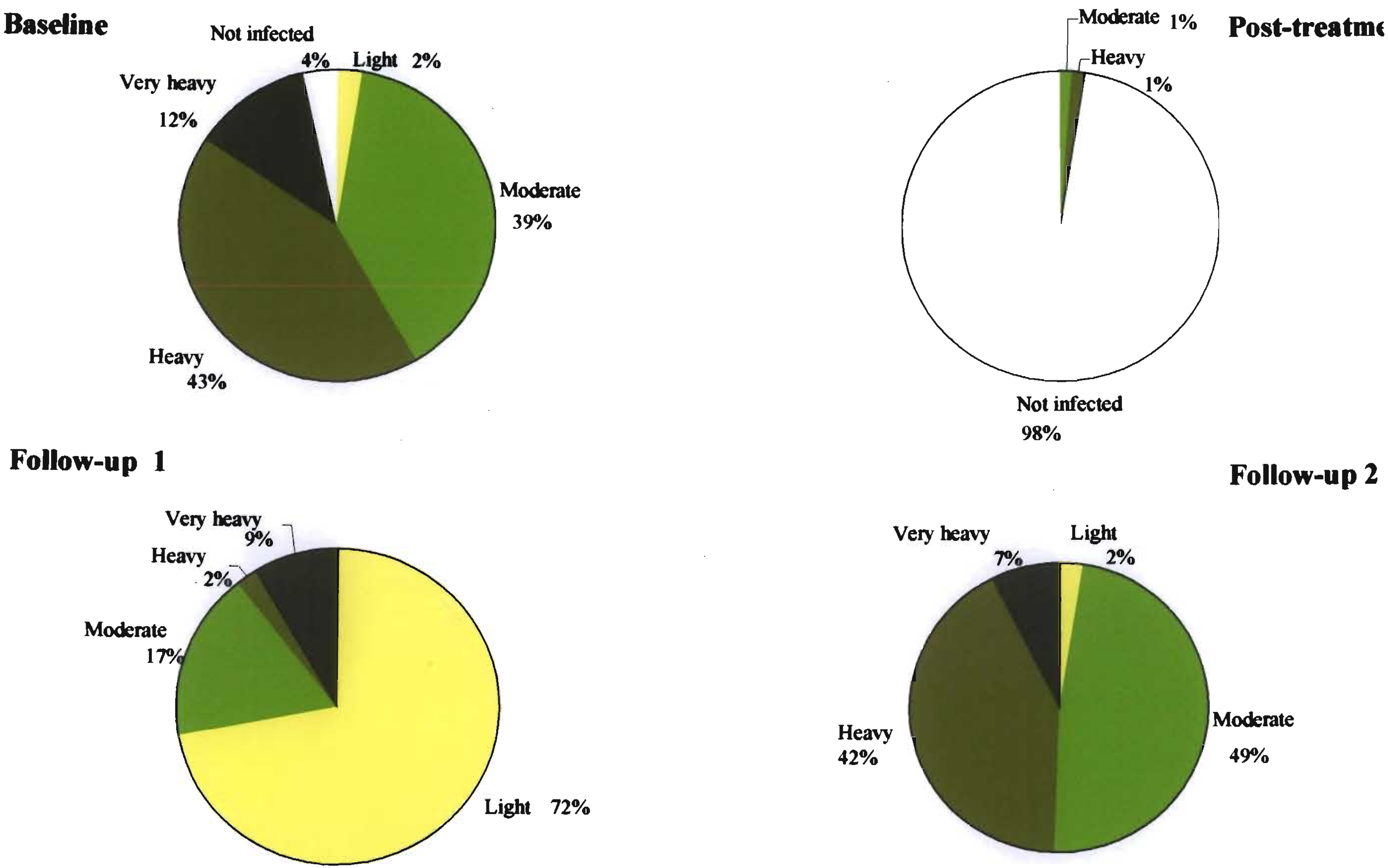


Figure 5.2e Quarry Road West (no. 5) *Ascaris lumbricoides* intensities of infection (e.p.g.) in 4 surveys during the study peri
Light = 1 - 4999; moderate = 5 000 - 49 999; heavy = 50 000 - 100 000; very heavy = > 100 000 e.p.g.

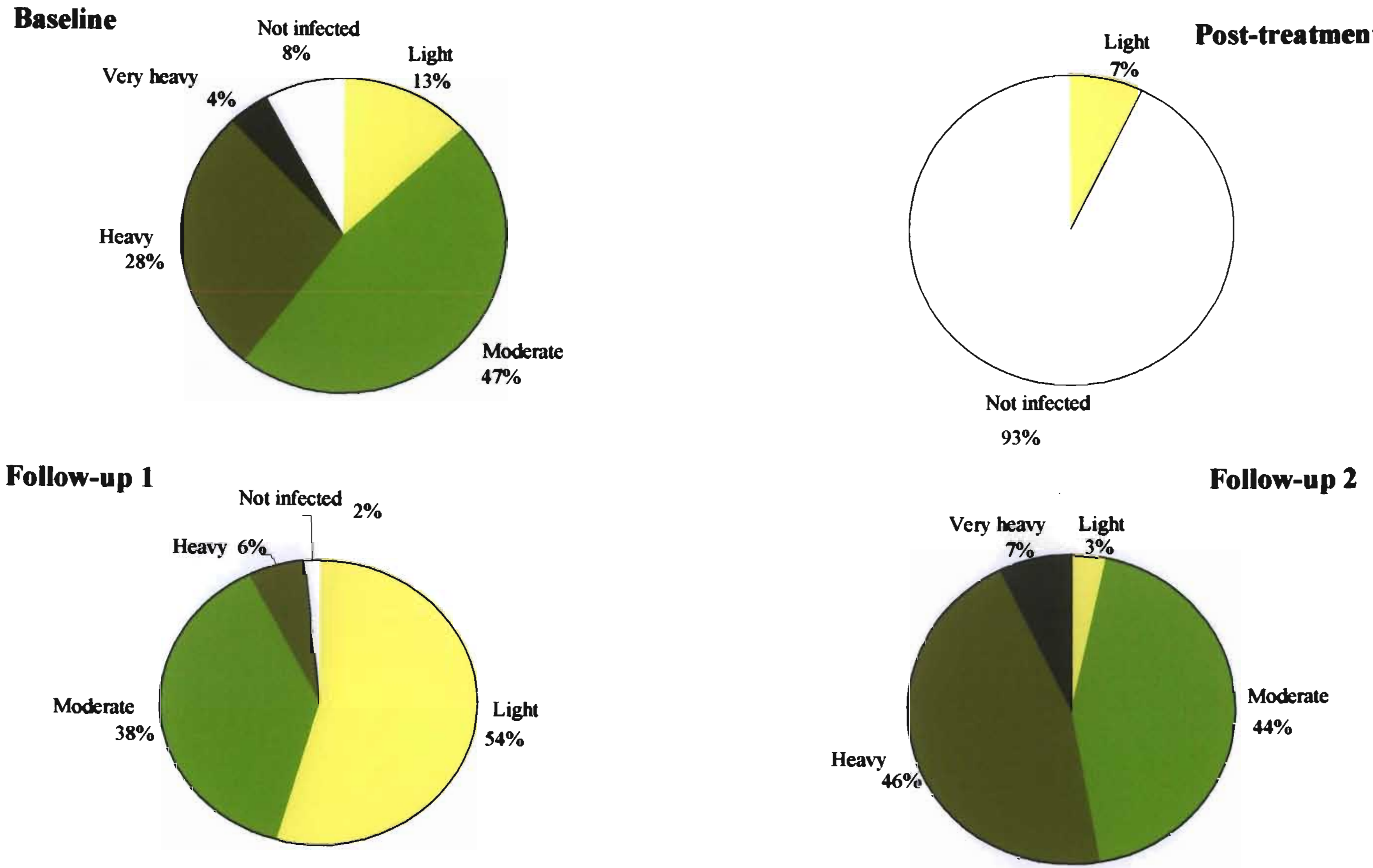


Figure 5.2f Simplace (no. 6) *Ascaris lumbricoides* intensities of infection (e.p.g.) in 4 surveys during the study period. Light = 1 - 4999; moderate = 5 000 - 49 999; heavy = 50 000 - 100 000; very heavy = > 100 000 e.p.g.

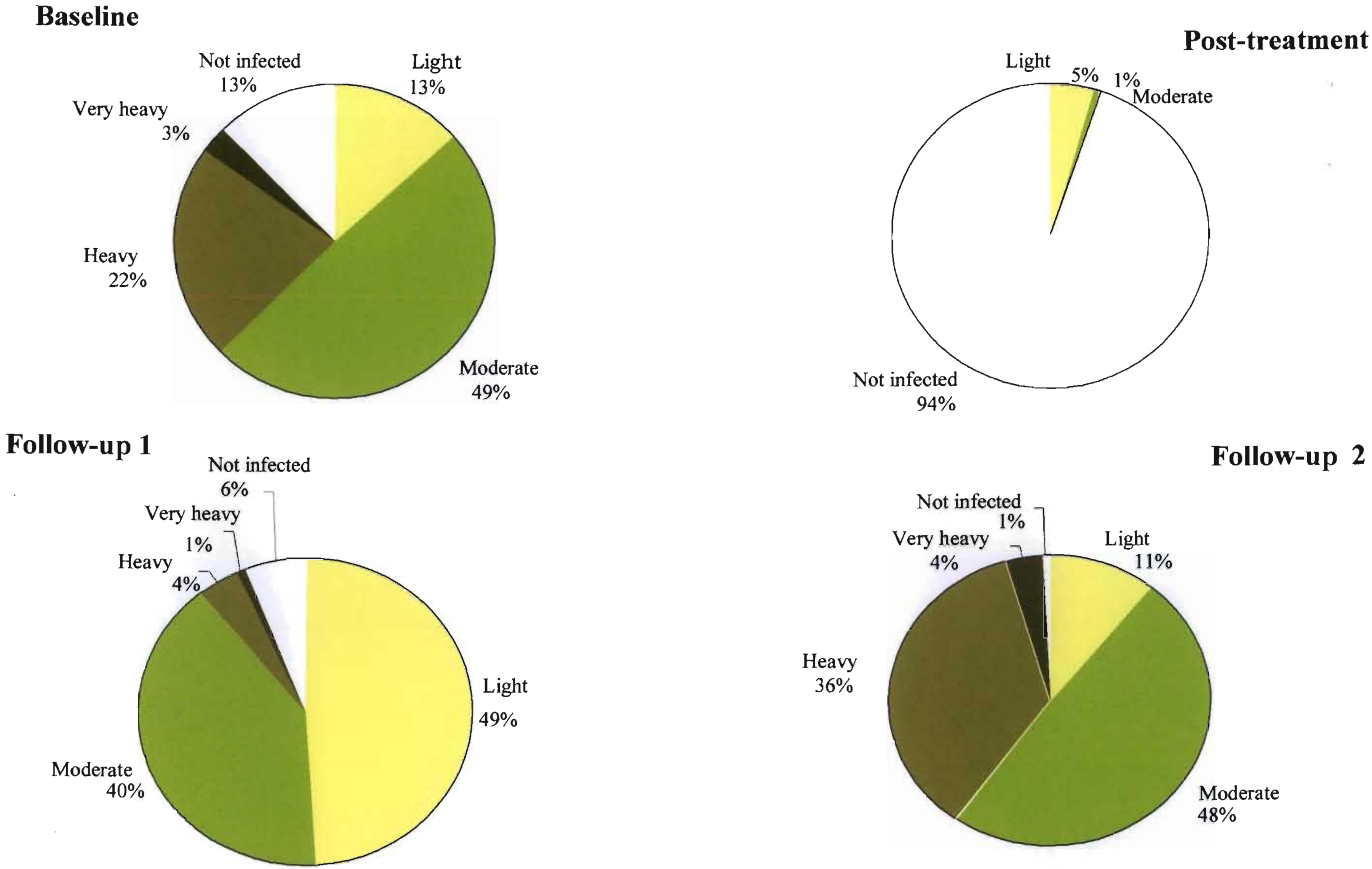


Figure 5.2g Briardene (no. 7) *Ascaris lumbricoides* intensities of infection (e.p.g.) in 4 surveys during the study period. Light = 1 - 4999; moderate = 5 000 - 49 999; heavy = 50 000 - 100 000; very heavy = > 100 000 e.p.g.

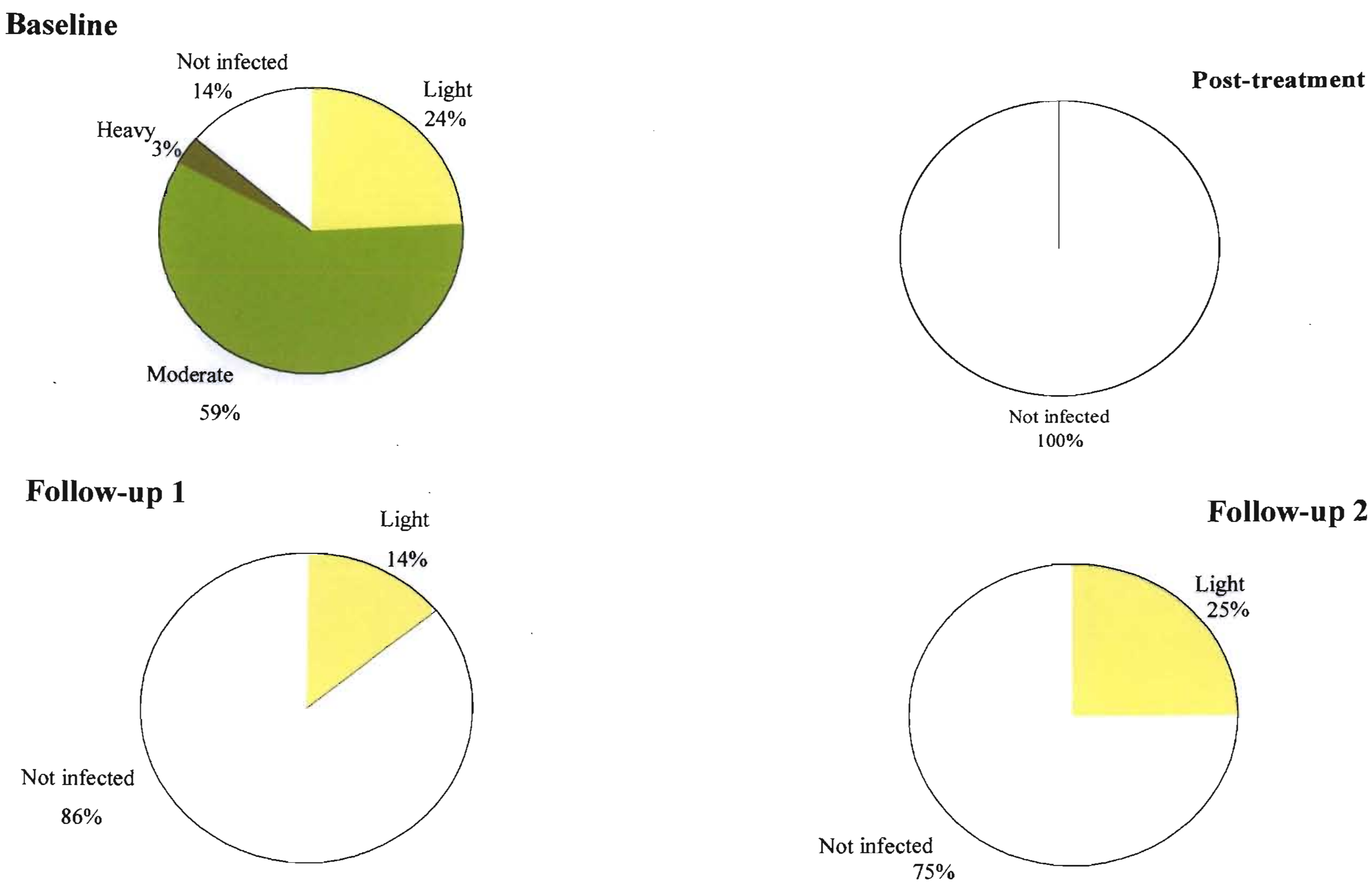


Figure 5.2h Smithfield (no. 8) *Ascaris lumbricoides* intensities of infection (e.p.g.) in 4 surveys during the study period. light = 1 - 4999; moderate = 5 000 - 49 999; heavy = 50 000 - 100 000; very heavy = > 100 000 e.p.g.

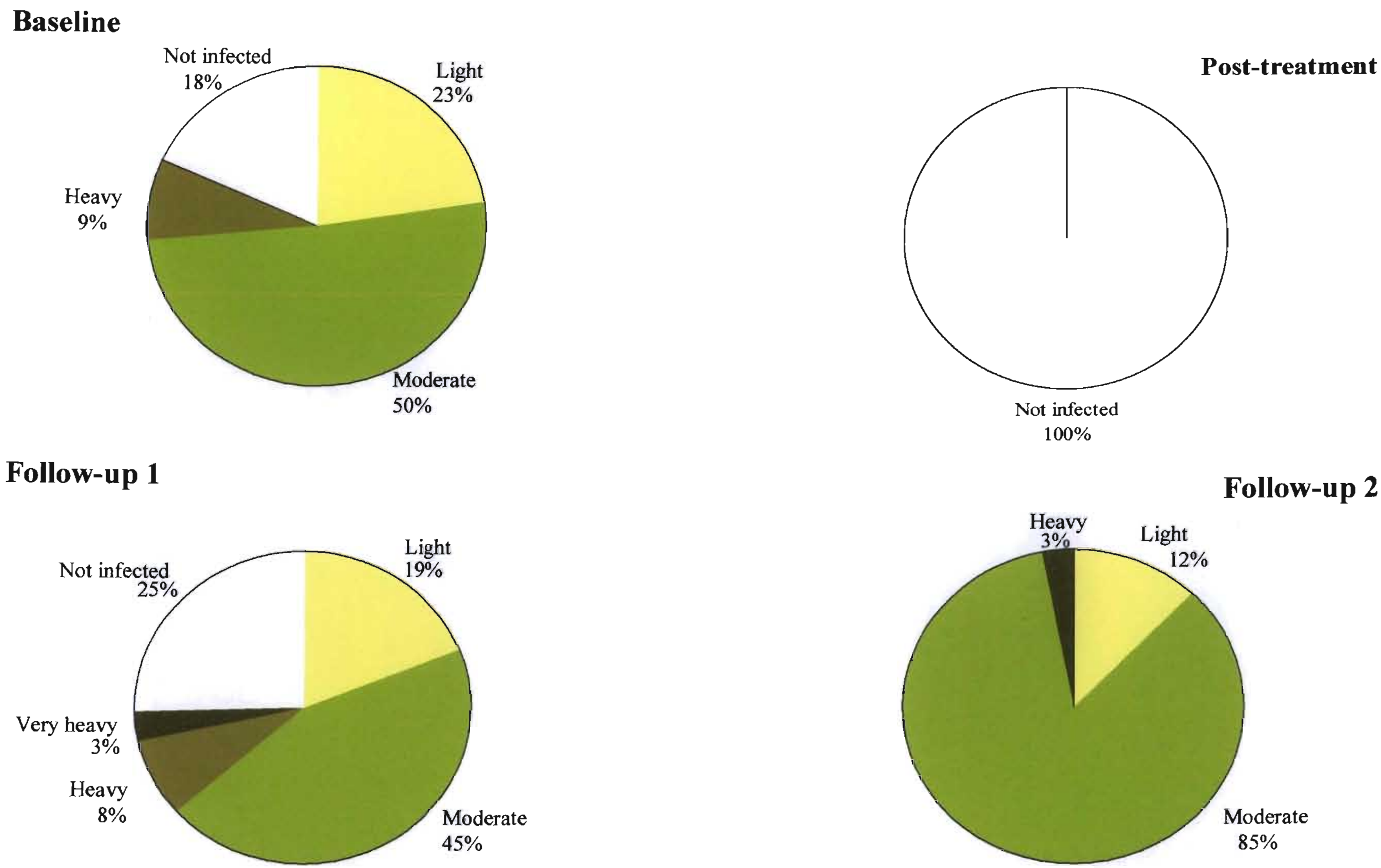


Figure 5.2i Park Station (no. 9) *Ascaris lumbricoides* intensities of infection (e.p.g.) in 4 surveys during the study period. light = 1 - 4999; moderate = 5 000 - 49 999; heavy = 50 000 - 100 000; very heavy = > 100 000 e.p.g.

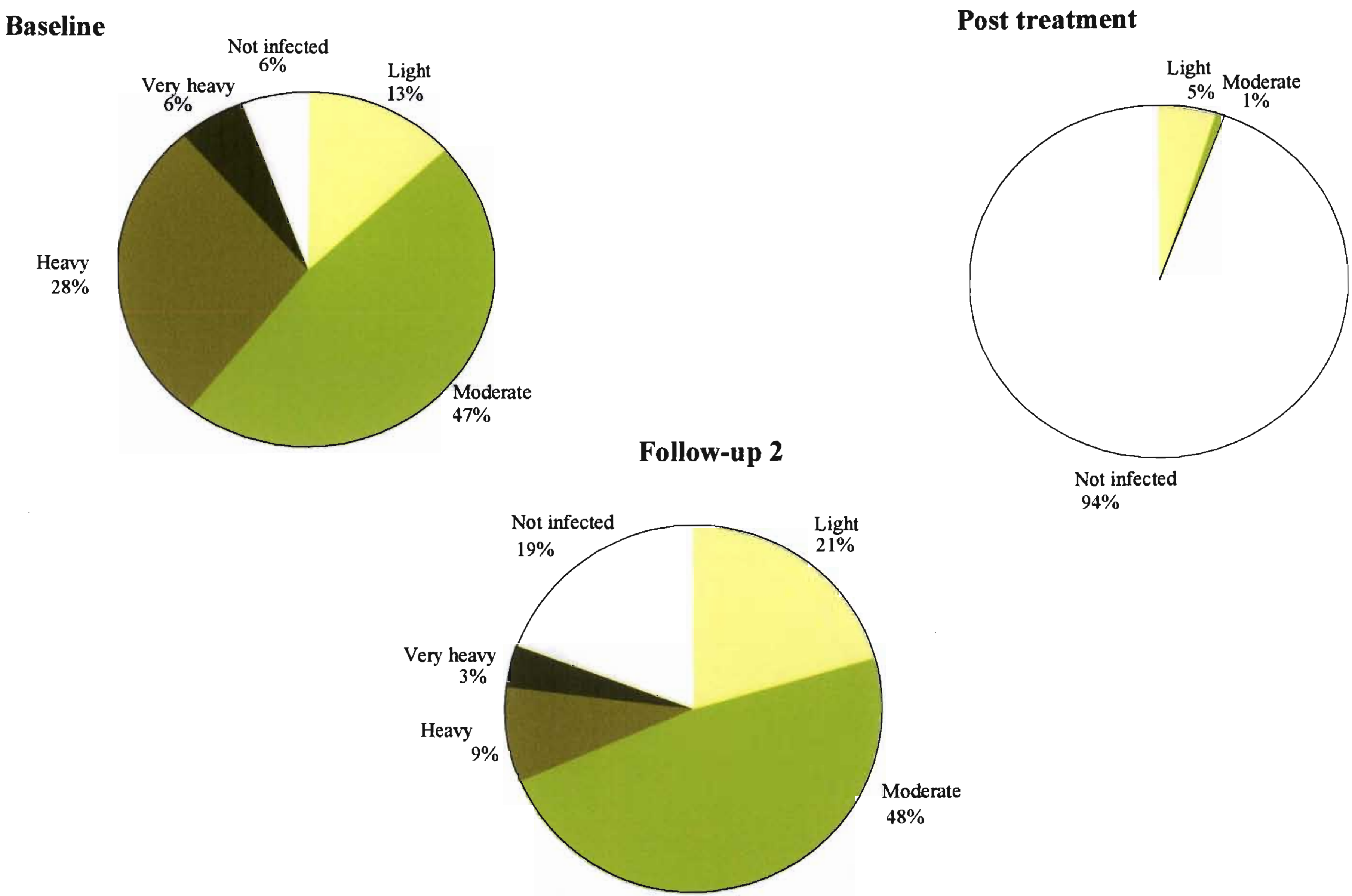


Figure 5.2j Canaan (no. 10) *Ascaris lumbricoides* intensities of infection (e.p.g.) in 4 surveys during the study period. No data for follow-up 1 survey because 75.0% of the families were relocating. Light = 1 - 4999; moderate = 5 000 - 49 999; heavy = 50 000 - 100 very heavy = > 100 000 e.p.g.

The prevalence of *T. trichiura* dropped to 43.6% but there was much variation in reinfection between the slums (Figure 5.1a-j). At Bottlebrush and Kennedy Lower, the *T. trichiura* reinfection prevalences were low, i.e. 28.5% and 20.2% respectively. Prevalence at follow-up 2 increased from follow-up 1 almost to pre-intervention level. There were thus highly significant differences between slums (χ^2 = 177.15 on 9 d.f. (p < 0.0001). Kennedy Lower had the lowest reinfection rate and Pemary Ridge had the highest (Table 3, Appendix C).

The results for Canaan were not recorded for follow-up 1 because 75.0% of the families who participated in the study were relocated to another more formal slum (Quarry Heights) (see Chapter 3, Plate I (p32). The children were only examined for follow-up 2 in the new area and those remaining at Canaan were also investigated during the second reinfection survey (Figure 5.1j).

No hookworm infection was recorded during follow-up surveys 1 or 2.

5.3 INTENSITY OF GEOHELMINTH INFECTIONS

Because the distribution of egg counts was highly skewed, the average intensity was calculated as the geometric mean eggs per gram (G.M.) for those infected, and intensity (e.p.g.) ranges were classified as light, moderate, heavy and very heavy as suggested by Renganathan *et al.*, (1995) with further category, very heavy, introduced to accommodate e.p.g. counts of > 100 000 for *A. lumbricoides* and > 20 000 for *T. trichiura.*

5.3.1 Intensities of *Ascaris lumbricoides* infection

5.3.1.1 Baseline intensities of *A. lumbricoides* infection amongst the 10 study slums

Variation between slums was highly significant (χ^2 = 123.98 on 36 d.f.; p<0.0001) (Figure 5. 2 a-j). At baseline 74.3% of children infected had moderate to very heavy intensities of *A. lumbricoides* infection. At Bottlebrush, Kennedy Lower, Lusaka, Pemary Ridge, Quarry Road West, Simplace, Briardene and Canaan 3.89% (38/996) of children were voiding more than 100 000 (e.p.g.) (Figure 5.2 a-f, i) whereas Smithfield 3.4 (1/29) and Park Station 8.5% (6/71) had the least number of heavy intensities (Figure 5.2h & 5.2i), (Table 4, Appendix C).

5.3.1.2 Post-treatment intensities of *A. lumbricoides* infection amongst the 10 study slums

After mass chemotherapy on all the children, very few children 1.0 % (10/996) at Kennedy Lower, Quarry Road West and Canaan, (Table 5, Appendix C), had moderate infections, and only one child

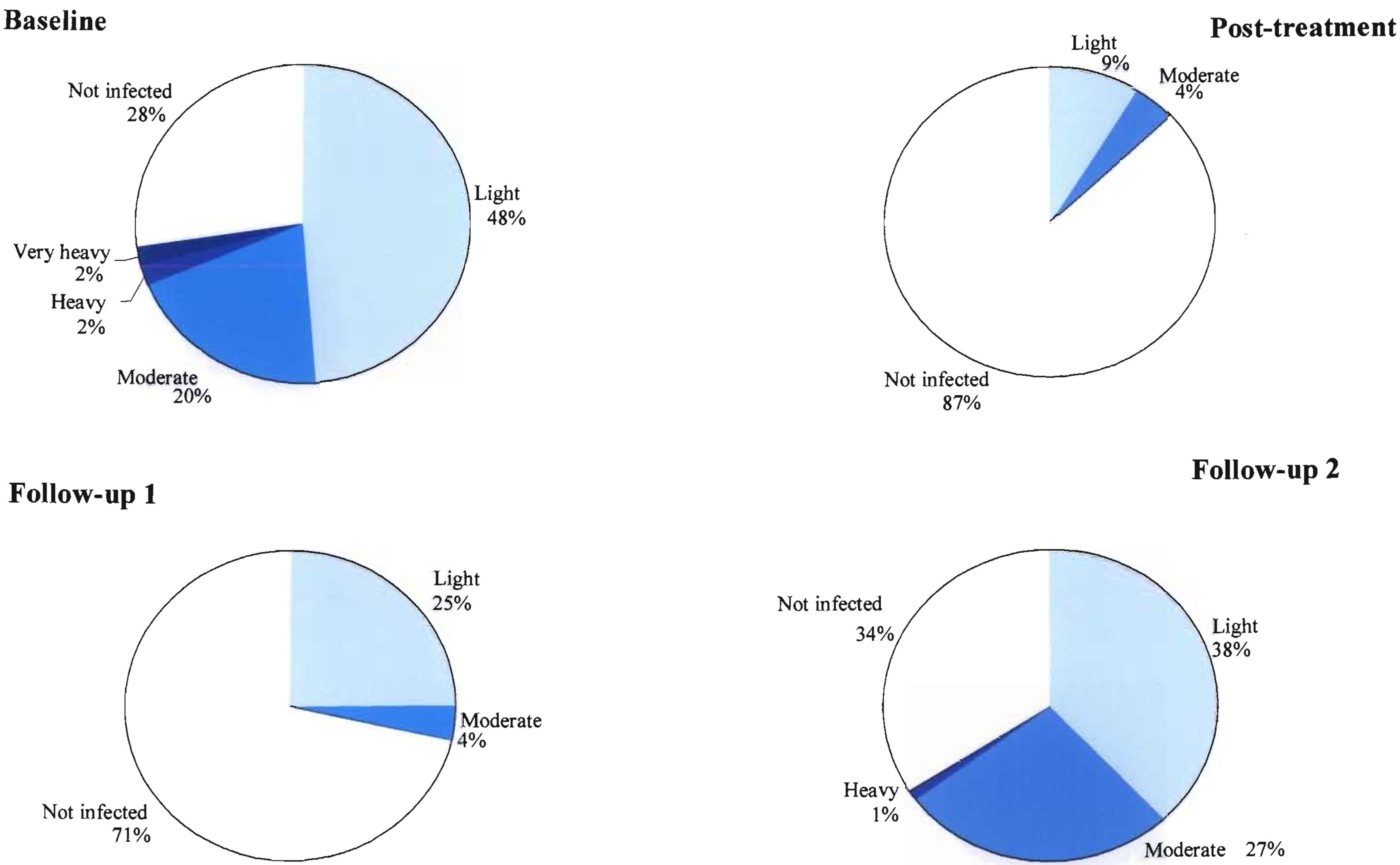


Figure 5.3a Bottlebrush (no. 1) *Trichuris trichiura* intensities of infection in 4 surveys during the study period. Light = 1 - 999; moderate = 1 000 - 9 999; heavy = 10 000 - 20 000; very heavy = > 20 000 e.p.g.

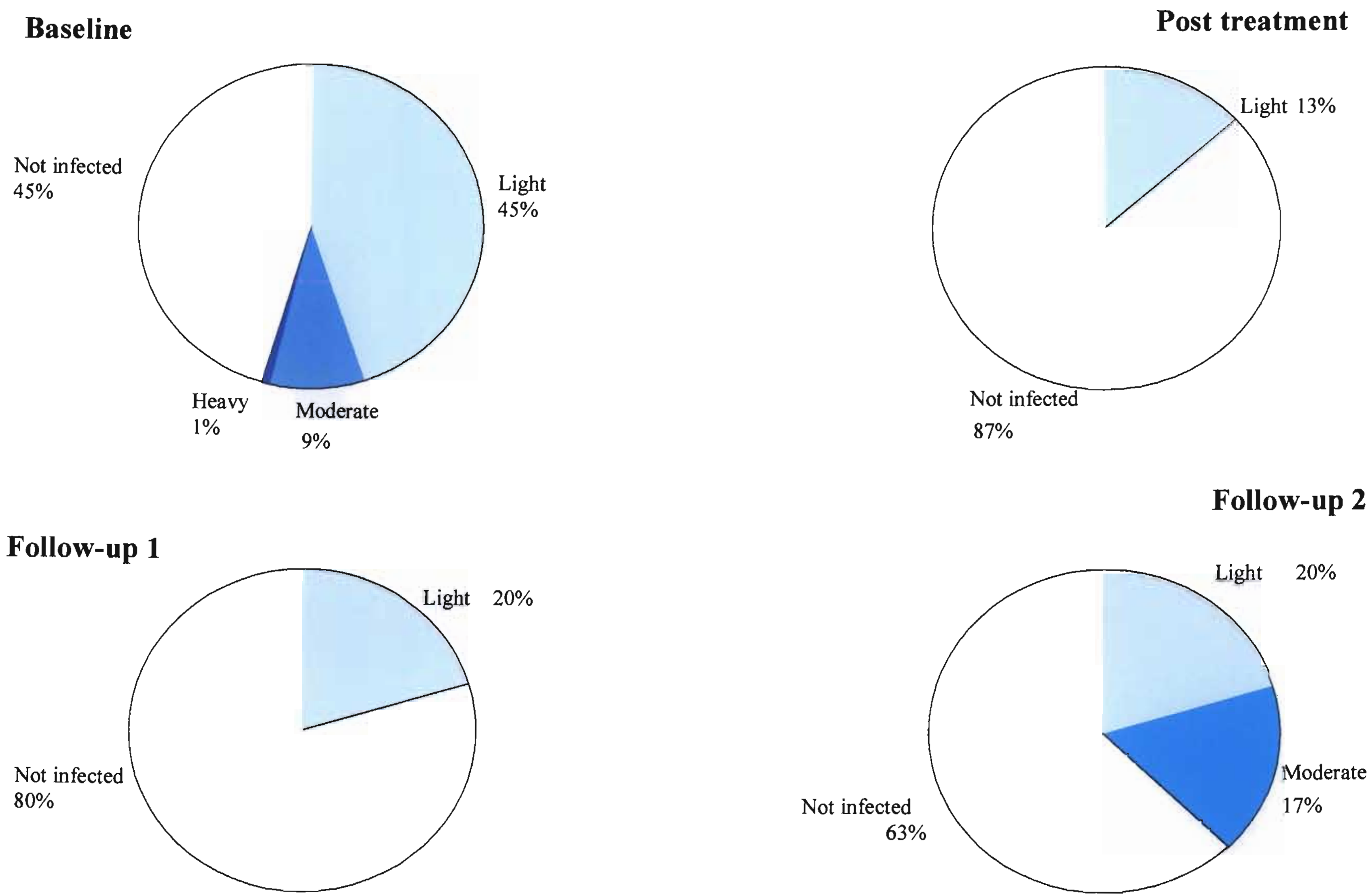


Figure 5.3b Kennedy Lower (no. 2) *Trichuris trichiura* intensities of infection in 4 surveys during the study period. Light = 1 - 999; moderate = 1 000 - 9 999; heavy = 10 000 - 20 000; very heavy = > 20 000 e.p.g.

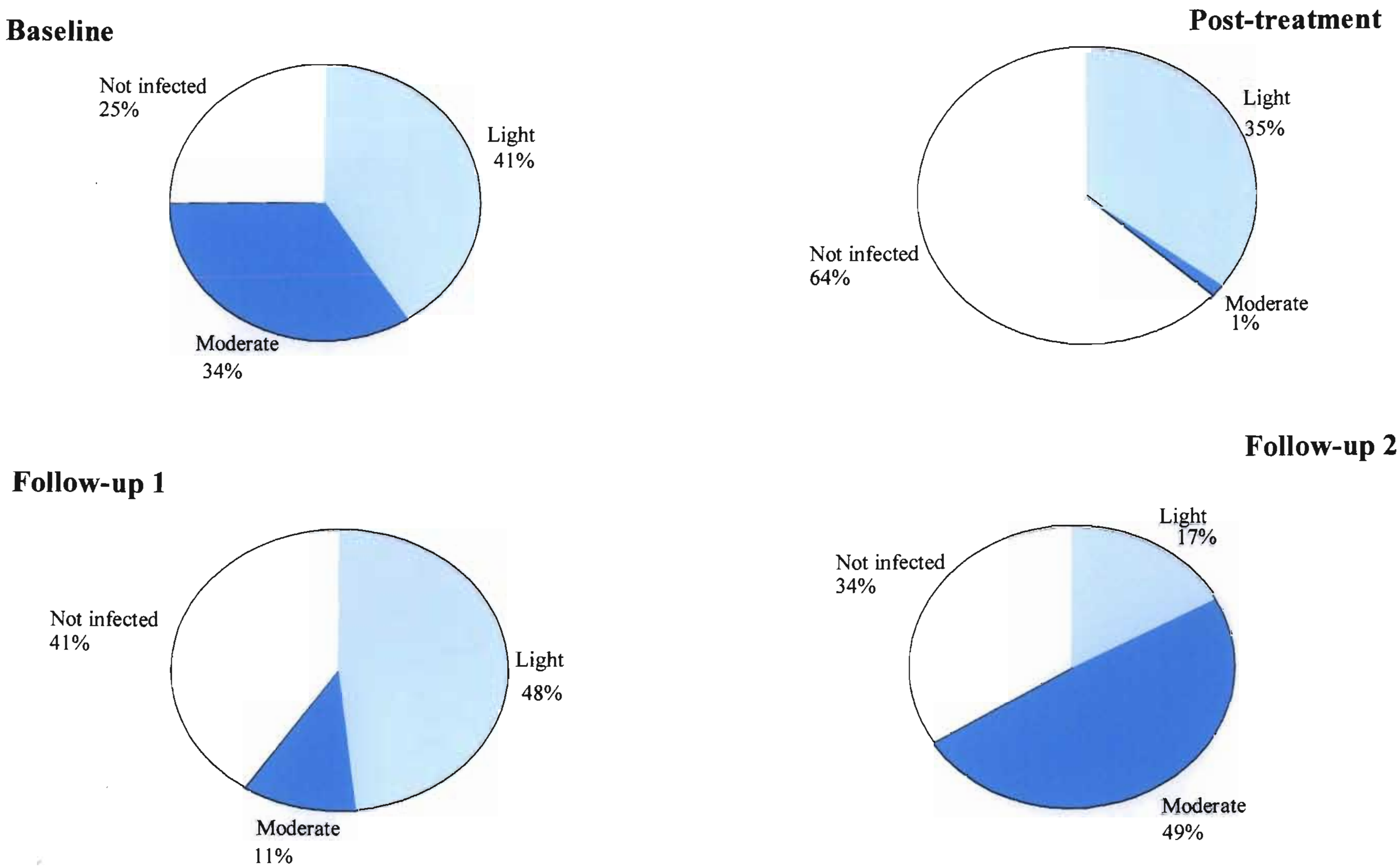


Figure 5.3c Lusaka (no.3) *Trichuris trichiura* intensities of infection in 4 surveys during the study period. Light = 1 - 999; moderate = 1 000 - 9 999; heavy = 10 000 - 20 000 ; very heavy = > 20 000 e.p.g.

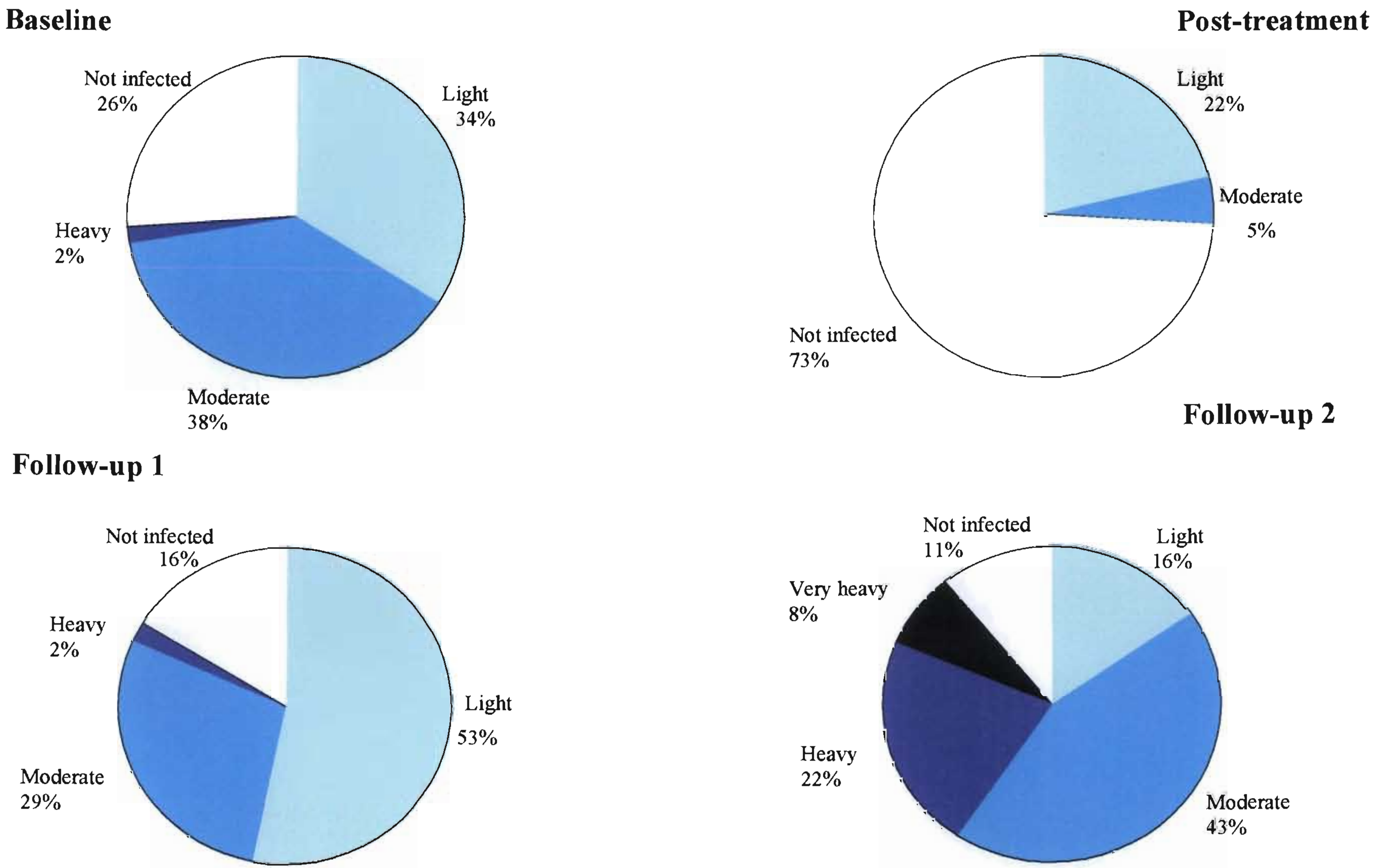


Figure 5.3d Pemary Ridge (no. 4) *Trichuris trichiura* intensities of infection in 4 surveys during the study period. Light = 1 - 999; moderate = 1 000 - 9 999; heavy = 10 000 - 20 000; very heavy = > 20 000 e.p.g.

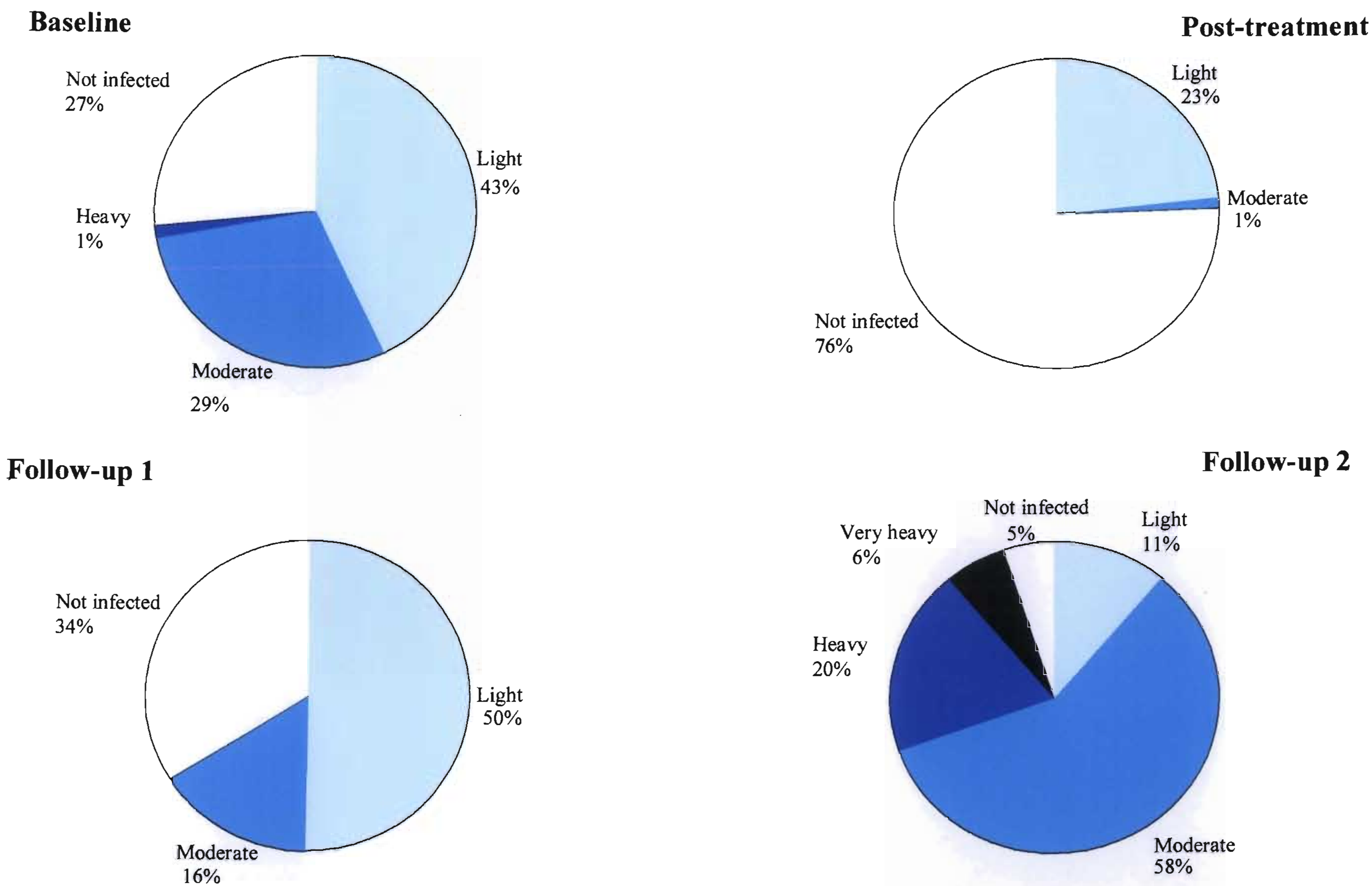


Figure 5.3e Quarry Road West (no. 5) *Trichuris trichiura* intensities of infection in 4 surveys during the study period. Light = 1 - 999; moderate = 1 000 - 9 999; heavy = 10 000 - 20 000; very heavy = > 20 000 e.p.g.

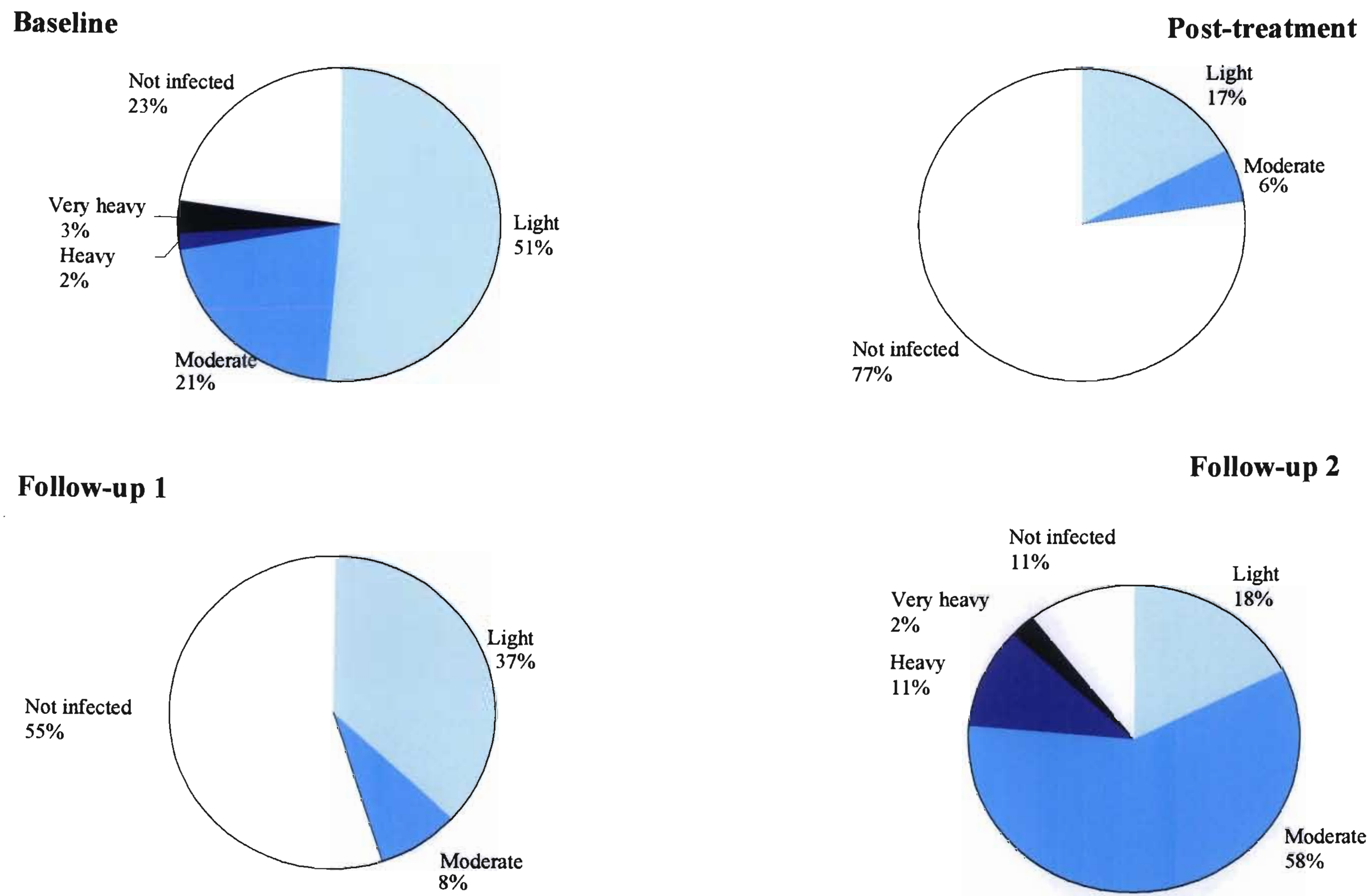


Figure 5.3f Simplace (no. 6) *Trichuris trichiura* intensities of infection in 4 surveys during the study period.
Light = 1 - 999; moderate = 1 000 - 9 999; heavy = 10 000 - 20 000; very heavy = > 20 000 e.p.g.

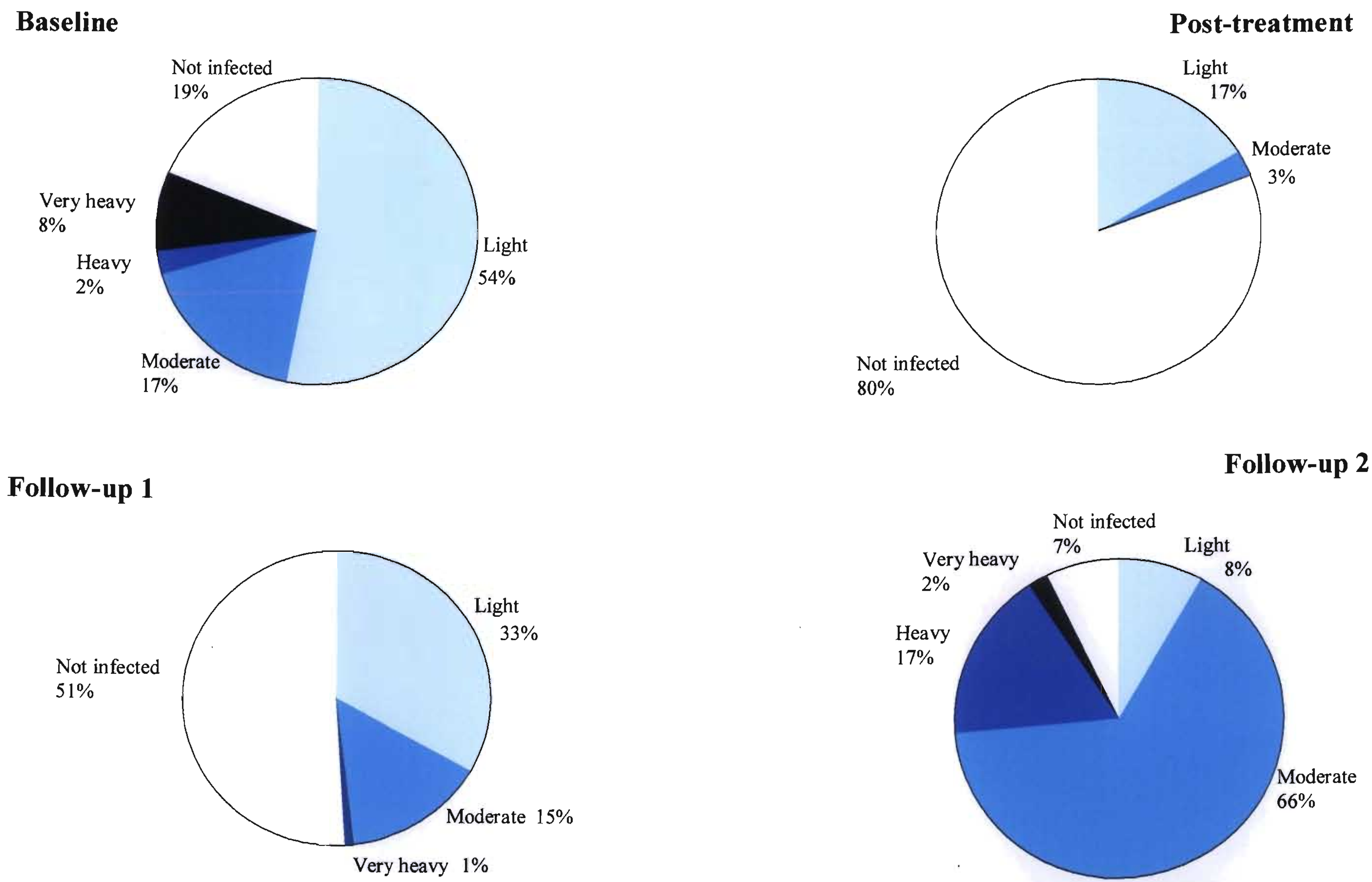


Figure 5.3g Briardene (no. 7) *Trichuris trichiura* intensities of infection in 4 surveys during the study period. Light = 1 - 999; moderate = 1 000 - 9 999; heavy = 10 000 - 20 000; very heavy = > 20 000 e.p.g.

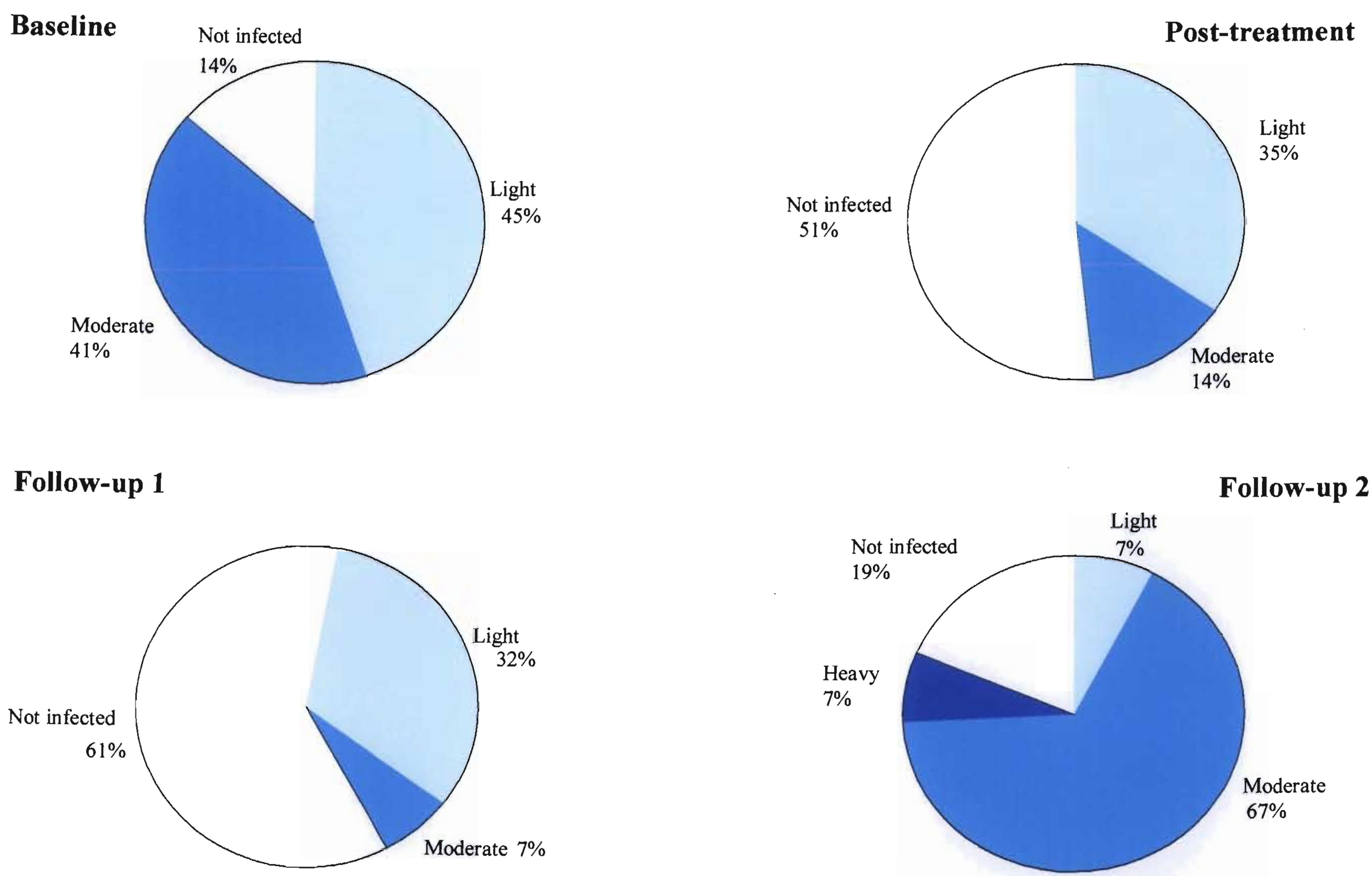


Figure 5.5h Smithfield (no. 8) *Trichuris trichiura* intensities of infection in 4 surveys during the study period. Light = 1 - 999; moderate = 1 000 - 9 999; heavy = 10 000 - 20 000; very heavy = > 20 000 e.p.g.

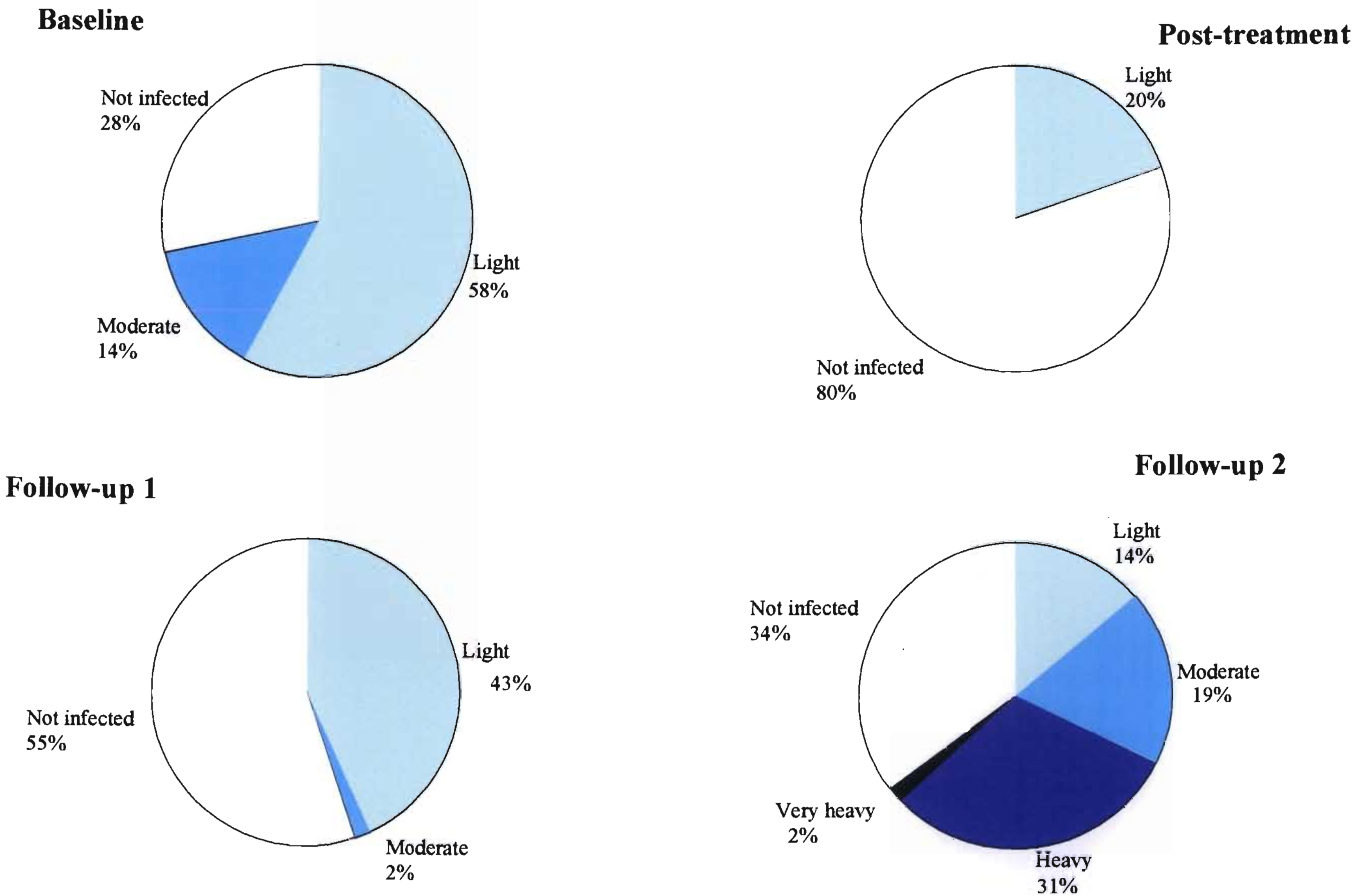


Figure 5.3i Park Station (no. 9) *Trichuris trichiura* intensities of infection in 4 surveys during the study period. Light = 1 - 999; moderate = 1 000 - 9 999; heavy = 10 000 - 20 000; very heavy = > 20 000 e.p.g.

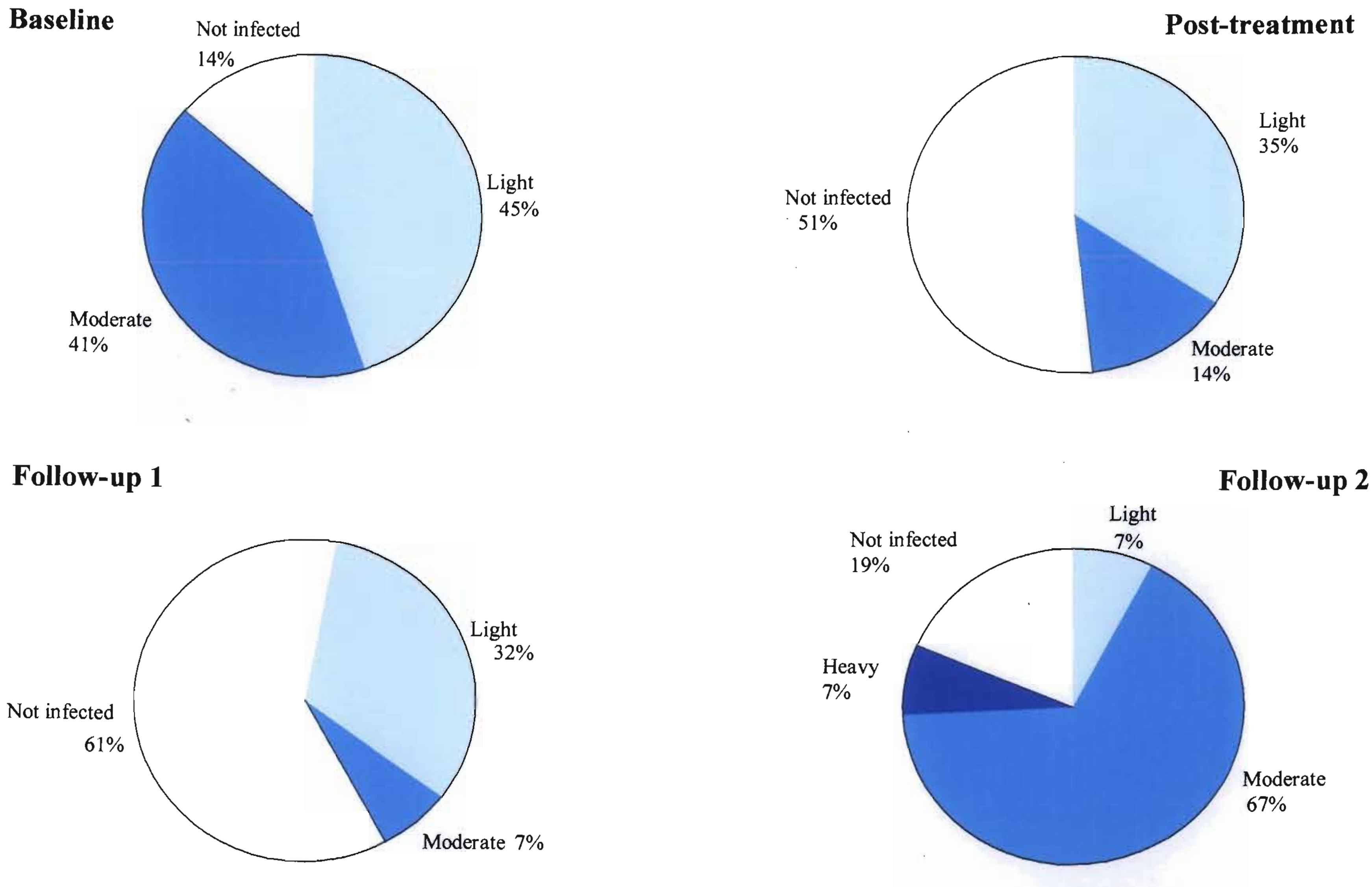


Figure 5.5h Smithfield (no. 8) *Trichuris trichiura* intensities of infection in 4 surveys during the study period. Light = 1 - 999; moderate = 1 000 - 9 999; heavy = 10 000 - 20 000; very heavy = > 20 000 e.p.g.

still had a very heavy infection (Quarry Road West) (Figure 5.2e). There was a highly significant difference between slums ($\chi^2 = 56.40$ on 27 d.f.; $p = 0.001$), with some slums like Bottlebrush, Lusaka, Simplace, Smithfield and Park Station having no moderate or heavy infections (Figure 5.2 a, c, f & h).

5.3.1.3 Follow-up 1 intensities of *A. lumbricoides* infection amongst the 10 study slums

At four to six months post treatment, there was a significant difference in intensities of *A. lumbricoides* infection among the slums ($\chi^2 = 433.90$ on 32 d.f.; $p < 0.0001$) but most importantly only 0.5% of children had very heavy infections (Appendix C, Table 6a). This is by comparison, significantly less than at baseline (Table 4, Appendix C).

5.3.1.4 Follow-up 2 intensities of *A. lumbricoides* infection amongst the 10 study slums

Intensities after 12 months also differed markedly between slums ($\chi^2 = 539.09$ on 36 d.f.; $p < 0.0001$) (Figure 5.2 a-j). By this stage more than half of the children at Pemary Ridge, Quarry Road West and Simplace, had heavy or very heavy *A. lumbricoides* infections, (Table 6a, Appendix C).

5.3.2 Intensities of *Trichuris trichiura* infection

5.3.2.1 Baseline intensities of *T. trichiura* infection amongst the 10 study slums

Before treatment 77.2% of children living in Simplace, Briardene, Park Station and Canaan, had light intensities of *T. trichiura* infection but the figures for individual slums differed widely ($\chi^2 = 91.10$ on 36 d.f.; $p < 0.0001$) (Figure 5.3 a-j), (Table 7, Appendix C).

5.3.2.2 Post-treatment intensities of *T. trichiura* infection amongst the 10 study slums

A comparison between slums (Figure 5.3 a-j) shows that after the first treatment with Albendazole all heavy and very heavy category infections had decreased to either moderate or light infections. The moderate infections decreased to a low as 2.8% of the children and the rest were either light or were no longer infected. The results for individual slums varied significantly ($\chi^2 = 63.15$ on 18 d.f.; $p < 0.001$). Smithfield had the largest number of moderate *T. trichiura* infections (13.8%). A second dose of Albendazole was administered after 30 days and all the very heavy and heavy infections were eliminated, moderate infections dropped from 20.6% to 2.8% and light infections from 48.8% to 17.8%, (Table 8, Appendix C).

5.3.2.3 Follow-up 1 intensities of *T. trichiura* infection amongst the 9 study slums

Children living in Canaan were not examined because 75.0% of the families participating in the study were in the process of relocation. After four to six months post-treatment, not only did Pemary Ridge have a high prevalence of *T. trichiura*, but intensities were also high. There was a very strong significant difference in severity of *T. trichiura* infection between slums ($\chi^2 = 177.34$ on 9 d.f.; $p < 0.0001$). The overall intensity of infection, however, was lower than at baseline. The number of eggs voided by children to the environment was reduced from 22.8% at baseline, (Table 7, Appendix C) to 8.8% at follow-up 1, (Table 9a, Appendix C).

5.3.2.4 Follow-up 2 intensities of *T. trichiura* infection amongst the 10 study slums

Intensities of *T. trichiura* infection after 12 months post-treatment differed markedly among slums. At Pemary Ridge, Quarry Road West, Simplace, Briardene and Park Station, more than 60.0% of the children had heavy and very heavy infections. Pemary Ridge still had the highest number of very heavy infections but Kennedy Lower had the least number of light to moderate infections. Quarry Road West had the highest reinfection rate with only 4.9% of the children there not reinfected. There was a stronger significant difference in intensity of *T. trichiura* infection between slums ($\chi^2 = 387.54$ on 36 d.f.; $p < 0.0001$), than for *T. trichiura* prevalence at baseline ($\chi^2 = 189.19$ on 9 d.f.; $p < 0.0001$), (Table 7 & 9b, Appendix C).

5.4. INTENSITY OF HOOKWORM INFECTION

5.4.1 Baseline intensities of hookworm infection amongst the 10 study slums

Intensity of hookworm infection was very low, 96.5% of those infected having light intensities. Only one child had a heavy intensity of infection. There was a significant difference in intensities between slums ($\chi^2 = 111.04$ on 27 d.f.; $p < 0.001$) (Table 5.1).

1

PREAMBLE

The start of a parasite control programme by the Department of Health of KwaZulu-Natal province in October 1997, brought into focus the fact that the planners had excluded the growing urban slum problem (called informal settlements or squatter areas in South Africa) within the province's major urban centres. The mobility of this squatter population, and the lack of any records on their communities had precluded them from being part of the planning process. However the fact that these slums are growing at a rapid rate around (and within) most towns and cities in KwaZulu-Natal, and other provinces, and have essentially become permanent residential areas, has meant that they can no longer be ignored and health services are now being provided. It is against this background of including urban slums in the KwaZulu-Natal government's Primary Health Care operations that this study of geohelminth endemicity (prevalence, intensity and incidence) and patterns of transmission (focality) among slum-dwelling children in Durban, South Africa was carried out.

GENERAL INTRODUCTION

Several species of geohelminths or soil-transmitted nematodes commonly infect people in South Africa, viz.: the common roundworm *Ascaris lumbricoides* (Linnaeus, 1758), the whipworm *Trichuris trichiura* (Linnaeus, 1771), the hookworm *Necator americanus* (Stiles, 1902), the threadworm *Strongyloides stercoralis* (Bavay, 1876) and the pinworm *Enterobius vermicularis* (Linnaeus, 1758). These are all cosmopolitan species and are especially common in the tropics and subtropics (Ukoli, 1984; Crompton & Tulley, 1997; Onwuliri *et al.*, 1992) where they have been rated as one of the leading cause of disease of school-going children, by the Connoly & Kvalsvig, (1993) and World Health Organization (1995). Two of them, *A. lumbricoides* and hookworm, are so common that they are ranked below only diarrhoeal disease and tuberculosis in terms of prevalence (World Bank, 1993; Pawlowski, 1984). It has recently been suggested that intestinal parasites, including the geohelminths, may play an important role in the progression of infection with Human Immunodeficiency Virus (HIV), by further disturbing the immune system whilst it is engaged in the fight against HIV (Fontanet *et al.*, 2000).

Until recently, little was known about geohelminth distribution and epidemiology in South Africa (van Niekerk *et al.*, 1979; Schutte *et al.*, 1981; Gunders *et al.*, 1993; Appleton &

1. 8 GENERAL OBJECTIVE

This is to study the transmission patterns of *Ascaris lumbricoides, Trichuris trichiura* and hookworm in children aged two to ten years in 10 established urban slums in Durban. These patterns will then be related to biotic; environmental; socio-cultural as well as socio-economic factors. This analysis will allow the identification of control measures suited to these slum environments.

1. 9 SPECIFIC OBJECTIVES

- to identify the common geohelminths infecting children aged 2-10 years in the 10 selected slums;
- to describe the infection status of these geohelminths;
- to investigate the relationship between geohelminth reinfection rates and selected biotic, and abiotic variables.

1. 10 ACTIVITIES

- to measure the prevalence and intensity of *A. lumbricoides, T. trichiura* and hookworm infections in children aged 2-10 years living in the 10 established urban slums in Durban;
- to measure reinfection rates of single and double infections of *A. lumbricoides* and *T. trichiura* in the selected cohorts of children over periods of 4½ - 6 months and 12 months after chemotherapy;
- to relate reinfection rates of single and double infections of *A. lumbricoides* and *T. trichiura* in each cohort to the biotic factors such as sex and age, and environmental risk factors such as altitude, aspect, slope, soil type, temperature and rainfall;
- to relate reinfection rates of single and double infections of *A. lumbricoides* and *T. trichiura* to selected socio-cultural and socio-economic factors;
- to relate *A. lumbricoides* and *T. trichiura* reinfection rates to the amount of soil found in the children's faeces and to the habit of soil-eating (geophagy);
- to formulate appropriate control measures and recommend their incorporation into the Primary Health Care, Parasite Control Programme in KwaZulu-Natal, Durban Metro Housing Development, Urban Strategy and Durban City Health Department.

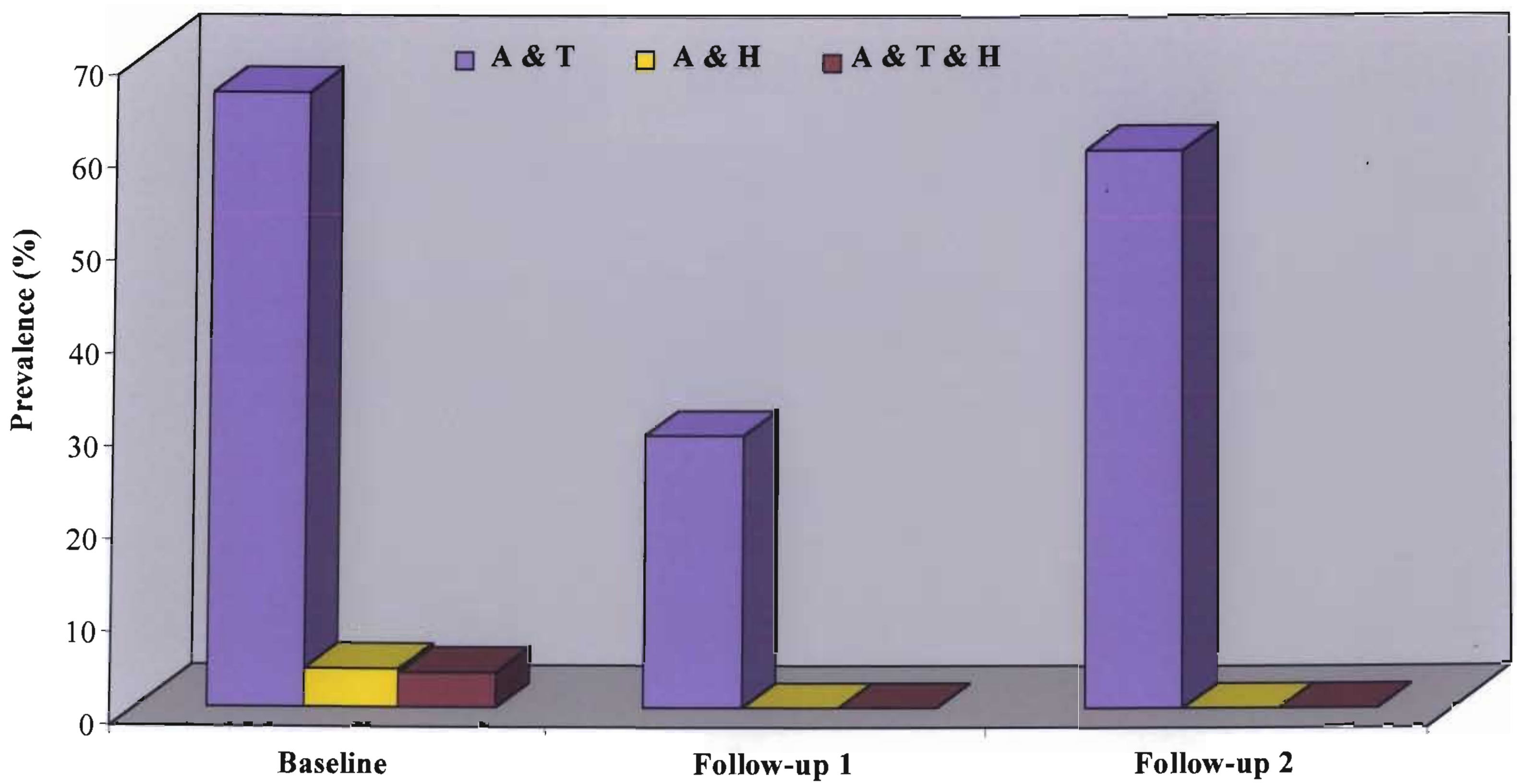


Figure 5.4 Interaction of the three geohelminth species in children at baseline, follow-up 1 and follow-up 2 when data are pooled. A = *A. lumbricoides* ; T = *T. trichiura* ; H = Hookworm.

Table 5.1 Baseline intensities of hookworm infection (e.p.g.) for all subjects examined in the 10 study slums.

Slum	N	Light %(n)	Moderate %(n)	Heavy %(n)
1. Bottlebrush	200	0.0 (0)	0.0 (0)	0.0 (0)
2. Kennedy Lower	122	0.0 (0)	0.8 (1)	0.0 (0)
3. Lusaka	70	4.3 (3)	0.0 (0)	0.0 (0)
4. Pemary Ridge	65	3.1 (2)	0.0 (0)	0.0 (0)
5. Quarry Road West	82	6.1 (5)	0.0 (0)	0.0 (0)
6. Simplace	123	11.4 (14)	6.5 (8)	0.0 (0)
7. Briardene	112	0.0 (0)	0.0 (0)	0.0 (0)
8. Smithfield	29	17.2 (5)	3.4 (1)	0.0 (0)
9. Park Station	71	7.1 (5)	1.4 (1)	0.0 (0)
10. Canaan	122	0.8 (1)	0.0 (0)	0.8 (1)
Total	996	3.5 (35)	1.1 (11)	0.1 (1)

5.5 CHEMOTHERAPY

Albendazole (400mg) proved a very effective drug against *A. lumbricoides* with an efficacy of 95.5 to 100.0% and an egg reduction of 98.9% after the first treatment. Those not cured after the first treatment were all cured after receiving the second treatment (Chapter 5, title page). The *T. trichiura* cure rate after first dose of Albendazole was between 51.7% - 87.0% but egg reduction was 91.1%. The drug was thus less effective after first treatment on *T. trichiura* infection (20.6% still infected) than on *A. lumbricoides* infection (4.5% still infected). Hookworm was 100% cured after the first treatment and did not reappear during subsequent surveys (Appendix C, Table 2). After four to six months post treatment (follow-up 1) the overall *A. lumbricoides* prevalence was 64%. During this period the prevalences at Pemary Ridge, Quarry Road West, Simplace, Briardene and Park Station had all risen above baseline level. After 12 months post-treatment (follow-up 2),

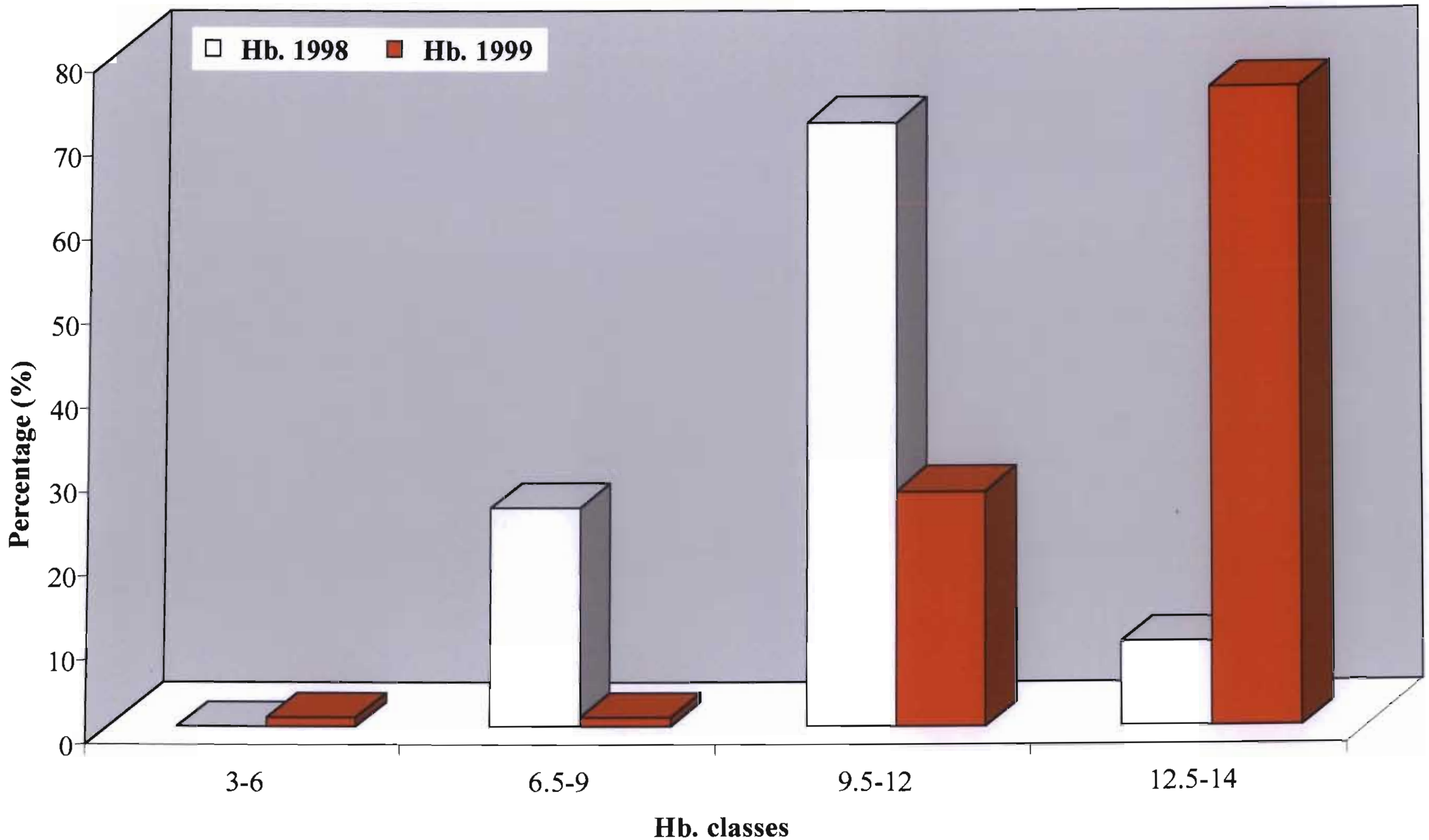


Figure 5.5 Distribution of haemoglobin concentrations (g/dl) in 1998 and 1999 (12 months later) (n = 105).

the overall *A. lumbricoides* prevalence was higher than follow-up 1 (4½ to 6 months post treatment), and comparable to baseline; Kennedy Lower and Lusaka had reached the baseline level. Pemary Ridge, Quarry Road West, Simplace, Briardene and Park Station had all exceeded the baseline level. *A. lumbricoides* egg output increased 4.6 fold from follow-up 1 to follow-up 2. The egg output for *T. trichiura* increased 9.4 fold from follow-up 1 to follow-up 2.

5.5.1 Egg output to the environment

The absence of geohelminth eggs in a stool after treatment was taken to indicate a cure. The cure rate for *A. lumbricoides* was 95.0%, for *T. trichiura* 72.2% and for hookworm 100.0% after first treatment. The egg reduction for *A. lumbricoides* from baseline to post-treatment was 98.6% (from 31 704 789 at baseline to 165 060 e.p.g. at post-treatment) and for *T. trichiura* it was 91.13% (1 182 355 at baseline to 3 148 e.p.g. at post-treatment). The actual total egg counts excreted to the environment in each slum at baseline and 12 months post-intervention (follow-up 2) are presented in (Table 10, Appendix C). During baseline survey the estimated total egg output for *A. lumbricoides* was 31 704 789 e.p.g. and 28 143 793 at follow-up 2, i.e. 4.6 times more than at follow-up 1. For *T. trichiura* the total egg output at baseline 1 182 355 , and 3 148 330 e.p.g. at follow-up 2 which represents an increase of 9.4 fold.

5.6 MULTIPLE GEOHELMINTH INFECTIONS (POLYPARASITISM)

5.6.1 Interaction between geohelmimth species in children in the 10 study slums

Almost four percent (3.9%) of the children had *A. lumbricoides, T. trichiura* and hookworm infections, 4.3% had *A. lumbricoides* and hookworm, and 4.3% had *T. trichiura* and hookworm infections (Figure 5.4). In Lusaka slum, the majority of children at baseline (79.3%) and at follow-up 2 (60.4%) had double infection of *A. lumbricoides* and *T. trichiura* (Table 5.2). Only 29.6% of the children at follow-up 1 had double infections of *A. lumbricoides* and *T. trichiura.*

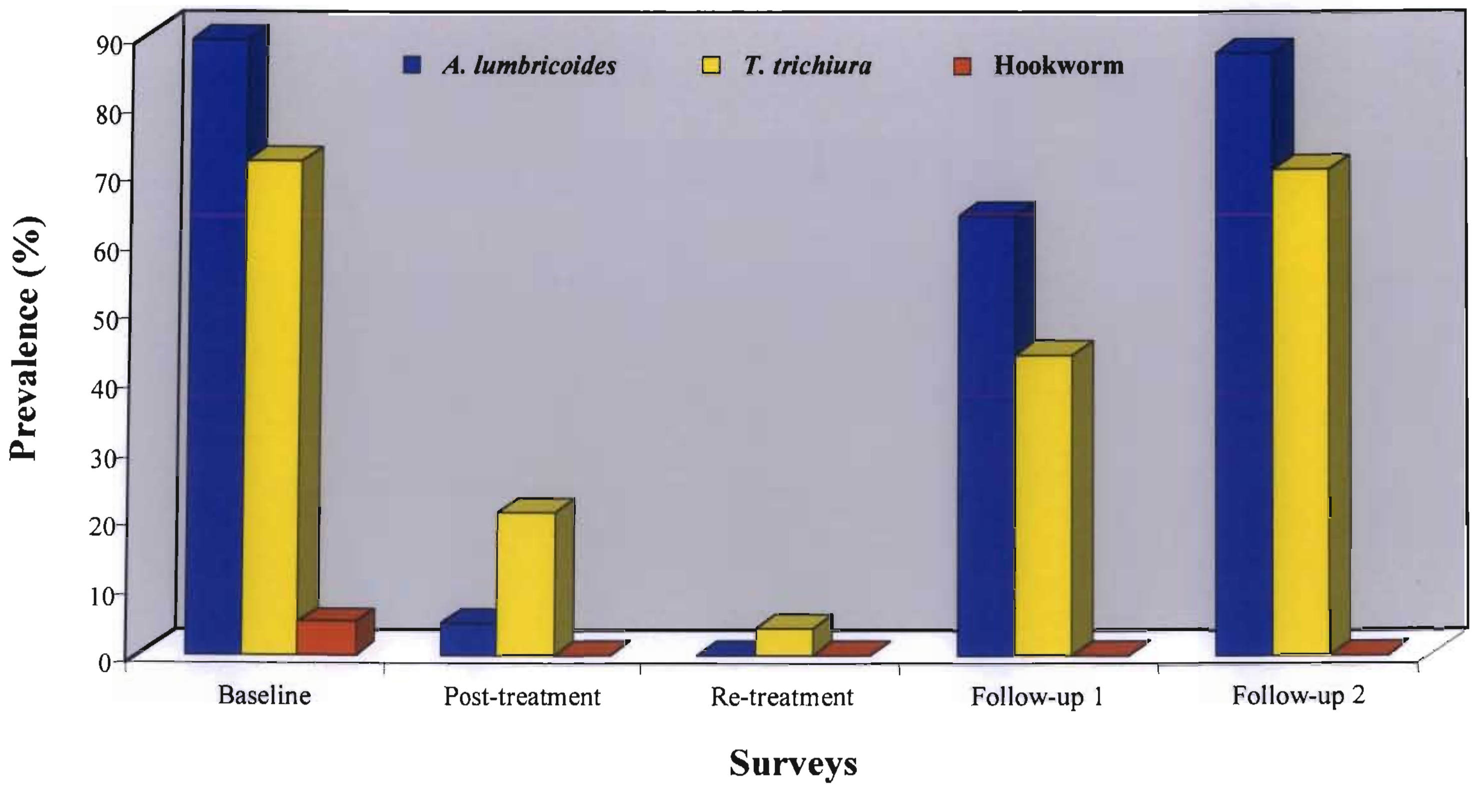


Figure 5.6 *Ascaris lumbricoides, Trichuris trichiura* and hookworm overall prevalences (%) in all surveys during the study period when data are pooled.

Table 5.2 Overall frequencies of numbers of geohelminths per child at baseline (n = 996)

Number of parasites	N (%)
A. lumbricoides & *T. trichiura* (baseline)	663 **(66.4)**
A. lumbricoides & hookworm (baseline)	43 **(4.3)**
T. trichiura & hookworm (baseline)	43 **(4.3)**
A. lumbricoides, T. trichiura & hookworm (baseline)	39 **(3.9)**
A. lumbricoides & *T. trichiura* (follow-up 1)	295 **(29.6)**
A. lumbricoides & *T. trichiura* (follow-up 2)	603 **(60.4)**

5.6.2 Effect of treatment on children's haemoglobin levels

In 1998 the mean haemoglobin (Hb.) level was 10.4g/dl (n=105) and in 1999 was 12.1g/dl (n=105). This was an increase of 16.0% and there was a significant improvement in Hb. level of the same children before treatment in 1998 and 12 months after treatment (t = -7.446; d.f = 107; SD=2.39; CI (-2.168 - -1.256); p< 0005) (Figure 5.5).

5.7 MORBIDITY AMONG CHILDREN IN THE 10 SLUMS DUE TO INTESTINAL PARASITE INFECTIONS AND ASSOCIATION WITH RELATED ILLNESSES DURING THE STUDY PERIOD

Morbidity due to ascariasis, trichuriasis, hookworm and schistosomiasis and other associated diseases is summarised in Table 5.3.

Table 5.3 Morbidity due to parasite infections in the study population.

Disease/illness	1998 % (n)	1999 % (n)
1. Gangrene (intestinal obstruction)	**0.1** (1)	**0.0** (0)
2. Intestinal obstruction (laparotomy)	**0.5** (5)	**0.2** (2)
3. Treated in hospital (vomiting worms, intestinal bolus, severe anaemia, TB and HIV positive)	**1.7** (17)	**0.3** (3)
4. Distended abdomen	**5.7** (57)	**4.3** (43)
5. Optic anaemia (visible signs)	**1.2** (12)	**1.0** (10)
6. Anaemia (Hb. < 11g/dl)	**2.8** (28)	**1.6** (16)
7. 3° malnutrition (Kwashiorkor)	**0.3** (3)	**0.3** (3)
8. Malnutrition (Protein Energy Malnutrition)	**2.3** (23)	**1.8** (18)
9. Dead – HIV /AIDS, TB, anaemia , malnutrition and epilepsy.	**0.2** (2)	**0.3** (3)

5.8 OVERALL GEOHELMINTH PREVALENCES WHEN DATA ARE POOLED

Prevalences of *Ascaris lumbricoides* and *Trichuris trichiura* differed significantly among the 10 study slums (Table 5.4). *A. lumbricoides* was the most common geohelminth followed by *T. trichiura* and finally *Necator americanus* or *Ancylostoma duodenale* (hookworm) which was only recorded in eight slums (Figure 5.6). The available data, show that the predominant hookworm species in South Africa is *N. americanus* and that *A. duodenale* 'occasionally' found (Appleton and Maurihungirire, 1999). The overall prevalence of *A. lumbricoides* was high, 89.2% at baseline (ranging from 81.7% in Park Station to 96.3% in Quarry Road West) to 100.0% at Pemary Ridge, Quarry Road West, Simplace and Park Station at follow-up 2. The overall prevalence of *T. trichiura* was also high, 71.6% at baseline, ranging from 54.5% at Kennedy Lower to 86.2% at Smithfield. The overall prevalence of hookworm (*N. americanus*) was very low, 4.7% at baseline, ranging from 0.0% in Bottlebrush and Briardene to 20.0% at Smithfield) (Figure 5.1 a-j).

Table 5.4 Associations between prevalences (%) of *Ascaris lumbricoides* and *Trichuris trichiura* at baseline and follow-up 2 in the 10 study slums when data are pooled.

Slum	Baseline		Follow-up 2	
	A. lumbricoides % (n)	*T. trichiura* % (n)	*A. lumbricoides* % (n)	*T. trichiura* % (n)
1. Bottlebrush	85.8 (165)	72. 5 (145)	65.6 (118)	65. 7 (119)
2. Kennedy Lower	91.8 (112)	54. 5 (66)	91.7 (100)	37. 6 (41)
3. Lusaka	88.6 (62)	74. 6 (53)	96.6 (62)	66. 2 (43)
4. Pemary Ridge	93.8 (61)	73. 8 (48)	100.0 (64)	89.1 (57)
5. Quarry Road West	96.3 (79)	73. 2 (60)	100.0 (81)	95. 1 (78)
6. Simplace	91.9 (113)	77. 2 (95)	100. 0 (123)	89. 4 (110)
7. Briardene	87.5 (98)	79. 5 (89)	99.1 (109)	95.1 (78)
8. Smithfield	86.2 (25)	86. 2 (25)	25. 0 (7)	81.5 (22)
9. Park Station	81.7 (58)	71. 8 (52)	100.0 (65)	64. 6 (42)
10. Canaan	94.3 (115)	66. 4 (81)	82. 0 (100)	46.7 (57)
	χ^2 = 24.81	**χ^2 = 27.94**	**χ^2 = 249.07**	**χ^2 = 177.15**
	p = 0.003	**p = 0. 001**	**p < 0. 0001**	**p < 0. 0001**

5.9 OVERALL GEOHELMINTH INTENSITIES WHEN DATA ARE POOLED

The intensities of *A. lumbricoides* and *T. trichiura* were also high, whereas hookworm was low (Figures 5.7a & 5.7b) and differed significantly amongst slums (Table 5.5). Above 70% of children had either moderate, heavy or very heavy *A. lumbricoides* infections. In contrast almost half of the children, i.e. 48.8% of those positive for *T. trichiura* in Simplace, Briardene, Park Station and Canaan, had light intensity of *T. trichiura* infections (Figures 5.2 a-j and Figures 5.3 a-j). The

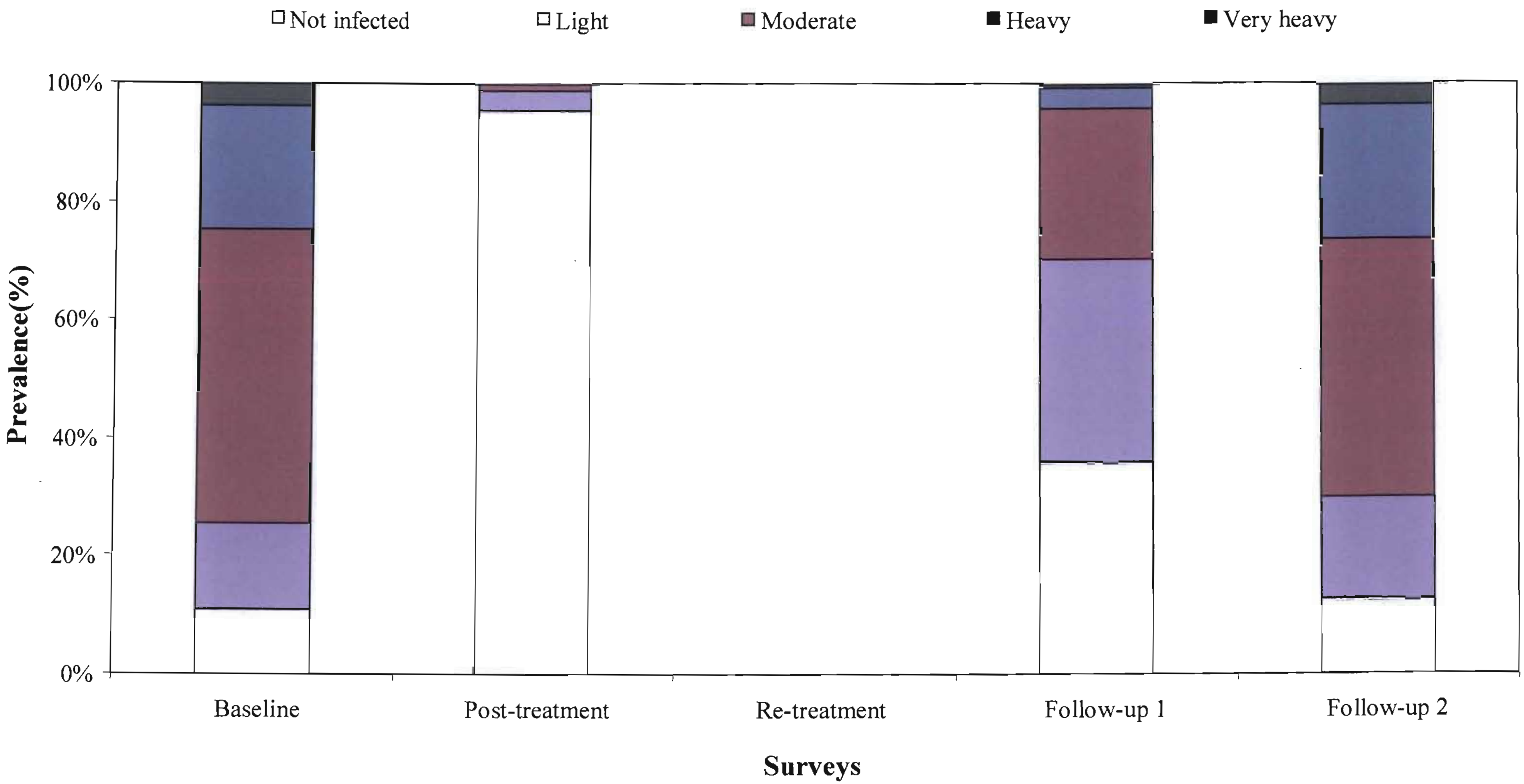


Figure 5.7a *Ascaris lumbricoides* overall intensity of infection (e.p.g.) in all surveys during the study period, when the data are pooled. Light = 1 - 4 999; Moderate = 5 000 - 50 000; Heavy = 50 000 - 100 000; Very heavy = > 100 000 e.p.g. No ascariasis infections recorded at re-treatment survey.

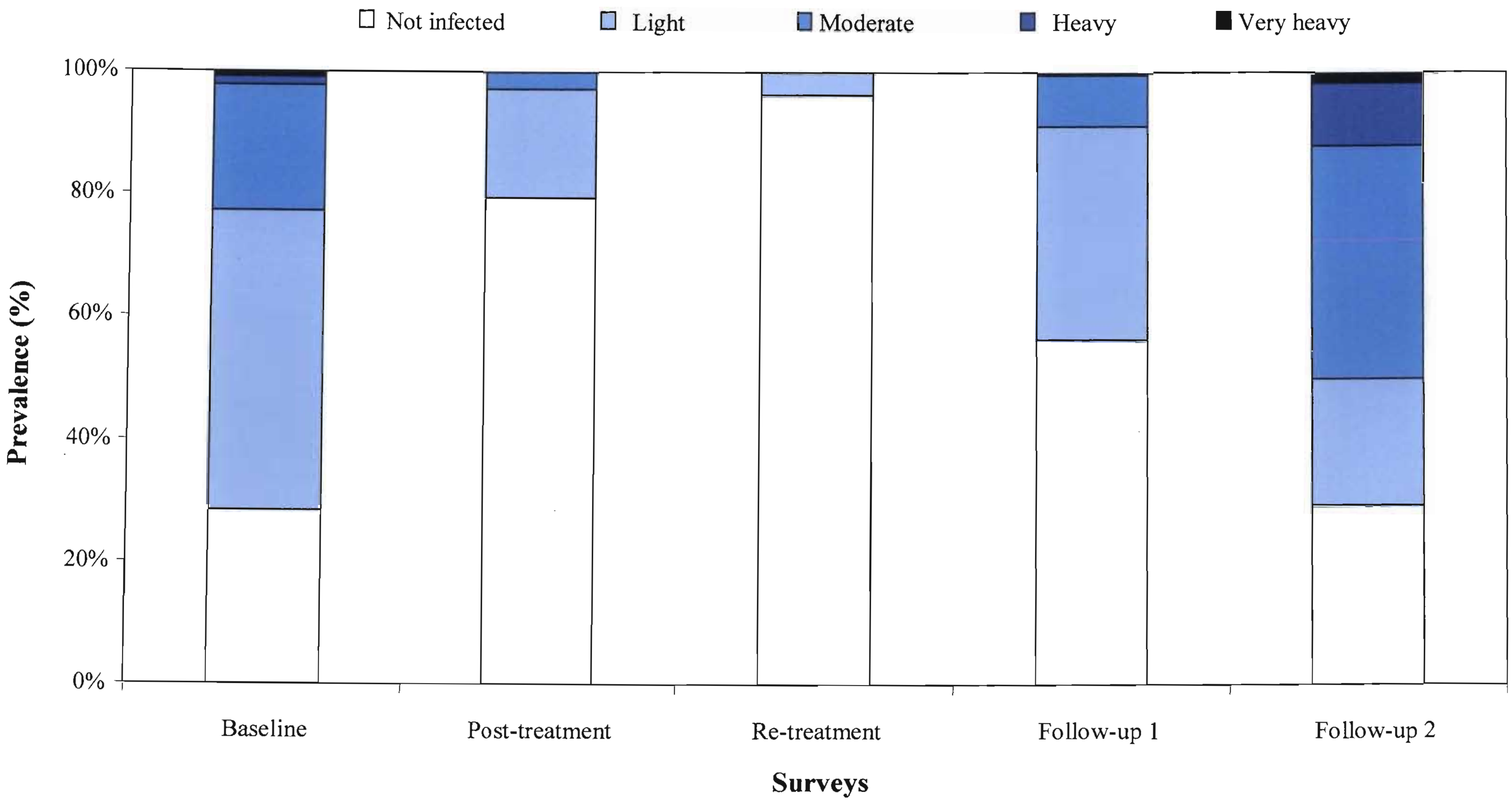
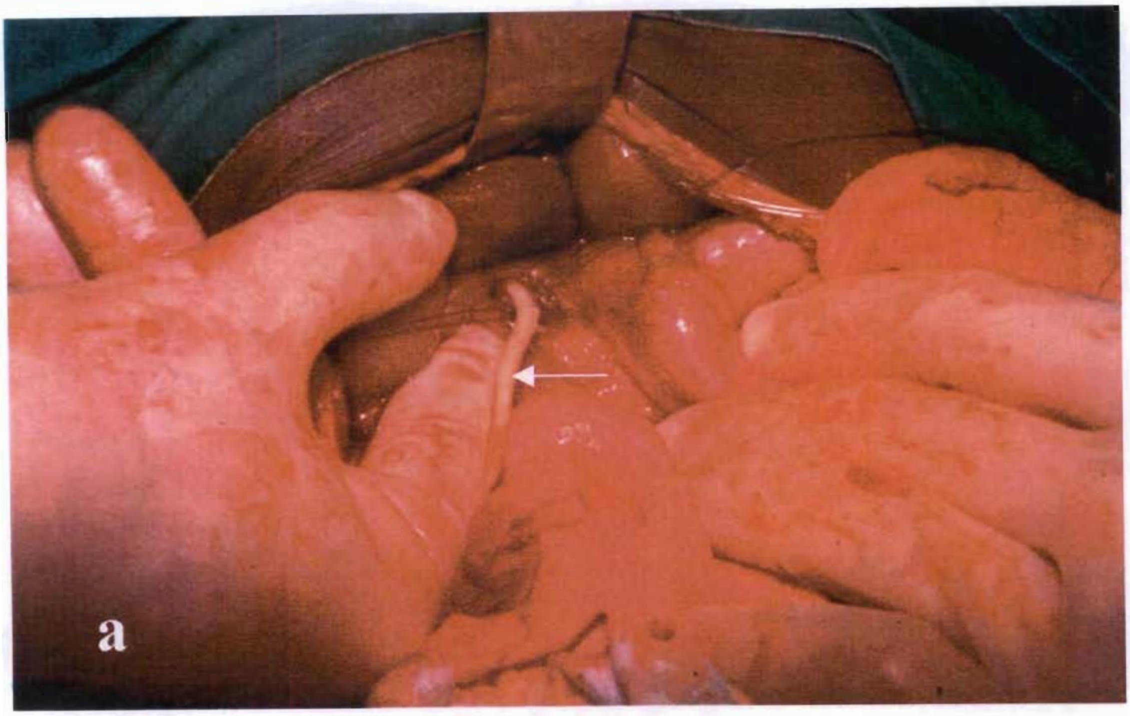


Figure 5.7b *Trichuris trichiura* overall intensity of infection (e.p.g.) in all surveys during the study period, when data are pooled. Light = 1 - 999; Moderate = 1 000 - 9 999; Heavy = 10 000 - 20 000; Very heavy = > 20 000 e.p.g.

CHAPTER 2



(a) *Ascaris lumbricoides* (◀—) **coming out of the liver** and **(b) (▲) pulled from the bile duct**. (Courtesy Prof. G.P. Hadley - Department of Paediatric Surgery, Nelson R. Mandela School of Medicine.

overall intensity of hookworm infection was very light with 98.9% of those infected having light intensities and only one child had a heavy intensity of infection (Table 5.6).

Table 5.5 Associations between the intensity of *Ascaris lumbricoides* and *Trichuris trichiura* infections (Geometric Mean egg counts per gram - GM) at baseline and follow-up 2, when data are pooled.

	Baseline		**Follow-up 2**	
Slums	*Ascaris* (GM)	*Trichuris* (GM)	*Ascaris* (GM)	*Trichuris* (GM)
1. Bottlebrush	2 096	99	221	70
2. Kennedy Lower	5 947	26	8 081	10
3. Lusaka	5 904	139	4 951	119
4. Pemary Ridge	10 834	121	33 744	1 437
5. Quarry Road West	30 754	136	33 985	2 908
6. Simplace	9 933	138	39 518	1 202
7. Briardene	5 861	340	23 474	2 205
8. Smithfield	1 836	340	14 986	732
9. Park Station	1 720	67	2 064	204
10. Canaan	13 480	49	2 065	23
	$F = 7.32$	**$F = 4.50$**	**$F = 67.68$**	**$F = 40.80$**
	$p < 0.0001$	$p < 0.0001$	$p < 0.0001$	$p < 0.0001$

Table 5.6 Baseline geometric mean (G.M) egg counts of *A. lumbricoides, T. trichiura* and hookworm for all subjects in each slum.

Slum	N	*Ascaris* Prevalence (%)	*Ascaris* Intensity (G.M)	*Trichuris* Prevalence (%)	*Trichuris* Intensity (G.M)	Hookworm Prevalence (%)	Hookworm Intensity (G.M)
1. Bottlebrush	200	82.5	2 096	72.5	99	0.0	1
2. Kennedy Lower	122	91.8	5 947	54.5	26	0.8	1
3. Lusaka	70	88.6	5 905	74.6	139	4.3	1
4. Pemary Ridge	65	93.8	10 588	73.8	164	3.1	1
5. Quarry Road West	82	96.3	30 754	73.2	121	6.1	1
6. Simplace	123	91.9	9 933	77.2	138	17.9	1
7. Briardene	112	87.5	5 861	79.5	136	0.0	1
8. Smithfield	29	86.2	1 836	86.2	340	20.0	1
9. Park Station	71	81.7	1 720	71.8	67	8.6	1
10. Canaan	122	94.3	13 480	66.4	49	1.6	1
Total	996	89.2	5 960	71.6	91	4.7	1

5.10 RESULTS OF URINE EXAMINATIONS

The overall prevalence of *Schistosoma haematobium* was 3.5%, where (of the total number of children) 5.2% (27) were males and 1.7% (8) were females. The prevalence of *S. haematobium* infection ranged from zero in Briardene to 27.6% in Smithfield (Table 5.7). There was a significant difference between urinary schistosomiasis infection among sexes in some slums:

Quarry Road West ($\chi^2 = 20.38$ on 6 d.f.; $p = 0.002$); Simplace ($\chi^2 = 14.52$ on 4 d.f.; $p = 0.006$) and Canaan ($\chi^2 = 19.51$ on 6 d.f.; $p = 0.003$). *S. haematobium* infections were was not studied further.

Table 5.7 *Schistosoma haematobium* prevalences in the 10 study slums (n = 996).

Slum	***S. haematobium*** **%** (n)
1. Bottlebrush	**4.5** (9)
2. Kennedy Lower	**2.5** (3)
3. Lusaka	**7.1** (5)
4. Pemary Ridge	**1.5** (1)
5. Quarry Road West	**1.2** (1)
6. Simplace	**3.3** (4)
7. Briardene	**0.0** (0)
8. Smithfield	**27.6** (8)
9. Park station	**9.1** (3)
10. Canaan	**0.8** (1)
Total	**3.5** (35)

Table 5.8 Evidence of urine contamination by other intestinal helminths and arthropods (n=996)

Parasite/s	% (n)
S. haematobium & hookworm	**0.1** (1)
S. haematobium & pinworm	**0.1** (1)
S. haematobium and *S. mansoni*	**0.1** (1)
Hymenolepis nana	**0.1** (1)
A. lumbricoides & tick	**0.1** (1)
A. lumbricoides & mite	**1.8** (18)
T. trichiura & mite	**6.2** (62)
Ticks	**1.0** (10)
Scabies mite	**0.1** (1)
No parasites seen in urine	**78.1** (778)

A total of 22.9% of the investigated females showed evidence of contamination by faecal transmitted parasites and other intestinal helminths, ticks and mites as summarised in Table 5.8 above. The presence of these parasites in urine is an indication of low standards of hygiene.

CHAPTER 6

Risk behaviour: **(a)** Eating outdoors with unwashed hands, **(b)** girls washing utensils in polluted water, **(c)** collecting water and washing clothes in polluted water, **(e)** girls playing in water and **(f)** boys playing in and eating sand.

a

b

c

d

e

f

6

RESULTS – II

STATISTICAL ANALYSIS OF RISK FACTORS

6.1 INTRODUCTION

There are a number of variables that either alone or in combination promote or prevent the process that might lead to geohelminth infections. The precise linkages between these different risk factors of the disease and the environment are difficult to ascertain – and to separate from the effects of other variables. This chapter is divided into two parts: First, descriptive summary of prevalence and intensity of ascariasis and trichuriasis at baseline and follow-up 2. Secondly, multivariate analysis of risk factors for prevalence and intensity of *A. lumbricoides* and *T. trichiura* infection and reinfection.

6.2 DESCRIPTIVE SUMMARY OF PREVALENCE AND INTENSITY OF ASCARIASIS AND TRICHURIASIS AT BASELINE AND FOLLOW-UP 2

Initially a descriptive approach was used to study the impact of risk factors on prevalence i.e. both infected and not infected children included, and intensity of *A. lumbricoides* and *T. trichiura* infections. This should be viewed as an exploratory first step due to the potential for confounding the effects of risk factors.

Possible associations between risk factors and prevalence of *A. lumbricoides* and *T. trichiura* were investigated using Chi-square (χ^2) tests (Holt *et al.*, 1980). The results are summarised in Table 6.1 and are briefly described in section 6.3. Analysis of variance (ANOVA) was used to test for differences between the levels of an individual risk factor in determining the intensity of *A. lumbricoides* and *T. trichiura* infection (Altman, 1997). The ANOVA was carried out on the log transformed egg counts (Table 6.2). Hookworm was not recorded at either follow-up 1 or 2 and was therefore omitted from the analysis.

Redundant or unreliable variables were excluded from the analysis. For example, children <5 years of age could not give reliable answers to questions on their geophageous behaviour, mothers did not give true information about hand-washing or personal hygiene, and the geohelminth status of adults (parents/caregivers) was not established. While these factors may

Table 6. 1 Associations between *A. lumbricoides* and *T. trichiura* prevalences (%) and individual risk factors at baseline and follow-up 2 in the 10 study slums when data are pooled. (-) = no data because presence of silica was not diagnosed during the baseline survey. n = 947.

	Level	Baseline		Follow-up 2	
Biological risk factors		*Ascaris* % (n)	*Trichuris* % (n)	*Ascaris* % (n)	*Trichuris* % (n)
1. Sex of child	*Females*	90.2 (432)	73.1 (350)	87.2 (402)	72.6 (334)
	Males	88.2 (456)	70.2(712)	87.9 (427)	68.9 (335)
		χ^2 = 1.014 p = 0.314	**χ^2 = 1.035 p = 0.309**	**χ^2 = 0.094 p = 0.759**	**χ^2 = 1.543 p = 0.214**
2. Age- groups (years)	*2 - 4*	86.8 (374)	63.6 (274)	89.7 (367)	70.7 (290)
	5 - 7	93.2 (287)	73.9 (227)	88.3 (257)	67.7 (195)
	8 – 10	87.8 (216)	81.3 (200)	82.2 (194)	73.0 (173)
		χ^2 = 8.05 p = 0.018	**χ^2 = 25.59 p < 0.0001**	**χ^2 = 8.015 p = 0.018**	**χ^2 = 1.79 p = 0.409**
Environmental risk factors					
3. Slum soil type	*Cartref*	84.1 (227)	73.0 (197)	73.8 (180)	65.7 (161)
	Dundee & Fernwood	95.2 (140)	73.5 (108)	99.3 (145)	92.5 (135)
	Milkwood	90.0 (521)	70.5 (408)	90.5 (504)	67.3 (374)
		χ^2 = 13.23 p = 0.001	**χ^2 = 0.864 p = 0.649**	**χ^2 = 65.33 p < 0.0001**	**χ^2 = 39.49 p < 0.0001**
4. Topographical position of dwelling	*Crest of hill*	87.1 (169)	71.1 (138)	84.5 (164)	61.3 (119)
	Mid / foot-slope	92.6 (225)	76.5 (186)	86.4 (210)	73.7 (179)
	Valley bottom	93.0 (173)	67.7 (126)	88.1 (163)	75.4 (138)
	Flat	87.0 (260)	71.5 (213)	90.3 (269)	72.1 (214)
		χ^2 = 8.09 p = 0.044	**χ^2 = 3.73 p = 0.29**	**χ^2 = 3.96 p = 0.266**	**χ^2 = 11.23 p = 0. 011**
Socio-cultural factors					
5. Amount of silica in stool in follow-up 2 survey	*No silica*	-	-	76.9 (103)	60.2 (80)
	Occasional	-	-	76.8 (53)	71.0 (49)
	Scanty	-	-	90.7 (107)	74.4 (87)
	+	-	-	91.2 (250)	68.9 (188)
	+ +	-	-	90.5 (229)	73.9 (187)
	+ + +	-	-	88.4 (76)	87.2 (75)
				χ^2 = 27.94 p < 0.0001	**χ^2 = 20.95 p < 0.0001**

Factor	Level	Baseline *Ascaris* % (n)	Baseline *Trichuris* % (n)	Follow-up 2 *Ascaris* % (n)	Follow-up 2 *Trichuris* % (n)
6. Children eating soil	*Geophageous*	95.3 (323)	72.2 (244)	92.0 (309)	77.6 (260)
	Non-geophageous	86.3 (515)	71.5 (427)	84.9 (500)	66.6 (391)
		$\chi^2 = 18.73$ $p < 0.0001$	**$\chi^2 = 0.047$ $p = 0.828$**	**$\chi^2 = 9.75$ $p = 0.002$**	**$\chi^2 = 12.43$ $p < 0.0001$**
7. Parents who eat soil	*Geophageous*	92.9 (234)	68.5 (172)	90.0 (226)	76.0 (190)
	Non-geophageous	88.4 (592)	73.3 (491)	86.4 (576)	68.9 (458)
		$\chi^2 = 3.97$ $p = 0.046$	**$\chi^2 = 2.05$ $p = 0.152$**	**$\chi^2 = 2.24$ $p = 0.135$**	**$\chi^2 = 4.462$ $p = 0.035$**

Socio-economic factors

Factor	Level	Baseline *Ascaris* % (n)	Baseline *Trichuris* % (n)	Follow-up 2 *Ascaris* % (n)	Follow-up 2 *Trichuris* % (n)
8. Quality of dwelling	*Brick*	88.0 (198)	74.7 (168)	87.6 (197)	63.1 (142)
	Mud	89.7 (78)	65.5 (57)	78.2 (68)	64.0 (55)
	Shack	92.5 (271)	69.6 (204)	90.0 (262)	76.3 (222)
		$\chi^2 = 11.72$ $p = 0.003$	**$\chi^2 = 2.28$ $p = 0.231$**	**$\chi^2 = 2.93$ $p = 0.231$**	**$\chi^2 = 10.03$ $p = 0.007$**
9. Average distance between dwellings	*<4 metres*	94.4 (221)	71.4 (167)	96.1 (224)	82.8 (193)
	4 – 20 metres	88.4 (336)	75.8 (288)	93.7 (355)	75.1 (284)
	> 20 metres	87.2 (272)	67.8 (211)	73.4 (226)	56.5 (650)
		$\chi^2 = 8.35$ $p = 0.015$	**$\chi^2 = 5.410$ $p = 0.067$**	**$\chi^2 = 85.15$ $p < 0.0001$**	**$\chi^2 = 45.89$ $p < 0.0001$**
10. Number of rooms per dwelling	1 - 3	89.8 (729)	72.3 (587)	89.1 (722)	72.0 (582)
	>4	89.1 (98)	69.7 (76)	76.4 (84)	62.4 (68)
		$\chi^2 = 0.049$ $p = 0.824$	**$\chi^2 = 0.313$ $p = 0576$**	**$\chi^2 = 14.54$ $p < 0.0005$**	**$\chi^2 = 4.32$ $p = 0.038$**
11. Inhabitants per dwelling	2 – 4	89.2 (263)	69.5 (205)	89.8 (265)	70.4 (207)
	5 – 8	87.9 (384)	74.1 (324)	84.9 (370)	71.5 (311)
	> 8	94.6 (176)	70.3 (130)	90.8 (803)	70.1 (129)
		$\chi^2 = 6.52$ $p = 0.038$	**$\chi^2 = 2.17$ $p = 0.337$**	**$\chi^2 = 6.13$ $p = 0047$**	**$\chi^2 = 0.164$ $p = 0.921$**
12. Sanitation	*Safe*	85.9 (238)	69.9 (193)	77.5 (214)	53.8 (148)
	Unsafe	91.4 (592)	73.1 (474)	91.8 (590)	78.0 (500)
		$\chi^2 = 6.22$ $p = 0.013$	**$\chi^2 = 0.99$ $p = 0.318$**	**$\chi^2 = 35.64$ $p < 0.0001$**	**$\chi^2 = 54.32$ $p < 0.0001$**
13. How do you dispose of your child's nappies?	*Safe*	92.1 (314)	76.5 (260)	94.1 (319)	83.3 (280)
	Unsafe	88.5 (484)	68.7 (376)	82.9 (450)	62.8 (341)
		$\chi^2 = 3.36$ $p = 0.067$	**$\chi^2 = 23.59$ $p < 0.001$**	**$\chi^2 = 5.96$ $p = 0.015$**	**$\chi^2 = 42.18$ $p < 0.0001$**

Factor	Level	Baseline *Ascaris* % (n)	Baseline *Trichuris* % (n)	Follow-up 2 *Ascaris* % (n)	Follow-up 2 *Trichuris* % (n)
14. Water source	*Tap in house*	91.0 (131)	71.5 (103)	85.4 (123)	51.4 (74)
	Tap not in the house but near< 500 metres	85.3 (81)	67.0 (65)	61.9 (60)	85.9 (238)
	Tap not in the house but far >500 metres	91.0 (284)	75.0 (234)	98.4 (304)	84.8 (262)
		$\chi^2 = 1.38$ $p = 0.241$	**$\chi^2 = 2.26$ $p = 0.133$**	**$\chi^2 = 46.82$ $p < 0.0001$**	**$\chi^2 = 42.42$ $p < 0.0001$**
15. Use of household bleach	*Yes*	60.0 (3)	80.0 (4)	80.0 (4)	60.0 (3)
	No	89.8 (834)	72.0 (668)	87.4 (805)	70.7 (649)
		$\chi^2 = 4.73$ $p = 0.030$	**$\chi^2 = 0.16$ $p = 0.691$**	**$\chi^2 = 0.25$ $p = 0.619$**	**$\chi^2 = 0.27$ $p = 0.601$**
16. Mother's level of education	*Primary education or none*	90.8 (505)	73.3 (407)	90.4 (501)	70.8 (391)
	Beyond primary Education level	87.6 (233)	72.6 (193)	82.3 (218)	71.2 (188)
		$\chi^2 = 0.35$ $p = 0.555$	**$\chi^2 = 0.16$ $p = 0.691$**	**$\chi^2 = 0.36$ $p = 0.551$**	**$\chi^2 = 0.31$ $p = 0.576$**
17. Father's level of education	*Primary or none*	90.3 (448)	72.4 (359)	88.2 (435)	70.3 (346)
	Beyond primary Education level	89.1 (369)	71.2(294)	86.9(359)	72.0 (296)
		$\chi^2 = 2.05$ $p = 0.152$	**$\chi^2 = 0.055$ $p = 0.814$**	**$\chi^2 = 11.15$ $p = 0.001$**	**$\chi^2 = 0.012$ $p = 0.911$**
18. Mother's level of employment	*Not employed*	90.5 (313)	74.6 (258)	87.0 (301)	75.1 (260)
	Formal	86.4 (38)	63.6 (28)	90.9 (40)	59.1 (26)
	Informal	89.8 (465)	70.8 (366)	87.7 (451)	69.3 (354)
		$\chi^2 = 0.73$ $p = 0.693$	**$\chi^2 = 3.01$ $p = 0.222$**	**$\chi^2 = 0.57$ $p = 0.752$**	**$\chi^2 = 6.65$ $p = 0.036$**
19. Father's level of employment	*No father*	87.0 (147)	87.5 (147)	75.6 (127)	64.5 (107)
	Not employed	85.1 (166)	74.7 (145)	88.7 (172)	64.6 (124)
	Formal	88.5 (46)	69.2 (36)	94.2 (49)	82.7 (43)
	Informal	91.3 (526)	72.9 (420)	86.9 (499)	72.1 (413)
		$\chi^2 = 6.11$ $p = 0.047$	**$\chi^2 = 0.671$ $p = 0.715$**	**$\chi^2 = 2.54$ $p = 0.281$**	**$\chi^2 = 7.60$ $p = 0.022$**
20. Total household income	*Low income less than R201 a month*	91.0 (421)	92.0 (421)	75.6 (328)	73.1 (327)
	Middle income one earn R201 but not more than R1 000 a month	89.8 (298)	83.9 (277)	76.2 (253)	72.3 (238)
	One get more than R1 000 a month	92.9 (13)	85.7 (12)	92.9 (13)	78.6 (11)
		$\chi^2 = 2.081$ $p = 0.556$	**$\chi^2 = 9.60$ $p = 0.022$**	**$\chi^2 = 12.36$ $p = 0.006$**	**$\chi^2 = 4.77$ $p = 0.189$**

Factor	Level	Baseline *Ascaris* % (n)	Baseline *Trichuris* % (n)	Follow-up 2 *Ascaris* % (n)	Follow-up 2 *Trichuris* % (n)
21. Caregiver	*Mother*	91.3 (536)	71.0 (416)	93.0 (546)	72.2 (423)
	Father	80.0 (16)	75.0 (15)	85.0 (17)	60.0 (12)
	Granny	89.4 (143)	70.6 (113)	86.2 (137)	68.4 (108)
	Crèche	83.3 (101)	73.3 (88)	65.3 (77)	70.9 (83)
		$\chi^2 = 8.23$ $p = 0.041$	**$\chi^2 = 1.005$ $p = 0.800$**	**$\chi^2 = 73.83$ $p < 0.001$**	**$\chi^2 = 2.51$ $p = 0.474$**
22. Cooking facility	*Paraffin*	96.5 (647)	82.1 (516)	92.9 (627)	73.9 (516)
	Gas	100.0 (3)	79.7 (55)	84.1 (58)	71.0 (49)
	Electricity	90.2 (119)	72.0 (95)	90.9 (120)	63.6 (84)
		$\chi^2 = 3.67$ $p = 0.299$	**$\chi^2 = 4.34$ $p = 0.227$**	**$\chi^2 = 1.92$ $p = 0.588$**	**$\chi^2 = 5.17$ $p = 0.160$**
23. Where do you get/buy fruit & vegetable from?	*Street vendors*	88.2 (75)	57.6 (51)	94.1 (82)	71.8 (63)
	Supermarkets	89.8 (431)	80.0 (359)	88.7 (428)	80.0 (346)
	Rubbish dump	89.1 (213)	74.1 (177)	85.4 (204)	76.2 (182)
		$\chi^2 = 0.52$ $p = 0.769$	**$\chi^2 = 3.55$ $p = 0.170$**	**$\chi^2 = 1.76$ $p = 0.416$**	**$\chi^2 = 4.97$ $p = 0.083$**
24. Children who are fed leftovers.	*No*	88.5 (23)	80.8 (21)	88.5 (23)	73.1 (19)
	Yes	89.9 (815)	72.0 (634)	87.8 (772)	71.1 (623)
		$\chi^2 = 0.057$ $p = 0.811$	**$\chi^2 = 0.959$ $p = 0.328$**	**$\chi^2 = 0.010$ $p = 0.922$**	**$\chi^2 = 0.047$ $p = 0.828$**
25. Food storage	*Fridge*	87.1 (135)	67.1 (104)	85.2 (132)	63.9 (99)
	Cupboard	88.8 (381)	73.1 (313)	86.9 (376)	72.8 (314)
	Bucket	97.3 (197)	81.8 (165)	97.5 (288)	78.5 (156)
		$\chi^2 = 9.04$ $p = 0.029$	**$\chi^2 = 3.52$ $p = 0.318$**	**$\chi^2 = 8.10$ $p = 0.044$**	**$\chi^2 = 6.313$ $p = 0.097$**
26. Child's origin	*Rural*	90.7 (255)	73.3 (206)	88.6 (249)	72.5 (203)
	Township	89.0 (355)	72.9 (290)	84.1 (334)	71.1 (281)
	Another slum	90.7 (166)	64.5 (118)	91.3(167)	61.7 (113)
	Rural towns	84.3 (43)	82.4 (42)	96.1 (49)	90.2 (46)
		$\chi^2 = 1.95$ $p = 0.582$	**$\chi^2 = 2.45$ $p = 0.484$**	**$\chi^2 = 4.12$ $p = 0.249$**	**$\chi^2 = 24.78$ $p < 0.0001$**

Table 6. 2 Associations between the intensity of *Ascaris lumbricoides* and *Trichuris trichiura* infections (Geometric mean egg counts - (GM) and individual risk factors at baseline and follow-up 2 when data are pooled. Variables not considered to affect the intensity of infection (but many affect prevalence) are omitted from this table. (-) = no data because the presence of silica was not diagnosed during the baseline survey. n = 947.

	Level	**Baseline**		**Follow-up 2**	
Biological risk factors		*Ascaris* (GM)	*Trichuris* (GM)	*Ascaris* (GM)	*Trichuris* (GM)
1. Sex of child	*Females*	6 578	105	4 276	259
	Males	5 441	78	5 430	174
		F = 0.77 **P = 0.380**	**F = 2.30** **P = 0.130**	**F = 1.10** **P = 0.294**	**F = 2.68** **P = 0.102**
2. Age-groups (years)	*2 - 4*	4 719	51	6 186	199
	5 - 7	9 430	108	4 953	162
	8 - 10	4 520	176	2 748	292
		F = 4.53 **P = 0.011**	**F = 13.70** **P < 0.0001**	**F = 4.08** **P = 0.017**	**F = 1.75** **P = 0.174**
Environmental risk factors					
3. Soil types in slums	*Cartref*	2 741	107	500	80
	Dundee & Fernwood	6 349	75	7 842	178
	Milkwood	19 191	138	33 884	2 135
		F = 16.26 **P < 0.0001**	**F = 2.85** **P = 0.058**	**F = 95.17** **P < 0.0001**	**F = 40.99** **P < 0.0001**
4. Topographical position of dwelling	*Crest*	4 314	84	3 176	93
	Foot or mid -slope	7 652	121	4 813	264
	Valley bottom	7 519	77	5 258	281
	Flat	5 727	96	5 670	251
		F = 1 132 **P = 0.340**	**F = 1.75** **P = 0.137**	**F = 1.33** **P = 0.255**	**F = 3.56** **P = 0.007**
Socio-cultural risk factors					
5. Amount of silica in stool in follow-up 2 survey	*No silica*	-	-	1 529	91
	"Occasional"	-	-	1 025	136
	Scanty	-	-	6 437	244
	+	-	-	7 132	184
	+ +	-	-	6 998	326
	+ + +	-	-	6 759	800
				F = 7.44 **P < 0.0001**	**F = 4.71** **P < 0.0001**

	Level	**Baseline**		**Follow-up 2**	
		Ascaris (GM)	*Trichuris* (GM)	*Ascaris* (GM)	*Trichuris* (GM)
6. Children eating soil	*Geophageous*	13 210	107	8 766	392
	Non-geophageous	3 901	85	3 297	145
		F = 29. 26 ***P* < 0.0001**	**F = 1.22** ***P* = 0.270**	**F =16.99** ***P* < 0.0001**	**F =15. 74** ***P* < 0.0001**
Socio-economic risk factors					
7. Number of rooms per dwelling	1 - 3	6 576	97	5 644	245
	4 or more	3 864	76	1 371	74
		F = 2.46 ***P* = 0.117**	**F = 0.591** ***P* = 0.442**	**F = 16.24** ***P* < 0.0001**	**F = 10.16** ***P* = 0.001**
8. Average distance between dwellings	*<4 metres*	14 428	96	16 803	699
	4 – 20 metres	5 623	120	9 947	342
	> 20 metres	3 456	69	723	48
		F = 12.57 ***P* < 0.0001**	**F = 2.74** ***P* = 0.065**	**F = 80.062** ***P* < 0.0001**	**F = 44.431** ***P* < 0.0001**
9. Inhabitants per dwelling	2 - 4	6 360	74	7 276	237
	5 - 8	4 933	113	3 317	216
	8 or more	9 938	88	5 853	174
		F = 2.89 ***P* = 0.056**	**F = 1.72** ***P* = 0.179**	**F = 4.91** ***P* = 0.008**	**F = 0.40** ***P* = 0.672**
10. Sanitation	*Safe*	4 699	101	3 308	169
	Unsafe	13 378	111	19 195	1 233
		F = 15.51 ***P* < 0.0001**	**F = 0.141** ***P* = 0.708**	**F = 42.49** ***P* < 0.0001**	**F = 83.71** ***P* < 0.0001**
11. Water source	*Tap in house*	7 605	84	2 284	33
	Tap not in the house but near < 500 metres	2 513	113	253	60
	Tap not in the house but far >500 metres	6 000	100	8 352	393
		F = 5.30 ***P* = 0.022**	**F = 1.55** ***P* = 0.214**	**F = 101.36** ***P* < 0.0001**	**F = 83.71** ***P* < 0.0001**
12. Use of household bleach	*Yes*	265	80	3 617	38
	No	6 200	94	4 666	210
		F = 4.41 ***P* = 0.036**	**F = 0.015** ***P* = 0.904**	**F = 0.026** ***P* = 0.871**	**F = 1.07** ***P* = 0.300**
13. Source of fruit & vegetables.	*Street vendors*	5 449	56	6 124	120
	Supermarkets	7 181	101	4 890	241
	Rubbish dump	5 010	111	4 052	262
		F = 0.82 ***P* = 0.486**	**F = 1.79** ***P* = 0.148**	**F = 0.75** ***P* = 0.524**	**F = 1.61** ***P* = 0.185**

be important, it was difficult to quantify the risk for children in terms of exposure to geohelminth infections.

6.3 MULTIVARIATE ANALYSIS OF RISK FACTORS FOR *A. LUMBRICOIDES* AND *T. TRICHIURA* INFECTION AND REINFECTION

Multiple regression techniques were used to identify the most important risk factors for infection and reinfection by each parasite for the collective study population. Potential risk factors are usually interrelated and therefore multiple regression models were used to assess the importance of risk factors allowing for the effects of others. No risk factors were determined for hookworm (see section 6.2).

6.4 POTENTIAL RISK FACTORS FOR INCLUSION IN THE MODELS

Risk factors that were considered are listed in Tables 6.1 & 6.2 and will be discussed briefly in the four categories, viz.: biological, environmental, socio-cultural and socio-economic. There was a change in the effects of a number of variables in terms of prevalences and intensities for both *A. lumbricoides* and *T. trichiura* from baseline to follow-up 2. The raw percentages are presented in (Appendix C, Table 11).

The following changes in some slums – relocation to a new area, *in-situ* upgrading, introducing a different type of water source (taps inside house) and sanitation (flush toilets), quality of house (from shack to brick house) and house crowding (average distance between houses), showed significant impact on prevalences and intensities for both *A. lumbricoides* and *T. trichiura* reinfection.

For example, with reference to water source at baseline, there was no dwelling in the study slums which had either a tap inside the house or a flush toilet. Introduction of the interventions mentioned above (e.g. introduction of piped water and flush toilet to houses, change from shack to brick house, or decreased housing density) could have had an impact at follow-up 2. As a result the prevalence either increased, remained the same or dropped and the impact of changing these variables was a clear reduction in intensity for both parasites at follow-up 2, as will be discussed in detail later.

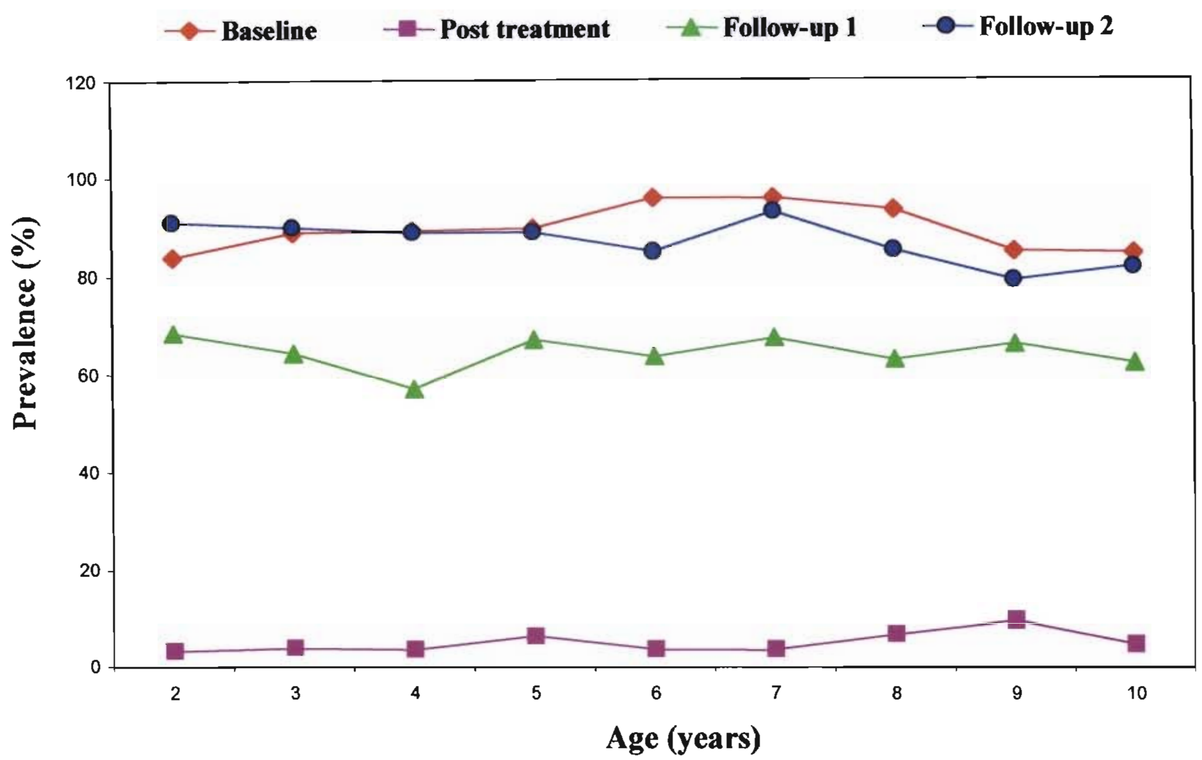


Figure 6.1a *A. lumbricoides* age-specific prevalences (%) in all surveys in the 10 slums when data are pooled.

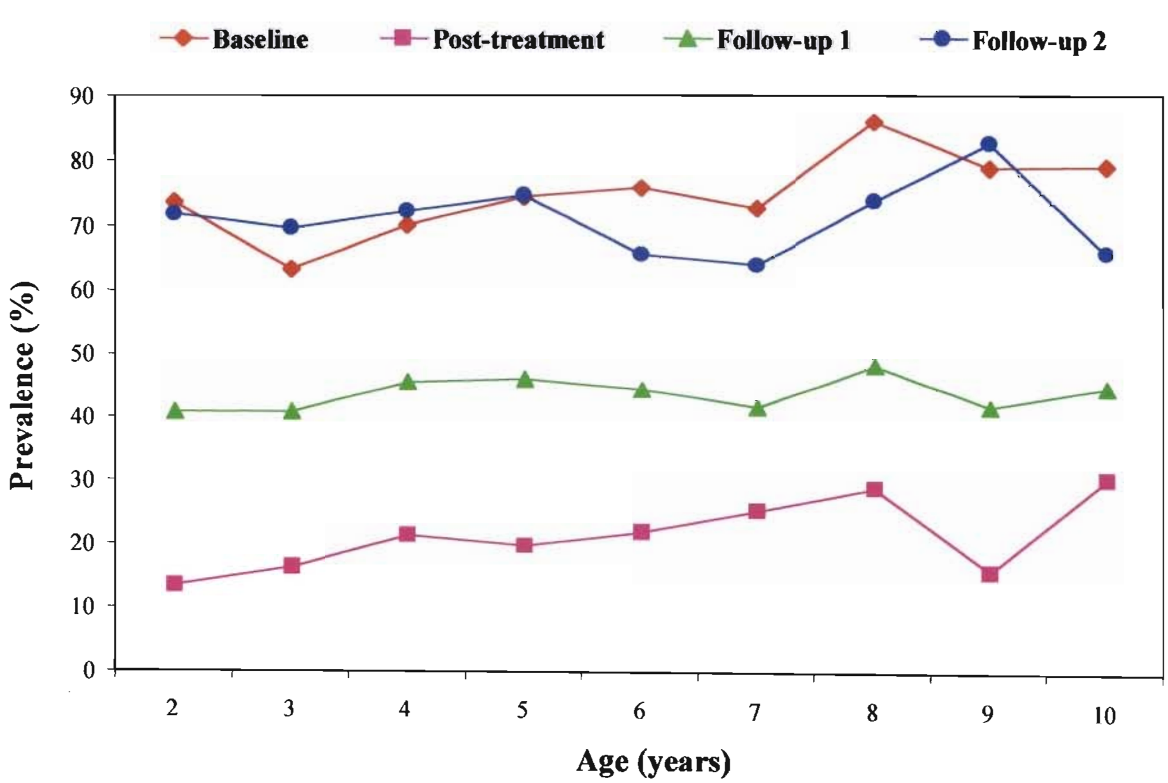


Figure 6.1b *T. trichiura* age-specific prevalences (%) in all surveys in the 10 slums when data are pooled.

6.4.1 Biological risk factors

Differences in prevalence between males and females at baseline and follow-up 2

No statistically significant difference was found in prevalences between sexes, although they tended to be higher in females. Similarly there was no significant difference in mean intensity between sexes in any of the surveys (Table 6.1 & 6.2).

Differences in prevalence and intensity of geohelminth infections in different ages at baseline and follow-up 2

Age-related prevalences (Figures 6.1a & b) and intensities of *A. lumbricoides* and *T. trichiura* in all 10 slums indicate that children 6, 7 & 8 years were the most heavily infected (Figures 6.2 & 6.3). A significant difference in prevalences between ages 6 and 7 years was observed for *A. lumbricoides* ($\chi^2 = 8.05$; $p = 0.018$) at baseline and at follow-up 2 ($\chi^2 = 8.01$; $p = 0.018$). For *T. trichiura* differences in prevalence were only observed in the 8-10 year ages at baseline ($\chi^2 = 30.15$; $p < 0.0001$). The ages in Tables 6.1 & 6.2 were categorized to simplify the analysis.

6.4.2 Environmental risk factors

Effect of soil types in slums on transmission

Children living in slums categorised by soil with low clay content, high sand content and very good drainage (Dundee & Fernwood types) had the highest ascariasis and trichuriasis prevalences. It was noticed however, that children living in slums with soils with a high clay content, low sand content and poor drainage (Milkwood type), had the highest number of heavy intensities for both parasite infections at baseline and at follow-up 2 (Table 6.2).

Effect of topographical position of dwelling on transmission

A. lumbricoides prevalence was highest in children living in homes built in the valley bottom and on mid and foot-slopes. At baseline *T. trichiura* prevalence was lowest in dwellings built in the valley bottom. At follow-up 2, there was no significant difference in *A. lumbricoides* prevalences although *T. trichiura* was much lower in homes built at the crest than elsewhere. The only significant difference in intensity was for *T. trichiura* at follow-up 2, with intensities lower at the crest than at the other positions. Children living in a flat slum

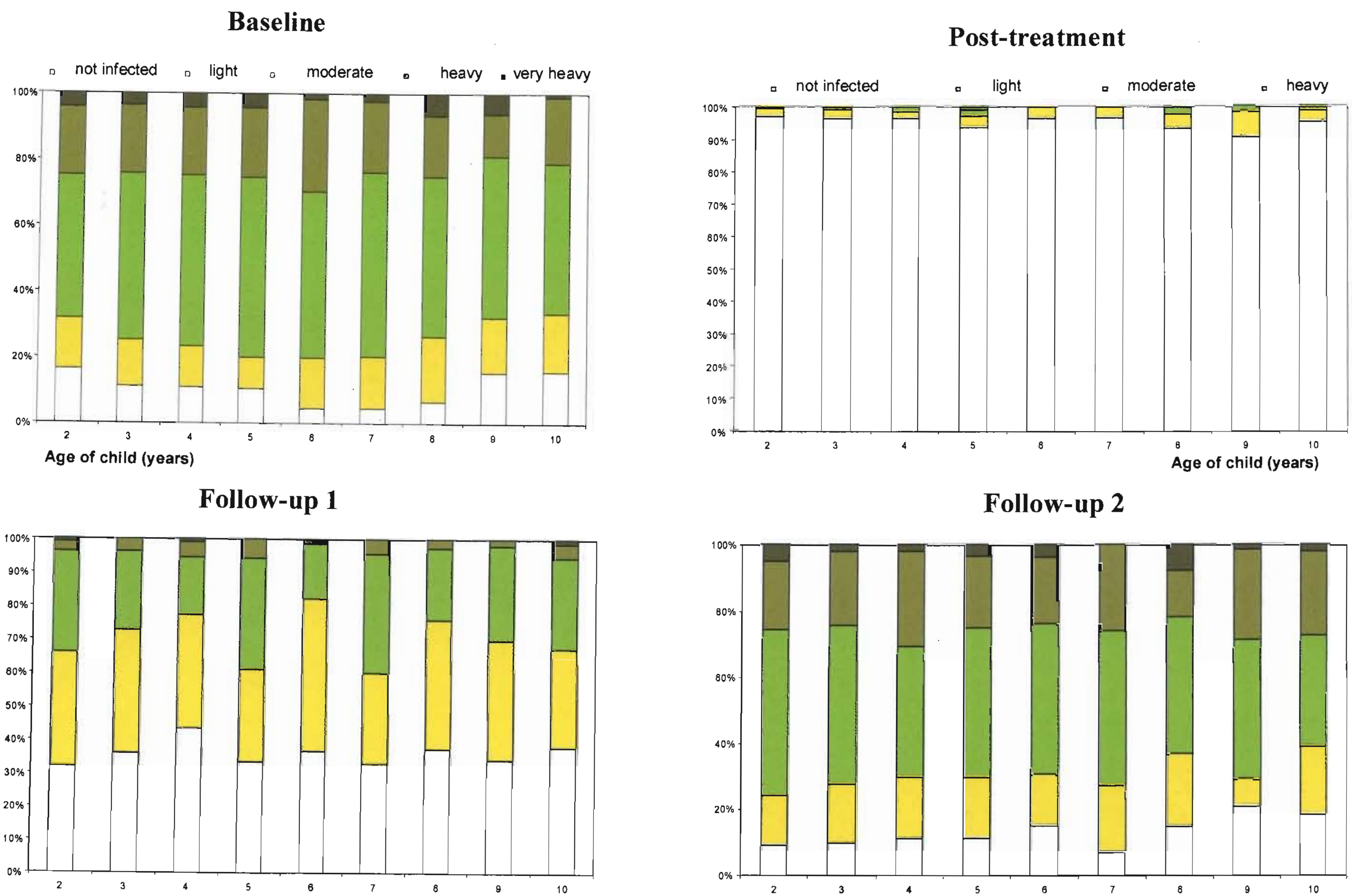


Figure 6.2 Age-specific intensity (e.p.g.) profile for *A. lumbricoides* infections in all surveys when data are pooled.

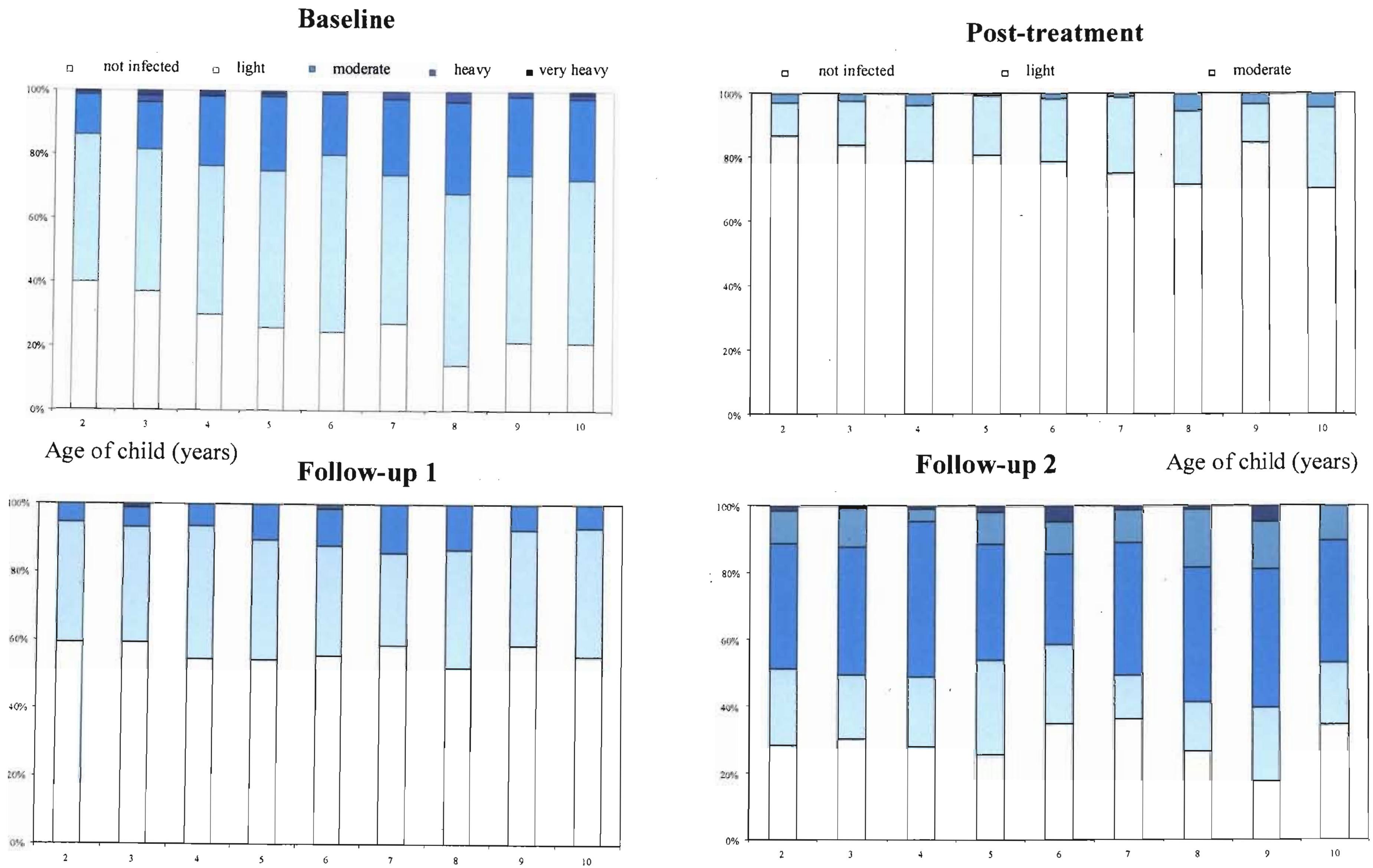


Figure 6.3 Age-specific intensity (e.p.g.) profile for *T. trichiura* infections in all surveys when data are pooled.

were more easily reinfected than those living in houses built on the crest, mid or foot-slopes and valley bottoms (Tables 6.1 & 6.2).

6.4.3 Socio-cultural risk factors

Evidence of silica in stool and its effect on transmission

Children with silica crystals in their stool samples were more frequently and more heavily infected with both parasites than those without silica. The heaviest infections were found in children with silica counts from scanty to (+ + +) while those with "occasional" or no silica were lightly infected. Silica in stool was not investigated at baseline (Table 6.2).

Effect of children's geophageous behaviour on transmission

Geophageous children tended to have considerably higher *A. lumbricoides* prevalences and higher intensities than the non-geophageous ones, both at baseline and follow-up 2. Geophagy did not have any significant effect on *T. trichiura* prevalences or intensities at baseline, but there were significantly more heavily infected geophageous children at follow-up 2 (Table 6.1 & 6.2).

Effect of mothers' geophageous behaviour on transmission

There was some evidence that at follow-up 2, children whose mothers ate soil were more likely to become infected and reinfected, than those whose mothers did not eat soil. Fathers were found not to eat soil (Table 6.1).

6.4.4 Socio-economic risk factors

Effect of quality of dwelling on transmission

For *A. lumbricoides* there was evidence that children living in shacks were likely to be more at risk of infection and experience heavier worm burdens, than children living in brick or mud houses. This was significant for *T. trichiura* prevalence at follow-up 2 (Table 6.1)

Effect of house-crowding (average inter-house distance) on transmission

At baseline and follow-up 2, children living in crowded slums (houses less than metres apart on average - see Frontiespiece) had a significantly higher chance of being infected with *A. lumbricoides* and *T. trichiura* than children living in dwellings which had larger spaces between them. There was also a significantly higher chance of children being heavily infected if they lived in crowded slums than in slums where the average distance between houses was >20m (Tables 6.1 & 6.2).

Effect of number of rooms per dwelling on transmission

There was a greater chance for a child being infected with both parasites if he/she lived in a home with less than three rooms, than if the house had four or more rooms. These differences were not found for either parasite at baseline (Table 6.1).

Effect of number of inhabitants per dwelling on transmission

Children living in homes with more than eight inhabitants had a higher risk of having ascariasis than those in less crowded homes. The number of inhabitants per dwelling did not have an effect on trichuriasis at baseline, but crowded households had children with heavy intensities for both parasites at follow-up 2. The heaviest infections at baseline for *A. lumbricoides* were in children who had two-four members per household (Tables 6.1 & 6.2).

Effect of sanitation on transmission

At baseline there was slight evidence that children with unsafe excreta disposal systems had higher prevalences of ascariasis and trichuriasis than those with safe systems. The four interventions introduced between 1998 and 1999, viz.: flush toilets in some slums, relocation to new areas, *in-situ* upgrading of the slum and chemotherapy had a clear impact by reducing the intensity of infection and reinfection rate for both parasites at follow-up 2 (Tables 6.1& 6.2).

Effect of water source on transmission

At baseline, none of the 10 study slums had taps in houses. Children who had a water source near to their house had the lowest prevalences of *A. lumbricoides*, whereas the lowest prevalences of *T. trichiura* were in those children with taps in their houses. Taps in the houses reduced prevalence and intensity at follow-up 2 for both parasite infections. The lowest prevalences and intensities for *A. lumbricoides* at follow-up 2 were, however, found in those dwellings with taps within 500 metres. This unusual result might have been due to the situation at Bottlebrush slum, where although the taps were in the yards, these were not counted as taps inside the houses (Tables 6.1 & 6.2).

Effect of level of education on transmission

The literacy levels of the father and mother did not have any influence on geohelminth infections. Children whose fathers had secondary or higher education were associated with significantly reduced reinfection prevalences of *A. lumbricoides*, (Table 6.1).

Effect of level of employment on transmission

Unemployed fathers had fewer infected children than employed fathers. Mothers with formal jobs had an influence in that the levels of *T. trichiura* infection were higher in their children than in children whose mothers were unemployed, (Table 6.1).

Effect of care-giver on transmission

Those children looked after at crèches had a lower risk of being reinfected by both *A. lumbricoides* and *T. trichiura* than those looked after by parents or grandmothers, (Table 6.1).

6.5 STATISTICAL MODELS

6.5.1 Risk factors for *A. lumbricoides* and *T. trichiura* infections

Regression modelling was used to investigate which were the most important risk factors for ascariasis and trichuriasis infections. This was done by fitting logistic regression models with the response being the absence/presence of infection (separately for the baseline and for follow-up 2 surveys) and fitting multiple regression models with the response being the log of the egg counts (i.e. intensity of infection). Again this was done separately for *A. lumbricoides* and *T. trichiura* and separately for baseline and follow-up 2 surveys. The multiple regression models for intensity (log egg-count) were fitted only for infected individuals, i.e. to investigate factors that influenced intensity of infection, conditional on the individual being infected.

To simplify interpretation of the results it was necessary to group some levels of different variables before analysis.

The following were then extracted from the 28 variables listed in Tables 6.1 & 6.2 as potential explanatory factors/variates (risk factors).

1. Slum – as a risk factor with 10 levels, i.e. a way one slum differ from another, such that some risk factors were operating at slum level (public domain), e.g. water source, sanitation and environmental factors specifically introduced in the slum, these could contribute to the probability of geohelminth infection, whereas, some were operating at household (domestic domain) level.
2. Soil type – a factor with 3 levels. Since this is a "slum level" factor, slum and soil type could not be fitted in the same model, but comparison of models with slum and with soil type allowed me to determine to what extent differences between slums could be attributed to (1 = Cartref, 2 = Milkwood and 3 = Dundee & Fernwood soils).
3. Sex of child (0 = female and 1 = male).
4. Age-group (1 = 2-4 years, 2 = 5-7 years and 3 = 8-10 years).

5. Topographical position of the dwelling (1 = crest of hill, 2 = mid or foot slope, 3 = valley bottom and 4 = flat).
6. Quality of dwelling (1 = brick, 2 = mud and 3 = other).
7. Origin of child (1 = rural, 2 = township, 3 = another slum and 4 = urban (rural town).
8. Number of rooms per dwelling (1 = 1 - 3 and 2 = 4 or more).
9. Inhabitants per dwelling (1 = 2 - 4, 2 = 5 - 8 and 3 = 9 or more).
10. Care-giver (1 = mother; 2 = father, 3 = grandmother and 4 = crèche).
11. Geophageous parent/guardian eats soil (0 = no and 1 = yes).
12. Mother's level of education (1 = none or primary and 2 = secondary or higher).
13. Father's level of education (1 = none or primary and 2 = secondary or higher).
14. Mother's employment status (1 = unemployed; 2 = formal sector and 3 = informal sector).
15. Father's employment status (1 = unemployed; 2 = formal sector and 3 = informal sector).
16. Total household income (1 = low (not above R200 per month); 2 = middle (at least one must earn above R200 p.m. and 3 = high (at least one above R1000 p.m.).
17. Water source (1 = tap inside the house; 2 = tap near house, i.e.<500 metres and 3 = tap far from house, i.e. ≥ 500 metres).
18. Fuel used for cooking (1 = paraffin; 2 = gas and 3 = electricity).
19. Sanitation - excreta disposal facility (0 = unsafe and 1 = safe).
20. Disposal of nappies (0 = unsafe and 1 = safe).
21. Where fruits and vegetables are acquired (1 = street vendors; 2 = supermarket and 3 = rubbish dump).
22. Whether or not the child is fed leftovers during the day (0 = no and 1 = yes).
23. Food storage (1 = fridge; 2 = cupboard and 3 = bucket).
24. Where meals are eaten? (1 = indoors only and 2 = sometimes outdoors).
25. Geophageous child (0 = no and 1 = yes).
26. Distance to the neighbouring dwellings (1 = < 4 metres on average; 2 = 4 –20 metres on average and 3 = > 20 metres on average).

In addition, the following potential explanatory variables were considered for the follow-up 2 survey.

27. Silica found in stool at the time of survey (0 = none; 1 = occasional; 2 = scanty; 3 = +; 4 = + + and 5 = + + +).
28. For *A. lumbricoides* prevalence, whether *A. lumbricoides* was present at baseline. For *T. trichiura* prevalence, whether *T. trichiura* was present at baseline.

Selection of variables was carried out by doing both forward selection and backward elimination and comparing the resulting models. This was done using the statistical program Genstat 5, as this program can carry out stepwise procedures using factors; whereas other packages such as SPSS can only carry out stepwise procedures using variates. The variance ratio for inclusion was set at 4 and for exclusion at 3 to ensure a parsimonious model.

6.5.1.1 Risk factors for prevalence of *A. lumbricoides* and *T. trichiura* infections at baseline and follow-up 2

6.5.1.1.1 The most important risk factors *A. lumbricoides* prevalence at baseline

As has been pointed out, since slum soil characteristics is a "slum level" variable, soil type and slum cannot both be included in the same model. Hence the results will be reported with slum included in the model. Including slum, the most important factors affecting ascariasis prevalence at baseline were found to be: slum, geophageous child, topographical position of the house, father's employment status (job) and number of inhabitants per dwelling. The results are summarised in Tables 6.3 (a-c) with an analysis of deviance, parameter estimates and the predicted prevalences (adjusting for other terms in the model), e.g. the predicted prevalence for a child who eats soil is what would be obtained if there was control for slum, topography, father's job and number of inhabitants per dwelling.

Table 6.3a Predictors of *Ascaris lumbricoides* prevalence at baseline (slum included). d.f. = degrees of freedom, and Dev. = Deviance. n.s = not significant.

Analysis of Deviance (sequential)			
Source	**d.f.**	**Dev.**	***p*- value**
Slum	9	20. 699	0. 014
Geophageous child	1	20. 123	<0. 001
Topography	3	11. 981	0. 007
Father's job	3	6. 188	0. 103
Age-group	2	8. 951	0. 011
Number of inhabitants per dwelling	2	6. 277	0. 043
Residual	877	523. 566	n.s.
Total	**897**	**597. 786**	

Table 6.3b Parameters from fitted models for *A. lumbricoides* prevalence at baseline. Est. = Estimate, S.E. = Standard Error, and OR = Odds Ratio.

Interpreted parameter estimates

Parameter	Est.	S.E.	OR	*p*-value
2. Kennedy Lower	0.663	0.446	1.94	0.139
3. Lusaka	0.297	0.483	1.35	0.536
4. Pemary Ridge	0.745	0.597	2.11	0.214
5. Quarry Road West	1.396	0.654	4.04	0.035
6. Simplace	0.416	0.417	1.52	0.319
7. Briardene	0.420	0.378	1.52	0.269
8. Smithfield	0.400	0.682	1.49	0.556
9. Park Station	-0.252	0.436	0.78	0.563
10.Canaan	1.624	0.528	5.07	0.003
Geophageous child	1.389	0.307	4.01	<0.001
Dwelling built on mid or foot slope	0.392	0.375	1.48	0.300
Dwelling built on valley bottom	0.607	0.392	1.83	0.124
Dwellings built on a flat area	-0.430	0.320	0.65	0.183
Father with formal job	0.266	0.534	1.31	0.618
Father with informal job	0.711	0.279	2.04	0.012
Fatherless child	0.958	0.450	2.61	0.035
5-7 years age-group	0.880	0.306	2.41	0.005
8-10 years age-group	0.213	0.274	1.24	0.437
5-8 inhabitants per dwelling	0.086	0.264	1.09	0.750
More than 9 inhabitants per dwelling	0.909	0.406	2.48	0.027

The most significant risk factors for *Ascaris lumbricoides* infection at baseline are: slum, geophageous child, topographical position of the house, father's employment status (job) and number of inhabitants per dwelling.

Table 6.3c Predicted/adjusted prevalences for *A. lumbricoides* at baseline.

By slum		
	1. Bottlebrush	85%
	2. Kennedy Lower	91%
	3. Lusaka	88%
	4. Pemary Ridge	92%
	5. Quarry Road West	95%
	6. Simplace	89%
	7. Briardene	89%
	8. Smithfield	89%
	9. Park Station	82%
	10. Canaan	96%
By geophagy		
	No	86%
	Yes	96%
By topographical position of the dwelling		
	Crest of hill	89%
	Mid/ foot slope	92%
	Valley bottom	94%
	Flat	85%
By father's job		
	Unemployed	84%
	Formal	87%
	Informal	91%
	No father present	93%
By age-group		
	2 - 4 years	87%
	5 - 7 years	94%
	8 - 10 years	89%
By number of inhabitants per dwelling		
	2 - 4	88%
	5 - 8	89%
	9 or more	94%

Tables 6.3 (a-c) show that at baseline Quarry Road West and Canaan had the highest infection rates whereas Park Station and Bottlebrush had the lowest infection rates. Geophageous behaviour increases prevalence of infection. A child living in a slum on level ground has less chance of being infected than a child living on the valley bottom or mid and foot slope. A child having an unemployed father has less risk of being infected than a child whose father has a job. Children without fathers are the worst infected or are more at risk of geohelminth infection than those who have fathers. The 5-7 years age-group has the highest prevalence of infection and, finally, households which have nine or more inhabitants per dwelling have higher prevalences of *A. lumbricoides*.

For *A. lumbricoides* prevalence at baseline, it can be seen that one difference between slums is the fact that they are built on different soil types; however after adjusting for soil type there are still differences between them, i.e. there are factors apart from soil-type that lead to differences in *Ascaris lumbricoides* prevalence between slums. The contribution of soil type to the differences between slums was then investigated. The results are shown by the analysis of deviance in Tables 6.4 (a-c).

Table 6.4a Analysis of Deviance (sequential) for *A. lumbricoides* prevalence at baseline.

Analysis of Deviance			
Source	**d.f.**	**Dev.**	***p*-value**
Model with slum included	20	74.22	<0.0001
Dropping slum from the model	9	19.22	0.023
Adding soil type to the model	2	7.40	0.025
Residual between	7	11.82	

Table 6.4b Parameters from fitted models for factors affecting *A. lumbricoides* prevalence at baseline. Est. = Estimate; S.E. = Standard error; OR = Odds Ratio.

	Parameter estimates			
Parameter	**Est.**	**S.E.**	**OR**	***p*-value**
Geophageous child	1.372	0.304	3.94	<0.0001
Dwelling built on mid/foot slope	0.410	0.361	1.51	0.257
Dwelling built on valley bottom	0.592	0.383	1.81	0.126
Dwellings built on level ground	-0.394	0.310	0.67	0.207
Father with formal job	0.241	0.521	1.27	0.646
Father with informal job	0.682	0.274	1.98	0.014
Fatherless child	0.981	0.448	2.67	0.030
5-7 years age-group	0.883	0.304	2.42	0.004
8-10 years age-group	0.162	0.269	1.18	0.550
5-8 inhabitants per dwelling	0.112	0.262	1.12	0.668
More than 9 inhabitants per dwelling	1.097	0.403	2.99	0.007
Milkwood soil	0.687	0.271	1.97	0.014
Fernwood & Dundee soil	1.524	0.513	4.59	0.004

Table 6.4c Predicted / adjusted prevalences, for factors affecting *A. lumbricoides* infection at baseline.

By topography	**Topography**	
	Crest	88%
	Mid/ foot slope	92%
	Valley bottom	93%
	Flat	84%
By father's job	**Father's job**	
	Unemployed	84%
	Formal	86%
	Informal	90%
	Father absent	93%
By child geophagy	**Geophageous child**	
	No	85%
	Yes	95%
By age-group	**Age-group**	
	2 - 4 years	86%
	5 - 7 years	88%
	8 - 10 years	95%
By number of inhabitants per dwelling	**Inhabitants per dwelling**	
	2 - 4	87%
	5 - 8	88%
	9 or more	95%

6.5.1.1.2 The most important risk factors for *T. trichiura* prevalence at baseline

As has been pointed out, since slum soil characteristics represent a "slum level" variable, soil type and slum cannot both be included in the same model. Hence the results will be reported with slum included in the model. Including slum, the most important factors affecting trichuriasis prevalence at baseline were found to be: characteristic of slum, age-group, total household income, disposal of nappies, fuel used for cooking, father's occupation, number of inhabitants per dwelling, topographical position of dwelling and where meals are eaten. The results are summarised in Tables 6.5 (a-c).

Slum: Adjusted prevalences ranged from 55% (Kennedy Lower), 62% (Quarry Road West, and 65% (Canaan) through to 83% (Briardene) and 85% (Smithfield).

Age group: *T. trichiura* prevalence seemed to increase with ascending age groups, being lowest in the 2 - 4 year group and highest in the 8 - 10year group.

Father's job: Prevalence was highest for a child with an unemployed father (77%) and lowest when the father is absent.

Household income: The results here are surprising with infection least in the low-income houses and highest in the high-income houses; it should be born in mind that there are only 19 children from high-income houses (of whom 17 were infected with *T. trichiura*).

Nappy disposal: Children whose guardians disposed of nappies safely were at lower risk than those whose guardians did not.

Fuel used for cooking: Prevalence was higher in houses where gas was used than in houses where paraffin or electricity was used.

Number of inhabitants per dwelling: Prevalence was lower in houses with 9 or more inhabitants.

Topographical position of dwelling: Prevalence was highest in children in homes built on mid/foot slope and crest of hill and lowest at homes in the valley bottom.

Where meals are eaten: Prevalence was higher for houses where all meals were taken inside the house.

Table 6.5a Analysis of Deviance (sequential) for *T. trichiura* prevalence at baseline (slum included).

Analysis of Deviance (sequential)

Source	**d.f.**	**Dev.**	***p*-value**
Slum	9	27.71	0.001
Age-group	2	19.11	<0.0001
Household income	2	10.19	0.006
Nappy disposal	1	4.22	0.040
Source of fuel	2	6.77	0.034
Father's job	3	6.48	0.090
Number of inhabitants per dwelling	2	4.87	0.088
Topography	3	8.88	0.031
Where meals are eaten	1	1.96	0.162
Residual	815	906.24	
Total	**840**	**996.44**	

Table 6.5b Parameters from fitted models for factors affecting *T. trichiura* prevalence at baseline. Est. = Estimate; S.E. = Standard error; OR = Odds Ratio.

Parameter estimates

Parameter	Est.	S.E.	OR	p-value
2. Kennedy Lower	-0.913	0.318	0.40	0.005
3. Lusaka	0.352	0.462	1.42	0.449
4. Pemary Ridge	-0.207	0.456	0.81	0.654
5. Quarry Road West	-0.567	0.446	0.57	0.207
6. Simplace	0.203	0.369	1.23	0.583
7. Briardene	0.585	0.354	1.80	0.102
8. Smithfield	0.748	0.702	2.11	0.287
9. Park Station	-0.152	0.452	0.86	0.734
10. Canaan	-0.417	0.352	0.66	0.240
5-7 years	0.567	0.191	1.76	0.004
8-10 years	0.834	0.216	2.30	0.0002
1 member of family earns >R200 p.m.	0.464	0.185	1.59	0.013
1 member of family earns > R1000 p.m.	2.139	0.852	8.49	0.013
Safe nappy disposal	- 0.653	0.284	0.52	0.023
Households that use gas for cooking	1.088	0.379	2.97	0.005
Households that use electricity for cooking	0.149	0.313	1.16	0.632
Father with formal job	- 0.563	0.423	0.57	0.86
Father with informal job	- 0.346	0.229	0.71	0.134
Fatherless child	- 0.920	0.324	0.40	0.005
5-8 inhabitants per dwelling	0.246	0.199	1.28	0.217
9 or more inhabitants per dwelling	-0.331	0.256	0.72	0.200
Dwelling built on crest of hill	0.191	0.300	1.21	0.523
Dwelling built on valley bottom	-0.434	0.287	0.65	0.134
Dwelling built on level ground	-0.336	0.274	0.71	0.221
Those who have meals outdoors	0.495	0.362	1.64	0.104

Table 6.5c Predicted / adjusted prevalences for factors affecting *T. trichiura* infection at baseline for model with soil type.

By Slum	**Slum**	Prevalence
	1. Bottlebrush	73%
	2. Kennedy Lower	55%
	3. Lusaka	79%
	4. Pemary Ridge	70%
	5. Quarry Road West	62%
	6. Simplace	77%
	7. Briardene	83%
	8. Smithfield	85%
	9. Park Station	71%
	10. Canaan	65%
By age-group	**Age-group**	
	2-4 years	64%
	5-7 years	75%
	8-10 years	79%
By father's job	**Father's job**	
	Unemployed	77%
	Formal	67%
	Informal	71%
	No father present	60%
By total household income per month	**Household income**	
	Low	67%
	Middle	75%
	High	93%
By nappy disposal	**Nappy disposal**	
	Unsafe	78%
	Safely	67%
By fuel used for cooking	**Fuel used for cooking**	
	Paraffin	70%
	Gas	86%
	Electricity	73%
By number of inhabitants per dwelling	**Number of inhabitants per dwelling**	
	2-4	71%
	5-8	75%
	9 or more	64%
By topographical position of dwelling	**Topographical position of dwelling**	
	Crest of hill	74%
	Mid or foot slope	77%
	Valley bottom	66%
	Flat	68%
By where meals are eaten	**Where meals are eaten**	
	Indoors	71%
	Outdoors	79%

6.5.1.1.3 The most important risk factors for *A. lumbricoides* prevalence at follow-up 2

Again a model including slum was fitted, after which the effect of soil type on the slum effect was investigated. The most important factors affecting *A. lumbricoides* prevalence at follow-up 2 were found to be slum, water source and the topographical position of the house. The results are summarised in Table 6.6 (a-c) with an analysis of deviance, parameter estimates and predicted prevalences.

Table 6.6a Analysis of Deviance (sequential) for risk factors affecting *A. lumbricoides* reinfection after chemotherapy.

Analysis of Deviance			
Source	**d.f.**	**Dev.**	***p*-value**
Slum soil type	9	221.34	<0.001
Water source	2	14.52	<0.001
Topography	3	8.47	0.037
Residual	898	439.26	
Total	912	683.59	

Table 6.6b Parameters from fitted models for factors affecting *A. lumbricoides* reinfection after chemotherapy. Est. = Estimate; S.E. = Standard error; OR = Odds Ratio.

Parameter estimates				
Parameter	**Est.**	**S.E.**	**OR**	***p*-value**
Kennedy Lower	1.794	0.394	6.01	< 0.001
Lusaka	13.5	16.1	700 000	0.40
Pemary Ridge	11.5	12.5	100 000	0.36
Quarry Road West	5.53	1.69	253	0.001
Simplace	11.04	8.75	62 000	0.207
Briardene	5.31	1.58	200	< 0.001
Smithfield	- 1.704	0.484	0.182	< 0.001
Park Station	11.5	12.7	101 000	0.362
Canaan	11.5	16.1	98 000	0.475
Water near house <500m	10.7	16.1	45 000	0.505
Water far from house >500m	8.8	16.0	6 400	0.585
Dwelling on mid/foot slope	- 0.812	0.339	0.444	0.016
Dwelling on the valley bottom	0.095	0.371	1.10	0.797
Dwelling on a level ground	- 0.068	0.339	0.935	0.842

Table 6.6c Predicted/adjusted prevalences for factors affecting *A. lumbricoides* reinfection after chemotherapy.

By slum	**Slum**	**Prevalence**
	Bottlebrush	40%
	Kennedy Lower	67%
	Lusaka	99%
	Pemary Ridge	97%
	Quarry Road West	84%
	Simplace	95%
	Briardene	84%
	Smithfield	15%
	Park Station	97%
	Canaan	97%
By water source	**Water source**	
	Tap inside house	37%
	Water near house <500m	90%
	Water far from house >500m	77%
By topography	**Topography**	
	Dwelling built on crest of hill	79%
	Dwelling built on mid/foot slope	73%
	Dwelling built on valley bottom	79%
	Dwelling built on level ground	78%

Thus at follow-up 2 the striking feature is the large amount of variability in *A. lumbricoides* between slums, with the predicted prevalences ranging from 15% (Smithfield) to 40% (Bottlebrush) to over 90% (Lusaka, Pemary Ridge, Quarry Road West, Simplace, Park Station and Canaan). The only other factor that seemed important was water source (with prevalence much lower where there was a tap in the house compared to a tap outside house), with slight evidence that prevalence was lower in a dwelling built on mid or foot slope than for other topographies.

Thus there is strong evidence that the differences in prevalences between slums cannot be explained entirely in terms of different soil types, i.e. the different soil types explain only some of the variability in prevalence between slums.

N.B. – As water was largely installed at slum level at follow-up 2, it becomes difficult to disentangle the effect of water source from the effect of the slum.

6.5.1.1.4 The most important risk factors for *T. trichiura* prevalence at follow-up 2

The analysis was done to consider the effect of slum only since soil type was not found to be a predictor of *Trichuris trichiura* infection. The most important risk factors affecting *T. trichiura* prevalence at follow-up 2 were found to be characteristic of the slum (see section 6.5.1), where the child lived before, whether the child was geophageous, the quality of the dwelling, the number of inhabitants per dwelling, whether the parents were geophageous, where food is obtained and whether or not the child was infected with *T. trichiura* at baseline. The results are summarised in Table 6.7 (a-c) with an analysis of deviance, parameter estimates and predicted prevalences.

Table 6.7a Analysis of Deviance for risk factors affecting *T. trichiura* reinfection after chemotherapy.

Analysis of Deviance			
Source	**d.f.**	**Dev.**	***p*-value**
Slum	9	162.20	< 0.001
Origin of child	3	13.29	0.004
Child geophageous behaviour	1	5.71	0.017
Quality of dwelling	2	5.07	0.079
Number of inhabitants per dwelling	2	5.72	0.057
Parent geophageous behaviour	1	1.75	0.186
Source of vegetable and fruit	2	4.88	0.087
T. trichiura infection status at baseline	1	9.15	0.002
Residual	866	855.28	n.s
Total	887	1063.05	

Table 6.7b Parameters from fitted models for factors affecting *T. trichiura* reinfection after chemotherapy. Est. = Estimate; S.E. = Standard error; OR= Odds Ratio.

	Parameter estimates			
Parameter	**Est.**	**S.E.**	**OR**	***p*-value**
Kennedy Lower	- 1.645	0.341	0.193	< 0.001
Lusaka	- 0.067	0.375	0.935	0.858
Pemary Ridge	1.171	0.459	3.225	0.011
Quarry Road West	1.980	0.577	7.241	< 0.001
Simplace	1.214	0.365	3.368	< 0.001
Briardene	1.961	0.447	7.105	< 0.001
Smithfield	0.501	0.563	1.650	0.374
Park Station	- 0.200	0.367	0.819	0.587
Canaan	-0.791	0.342	0.453	0.021
Originate from township	0.129	0.205	1.138	0.527
Originate from another slum	0.058	0.294	1.060	0.843
Originate from rural towns	1.771	0.587	5.877	0.003
Geophageous children	0.285	0.214	1.330	0.182
Mud dwelling	0.414	0.376	1.512	0.272
Mixed material dwelling	0.601	0.249	1.824	0.016
5-8 inhabitants	0.486	0.206	1.626	0.019
9 or more inhabitants	0.289	0.253	1.335	0.253
Geophageous parents	0.358	0.231	1.430	0.122
Fruit & vegetables from supermarket	0.064	0.252	1.066	0.800
Fruit & vegetables from dump	0.647	0.317	1.909	0.042
T. trichiura infected at baseline	0.560	0.184	1.751	0.002

Table 6.7c Predicted / adjusted prevalences for factors affecting *T. trichiura* reinfection after chemotherapy.

		Prevalence
By slum		
	Bottlebrush	70 %
	Kennedy Lower	33 %
	Lusaka	68 %
	Pemary Ridge	88 %
	Quarry Road West	94 %
	Simplace	88 %
	Briardene	94 %
	Smithfield	79 %
	Park Station	65 %
	Canaan	52 %
By where child stayed before		
	Rural	69 %
	Township	71 %
	Another slum	70 %
	Rural towns	91 %
By child geophageous behaviour		
	No	70 %
	Yes	74 %
By quality of dwelling		
	Brick	64 %
	Mud	71 %
	Shack or other	74 %
By no. of inhabitants per dwelling		
	4 or less	67 %
	5-8	75 %
	9 or more	72 %
By Geophageous behaviour of parents		
	No	70 %
	Yes	75 %
By source of fruit & vegetables		
	Street vendors	70 %
	Supermarket	71 %
	Rubbish dump	80 %
By *T. trichiura* infection status	*T. trichiura* not infected at baseline	65 %
	T. trichiura infected at baseline	74 %

It can be seen that there is a wider range of risk factors affecting *T. trichiura* reinfection rates than *A. lumbricoides*. These include:

1. Slum characteristics, with trichuriasis reinfection rate lower at Kennedy Lower and Quarry Heights (new Canaan);
2. Where the child stayed before (*T. trichiura* infection is higher in children who lived previously in rural towns);
3. Geophageous behaviour of the child (infection is higher in children who admit that they eat soil);
4. The quality of the dwelling (with infection lower for children living in brick houses);
5. Number of inhabitants per dwelling (with infection lower for 4 or less people per house);
6. Geophageous mothers (infection is slightly higher for children with geophageous mothers).
7. Source of fruit and vegetables (with infections higher for those children who get food from the dump).
8. *T. trichiura* infection status at baseline (the chance of being reinfected was higher if child was infected at baseline, but there was still a 65% chance of reinfection for those who were not infected at baseline).

6.5.1.2 Risk factors for intensity of *Ascaris lumbricoides* and *Trichuris trichiura* infections at baseline and follow-up 2

6.5.1.2.1 The most important risk factors for *A. lumbricoides* intensity at baseline

In addition to modelling factors that affect the prevalence (presence or absence of *A. lumbricoides* infection in individual children at baseline), models were fitted to the intensity data (conditional on the child being infected). This would investigate factors that caused more (or less) intense infections, but not that (necessarily) predicted infection in the first place. The response variable was log transformed egg counts, and only infected children were included. For *A. lumbricoides* intensity at baseline, the important factors were found to be slum characteristic and child geophageous behaviour. The results are summarised in Table 6.8 (a-c).

Table 6.8a Analysis of Variance (sequential) for factors affecting *Ascaris lumbricoides* intensity at baseline. d.f. = degrees of freedom; SS =Sum of squares; MS = Means sum of squares.

Source	d.f.	SS	MS	F-ratio	*p*- value
		Analysis of Variance			
Slum	9	33.795	3.755	7.88	< 0.001
Geophageous child	1	3.724	3.724	7.82	0.005
Residual	827	393.9736	0.476		
Total	**837**	**431.4929**	**0.516**		

Table 6.8 b Parameters from fitted models for factors affecting *A. lumbricoides* intensity at baseline. Est. = Estimate; S.E. = Standard error.

Parameter	Est.	S.E.	*t*-value	*p*-value
Kennedy Lower	0.116	0.0884	1.31	0.189
Lusaka	0.197	0.108	1.82	0.069
Pemary Ridge	0.262	0.105	2.50	0.013
Quarry Road West	0.597	0.101	5.92	< 0.001
Simplace	0.328	0.0859	3.82	< 0.001
Briardene	0.2985	0.0915	3.26	0.001
Smithfield	- 0.210	0.149	-1.41	0.160
Park Station	- 0.057	0.110	-0.52	0.606
Canaan	0.3904	0.0851	4.51	< 0.001
Geophageous children	0.1395	0.0499	2.80	0.005

Table 6.8c Predicted Geometric Mean (GM) egg intensities, for factors affecting *A. lumbricoides* intensity at baseline.

		Log (egg counts)	*Ascaris* intensity (GM)
By slum			
	Bottlebrush	4.011	10 257
	Kennedy Lower	4.127	13 397
	Lusaka	4.207	16 106
	Pemary Ridge	4.273	18 750
	Quarry Road West	4.608	40 551
	Simplace	4.339	21 827
	Briardene	4.309	20 370
	Smithfield	3.801	6 324
	Park Station	3.954	8 995
	Canaan	4.401	25 177
By geophagy	**Geophageous children**		
	No	4.172	14 859
	Yes	4.312	20 512

Thus there are large differences in intensity of infection between slums, with children from Quarry Road West, Simplace, Briardene and Canaan (old) having the heaviest *A. lumbricoides* infections, and those from Smithfield and Park Station having the lightest infections. In addition, geophageous children on average had higher intensities of infection than children who did not eat soil.

6.5.1.2.2 The most important risk factors for *T. trichiura* intensity at baseline

In addition to modelling factors that affect the prevalence (presence or absence of *Trichuris trichiura* infection in individual children at baseline), models were fitted to the intensity data (conditional on the child being infected). This would investigate factors that caused more (or less) intense infections, but not that (necessarily) predicted infection in the first place. The response variable was log transformed egg counts, and only infected children were included.

For *T. trichiura* intensity at baseline, the important factors were found to be slum, fuel used for cooking, safe excreta disposal, food storage, source of fruit and vegetables, geophageous behaviour of child. The results are summarised in Table 6.9 (a-c).

Table 6.9a Analysis of Variance (sequential) for factors affecting *T. trichiura* intensity at baseline. d.f. = degrees of freedom; SS =Sum of squares; MS = Means sum of squares.

Analysis of Variance					
Source	**d.f.**	**SS**	**MS**	***F*-value**	***p*-value**
Slum	9	13.780	1.531	4.22	<0.001
Fuel used for cooking	2	2.238	1.119	3.08	0.047
Sanitation	1	2.044	2.044	5.63	0.018
Food source	2	3.704	1.852	5.10	0.006
Food storage	2	1.313	0.656	1.81	0.165
Child geophageous	1	0.985	0.985	2.71	0.100
Residual	634	230.189	0.363		
Total	651	254.253			

Table 6.9b Parameters from fitted models for factors affecting *T. trichiura* intensity at baseline. Est. = estimate; S.E. = Standard Error.

Parameter estimates				
Parameter	**Estimate**	**S.E.**	***t*-value**	***p*-value**
Kennedy Lower	- 0.291	0.134	- 2.18	0.030
Lusaka	- 0.040	0.132	- 0.30	0.762
Pemary Ridge	0.080	0.110	0.72	0.472
Quarry Road West	- 0.087	0.115	- 0.76	0.450
Simplace	- 0.103	0.086	- 1.20	0.230
Briardene	- 0.251	0.102	- 2.47	0.014
Smithfield	0.083	0.144	0.58	0.565
Park Station	- 0.432	0.116	- 3.72	< 0.001
Canaan	- 0.397	0.108	- 3.67	< 0.001
Fuel – gas	0.199	0.093	2.15	0.032
Fuel – electricity	0.189	0.091	2.08	0.038
Safe excreta disposal	- 0.142	0.070	- 2.02	0.044
Food stored in cupboard	- 0.0024	0.0732	- 0.03	0.974
Food stored in bucket	0.176	0.089	1.96	0.050
Fruit & vegetables source supermarket	- 0.070	0.071	- 0.99	0.323
Fruit & vegetables source dumping site	0.178	0.120	1.49	0.138
Geophageous children	0.083	0.050	1.65	0.100

Table 6.9c Predicted mean intensities for factors affecting *T. trichiura* intensity at baseline. G.M = Geometric Mean.

		Log egg counts	GM
By slum			
	Bottlebrush	2.892	780
	Kennedy Lower	2.601	399
	Lusaka	2.852	711
	Pemary Ridge	2.971	935
	Quarry Road West	2.804	637
	Simplace	2.788	614
	Briardene	2.640	437
	Smithfield	2.974	942
	Park Station	2.460	288
	Canaan	2.495	313
By fuel used for cooking			
	Paraffin	2.696	497
	Gas	2.895	785
	Electricity	2.886	769
By excreta disposal			
	Unsafe	2.794	622
	Safe	2.652	449
By where food is stored			
	Fridge	2.701	502
	Cupboard	2.699	500
	Bucket	2.877	745
By source of fruit & vegetables			
	Street vendors	2.745	556
	Supermarkets	2.674	472
	Rubbish dumps	2.923	838
By child geophagy			
	Yes	2.709	512
	No	2.792	619

Thus there are large variations in intensities of infection between slums, with children from Pemary Ridge and Smithfield having the heaviest *T. trichiura* infection and those from Park Station, Kennedy Lower and Canaan having the lightest infection.

In addition, there are a number of other important factors, many having to do with general hygiene behaviour and which are thus susceptible to health promotion interventions namely:

1. Fuel for cooking (least severe for paraffin);
2. Excreta disposal (less severe if this is safe);
3. Food storage (more severe for bucket);
4. Fruit and vegetables source (more severe for rubbish dump);
5. Child's geophageous behaviour (more severe if he/she eats soil).

6.5.1.2.3 The most important risk factors for *A. lumbricoides* intensity at follow-up 2

As for baseline, a model was fitted using as the response variable the log of egg counts and only including children who were *A. lumbricoides*-infected. The most important risk factors for ascariasis reinfection were found to be slum and whether or not the child ate leftovers during the day. The results are summarised in table 6.10 (a-c).

Table 6.10a Analysis of Variance (sequential) for factors affecting *A. lumbricoides* reinfection intensity after chemotherapy. d.f. = degrees of freedom; SS =Sum of squares; MS = Means sum of squares

Analysis of Variance					
Source	**d.f.**	**SS**	**MS**	**F- ratio**	***p*-value**
Slum	9	106.495	11.833	40.51	<0.001
Eating leftovers	1	1.267	1.267	4.34	0.038
Residual	784	229.022	0.292		
Total	794	336.785			

Table 6.10b Parameters from fitted models for factors affecting *A. lumbricoides* reinfection intensity. Est. = Estimate; S.E. = Standard Error.

	Parameter estimates			
Parameter	**Estimate**	**S.E.**	**t-value**	***p*-value**
Kennedy Lower	0.700	0.076	9.23	< 0.001
Lusaka	0.209	0.087	2.41	0.016
Pemary Ridge	0.959	0.085	11.31	< 0.001
Quarry Road West	1.000	0.083	12.07	< 0.001
Simplace	1.022	0.071	14.43	< 0.001
Briardene	0.815	0.074	10.94	< 0.001
Smithfield	-0.537	0.211	-2.55	0.011
Park Station	0.601	0.085	7.05	< 0.001
Canaan	0.436	0.075	6.19	< 0.001
Children who is fed leftovers	-0.242	0.116	-2.08	0.038

Table 6.10c Predicted mean intensities for factors affecting *A. lumbricoides* reinfection intensity after chemotherapy.

By slum		**Log (intensity)**	***Ascaris* intensity (GM)**
	Bottlebrush	3.576	3 767
	Kennedy Lower	4.276	18 880
	Lusaka	3.785	6 095
	Pemary Ridge	4.536	34 356
	Quarry Road West	4.576	37 670
	Simplace	4.598	39 628
	Briardene	4.392	24 660
	Smithfield	3.040	1 096
	Park Station	4.177	15 031
	Canaan	4.039	10 940
By child who are fed leftovers			
	No	4.439	27 479
	Yes	4.197	15 740

There is a great deal of variation in intensity of reinfection between slums, with Smithfield, Bottlebrush and Lusaka having the lightest *A. lumbricoides* reinfection intensity and Pemary Ridge, Quarry Road West and Simplace the most severe. The other factors do not seem to affect ascariasis intensity, with the surprising exception of whether or not the child ate leftovers (children who ate leftovers had less severe reinfection).

6.5.1.2.4 The most important risk factors for *T. trichiura* intensity at follow-up 2

As for baseline a model was fitted using as the response variable the log of egg counts and only including those infected individuals. At follow-up 2 the most important factors which affect *T. trichiura* reinfection intensity were found to be slum characteristic, gender, age-group, quality of house, water source and average distance between dwellings. The results are summarised in Table 6.11 (a-c).

Table 6.11a Analysis of Variance (sequential) for factors affecting *T. trichiura* reinfection intensity after chemotherapy. d.f. = degrees of freedom; SS =Sum of squares; MS = Means sum of squares

Analysis of Variance

Source	d.f.	SS	MS	F-ratio	*p*-value
Slum	9	78.556	8.728	25.13	< 0.001
Sex of child	1	1.272	1.272	3.66	0.056
Age-group	2	1.596	0.798	2.30	0.101
Quality of house	2	1.941	0.971	2.79	0.062
Water source	2	1.706	0.853	2.46	0.087
Average inter-house distance	2	1.573	0.787	2.26	0.105
Residual	629	218.509	0.347		
Total	647	305.153			

Table 6.11b Parameters from fitted models for factors affecting *T. trichiura* reinfection intensity after chemotherapy. Est. = estimate; S.E. = Standard Error.

Parameter estimates

Parameter	**Estimate**	**S.E.**	***t*-value**	***p*-value**
Kennedy Lower	-0.093	0.108	-0.86	0.391
Lusaka	0.758	0.204	3.72	< 0.001
Pemary Ridge	0.783	0.131	5.99	< 0.001
Quarry Road West	0.970	0.136	7.15	< 0.001
Simplace	0.701	0.109	6.42	< 0.001
Briardene	0.823	0.107	7.67	< 0.001
Smithfield	0.658	0.140	4.72	< 0.001
Park Station	0.777	0.137	5.67	< 0.001
Canaan	0.457	0.165	2.77	0.006
Males	-0.084	0.047	-1.80	0.072
5 - 7 years	0.032	0.055	0.57	0.568
8 - 10 years	0.138	0.059	2.36	0.019
Mud houses	-0.059	0.110	-0.54	0.591
Shacks and mixed material dwellings	0.105	0.075	1.41	0.160
Tap near house < 500m	0.401	0.167	2.40	0.017
Tap far from house > 500m	0.416	0.163	2.55	0.011
Average inter-house distance <4metres	0.151	0.073	2.06	0.039
Average inter-house distance > 20 metres	0.171	0.100	1.71	0.088

Table 6.11c Predicted trichuriasis intensities for factors affecting *T. trichiura* reinfection intensity after chemotherapy. GM = Geometric mean.

By slum		Log (intensity)	*Trichuris* intensity(GM)
	Bottlebrush	2.722	527
	Kennedy Lower	2.629	426
	Lusaka	3.480	3 020
	Pemary Ridge	3.505	3 199
	Quarry Road West	3.692	4 920
	Simplace	3.423	2 649
	Briardene	3.545	3 508
	Smithfield	3.381	2 404
	Park Station	3.499	3 155
	Canaan	3.179	1 510
By sex			
	Female	3. 325	2 118
	Male	3. 241	1 742
By age-group			
	2 - 4 years	3. 238	1 730
	5 - 7 years	3. 269	1 858
	8 - 10 years	3. 376	2 377
By quality of dwelling			
	Brick	3. 215	1 641
	Mud	3. 156	1 432
	Shack or mixed material	3. 320	2 089
By water source			
	Inside house	2. 922	836
	Near house < 500m	3. 323	2 104
	Far from house > 500m	3. 338	2 178
House crowding			
	< 4 metres	3. 172	1 486
	4 - 20 metres	3. 323	2 104
	> 20 metres	3. 343	2 203

Again there is a great deal of variation between slums with Quarry Road West and Briardene having the heaviest intensities and Bottlebrush and Kennedy Lower having the lightest intensities. There are a number of others factors that influence trichuriasis intensity, such as:

1. Sex of child (females were more heavily infected than males);
2. Age-group (the <5 years old children had the most number of light intensities);
3. House quality (children living in shacks and dwellings build of mixed material were more heavily infected than those living in formal housing);
4. Water source (children with taps inside their houses had lighter intensities than those with taps <500m and >500m from the house) and
5. House crowding (trichuriasis reinfection intensity was lightest for children living in the most crowded households).

CHAPTER 7

Smithfield: showing low housing density and has, i.e. >20m average distance between dwellings. It also has 77% sanitation coverage.

7

GENERAL DISCUSSION

7.1 INTRODUCTION

At the start of this general discussion it is necessary to point out that there were several limitations on this study which might have influenced interpretation of the results. These were as follows:

1. It was assumed that conditions in the slums would remain stable. Instead there were continual changes in infrastructure in some slums in terms of basic parameters such as sanitation, water supply, housing and population density. This made it difficult to correlate reinfection rates with risk factors in these slums.
2. Initially slums were stratified according to sanitation coverage but this changed in some cases as described in Chapter 3. The quality of sanitation was also overlooked.
3. The uncontrolled influx of new children, many of whom were infected but excluded from the analysis, made it difficult to define the main source of new infections.
4. Stoppages of water supply and refuse removal, and removal of toilets because of mismanagement of payment of service accounts, relocation to new areas, *in-situ* upgrading and the effect of floods and fires all added to the difficulty of determining to what extent the environmental risk factors affected transmission.

The results of this study show that with few exceptions, the aspects mentioned above, varied in a consistent manner between slums whose principal differences were their levels of sanitation, soil type and housing density. For instance, changes in (i) immigration (ii) quality of sanitation and coverage, (iii) *in-situ* upgrading and (iv) relocation to new areas, all had an effect on the transmission potential of geohelminths. The constant influx of migrants and immigrants coming with new infections, together with increases in household sizes and numbers increased the likelihood of transmission. Children have been shown to be responsible for the dissemination of geohelminth infections and were also the main source of reinfection. Some newcomers to the communities were also found to be heavily infected.

In this chapter the following aspects of epidemiology of the three geohelminths in the Durban study slums will be considered:

1. Prevalence of geohelminth infections;
2. Intensity of geohelminth infections;
3. Chemotherapy;
4. Predisposition to geohelminth infection after chemotherapy;
5. Risk factors for geohelminth infection;
6. Statistical models for *A. lumbricoides* and *T. trichiura* infection and reinfection.

7.2 PREVALENCE OF GEOHELMINTH INFECTIONS

The prevalence and intensity of *A. lumbricoides* and *T. trichiura* infection in the study population show that these nematodes are highly endemic in the slum areas of Durban. During the two-year study period, ascariasis prevalence ranged from 82.9% - 100% and trichuriasis from 54.5% - 95.1%. This confirms the results of the only two other surveys previously conducted in Durban slums. The first study on geohelminths dates back to 1952 when Eldson-Dew & Freedman found that the prevalences of ascariasis and trichuriasis in adult black migrant labourers (males only) from rural South Africa who came to work in Durban city and lived in the overcrowded Cato Crest slum doubled to 50.8% and 61.9% respectively within two years. The second study was conducted at Besters where Coutsoudis *et al.*(1994) found that 91% of the children had parasites: 61% had *T. trichiura* and 59% had *A. lumbricoides*, hookworm was not recorded. They did not measure intensities.

Over the study period the prevalence of *T. trichiura* remained high in all slums but its intensity declined. Transmission potential of this parasite was homogeneous. The prevalence of *A. lumbricoides* remained high in some slums but low in others so that the transmission potential was clustered (heterogeneous). In the slum Lusaka for instance, the prevalence of both parasites remained high even after the introduction of flush toilets, but the intensity (of both) declined. At Briardene the topsoil was removed (and presumably helminth eggs as well) as part of *in-situ* upgrading operations, but the flush toilets had no water, hence prevalences remained high. Smithfield with high sanitation coverage and low housing density (see Chapter 7 title-page), had the lowest *A. lumbricoides* reinfection rates, although the reinfection prevalence of *T. trichiura* was high in this slum.

Prevalence, intensity of infection and reinfection rates were high in all children living at Quarry Road West, Pemary Ridge and Simplace. These three slums had the worst sanitary conditions, either because of a lack of community sanitation giving very low sanitation coverage or very crowded conditions, and they were always affected by flooding.

At follow-up 2, *A. lumbricoides* prevalence and intensity exceeded the pre-treatment levels in four slums (Pemary Ridge, Quarry Road West, Simplace and Park Station). This was due to the dramatic increase in population densities in these slums. *A. lumbricoides* prevalences decreased at Smithfield, Bottlebrush, Lusaka and Canaan to less than pre-treatment levels. Prevalences reached the pre-treatment level at Kennedy Lower and Briardene.

In the present study, hookworm prevalences were very low (average 4.7%) and it was not reported at Besters at all by Coutsoudis *et al.* (1994). By way of contrast other epidemiological surveys conducted in KwaZulu-Natal found the following average hookworm prevalences: 37.2% (Schutte *et al.*, 1981); 30.8% (Appleton & Gouws, 1996); 45.0% (Mabaso, 1999), 11.6 - 88.2 % (Appleton *et al.*, 1999) and 90.0% (Saathoff, 2001).

Of the three geohelminths of concern in this study, *A. lumbricoides* was the most interesting because: (i) it was the most prevalent (>80.0%) in all slums at baseline, (ii) it responded well to treatment, (iii) it showed greater morbidity than the other two and (iv) slum communities knew about it. Several factors might have contributed to the high endemicity of *A. lumbricoides* and *T. trichiura*, viz.:

1. The study slums lie below 300m a.s.l. They therefore experience high temperatures and relative humidities and these are favourable for rapid development of the larval stages.
2. The absence of frost in the study area.
3. The most common soil types, Milkwood and Cartref, have poor drainage.
4. Most of these slums are built in shaded areas and the houses are built close together which provides additional shade for the eggs developing in the soil.

7.3 INTENSITY OF GEOHELMINTH INFECTIONS

This study acknowledges that worm fecundity is related to worm density in a non-linear manner (Anderson & May, 1992; Bradley *et al.*, 1992) and therefore the worm expulsion method is a more reliable method of measuring parasite intensity than egg counts. But it was found to be logistically difficult to carry out, particularly since large samples were involved. It is tedious and unpleasant. Moreover, there are difficulties in recovering small and immature worms from faeces. Instead this study measured the intensity of geohelminth infections indirectly as eggs per gram of faeces (e.p.g.).

Analysis of the frequency distribution of *A. lumbricoides* and *T. trichiura* intensities of infection showed that egg distributions were highly aggregated. Many children in this study had light infections and only few had heavy infections, a common finding (Croll & Ghadirian, 1981; Croll *et al.*, 1982; Bundy *et al.*, 1985; Haswell-Elkins, *et al.*, 1987; Chandiwana, *et al.*, 1989; Crompton *et al.*, 1989; Holland *et al.*, 1989; Thein *et al.*, 1991; Chan *et al.*, 1992; Chan *et al.*, 1994b; Bundy & Cooper, 1993; Anderson & May 1992). This was clearly shown by *A. lumbricoides* infection in Smithfield where one child (3.5%) of the 29 children voided more than 50 000 e.p.g. while the majority had light to moderate infections (Appendix C, Table 4). When data were pooled, 3.4% (32/947) of the total population had egg counts above 100 000 e.p.g. while the majority of the children had light to moderate infections at follow-up 2 survey. The results show that a greater proportion of children heavily infected with *A. lumbricoides* and *T. trichiura* before treatment, tended to become heavily reinfected and therefore, seem to be predisposed to this state. These results are in agreement with studies on *A. lumbricoides* and *T. trichiura* reported from different countries (Anderson & Medley, 1985; Schad and Anderson, 1985; Bundy *et al.*, 1987; Haswell-Elkins *et al.*, 1987; Thein-Hlaing *et al.* 1987; Kan *et al.*, 1982, 1984, 1989; Holland *et al.*, 1989; Forrester *et al.*, 1990, Chan *et al.*, 1992; Hall *et al.*, 1992; Chan *et al.*, 1994; Albonico *et al.*, 1994,1995). The factors responsible for predisposition to heavy infection rates are still unknown but growing evidence suggests that they may include spatial, behavioural, genetic and socio-economic factors (Schad & Anderson, 1985; Bundy *et al.*, 1987; Anderson & May, 1992).

Low intensities of both *A. lumbricoides* and *T. trichiura* infections at Lusaka, Briardene, Canaan; Bottlebrush and Smithfield slums, might be attributed to a decrease in the number of eggs in the environment due to the removal of topsoil (and presumably helminth eggs as well) as part of *in-situ* upgrading. Additional factors could be the introduction of water-borne sewage, relocation, high sanitation coverage and low housing density.

7.4 DRUG EFFICACY (CHEMOTHERAPY)

Targeted chemotherapy has been shown to achieve an overall reduction in the prevalence and intensity of *A. lumbricoides* and *T. trichiura* in children aged 2-15 years at one-fifth of the drug's purchase cost for mass chemotherapy (Misra, *et al.*, 1985; Maisonneuve *et al.*, 1985; Crompton, *et al.*, 1989; Bundy *et al.*, 1990; Guyatt *et al.*, 1993, 1995). On the other hand *T. trichiura* is well known to be tolerant to benzimidazole drugs (Jongsuksuntigul *et al.*, 1991). The mass treatment of rural school children in KwaZulu-Natal, i.e. a series of five treatments at 400mg single dose oral Albendazole at intervals of four months (Evans *et al.*, 1997), resulted in the prevalence of *T. trichiura* decreasing from 25% to 8%, and egg counts per gram of stool (G.M.) decreased from 295 e.p.g. to 1 e.p.g. For *A. lumbricoides,* prevalences decreased from 7% to 0.5% and eggs were effectively eliminated from stool. Hookworm was not detected after first treatment and prevalence was only 4% before treatment. In Maputaland (Saathoff, 2001), *A. lumbricoides* baseline prevalence vs. reinfection survey five months post-treatment was 23% vs. 4% and intensity counts (G.M.) were 2716 e.p.g. vs. 172 e.p.g. *T. trichiura* prevalences were 59% vs. 53% and intensity counts 336 e.p.g. vs. 251 e.p.g. respectively. Hookworm prevalences were 83% vs. 25% and intensity counts 1040 e.p.g. vs. 179 e.p.g. In the present study, *A. lumbricoides* baseline prevalence vs. follow-up 1 survey 4½ to 6 months post-treatment was 89.2% vs. 64% and intensity counts were 5 888 e.p.g. vs. 188 e.p.g. *Trichuris trichiura* prevalences were 71.6% vs. 43.6% and intensity counts 91 e.p.g. vs. 12 e.p.g. respectively. *A. lumbricoides* baseline prevalence vs. follow-up 2 survey 12 months post-treatment was 89.2% vs. 87.5% and intensity counts were 5 888 e.p.g. vs. 4834 e.p.g.. *T. trichiura* prevalences were 71.6% vs. 70.7% and intensity counts 91 e.p.g. vs. 212 e.p.g. respectively.

7.5 PREDISPOSITION TO GEOHELMINTH INFECTIONS AFTER TREATMENT

In this study greater variation between prevalences in slums was observed at follow-up 1 and follow-up 2 than at baseline. The effect of the chemotherapy showed a different characteristic in each of the 10 study slums. They had either low reinfection rates 12 months post-treatment (e.g. Smithfield) (Group I), moderate reinfection rates (e.g. Bottlebrush, Kennedy Lower, Lusaka, Canaan and Briardene) (Group II) or high reinfection rates (e.g. Pemary Ridge, Quarry Road West, Simplace and Park Station) (Group III), suggesting that characteristics of individual slums played an important role in determining the success of the helminth control measures.

Morbidity produced by geohelminths in the Durban slums varied greatly from one slum to another. The reasons for this may have been the differences in intensity of geohelminth infections and /or association of geohelminth infection with other parasites and diseases (such as bilharzia, TB, different degrees of malnutrition, anaemia, HIV/AIDS and other nutritional deficiencies/disorders). In addition interventions such as poor sanitation, maintenance of V.I.P. latrines and use thereof, as well as housing density, constantly exposing certain children to the high densities of infective eggs which were already there before treatment. The constant influx of new people bringing new infections was a complicating factor.

There were three distinct trends in transmission rate in terms of the prevalence and intensity of reinfection in the 10 study areas. These were categorized in terms of the "rate of infection" as defined by Anderson & May (1992), i.e. the per capita rate at which individuals acquire parasites. The trends are:

7.5.1 High rate of infection (Group I)

A situation where the average prevalence of the whole population was above 60.0% before treatment and above 50.0% at follow-up 1, and almost 100.0% at follow-up 2, with a heavy intensity of infection in certain individuals, and the likelihood that there is constant exposure to large numbers of infective geohelminth eggs already in the environment. In these slums the ascariasis and trichuriasis infections were distributed homogeneously. The prevalence at follow-up 1 at Pemary Ridge and Quarry Road West was 100.0% and 2.0% of the children in these slums were voiding more than 100 000 e.p.g. to the environment. The prevalence at follow-up 2 exceeded baseline at Pemary Ridge, Simplace, Quarry Road West and Park Station (all 100%). The number of shacks built at Quarry Road West increased three-fold in just 12 months. Pemary Ridge and Quarry Road West had the poorest sanitation and all the pit-latrines had been washed away by floods earlier in the year. The increase in prevalence at Simplace at follow-up 2 might have been due to the increase in the numbers of shacks and people.

7.5.2 Moderate rate of infection (Group II)

A situation where the average prevalence of ascariasis was below 50.0% at follow-up 1 but above 60% at follow-up 2. Examples were slums with VIP toilets, i.e. Bottlebrush (100% coverage, well maintained) and Kennedy Lower (70% coverage but not fully maintained). Lusaka and Briardene both underwent *in-situ* upgrading. Seventy five percent of families in Canaan were relocated to Quarry Heights where houses had flush toilets. It is suggested that improvements in sanitation and removal of topsoil during upgrading had the effect of reducing the numbers of eggs in the environment. Furthermore, newcomers might have been introducing new infections because they had not been treated and children still practiced indiscriminate defaecation. It was observed that mothers and other adults still saw no harm in their children

CHAPTER 3

Slum areas within the Durban Metropolitan Area: Canaan **(10)**, Kennedy Lower **(2)** and Quarry Road West **(5)**.

defecating outside. For instance, in Quarry Heights where people had to buy water for toilet use, it was mostly the adults who used flush toilets and the children used the surrounding bush. In slums which were upgraded and given better sanitation coverage, the intensity of infection was very low when compared to baseline intensities despite infrastructure being similar to those with a high force of infection.

7.5.3 Low rate of transmission (Group III)

A situation where the prevalence of *A. lumbricoides* was less than 50.0% at follow-up 1 and also at follow-up 2. It seems that *A. lumbricoides* infection here has a focal distribution (perhaps familial) which was related to lower crowding (Chapter 7 title-page) and to certain behavioural practices. There were very few children below 5 years old at Smithfield. It has been observed in other studies that the presence of children <5 years in a family can increase the risk of *Ascaris lumbricoides* infection by 2.7 times (Olsen, 1999). In spite of the low *A. lumbricoides* reinfection rate in Smithfield, *T. trichiura* prevalence remained high which suggests that the transmission potential for the two parasites might be different though they may use the same route of infection. In this slum *A. lumbricoides* showed heterogeneous transmission in both domestic and public domains while *T. trichiura* showed homogeneous transmission in public domain only. This supports earlier conclusions by Killewo *et al*., (1991) that hookworm in Tanzanian urban slums was transmitted from the public domain and *A. lumbricoides* from the domestic domain. The terms "domestic domain" and "public domain" were coined by Cairncross *et al*., (1996) to describe the distinction between the transmission of infectious diseases within the area normally occupied by and under the control of a household (domestic domain), and in public places of work, schooling, commerce, recreation, streets and field (public domain).

Thus classification of force of infection can be used to target interventions as follows:

1. Those slums with high force of infection need 2X treatment per year
2. Those slums with moderate force of infection need 1X treatment per year
3. Those slums with low force of infection need selective treatment each year

Clustering of intestinal helminth infections by household is a well-known phenomenon. Indeed, Cort *et al*., (1929) concluded from their studies that the family, and not the individual, should be considered the unit of infection. What is new in this study is that in Smithfield, 25.0% of the reinfected children had ascariasis infection at follow-up 2, whereas trichuriasis infection was

81.5% in the same slum, suggesting that although the two parasites have similar modes of transmission, *A. lumbricoides* might be transmitted from the family domain whereas *T. trichiura* might be transmitted from the public domain.

There are two ways in which the environmental transmission of these geohelminths could produce a pattern of infection clustered by household. First, a substantial amount of transmission could be occurring within the home, from one member to another. Second, depending on the characteristics of some households (for example, in a household living beside a defaecation area), the cases of infection are likely to be clustered in such a household in a non-random way.

Whichever is the primary cause of the household clustering of infections, i.e. intra- or inter-household transmission, the conclusion is the same; that in the communities which lack sanitation and are overpopulated with very high housing densities, most transmission is unaffected by the characteristics of the household itself. This constant exposure to infection has been substantially reduced in communities which live in less crowded conditions and have high sanitation coverage, with proper toilets that can be used by children.

Anderson and May (1992) pointed out that predisposition to reinfection may have its origins in either variations in host susceptibility or in repeated exposure. Such predisposition has been shown here to be largely dependent on environmental conditions. The high degree of predisposition to reinfection encountered in the communities with improved sanitation, must therefore be explained largely in terms of the environmental conditions in which the child and his/her household lives. This may refer (i) to environmental or personal hygiene in general or (ii) to the degree in which the household environment has remained contaminated with infective eggs, or larvae excreted before treatment, or introduced by non-study participants or newcomers.

The second point, of course, cannot account for the association found between infections with different species of geohelminth in the same children. Moreover, the lack of interaction between species found in two studies (Croll & Ghadirian, 1981; Olsen *et al.*, 2000) implies that there is no biological factor intrinsic either to the host or the parasites, which would account for it. Rather, the fact that the environment of certain households in overcrowded slums renders them far more exposed to faecal contamination than others, is the explanation supported in this study. The tendency for the interaction to be stronger in neighbourhoods with better sanitation (properly maintained V.I.P. latrines, chemical toilets and properly built toilets), only underlines the environmental explanation and confirms the public/domestic transmission paradigm used above.

7.6 MULTIPLE GEOHELMINTH INFECTIONS

Ascaris lumbricoides and *Trichuris trichiura*, the two most prevalent soil-transmitted helminth infections in the study slums, are among the most common infections in the world, and each has been estimated to infect between one-sixth and one-quarter of the world's population (Stephenson & Holland, 1987). These infections often occur together in the same communities and in the same people. The same observations have been found in this study as 66.4% of the children at baseline, 29.6% at follow-up 1 and 60.4% at follow-up 2 were infected with both parasites. Almost 4% of the children had more than three intestinal parasites other than geohelminths (see section 5.6).

7.7 THE RURAL VS. URBAN GEOHELMINTH PROBLEM IN KWAZULU-NATAL

Data on geohelminth infection in rural KwaZulu-Natal show that the prevalences of *A. lumbricoides* and *T. trichiura* are often high (see Chapter 1). *N. americanus* on the other hand, has shown a clear decrease in prevalence from north to south, from 88.2% close to the Mozambique border to 42% at Bashise, near the Eastern Cape border (Appleton *et al.*, 1999). Saathoff (2001) has recorded a hookworm prevalence above 83% in Maputaland, north-eastern KwaZulu-Natal. The low prevalence of hookworm in the Durban slums might be attributed to the following:

1. This study was conducted in children (2-10 years old), whereas hookworm infections are more common in 15 - 40 age groups (Anderson & Schad, 1985; Haswell-Elkins *et al.*, 1988; Bradley *et al.*, 1992). Guyatt *et al.*, (1990) and Bundy *et al.* (1991) reported that peak intensities of *A. lumbricoides* and *T. trichiura* occurred in children under 10 years of age and of hookworm in adults over 20 years of age.
2. The soil type might not have been conducive for development of the infective stage larvae. In other words the few cases seen might have been imported.
3. At the start of the project, laboratory assistants may have reported light infections as false negatives because of lack of experience or because they did not always examine Kato-Katz preparations within ½ - 1 hr of being made.

4. Because of its low force of infection, hookworm did not reappear during the follow-up surveys.

7.7.1 Global slum prevalences and worm burden

The high prevalences and heavy intensities of *A. lumbricoides* in urban slums observed in Durban are comparable to those reported from other endemic regions of the world. These include Mexico (Forrester *et al.*, 1988), Iran (Arfaa & Ghadirian, 1977; Croll *et al.*, 1982), South Korea (Seo, 1990), Bangladesh (Tanner *et al.*, 1986; Holland *et al.*, 1988), Myanmar (Burma) (Thein-Hlaing *et al.,* 1984, 1987), St Lucia (Bundy, *et al.*, 1987, 1988), India (Gupta, 1985; Sorenson *et al.*, 1996), the Phillipines (Garcia *et al.*, 1961; Cabrera, *et al.*, 1975; Monzon,1991), Malaysia (Kan, 1982, 1984, 1985a, 1985b; Kan *et al*, 1989; Chan, 1991; Kan *et al*, 1991) Papua New Guinea (Pritchad *et al.*, 1990), Nigeria, (Holland *et al.*, 1989) and Thailand (Ittiravivongs *et al.*, 1992).

The present study in South Africa measured the reinfection rates of *A. lumbricoides*, *T. trichiura* and hookworm. These reinfection rates were comparable to those reported for *Ascaris lumbricoides* in India and Papua New Guinea where prevalence reached pre-treatment levels after four months respectively (Pritchard *et al.*, 1990).

7.8 RISK FACTORS FOR GEOHELMINTH INFECTIONS

Risk factors became more numerous and more significant, particularly for *A. lumbricoides* and *T. trichiura*, because 10 different study slums were compared. Important differences existed between *A. lumbricoides* and *T. trichiura*, both in terms of risk factors and in reinfection rates. These features also varied significantly between different slums and were attributed to variation in slum environment. Important risk factors were water source, sanitation, and topography of the slum. Although changes in slum environment over time (during the study) prevented firm conclusions from being reached, they highlighted the vital importance of the slum environment in determining overall transmission patterns.

7.8.1 Biological risk factors

7.8.1.1 Age and sex of child

The age distribution of *A. lumbricoides* infections followed the patterns reported by other authors, i.e. from infancy to a peak at age 5 -10 years (Elkins *et al.*, 1986; Bundy *et al.*, 1987, Forrester *et al.*, 1988; Chandiwana *et al.*, 1989; Upatham *et al.*, 1992), which suggest different behavioural patterns or varying exposure to infection in different age-groups.

The prevalence of ascariasis and trichuriasis among males and females did not differ significantly, suggesting that the two sexes were equally exposed to an environment contaminated by approximately the same numbers of eggs (Elkins *et al.*, 1986).

The increased significance of the characteristics of individual children on reinfection implies that background transmission (i.e. transmission that occurs due to the viable eggs already there before the intervention was introduced), which had not been controlled before, depends more on slum characteristics than on the component which has been interrupted by chemotherapy, i.e. *in-situ* upgrading, relocation or improved sanitation facilities. With the exception of a child's age and sex, the risk factors found are in fact all characteristics of the household, rather than the individual. If residual transmission was more dependent on household characteristics, it would follow that relatively more of it should occur within or close to the household environment, rather than in the public domain.

Why slum-dwelling children are the most frequently and heavily affected

Open sites in the study slums that were used by children for play and sport, are often contaminated with faecal matter. The increase in mobility of infants as they learn to crawl and then to walk, and their natural curiosity to explore, exposes them to many environmental hazards, especially where space and facilities are lacking, both indoors and outdoors. For example, in poor and overcrowded dwellings it is difficult to keep household chemicals, e.g. bleach, out of their reach. Where provision for safe play-sites is lacking, children play on the roads, garbage tips and other contaminated places. Here, as with many environmental problems, the level of risk is usually compounded by social factors such as lack of adult supervision because most adults have to work during the day. Adolescents and adults seldom have direct contact in these surfaces.

7.8.1 Environmental risk factors

7.8.1.1 Soil conditions

Sand grains are larger and heavier than *A. lumbricoides* eggs, and the colloidal elements of soil (clay) are lighter. Silt particles have about the same size and density as the eggs of *A. lumbricoides*. Therefore, when sand, coarse silt, medium-sized silt, helminth eggs, fine silt, and clay are all suspended together in water, as they are during and immediately after heavy rain, these different particles settle in strata in the order listed (Beaver, 1975). This sedimentation sequence puts the *A. lumbricoides* eggs under a blanket of clay and fine silt which protects them from solar radiation and desiccation. Lying near the surface, they develop rapidly to the infective stage and are readily picked up by geophageous children or adults, or transported to favourable locations, e.g. in food or water, to be swallowed by others.

7.8.1.2 Survival of geohelminths eggs in the soil

The survival of *A. lumbricoides* eggs is determined by the combined effects of ecological and climatic factors such as high rainfall (washing out by heavy rain), environmental temperatures between 20 - 30°C, altitude, high relative humidity and hygroscopic soils. *Ascaris lumbricoides* eggs lie dormant in dry conditions while *T. trichiura* eggs are much less resistant to desiccation. The nature of the soil is known to influence the maturation of the eggs; those deposited on clay surviving better than those on sandy soil (Beaver, 1975; Storey & Phillips, 1985; Ratard *et al.*, 1991). The resistance capacity of *A. lumbricoides* eggs has a profound influence on the epidemiology of this parasite. This is because the ascaroside layer of the egg shell makes it possible for the eggs to remain viable for extended periods, reportedly up to 10 years (Crompton *et al.*, 1985). In damp soil, temperature affects the length of embryo development, from 3 weeks at 36°C to 2 to 4 months at an optimum of 25°C. The minimum time required for complete development in the egg at 28°C is 18 days (Maung, 1973).

7.8.1.3 Rainfall

The amount of precipitation and the pattern of its seasonal distribution is also a basic factor influencing transmission. Rainfall not only provides essential moisture but also redistributes eggs both horizontally and vertically. Horizontal transport spreads the eggs over wide areas but it also tends to concentrate helminth eggs wherever puddles are formed (Prost, 1987). Vertical transport occurs when heavy rains wash eggs down valleys in areas built on steep slopes

(Pawlowski, 1987). Splashes of raindrops can deposit eggs on surfaces 30cm above ground level (Beaver 1952). Local topographical and climatic conditions can therefore exacerbate problems where, during heavy rain, water can wash eggs off hilltops so that they can accumulate lower down, trapped within the valley below. The erosion of the topsoil layer by heavy rain and subsequent sedimentation, further concentrates the eggs in soil along paths and children's play areas. The effect of ongoing erosion of the river banks as a result of flooding at Quarry Road West and Pemary Ridge, probably intensified the spread of infective eggs in the domestic environment in these slums.

7.8.2 Socio-cultural risk factors

7.8.3.1 Geophagy

Only three studies in Africa have looked at the association between geophagy and increased risk of infection with *A. lumbricoides* and *T. trichiura.* Geophageous children were getting re-infected with these nematodes at a considerably higher rate and at higher intensities than non-geophageous children. For example in Kenya, 77% of children (Geissler *et al.*, 1998a), Maputaland 69% (Saattoff, 2001) and in this study 87.6% for *A. lumbricoides* and 71.5% for *T. trichiura*, had silica in their stools. The mean prevalence of ascariasis in geophageous and non-geophageous children in Kenya was 15.8% vs. 8.7% and the intensity was 776 e.p.g. vs. 95 e.p.g. (Geissler, 1998a). In Maputaland (South Africa) the levels were 85.7% vs. 74.4% and 2716 e.p.g. vs. 172 e.p.g. respectively (Saattoff, 2001). In this study the figures were 95.3% vs. 86.3% and 13 210 e.p.g. vs. 3 901 e.p.g. The children (>5 years old) were very selective with respect to the kind of soil they preferred. Children younger than five years old could not give reliable answers as to why, and what kind of soil they chose. Geophageous mothers and friends had a great influence in children's soil eating habits. Children easily contaminated soils in slums because of a lack of latrine use and lack of space between houses, to build latrines. Furthermore toilets were badly designed for child use and in some slums there was actually no space to build them. From observations in this study, it seems that the conscious choice of specific soil types failed to protect children from contamination.

Geophagy might be one of the leading factors in the transmission of *A. lumbricoides* and *T. trichiura.* More studies in other provinces in South Africa should be conducted to provide comparative evidence on geophagy in all the age groups involved. In future studies, the viability of eggs excreted under different climatic conditions should be determined, and the transmission of other intestinal helminth and protozoan infections included.

7.8.3.2 Association between geophagy and geohelminth infection

The results of the reinfection data lend further support to a causal relationship between geophagy, crowding and geohelminth infection, in that it could be shown that consumption of soil was a major factor contributing to reinfection with *A. lumbricoides*. That the highest intensities of reinfection were associated with geophagy, supports the hypothesis that geophagy contributes to the overdispersed distribution of geohelminth infection in slum communities.

The lower intensities of *T. trichiura* at follow-up 2 could be explained by higher sensitivity to desiccation of the eggs of this parasite when compared to those of *A. lumbricoides,* reducing the soil contamination with infective eggs and thus also the transmission potential of geophagy for *T. trichiura*. The absence of eggs, however, from the soil samples, in spite of the similar specific weights of the eggs of both geohelminths (Wong & Bundy, 1990, 1991), could indicate that some other mechanism is preventing the eggs of *T. trichiura* from being distributed in the same way as those of *A. lumbricoides*. One explanation could be the difference in the number of eggs excreted by the two nematodes exacerbated by the effect of shade. For example, *T. trichiura* had a heavy intensity (>20 000 e.p.g.), in 29.7% of children at Pemary Ridge (built in a forest). This was higher than at Quarry Road West (not built in a forest but shading provided by crowded dwellings, although their prevalences were similar (100%). Another explanation might be also be that the eggs of *T. trichiura* are more easily distributed by rain as they lack the sticky albumin coat found on the surface of *A. lumbricoides* eggs which attaches the latter to the soil particles (Crompton *et al.,* 1989). Further micro-epidemiological studies of possible reservoir hosts, insect activities, and human behaviour are required to understand the interplay of these different factors. For example, Evans (1988) found that the activities of dung beetles played an important role in the dissemination of hookworm eggs in the soil.

7.8.4 Socio-economic risk factors

7.8.4.1 Sanitation and house crowding

The physical consequences of high housing density can influence geohelminth transmission, as shown at Quarry Road West, Simplace, Canaan, and Pemary Ridge, where there was not enough space to build toilets. Excreta disposal facilities in these slums were not only unhygienic but dangerous for child use. The toilets were so badly built that parents prevented their children from using them. Focal transmission points were thus created around the latrines and so increased the chances of infection in the immediate area. This appeared to be the situation in Bottlebrush and Kennedy Lower where, despite the high sanitation coverage, there was little reduction in intensity of *A. lumbricoides* infection. The lack of sanitation facilities, coupled with overcrowding, resulted in the spread of eggs, bringing about widespread contamination of water, food, sticky unwashed fingers, long nails, flies and cockroaches (Crompton *et al.*, 1989).

The decline in *A. lumbricoides* prevalence and intensity of infection at Smithfield, Bottlebrush, Lusaka and Canaan, indicates that the sanitation coverage and upgrading measures, chemotherapy and reduced house crowding succeeded in lowering the number of infective eggs in the environment, or at least were important components in controlling transmission.

Simplace had the highest number of heavy trichuriasis intensities and Kennedy Lower had the least. Although Bottlebrush and Kennedy Lower had the same type of sanitation, Bottlebrush had 24.0% of children with moderate to heavy intensities compared to 9.9% at Kennedy Lower. Park Station had 14.1% of the children with moderate to heavy intensities compared to slums with the same low sanitation coverage.

Despite their upgraded status, slums like Briardene and Quarry Heights (new Canaan), still lacked health education and adequate water supplies so that personal and general hygiene practices and the proper use of latrines were not encouraged. Children here still defaecated indiscriminately.

Several researchers have stated that education and the proper use and maintenance of latrines are crucial to the control of nematode infections. The majority of these studies were done in rural areas and similar studies should be extended to community sanitation in urban areas (Cairncross, 1989; Crompton *et al.*, 1989).

In contrast to the dramatic decline in helminth infections in the developed countries during the past century, intestinal helminth infections still represent a major problem in urban and rural areas in most of the developing countries (Savioli *et al.*, 1992; Crompton & Savioli, 1993; World Bank, 1993). Sanjur (1989), in reviewing the current empirical evidence, concluded that no single factor appears to be responsible for either the development or the distribution of nematode infections in communities or households. Several factors of a medical, biological, environmental, political, social, economic and cultural nature, and behaving in a synergistic and dynamic fashion, appear to be more significant than any single factor working independently.

7.8.4.2 Food hygiene

Food contamination is intimately linked to the sanitary conditions of food preparation, source (e.g. dumping sites) and handling. This explains why children as young as three months have been found to be infected in this study. In addition, within a home there are inter-connections and interactions between factors such as water, sanitation, personal hygiene, customs (e.g. eating with hands), geophagy (especially among pregnant mothers) and contaminated food that are collectively responsible for geohelminth transmission.

7.9 STATISTICAL MODELS FOR *A. LUMBRICOIDES* AND *T. TRICHIURA* INFECTIONS

As noted above, analysis of the cause of disease usually points to a wide range of factors (environmental, social, economic, political, and genetic) and it is therefore difficult to separate the relative role of one from the other. In addition, identifying the causes is complicated by the fact that environmental factors often operate concurrently, are interrelated and many contribute by very indirect paths. Therefore to understand the ecology of soil-transmitted helminthiasis in communities living in slums, a better appreciation is required of the factors that influence the transmission dynamics of *A. lumbricoides* and *T. trichiura*. The important risk factors for infection and reinfection by these two parasites may differ because of the differences in the biology of their eggs and their resistance to climatic factors, and this effect could be more important than the effect of other risk factors.

Further analysis becomes complex due to the fact that these factors incorporate a wide range of variables which often operate at the same time and make it difficult to reach firm conclusions. They may also influence transmission only indirectly. Changes in the slum environment over time are also important and highlight the vital importance of the slum environment in determining the overall transmission patterns of these nematodes.

CHAPTER 8

Some of the Project Laboratory Assistants:

Standing - from left to right: Sibongile, Sindy and Rose.
Seated - from left to right: Thandiwe, Buyi and Eunice.

8

CONCLUSIONS AND RECOMMENDATIONS

8.1 INTRODUCTION

This study is one of only a few on geohelminth transmission in urban slums. Geohelminth infections are not only prevalent in subtropical areas because of the combined effects of ecological and climatic factors on the parasites and their infective stages, but also because of human behavioural and cultural practices, customs, traditions and socio-economic conditions. The ecological and climatic factors however, are by far the most important.

Conclusions that can be drawn from the findings of this study are as follows:

1. The prevalences of *A. lumbricoides* and *T. trichiura* were high. Whereas the intensity of infections varied from light to very heavy, a small proportion of children (3.8%) have intensities which are an order of magnitude higher than anything reported thus far from the rural areas of South Africa.

2. These levels of infection are comparable with those reported from slums in other developing countries in terms of prevalence. Intensities are difficult to compare because most studies have measured intensity of infection differently, i.e. the worm expulsion method, direct faecal smears or formal-ether concentration technique.

3. Chemotherapy was, as expected, effective against *A. lumbricoides* and hookworm but much less so against *T. trichiura.*

4. Reinfection was rapid in some slums but slow in others, which was related to the different characteristics of each of the study slums. They had either low, moderate or high reinfection rates, suggesting that the characteristics of individual slums will play a role in determining appropriate control measures.

5. The most important risk factors influencing transmission of *A. lumbricoides* infection were the characteristics of slum, geophagy, topographical position of the dwelling, father's employment status and number of inhabitants per dwelling.

6. The most important risk factors influencing *T. trichiura* transmission were characteristics of slum, topographical position of the dwelling, age-group, total monthly household income, disposal of nappies, fuel used for cooking, fathers' occupation, number of inhabitants per dwelling and where meals were eaten.

7. The most important risk factors influencing *A. lumbricoides* reinfection were characteristics of slum, water source and topographical position of the dwelling.

8. The most important risk factors influencing *T. trichiura reinfection* were characteristics of slum, where child stayed before, geophagy, quality of dwelling, number of inhabitants per dwelling, source of fruit and vegetables and their being infected at baseline.

9. Heterogeneity of *A. lumbricoides* and *T. trichiura* transmission in these slums suggests that some areas are more suitable than others. For example crowding (<4m between dwellings), supported high reinfection rate and low intensity of trichuriasis reinfection, whereas reinfection intensities of ascariasis were high. It seems likely that differences in environmental factors such as soil temperature, soil moisture and direct sunlight are operating here and should be investigated further. In other words soil microclimate may be important.

10. It appears that the high prevalences and intensities of *A. lumbricoides* and *T. trichiura* found in the slums built in and around the City of Durban and in rural KwaZulu-Natal, like those elsewhere in Africa, are associated with very poor living conditions in these communities (Holland, *et al.*, 1988). It is with this background that the epidemiological data reported here will form important baseline information for evaluating the outcome of the sanitation implementation in Durban slums by the North-South-Central Metropolitan Council and the aim to reduce morbidity, mortality and transmission of parasites by the Ministry of Health in KwaZulu-Natal.

The restoration of geohelminth infections to the global health agenda has refocused research attention on these parasites. The hookworms, perhaps because of their association with acute disease, were the first geohelminths considered to be of importance to health, and a hookworm eradication programme was mounted by the Rockefeller Foundation in the early decades of the 20th century (Bundy & Cooper 1989). Control programmes against ascariasis were implemented in some countries in the 1950s, achieving notable success in Japan, Israel and Taiwan, but it was not until 1975 that a major international initiative was started against gastrointestinal nematodiases in general. For ascariasis there has been a dramatic increase in research effort in the last decades (reviewed by Crompton *et al.*, 1985 & 1989). In contrast, trichuriasis, the second most common of these infections, has remained a neglected disease (Bundy & Cooper, 1989).

It is hard to avoid the conclusion that the reduction in intensities of *A. lumbricoides* and *T. trichiura* at reinfection is because of the removal of topsoil during *in-situ* upgrading and sanitation improvements (from pit-latrine to flush toilets) at Lusaka, Bottlebrush (maintenance of VIP latrines) and Canaan (relocation to a new area).

If effective interventions are to succeed in slums, there is a need to understand geohelminth transmission and diversity within and between cities which have slums in South Africa. Assumptions are made that environmental problems in one city are the major problem factors in others as well. National, provincial or local agencies have difficulty in coping with the variety of hazards. As a result, there are other Government "action programmes on urban and rural environment", which may be of priority e.g. at the present moment, KwaZulu-Natal is faced with cholera, HIV (AIDS) and tuberculosis epidemics. This therefore leads to the government giving little attention to geohelminth problems, which are seen as relatively minor. Most health programmes lack manpower and financial resources to do much, and many lack the accountable structure which helps ensure they are aware of their citizens' needs and priorities.

Awareness of morbidity or mortality due to geohelminths, and their effects on health, growth and school performance, is generally low. It is not just parents, however, who are unaware of how debilitating helminthic infections can be; teachers, on the whole, not only don't see parasites as a priority issue, but they also don't know how worm burdens might affect children's behaviour in the classroom (Appleton & Kvalsvig, 1994, WHO, 1995, 1998).

Caution

- In endemic areas like urban slums, the high-risk groups (i.e. heavily infected) must be treated under medical supervision. A fatality occurring within days of treatment, even if unrelated, is frequently attributed to the treatment and can adversely affect community participation.
- The timing of the campaign is also important. For example it is difficult to do surveys during school holidays, on weekdays or when it is raining heavily.
- The strategy of chemotherapeutic interventions should be integrated with other activities of local health services, e.g. housing development projects, environmental health campaigns, primary health care and immunisation programmes.
- Selective chemotherapy (treatment of positives only) is not recommended in these areas, as it might create a strong reaction from those who are excluded.
- Active participation of the community leaders in the planning and execution of any intervention is mandatory. The schedule should suit the community and be agreed to by them. Indeed, administering treatment in the slums, transporting children to hospitals and sometimes to clinics, ensured a very high compliance throughout the present study. Hiring and training of laboratory assistants and providing temporary jobs for field workers, had the advantages of keeping constant communication with the study population and addressing problems whenever they arose. This is crucial for the success of any community-based control programme.

It is therefore surprising that most geohelminth control measures, so far, have used chemotherapy as the only means to reduce the number of the infective stages excreted to the environment in order to reduce morbidity and mortality due to geohelminths infections. For a control programme to achieve its objectives, the following holistic interventions are needed to control morbidity at the community level: (1) chemotherapy; (2) sanitation; (3) health education; (4) community participation and (5) monitoring and evaluation.

8.2 RECOMMENDATIONS

Table 8.1 Proposed solutions for controlling risk factors influencing geohelminth transmission in the study slums.

Parameters	**Proposed solution**	
CONTROL FEASIBLE		
Biological risk factors		
	Rate of infection/transmission	
Target group -		
Age of child (6months – 10 years)	High	Mass chemotherapy of slum population 2X per year
Sex of child (males and females)	Moderate	Selective chemotherapy 1X per year
	Low	Selective treatment
Socio-cultural risk factors		
Handling of excreta (night soil)	Health education	
Geophagy	Health education	
Socio-economic risk factors		
Level of education	Government intervention	
Level of employment	Government intervention	
Household income	Government intervention	
Water source	Government intervention	
Housing density	Government intervention	
Sanitation	Government intervention	
Migration and circulation	Government intervention	
Household environmental hygiene	Government intervention	
Personal hygiene	Health education	
Food hygiene	Health education	
	Health education	
CONTROL NOT FEASIBLE		
Environmental risk factors		
Number of inhabitants (socio-cultural factor)		
Altitude		
Aspect		
Slope		
Shade		
Rainfall		
Temperature		

8.3 CHEMOTHERAPY

Although this study has demonstrated that treatment is cheap and affordable and has given temporary cure from geohelminth infections (WHO, 1995, 1998), eradication may prove difficult because of the high reinfection rate from the contaminated environment in some slums where there is high force of infection. The results of this study have significant implications for the use of targeted, mass and selected chemotherapy at the community levels in the urban slums for the control of morbidity due to soil-transmitted nematodes (Table 8.1).

This study suggests that, in the Durban slums, three chemotherapy strategies should be used:

1. Mass chemotherapy twice a year at Pemary Ridge, Quarry Road West, Simplace, Park Station and Canaan (Q-section), because these slums have a high rate of reinfection.

2. Mass chemotherapy once a year, i.e. treatment of all persons at Bottlebrush, Kennedy Lower, Quarry Heights (new Canaan), Briardene and Lusaka because these slums have a moderate force of reinfection.

3. Selective / targeted chemotherapy at Smithfield which has a low rate of reinfection, i.e. treatment of specific groups likely to suffer the greatest morbidity, notably children from 6 months – 10 years. This will improve children's growth, activity and learning capabilities.

Some attempts have been made to reduce the prevalence and intensity of helminthic infections in developing countries. In particular, mass treatment with anthelminthic drugs has been recommended by several national and international organisations as a basis for helminth control (Bundy, *et al*., 1990). In this study albendazole was a highly effective, safe and relatively inexpensive method of reducing morbidity caused by geohelminth infections. More fundamental questions are their sustainability as a public health measure and the provision of financial and manpower resources if treatment has to be repeated.

8.4 RISK FACTORS

An appropriate community-based control programme suited to slums will depend on the reinfection rate (rate of infection) in each slum. Risk factors shown to be important for geohelminth transmission can be classified into two categories, according to the possibility of controlling their influence viz.:

1. Those factors which are easy and feasible to implement, e.g. putting salt in the ground to kill infective stages, *in-situ* upgrading of slum involving, among other things, the removal of topsoil, relocation to a new area, monitoring newcomers for infection, regular treatment with cheap, single dose anthelmintic, and health education (see Table 8.1).

2. Those factors that interact with socio-economic and socio-cultural conditions and are difficult to implement. Generally they cannot be removed, e.g. overcrowding, sex of child, age of child, number of people per dwelling, climatic, and environmental (temperature, rainfall, soil structure, shade) factors (Table 8.1).

Although the basic epidemiology of geohelminths is relatively straightforward, their quantitative epidemiology is more complex. Further analysis of risk factors deemed to be the most important in geohelminth transmission becomes very complex due to the fact that these factors incorporate a wide range of variables, they often operate at the same time, and they may influence transmission indirectly. These features, which varied significantly between different slums, were attributed to variation in the slum environment. Other important risk factors for reinfection were water source, sanitation and topography of slum. Changes in the slum environment over time made reaching firm conclusions difficult, but highlighted the importance of determining overall transmission patterns.

The effects of sanitation on geohelminth infections are slow in developing, and therefore if these infections are to be used as indicators for the effect of the intervention, periodic anthelmintic treatment and health education should be maintained until sanitation has had an impact on transmission (Kilama, 1989; Cairncross, 1989 & Bradley *et al.*, 1993). Toilets must be maintained, accessible and be used by all, including children. This is a problem in the slums because most of them have no streetlights and therefore females and children do not use toilets at night. The introduction of toilets can also be expected to reduce levels of dysentry, diarrhoea and other infectious diseases.

8.5. SLUM COMMUNITY'S KNOWLEDGE, ATTITUDES, BELIEFS AND PERCEPTIONS ABOUT INTESTINAL WORMS

If there are active health education programmes and the issue of illiteracy among slum communities is addressed, this will generate the capacity in the people to seek solutions to their own problems. Modification of human behavioural change is of great importance in the transmission of geohelminths, as success or failure of control programmes often hinges on changes in behavioural patterns. Cultural taboos, e.g. mothers who do not believe that their children's faeces contain anything "harmful", eating with hands, teaching children at a very late age to use toilets and HIV positive men believing that raping a virgin prevent them one from developing AIDS, make it difficult for girls to reach toilets at night. The females (young and adult) then resort to using refuse bags for excreta disposal. Women's groups can be shown audio-visual material to educate them about morbidity due to geohelminths. Improving their knowledge of the parasites' life-cycles and their transmission routes will lead to a better understanding of the problem, thus reducing the risk of infection. For example, mothers in slums believe that a child with a distended abdomen is full and very healthy because he/she looks big. In this study, the community also feared that the treatment given to their children was so effective that it would kill the mother worm '*isikelemu sempilo"*, meaning the worm of health. Although they see the link between overcrowding and influenza and tuberculosis, they don't link this to geohelminth transmission. They also believe that once there are abdominal sounds after the child has had a meal, it means the worms are happy.

It has been proposed by Ukoli (1984) and Kamunvi *et al.* (1993) that changing human behaviour as well as socio-cultural and traditional practices, will help bring about control. This comes from the notion that the disease condition prevails because the people are backward and are unwilling to change their primitive ways. It is widely believed that traditions die hard in rural Africa and that people are resistant to change, even when designed and introduced to improve their lot. This attitude is based on a misinterpretation of some African cultural values and practices. Even in communities like KwaZulu-Natal where geohelminth prevalences are very high, and people take *Ascaris* infection for granted, ascariasis is a serious cause of morbidity and mortality and is an important public health problem. Awareness of the aetiology of geohelminth infections and their effects on health, growth and school performance is generally low, and it is not just the parents who are unaware of how debilitating helminth infections can be. My own experience is that most parents think that malnourished children with distended abdomens are fat rather than ill.

It is doubtful whether deep-rooted habits like geophagy can be altered. Given its probable significant health impact, however, there should be a thorough investigation of this human practice, including also its possible beneficial aspects. Only a well founded health education programme will have a chance of motivating such changes (Bundy & Blumenthal, 1990).

8.6 MONITORING AND EVALUATION

This study monitored the effect of chemotherapy by measuring prevalences and intensities of geohelminth infections before and after treatment. Reinfection rates were determined to establish the time interval needed for subsequent treatments. Eradication, or at least control of geohelminths, and its incorporation into the existing rural school based control programme, is imperative in the slums. This will not only lead to improvement of human health but also raise the level of the quality of life and productive capacity of the disadvantaged people in KwaZulu-Natal. A large proportion of children in this country is growing up in circumstances of extreme poverty and disadvantage. Their future holds only the prospect of hunger, disease, poor education. In order for them to grow, develop and thrive, children require adequate nutrition, environmental protection, essential health care and an emotionally nurturing family setting.

The impact/direct benefits of any geohelminth control programme/infectious disease intervention may not be immediately apparent because of other factors that indirectly affect geohelminth transmission, e.g. the constant influx of infected people to the slums. Thus, the successful control of geohelminth infections will be ineffective if it is not integrated into general resource development programmes in the Durban Unicity. Failure to control parasitic diseases will really not be due to technical problems like drug efficacy, delivery and monitoring of prevalences and intensities, or incomplete knowledge of the life cycles of the parasites, but due to human factors as well, such as:

1. Slum children do not (always) go to school and therefore will not be treated via any control effect.
2. Lack of data on morbidity and mortality due to geohelminth infections.
3. Shortage of manpower (especially trained parasitologists and technicians) both in quality and quantity at all levels.
4. Inadequate financial provision.
5. Lack of drive by government.
6. Failure of authorities to appreciate the advantages (because of the absence of convincing evidence of socio-economic benefits) to be derived from control.
7. Instabilities like change of infrastructure, relocations, developments, influx of immigrants and migrants into slums.
8. Emphasis wrongly placed by the authorities on causes of mortality (because of the dramatic effect of death) rather than morbidity, thereby ignoring conditions which produce prolonged illness and suffering of people, especially children and infants, and the subsequent reduction of their productivity and capacity to enjoy life to the full.

8.7 FURTHER RESEARCH

The challenge of geohelminth control in these slums will be to determine the degree of environmental contamination by human faeces containing infective eggs, this study having shown the number of eggs produced by these children per gram of stool daily. Soil contamination by geohelminth eggs and larvae in these slums must also be studied, and the distribution and survival rate of these infective stages within the micro-habitat should be further investigated.

The lack of influx control to urban areas will definitely exacerbate the problem as many communities in South Africa are in a state of dynamic transition rather than being stable, and this increases the risk of infections.

Studies on the nutritional status of the community, especially the Protein Energy Malnutrition (PEM) and haemoglobin levels, should also be undertaken. The prevalences and intensities of geohelminth infections should also be determined in adults so that the actual parasite-induced morbidity in the community can be assessed.

Integrating school-based interventions with community-based interventions will improve coverage and promote optimal retreatment schedules.

To date South Africa has not established the proportion of morbidity and mortality resulting from parasitic infections.

8.8 FUTURE REFLECTIONS

Geohelminthiases will continue to thrive in South Africa and elsewhere. Chemotherapy for geohelminths in some endemic areas, such as the present study, is of little value because of the inescapable problem of reinfection. Chemotherapy may be the only effective short-term weapon against geohelminths, and while reinfection may seem like a setback, ascariasis control can be incorporated into Primary Health Care (Crompton *et al.*, 1989). This is especially so if advantage is taken of the apparent strong abhorrence for the worms that exists in many communities, especially among children. Even people not used to participating in epidemiological research/scientific studies or suspicious of its effects do come for treatment to expel *A. lumbricoides*. Community based control measures against ascariasis offer a powerful and visible demonstration that modern medicine is safe and effective, thus helping people to develop their confidence and be encouraged to participate in other elements of Primary Health Care (PHC) (WHO, 1985, 1998).

8.9 STRATEGIES FOR CONTROL

To establish control effectively, information on the distribution of infection is needed and should address both the public and domestic domain.

Control of helminth infections can be aimed at

- Transmission control (feasible)
- Morbidity control

Control programmes can be conducted at

- National level
- Provincial level
- School level
- Community level

At present, South Africa has only three intestinal helminth control programmes, in KwaZulu Natal, Mpumalanga and Eastern Cape provinces.

Morbidity control approaches available may be:

- Deworming children through the existing PHC system
- School based chemotherapy and health education programme, e.g. integrated with the KwaZulu-Natal Nutrition Programme (Feeding Scheme)

8.10 PROPOSED CONTROL STRATEGIES IN SLUMS

- Control strategy - mass and selective chemotherapy, health education and introducing and maintaining sanitation
- Target population - children 6 months - 12 years and the whole population in some slums
- Drug of choice - 400mg albendazole or suspension
- Drug delivery system - nursing department (Durban City Health Department) and clinics serving these slum communities
- Monitoring system - monitoring of prevalence, morbidity and transmission of geohelminth infection by a full-time manager.

In view of the lack of epidemiological data and a national intestinal helminth control programme in South Africa there is a need to:

1. Collect epidemiological data across the country to improve the database for geohelminths' prevalence and intensities, which can be used for prediction of infection patterns. Epidemiological data on geohelminths' in South Africa is very scarce.
2. Develop geohelminth interventions, e.g. chemotherapy, health education, sanitary infrastructure provision and eradication of infective stages already in the environment.
3. Evaluate the risk factors involved in the transmission of intestinal helminth infections in the different parts of the country.
4. Use Geographical Information Systems (GIS) to collate, map and analyze available prevalence data.
5. Use Remotely Sensed models (RS) to investigate the ecological limits of infection and predict helminth infection patterns in unsampled areas.
6. Use RS/GIS in designing sampling protocols and in planning and implementing control programmes.

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UNIVERSITY OF NATAL
DURBAN CAMPUS

Faculty of Science
School of Life and Environmental Sciences
George Campbell Building
Durban 4041 South Africa
Telephone +27 (0)31 2603192
Facsimile +27 (0)31 2602029
e-mail: info@biology.und.ac.za

APPENDIX A

CITY HEALTH DEPARTMENT, DURBAN

CONSENT FORM : CHILD HEALTH CLINICS

I, ... parent/legal guardian
(Name of parent or guardian)

of.. do hereby give my consent to his/her
(Name of child)

medical examination and to such treatment as may be considered necessary or desirable at any Child Health Clinic operated by the City Health Department, Durban, including the following:

- Immunization against infectious disease;
- Administration of medications and drugs, whether orally or by injections;
- Treatment of minor ailments and injuries;
- Primary screening and diagnostic tests, including the taking of blood samples.

I understand that certain of the aforementioned treatments and medical procedures may have side effects and that certain risks are present therein and I agree to accept the same in the interests of the health of my child.

I agree that this consent will continue to remain in effect for all visits of my said child to a Child Health Clinic, whether accompanied by myself or by any other responsible person acting on my behalf, but I reserve the right at any time to withdraw this consent either generally or in relation to a specific treatment or medical procedure by written notice delivered to the person in charge of the clinic at which my child is attending.

Signed: .... Capacity: ....
(State whether parent or legal guardian)

Address: ....

....

Durban Corpn. M.O. 115

Telephone No. ....

Witness: .... Date: ....

INFORMAL SETTLEMENT PARASITE RESEARCH PROJECT

This child (Name: ____________________________________; Ref. No. ________) is part of a study on worm transmission in informal settlements around Durban and has been diagnosed heavily infected. He/she has therefore been referred to ______________________________ Clinic for referral to hospital. Please record the treatment given on both parts of this form and deposit one half in the box provided. This project is being supported by the Durban City Health Department and has been approved by the University of Natal Ethics Committee.

Should any problems arise, please contact Thabang Mosala on 083 7021072.or Prof. CC Appleton on 2601187.

Date	Name of Doctor	Hospital	Treatment	Comments

✂---

Name: ——————————; Ref. No. ——

Date	Name of Doctor	Hospital	Treatment	Comments

APPENDIX B

GEOHELMINTH TRANSMISSION AMONG SLUM-DWELLING CHILDREN IN DURBAN, SOUTH AFRICA

QUESTIONNAIRE

Biological factors

1. Name of slum

1 *BB*	**2** *KL*	**3** *LU*	**4** *PR*	**5** *QR*	**6** *SP*	**7** *BR*	**8** *SM*	**9** *PS*	**10** *CA*

Date

Name of interviewer

1 **sindy**	**2** **car**	**3** **rose**	**4** **angel**	**5** **thandi**	**6** **sibo**	**7** **buyi**	**8** **nonhl**	**9** **eunice**	**10** **jabu**

Child study number **ID e.g. 1001** = first child in slum

2. Interviewee

Parent **(1)**	*Guardian* **(2)**

Physical address

3. Sex of child (o)

Female **(0)**	*Male* **(1)**

4. Age of child (years)

Environmental factors

5. Altitude

6. Soil type

Cartref **(1)**	*Milk wood* **(2)**	*Fernwood & Dundee* **(3)**

7. Aspect

8. Topographical position of the dwelling (o)

Crest **(1)**	*Scarp, mid or foot slope* **(2)**	*Valley bottom* **(3)**	*Flat* **(4)**

Socio-economic factors

9. Quality of dwelling (o)

Corrugated iron **(1)**	*Cardboard* **(2)**	*Asbestos* **(3)**	*Brick* **(4)**	*Mud* **(6)**	*Wooden planks* **(7)**	*Mixed material* **(8)**

Key:

(O) = Observations

Italic text = categories

Normal text = variables

10. How long have this child stayed in this settlement?

Number of years / year arrived	

11. Where did you stay before coming to stay here in this settlement? - child's origin

12. What made you like to come and stay here in this slum?

Rural **(1)**	*Township* **(2)**	*Another slum* **(3)**	*Urban* **(4)**

13. How many rooms per dwelling? (o)

14. Number of inhabitants per dwelling?

15. Child care-giver?

16. Child care-giver during the day?

Mother **(1)**	*Father* **(2)**	*Grand Parents* **(4)**	*Crèche* **(8)**	**Total**
Mother **(1)**	*Father* **(2)**	*Grand Parents* **(4)**	*Crèche* **(8)**	**Total**

17. Child care-giver during the holidays?

Mother **(1)**	*Father* **(2)**	*Grand Parents* **(4)**	*Crèche* **(8)**	**Total**

18. For the last six months which places did this child visit?

Did not visit **(0)**	*Rural* **(1)**	*Slum* **(2)**	*Urban* **(3)**	*Township* **(4)**

Socio-cultural factors

19. Do you eat soil?

Yes **(1)**	*No* **(0)**

IF YES FROM ABOVE

20. Where do you get the soil?

21. How often do you eat soil?

From the ground **(1)**		*From the house walls* **(2)**	*Buy from the market* **(4)**	**Total**
Daily **(1)**	*Weekly* **(2)**	*When you are pregnant?* **(4)**		**Total**

Knowledge, attitudes, perceptions and beliefs of parents/guardians about worms

▪ Did the worms come out after treatment?	*Yes* (1)	*No* (0)	
▪ When did the worms come out after taking treatment?	*After a day* (1)	*After a week* (2)	*Did not see* (3)
▪ Did you see any improvement in the child's health after treatment?	*Yes* (1)	*Signs of improvement according to Parent /guardian*	
	Appetite improved	*Yes* (1)	*No* (0)
	Looks healthy	*Yes* (1)	*No* (0)
	S/he now plays with other children	*Yes* (1)	*No* (0)
	Performs better in school	*Yes* (1)	*No* (0)
	Stopped coughing	*Yes* (1)	*No* (0)
	Gained weight	*Yes* (1)	*No* (0)
	The stomach has gone down	*Yes* (1)	*No* (0)
▪ Will you allow us to treat your child again?	*Yes* (1)	*No* (0)	
▪ If *No* above, why?			

Socio-economic factors

LEVEL OF EDUCATION (What is your highest qualification?)

22. Mother

None (0)	*Primary* (1)	*Secondary* (2)	*Tertiary* (3)

23. Father

None (0)	*Primary* (1)	*Secondary* (2)	*Tertiary* (3)

24. Guardian

None (0)	*Primary* (1)	*Secondary* (2)	*Tertiary* (3)

LEVEL OF EMPLOYMENT (What type of job are you doing?)

25. Mother

None (0)	*Formal* (1)	*Informal* (2)

24. Father

None (0)	*Formal* (1)	*Informal* (2)

25. Guardian

None (0)	*Formal* (1)	*Informal* (2)

HOUSEHOLD INCOME PER MONTH

26. **Mother**

Less than R200.99 (1)	*R301 – R999.99* (2)	*More than R1 000* (3)

27. **Father**

Less than R200.99 (1)	*R301 – R999.99* (2)	*More than R1 000* (3)

28. **Guardian**

Less than R200.99 (1)	*R301 – R999.99* (2)	*More than R1 000* (3)

29. Distance between dwelling and water source (O)

Tap inside house **(0)**
Tap not in house but near < 500metres **(1)**
Tap not in house but far > 500metres **(2)**

30. Tap in the house (O)		*Yes* (1)			*No* (0)
31. Tap in the yard (O)		*Yes* (1)			*No* (0)
32. Purchase water from standpipe (O)		*Yes* (1)			*No* (0)
33. Rain tank in the yard (O)		*Yes* (1)			*No* (0)
34. River (O)		*Yes* (1)			*No* (0)
35. How do you transport water home	*Wheelbarrow* (2)	*Head* (1)	*Not stored* (3)		*Total*
36. What kind of container do you use to store your water?	*Plastic container* (1)	*Metal container* (2)	*Do not store* (4)		*Total*
37. How long is water stored?	*day* (1)	*week* (2)	*month* (3)		*> month* (4)
38. How often do you wash your water container?	*Do not wash* (0)	*Daily* (1)	*Weekly* (2)		*Monthly* (4)
3. Is the container closed or open? (O)		*Closed* (1)	*Open* (0)		
40. Why is the container open?					
41. Who collects the water	*Mother* (1)	*Father* (2)	*Children* (4)	*Guardian* (8)	*Total*
42. How often do you collect water?	*Daily* (1)	*Several times a day* (2)	*Weekly* (4)	*Guardian* (8)	*Total*

43. Do you use any of the following for cooking?	*Wood* **(1)**	*Paraffin* **(2)**	*Gas* **(4)**	*Electricity* **(8)**	**Total**
44. Use household bleach?	*Yes* **(1)**		*No* **(0)**		
45. Is water boiled before use?	*Yes* **(1)**		*No* **(0)**		

46. Do you have your own toilet (O)	*Yes* **(1)**	*No* **(0)**
47. Distance between house and excreta disposal facility	*< 500metres* **(0)**	
	> 500metres **(1)**	

48. ADULT SANITATION HABITS DURING DAYTIME

MALES		FEMALES	
Safe **(0)**	*Unsafe* **(1)**	*Safe* **(0)**	*Unsafe* **(1)**

49 .ADULT SANITATION HABITS DURING THE NIGHT

MALES		FEMALES	
Safe **(0)**	*Unsafe* **(1)**	*Safe* **(0)**	*Unsafe* **(1)**

50. CHILDREN SANITATION HABITS DURING DAYTIME

BOYS		GIRLS	
Safe **(0)**	*Unsafe* **(1)**	*Safe* **(0)**	*Unsafe* **(1)**

51. CHILDREN SANITATION HABITS DURING THE NIGHT

BOYS		GIRLS	
Safe **(0)**	*Unsafe* **(0I**	*Safe* **(0)**	*Unsafe* **(1)**

KEY:

SAFE (1)
Flush toilet
Chemical toilet
VIP privy
Pit-latrine

UNSAFE (0)
Bucket
Bush
River
"Stamkoko"

Kvalsvig, 1994), and most of what is known now is from KwaZulu-Natal province along the country's sub-tropical eastern seaboard and the environs of Cape Town in the Western Cape (Gunders, *et al.*, 1993; Millar *et al.*, 1989)). The few studies relating to the other seven provinces were conducted on a largely *ad hoc* basis. The coastal lowlands of KwaZulu-Natal are probably the worst affected part of the province (and perhaps of the country) (Schutte *et al.*, 1981; Appleton & Gouws, 1996) with children living here frequently being infected by the three most common species, *A. lumbricoides, T. trichiura* and *N. americanus*, at prevalences between 70 and 100% (Appleton *et al.*, 1999). A review of this literature was provided by Mosala (1996) and will not be repeated here.

1.1 THE GEOHELMINTH PROBLEM IN SOUTH AFRICA

Of all the geohelminth diseases found in South Africa, ascariasis undoubtedly causes the most morbidity. Ascariasis complications constituted 10-15% of all acute surgical procedures on children in two major South African hospitals, e.g. the Red Cross Children's Hospital, Cape Town, and King Edward VIII Hospital, Durban, (Louw, 1966, 1974; Coovadia & Wittenberg, 1998). These complications usually present as intestinal obstructions (boluses) which may have to be removed surgically. Bradley & Buch (1994) reported seven such cases within a 14-month period at a hospital in the KwaZulu-Natal midlands. Even in areas where *A. lumbricoides* is very low (<5%) such as the mountainous parts of Qwa-Qwa at 2000m, boluses are also seen (Mosala, 1996). Biliary ascariasis is also common in South Africa (Louw, 1974).

Davies & Rodé (1982) gave statistics for ascariasis complications at a hospital in Cape Town. Among 1090 acute emergencies due to *A. lumbricoides* over a 20-year period, 623 (57%) were caused by intestinal boluses, 424 (39%) by biliary infections and 43 (4%) by pancreatic infections. Medical records from King Edward VIII Hospital in Durban showed that between January 1994 and March 2000, the annual number of gastro-intestinal tract (GIT) complications due to ascariasis in children aged from 3 months to 12 years ranged from 8 in 1999 to 22 in 1996. Each year the hospital deals with ±200 GIT complications due to ascariasis in all age groups (Prof. G. P. Hadley, Dr. D. Mji & Dr. D. Mji, pers. comm.). According to these paediatric surgeons, adult *A. lumbricoides* have been found blocking the following organs: the intestinal lumen (causing distension and blockage leading to gangrene – see Chapter 1 title-page), liver, biliary tree, pancreatic duct, trachea, eustachian tubes, urino-genital ducts, naso-gastric tubes, appendix and peritoneal cavity (after penetrating the intestine wall). One 4-month old child passed ±200 worms (Dr S. Ramjii, pers. comm.). Blockage of the intestine lumen or

- Reasons for not using toilet

Its not safe because of the many criminals in the informal

Socio-cultural factors - adult risk behaviour

Do you washes hands…

	Never	*Occasionally*	*Always*
66. With soap and water	**(0)**	**(1)**	**(2)**
67. With water only	**(0)**	**(1)**	**(2)**
68. Before eating	**(0)**	**(1)**	**(2)**
69. After defecation	**(0)**	**(1)**	**(2)**
70. In the morning	**(0)**	**(1)**	**(2)**
71. Before going to bed	**(0)**	**(1)**	**(2)**
72. After changing nappies	**(0)**	**(1)**	**(2)**
73. Before preparing meals	**(0)**	**(1)**	**(2)**
74. Do you use hands when eating?	**(0)**	**(1)**	**(2)**
75. Do you cut and clean your nails (o)?	**(0)**	**(1)**	**(2)**

Socio-economic factors - food hygiene

76. Where are vegetables and fruits obtained from?	*Garden* **(1)**	*Street* **(2)**	*Supermarket* **(4)**	*Rubbish hip* **(8)**	**Total**
77. Do you store your food? (O)	*Yes* **(1)**			*No* **(0)**	
78. Where is food stored? (O)	*Fridge* **(1)**		*Cupboard* **(2)**	*Bucket* **(4)**	**Total**
79. If No why are you not storing your food?					
80. How do you prepare your food?	*Fry* **(1)**	*Boil* **(2)**		**Total**	
81. Where are your meals taken?	*Indoor* **(1)**	*Outdoor* **(2)**		*Both* **(3)**	
82. Are your children fed leftovers?	*Yes* **(1)**	*No* **(0)**			

CHILD QUESTIONNAIRE

Socio-cultural factors - geophagy

(Sandwich bag given to the child to put the type and quantity of soil he / she eats per time)

83. Do you eat soil?	*Yes* **(1)**		*No* **(0)**		
84. Where do you get it from?	*From the ground* **(1)**	*From the house wall* **(2)**	*Buy from the market* **(4)**	**Total**	
85. How often do you eat soil?	*Daily* **(1)**	*Weekly* **(2)**	**Other (3)**		
86. Why do you eat soil?	*Its nice* **(1)**	*Imitates mother* **(2)**	*Imitate friends* **(4)**	*Suppresses hunger* **(8)**	**Total**
87. How much do you eat at one time?		Weight (g)			
88. What kind of soil do you like most (specify)?		Sandy **(1)**	Clay **(2)**	Loamy(4)	**Total**

89. Distance between house and water source (o)	**Paces** (measure each of the interviewers pace, then convert to metres)			
90. Distance between house where the child lives and neighbours. (o)	Neighbor 1 (paces)	Neighbor 2 (paces)	Neighbor 3 (paces)	Neighbor 4 (paces)
	Metres	Metres	Metres	Metres
91. Hygienic condition of sanitation facility ✸	*Safely built for child use* **(0)**		*Unsafe for child use* **(1)**	

✸ Toilet gratings

	Grade		Description
(1)	*good*	-	clean flush toilet (safe)
(2)	*satisfactory*	-	VIP or chemical toilet which is clean and not full (safe)
(3)	*functional*	-	pit latrine or water pipe toilet (safe)
(4)	*bad*	-	badly built and unhygienic latrine (unsafe)
(5)	*full*	-	VIP, latrine or chemical which is full (unsafe)
(6)	no toilet / bush	-	N/A (98) (unsafe)

THANK YOU FOR YOUR TIME

APPENDIX C

RESULTS I - (PARASITOLOGY RAW DATA)

PREVALENCES AND INTENSITIES OF GEOHELMINTH INFECTIONS IN THE 10 STUDY SLUMS (RAW DATA)

Table 1 Baseline prevalences of *Ascaris lumbricoides, Trichuris trichiura* and hookworm infections by slum for all subjects examined.

Slum	Total examined	*A. lumbricoides*	*T. trichiura*	Hookworm
		% (N)	% (N)	% (N)
1.Bottlebrush	200	**85.5** (165)	**72.5** (145)	**0.0** (0)
2.Kennedy Lower	122	**91.8** (112)	**54.5** (66)	**0.8** (1)
3.Lusaka	70	**88.6** (62)	**74.6** (53)	**4.3** (3)
4.Pemary Ridge	65	**93.8** (61)	**73.8** (48)	**3.1** (2)
5.Quarry Road West	82	**96.3** (79)	**73.2** (60)	**6.1**(5)
6.Simplace	123	**91.9** (113)	**77.2** (95)	**17.9**(22)
7.Briardene	112	**87.5** (98)	**79.5** (89)	**0.0**(0)
8.Smithfield	29	**86.2** (25)	**86.2** (25)	**20.0** (6)
9.Park Station	71	**81.7** (58)	**71.8** (52)	**8.6** (6)
10.Canaan	122	**94.3** (115)	**66.4** (81)	**1.6** (2)
Average	996	**89.2** (888)	**71.6** (713)	**4.7**(47)

Table 2 Post-treatment survey prevalences of *A. lumbricoides, T. trichiura* and hookworm infections by slum for all subjects examined.

Slum	Total examined	*A. lumbricoides*	*T. trichiura*	Hookworm
		% (N)	% (N)	% (N)
1.Bottlebrush	200	**5.0** (10)	**13.0** (26)	0.0 (0)
2.Kennedy Lower	122	**2.5** (3)	**13.2** (16)	0.0 (0)
3.Lusaka	70	**2.9** (2)	**36.6** (26)	0.0(0)
4.Pemary Ridge	65	**9.2** (6)	**26.2** (17)	0.0 (0)
5.Quarry Road West	82	**2.4** (2)	**24.2** (20)	0.0(0)
6.Simplace	123	**7.3** (9)	**22.8** (28)	0.0(0)
7.Briardene	112	**5.4** (6)	**18.8** (21)	0.0(0)
8.Smithfield	29	**0.0** (0)	**48.3** (14)	0.0 (0)
9.Park Station	71	**0.0** (0)	**19.7** (14)	0.0 (0)
10.Canaan	122	**5.8** (7)	**18.9** (23)	0.0 (0)
Average	**996**	**4.5** (45)	**20.6** (205)	**0.0(0)**

Table 3 Reinfection after treatment prevalences of *A. lumbricoides* and *T. trichiura* by slum for all subjects examined in the 10 study slums. Follow-up surveys 1 (4 ½-6 months post- treatment) and 2 (12 months post-treatment) prevalence.

	Follow-up 1	Follow-up 2	*A. lumbricoides* follow-up 1	*A. lumbricoides* follow-up 2	*T. trichiura* follow-up 1	*T. trichiura* follow-up 2
Slum	N	N	% (N)	% (N)	% (N)	% (N)
1. Bottlebrush	166	180	23.5 (39)	65.6 (118)	28.5 (47)	65.7(119)
2. Kennedy Lower	120	109	32.5 (39)	91.7 (100)	20.2 (24)	37.6 (41)
3. Lusaka	53	64	66.0 (35)	96.9 (62)	59.3 (32)	66.2 (43)
4. Pemary Ridge	49	64	100.0 (49)	100.0 (64)	83.7 (41)	89.1 (57)
5. Quarry Road West	82	82	91.5 (75)	98.8 (81)	65.9 (54)	95.1(78)
6. Simplace	120	123	98.3 (118)	100.0 (123)	45.0 (54)	89.4(110)
7. Briardene	100	110	94.0 (94)	99.1 (109)	49.0 (49)	92.7(101)
8. Smithfield	28	28	14.3 (4)	25.0 (7)	39.3 (11)	81.5 (22)
9. Park station	63	65	81.7 (58)	100.0 (65)	44.6 (29)	64.6 (42)
10.Canaan	*	122	*	82.0 (100)	*	46.7 (57)
Average	**781**	947	**64.0** (500)	**87.5** (829)	**43.6** (341)	**70.7**(670)

* = Canaan children were not examined during the follow-up 1 survey because 75.0% of the families were relocating to a new area (Quarry Heights).

Table 4 Baseline intensities of *A. lumbricoides* infection (e.p.g.) for all the subjects examined in the 10 study slums.

Slum	No. examined	Light infection	Moderate infection	Heavy infection	Very heavy infection
		%(N)	%(N)	%(N)	%(N)
1.Bottlebrush	200	20.5 (41)	44.5 (89)	14.0 (28)	3.5 (7)
2.Kennedy Lower	122	16.4 (20)	62.3 (76)	12.3 (15)	0.8 (1)
3.Lusaka	70	8.6 (6)	60.0 (42)	18.6 (13)	1.4 (1)
4.Pemary Ridge	65	13.8 (9)	49.2 (32)	24.6 (16)	6.2 (4)
5.Quarry Road West	82	2.4 (2)	39.0 (32)	42.7(35)	12.2 (10)
6.Simplace	123	13.0 (16)	47.2 (58)	27.6(34)	4.1 (5)
7.Briardene	112	13.4 (15)	49.1 (55)	22.3(25)	2.7 (3)
8.Smithfield	29	24.1 (7)	58.6 (17)	3.4 (1)	0.0 (0)
9.Park Station	71	22.5 (16)	50.7 (36)	8.5 (6)	0.0 (0)
10.Canaan	122	13.1 (16)	47.5 (58)	27.9 (34)	5.7 (7)
Average	996	**14.9** (148)	**49.7** (495)	**20.8**(207)	**3.8** (38)

***A. lumbricoides* egg counts classification**

Light = 1 – 4 999 e.p.g. (eggs per gram of stool); moderate = 5 000 – 49 999 e.p.g.; heavy = 50 000 – 100 000 e.p.g. ; very heavy = >100 000 e.p.g. (Renganathan *et al.* 1995)

Table 5 Post-treatment intensities of *A. lumbricoides* infection (e.p.g.) for all the subjects examined by slum.

		Light infection	Moderate infection	Heavy infection
Slum	No. examined	% (N)	% (N)	% (N)
1.Bottlebrush	200	**5.0** (10)	**0.0** (0)	**0.0** (0)
2.Kennedy Lower	122	**1.6** (2)	**0.8**(1)	**0.0** (0)
3.Lusaka	70	**2.9** (2)	**0.0** (0)	**0.0** (0)
4.Pemary Ridge	65	**0.0** (0)	**9.2** (6)	**0.0** (0)
5. Quarry Road West	82	**0.0** (0)	**1.2** (1)	**1.2** (1)
6. Simplace	123	**7.3** (9)	**0.0** (0)	**0.0** (0)
7. Briardene	112	**4.5** (5)	**0.9** (1)	**0.0** (0)
8. Smithfield	29	**0.0** (0)	**0.0** (0)	**0.0** (0)
9. Park Station	71	**0.0** (0)	**0.0** (0)	**0.0** (0)
10. Canaan	122	**5.0** (6)	**0.8** (1)	**0.0** (0)
Average	996	**3.4** (34)	**1.0** (10)	**0.1**(1)

Table 6.a Follow-up 1 (4½-6)months intensities of *A. lumbricoides* infection (e.p.g.) in the 9 study slums. Canaan was not included because 75.0% of the families were relocating. (n=781).

		Not *A. lumbricoides* infected	**Light infection**	**Moderate infection**	**Heavy infection**	**Very heavy infection**
Slum	Follow-up period (months) **(days)**	% (N)	% (N)	% (N)	% (N)	% (N)
1.Bottlebrush	6.0 **(181)**	**76.5** (127/166)	**7.8** (13)	**13.9** (23)	**1.8** (3)	**0.0** (0)
2. Kennedy Lower	6.1 **(183)**	**67.5** (81/120)	**27.5** (33)	**4.2** (5)	**0.8** (1)	**0.0** (0)
3. Lusaka	4.8 **(143)**	**34.0** (18/53)	**20.8** (11)	**36.6** (21)	**5.7** (3)	**0.0** (0)
4. Pemary Ridge	4.6 **(138)**	**0.0** (0/49)	**46.9** (23)	**46.9** (23)	**4.1** (2	**2.0** (1)
5. Quarry Road West	6.3 **(188)**	**8.5** (7/82)	**72.0** (59)	**17.1** (14)	**2.4**(2)	**0.0**(0)
6. Simplace	6.8 **(204)**	**1.7**(2/120	**54.2**(65)	**38.3**(46)	**5.8**(7)	**0.0** (0)
7.Briardene	6.3 **(188)**	**6.0** (6/100)	**49.0** (49)	**40.0** (40)	**4.0**(4)	**1.0** (1)
8. Smithfield	5.2 **(156)**	**85.7** (24/28)	**14.3** (4)	**0.0**(0)	**0.0** (0)	**0.0** (0)
9. Park Station	5.5 **(165)**	**25.4** (16/63)	**19.0** (12)	**44.4** (28)	**7.9** (5)	**3.2** (2)
Average	4 – 6 months **(143-204)**	**36.0** (281/781)	**34.4** (269)	**25.6** (200)	**3.5**(27)	**0.5** (4)

Table 6b Follow-up 2, 12 months intensities of *A. lumbricoides* infection (e.p.g.) in the 10 slums. (n=947).

	Not infected	Light infection	Moderate infection	Heavy infection	Very heavy infection
Slum	% (N)	% (N)	% (N)	% (N)	% (N)
1. Bottlebrush	**34.4** (62/180)	**36.7** (66)	**19.4** (35)	**8.3** (15)	**1.1** (2)
2. Kennedy Lower	**8.3** (9/109)	**9.2** (10)	**60.6** (66)	**21.1** (23)	**0.9** (1)
3. Lusaka	**3.1** (2/64)	**45.3** (29)	**43.8** (28)	**7.8** (5)	**0.0** (0)
4. Pemary Ridge	**0.0** (0/64)	**9.4** (6)	**32.8** (21)	**45.3** (29)	**12.5** (8)
5. Quarry Road West	**1.2** (1/82)	**2.4** (2)	**47.6** (39)	**41.5**(34)	**7.3** (6)
6. Simplace	**0.0** (0/123)	**3.3** (4)	**43.9** (54)	**45.5**(56)	**7.3** (9)
7. Briardene	**0.9** (1/110)	**10.9** (12)	**49.1** (54)	**35.5**(39)	**3.6** (4)
8. Smithfield	**75.0** (21/28)	**21.4** (6)	**3.6** (1)	**0.0**(0)	**0.0** (0)
9. Park Station	**0.0** (0/65)	**12.3** (8)	**84.6** (55)	**3.1** (2)	**0.0** (0)
10. Canaan	**18.0** (22/122)	**18.9** (23)	**51.6** (63)	**9.8** (12)	**1.6** (0)
Average	**12.5** (118/947)	**17.5** (166)	**43.2** (416)	**22.7**(215)	**3.4** (32)

Table 7 Baseline intensities of *T. trichiura* infection (e.p.g.) for all the subjects examined in the 10 study slums.

		Light infection	Moderate infection	Heavy infection	Very heavy infection
Slum	No. examined	% (N)	% (N)	% (N)	% (N)
1. Bottlebrush	200	**48.5** (97/200)	**20.0** (40)	**2.0** (4)	**2.0** (4)
2. Kennedy Lower	122	**44.6** (54/122)	**9.1** (11)	**0.8** (1)	**0.0** (0)
3. Lusaka	70	**40.8** (29/70)	**33.8** (24)	**0.0** (0)	**0.0** (0)
4. Pemary Ridge	65	**33.8** (22/65)	**38.5** (25)	**1.5** (1)	**0.0** (0)
5. Quarry Road West	82	**42.7** (35/82)	**29.3** (24)	**1.2**(1)	**0.0**(0)
6.Simplace	123	**51.2** (63/63)	**21.1** (26)	**1.6**(2)	**3.3** (4)
7.Briardene	112	**57.1** (64/112)	**18.8** (21)	**2.7**(3)	**0.9** (1)
8.Smithfield	29	**44.8** (13/29)	**41.4** (12)	**0.0** (0)	**0.0** (0)
9.Park Station	71	**57.7** (41/71)	**14.1** (10)	**0.0** (0)	**0.0** (0)
10.Canaan	122	**55.3** (68/122)	**9.8** (12)	**0.8** (1)	**0.0** (0)
Average	996	**48.8** (486/996)	**20.6** (205)	**1.3**(13)	**0.9** (9)

***T. trichiura*. Egg counts classification**

Light = 1 – 999 e.p.g.; moderate = 1 000 – 9 999 e.p.g. ; heavy = 10 000 – 20 000 e.p.g. ;

very heavy = 20 000 e.p.g. (Renganathan *et al.* 1995)

Table 8 Post treatment intensities of *T. trichiura* infection (e.p.g.) for all the subjects examined in the 10 study slums.

	Light infection	Moderate infection	Not *T. trichiura* infected
Slum	% (N)	% (N)	% (N)
1.Bottlebrush	**9.0** (18/200)	**4.0**(8)	**87.0**(178)
2.Kennedy Lower	**13.2** (16/122)	**0.0** (0)	**86.8**(106)
3.Lusaka	**35.2** (25/70)	**1.4** (1)	**63.4** (44)
4.Pemary Ridge	**21.5** (14/65)	**4.6** (3)	**73.9** (48)
5.Quarry Road West	**23.2** (19/82)	**1.2** (1)	**75.6**(62)
6.Simplace	**17.1** (21/123)	**5.7** (7)	**77.2**(95)
7.Briardene	**16.1** (18/112)	**2.7** (3)	**81.2**(91)
8.Smithfield	**34.5** (10/29)	**13.8** (4)	**51.7**(15)
9.Park Station	**19.7** (14/71)	**0.0** (0)	**80.3** (57)
10.Canaan	**18.0** (22/122)	**0.8** (1)	**27.9** (99)
Average	**17.8** (177/996)	**2.8** (28)	**20.8**(791)

Table 9a Follow-up 1 survey intensities of *T. trichiura* infection (e.p.g) for all the subjects examined in the 10 slums. (n=781).

Slum	Not *Trichuris* infected %(N)	Light infection %(N)	Moderate infection %(N)	Heavy & very heavy infection %(N)
1. Bottlebrush	**69.6** 9 (115/166)	**24.8** (41)	**3.6** (6)	**2.0** (4)
2. Kennedy Lower	**79.8** (96/120)	**20.2** (24)	**0.0** (0)	**0.0** (0)
3. Lusaka	**40.8** (21/53)	**48.1** (26)	**11.1** (6)	**0.0** (0)
4. Pemary Ridge	**16.3** (8/49)	**53.1** (26)	**28.6** (14)	**2.0** (1)
5. Quarry Road West	**34.1** (28/82)	**50.0** (41)	**15.9** (13)	**0.0** (0)
6. Simplace	**55.0** (66/120)	**36.7** (44)	**8.3** (10)	**0.0** (0)
7. Briardene	**51.0** (51/100)	**33.0** (33)	**15.0** (15)	1 (1)
8. Smithfield	**60.8** (17/28)	**32.1** (9)	**7.1** (2)	**0.0** (0)
9. Park Station	**55.4** (34/63)	**43.1** (28)	**1.5** (1)	**0.0** (0)
Average	**56.4** (440/781)	**34.8** (272)	**8.6** (67)	**0.0** (2)

Table 9b Follow-up 2 intensities of *T. trichiura* infection (e.p.g.) for all the subjects examined in the 10 slums. (n=947).

Slum	Not Infected	Light infection	Moderate infection	Heavy infection	Very heavy infection
	%(N)	%(N)	%(N)	%(N)	%(N)
1. Bottlebrush	34.3 (61/180)	38.1 (69)	26.5 (48)	1.1 (2)	0.0 (0)
2. Kennedy Lower	62.4 (68/109)	20.2 (22)	17.4 (19)	0.0 (0)	0.0 (0)
3. Lusaka	33.9 (21/64)	16.9 (11)	49.2 (32)	0.0 (0)	0.0 (0)
4. Pemary Ridge	10.9 (7/64)	15.6 (10)	43.8 (28)	21.9(14)	7.8 (5)
5. Quarry Road West	4.9 (4/82)	11.0 (9)	58.5 (48)	19.5(16)	6.1(5)
6. Simplace	10.6 (13/123)	17.9 (22)	58.5 (72)	10.6(13)	2.4 (3)
7. Briardene	7.4 (9/110)	8.3 (9)	65.1 (71)	17.4(19)	1.8 (2)
8. Smithfield	18.5 (6/28)	7.4 (2)	66.7 (18)	7.4 (2)	0.0 (0)
9. Park Station	35.4 (23/65)	13.8 (9)	18.5 (12)	30.8(20)	1.5 (1)
10. Canaan	53.2 (65/122)	27.9 (34)	10.7 (13)	8.2 (10)	0.0 (0)
Average	**29.3**(277/947)	**20.8** (197)	**38.1** (361)	**10.1**(96)	**1.7** (16)

APPENDIX D

Table 11. *A. lumbricoides* and *T. trichiura* prevalences by risk factor at baseline, follow-up 1 and follow-up 2 when data from all 10 slums are pooled.

FACTOR		**Baseline**		**Follow-up 1**		**Follow-up 2**	
Slum	*Category*	*Ascaris* % (n)	*Trichuris* % (n)	*Ascaris* % (n)	*Trichuris* % (n)	*Ascaris* % (n)	*Trichuris* % (n)
Bottlebrush (1)		85.8(165)	72.5(145)	23.5(39)	28.5(47)	65.6(118)	65.7(119)
Kennedy Lower (2)		91.8(112)	54.5(66)	32.5(39)	20.2(24)	91.7(100)	37.6(41)
Lusaka (3)		88.6(62)	74.6(53)	66.0(35)	59.3(32)	96.6(62)	66.2(43)
Pemary Ridge (4)		93.8(61)	73.8(48)	100.0(49)	83.7(41)	100.0(64)	89.1(57)
Quarry Road West (5)		96.3(79)	73.2(60)	91.5(75)	65.9(54)	98.8(81)	95.1(78)
Simplace (6)		91.9(113)	77.2(95)	98.3(118)	45.0(54)	100.0(123)	89.4(110)
Briardene (7)		87.5(98)	79.5(89)	94.0(94)	49.0(49)	99.1(109)	95.1(78)
Smithfield (8)		86.2(25)	86.2(25)	14.3(4)	39.3(11)	25.0(7)	81.5(22)
Park Station (9)		81.7(58)	71.8(52)	81.7(58)	44.6(29)	100.0(65)	64.6(42)
Canaan (10)		94.3(115)	66.4(81)	**	**	82.0(100)	46.7(57)
Slum soil type	*Cartref*	84.1(227)	73.0(197)	33.8(74)	35.8(74)	73.8(180)	65.7(161)
	Dundee & Fernwood	95.2(140)	73.5(108)	94.7(124)	72.5(95)	99.3(145)	92.5(135)
	Milkwood	90.0(521)	70.5(408)	70.1(302)	38.8(168)	90.5(504)	67.3(374)
Interviewee	*Parent*	89.5(655)	72.1(527)	64.1(371)	44.7(259)	87.3(637)	70.6(514)
	Guardian	90.5(172)	71.6(136)	63.3(466)	40.0(60)	88.9(169)	72.0(136)

Sex	*Females*	90.2 (432)	73.1(350)	63.1(234)	50.9(189)	87.2(402)	72.6(334)
	Males	88.2(456)	70.2(712)	64.9(266)	36.8(151)	87.9(427)	68.9(335)
Age of child	*2*	83.6(138)	60.0(99)	68.2(88)	40.8(53)	90.8(138)	71.7(109)
	3	88.9(120)	63.0(85)	64.1(66)	40.8(52)	90.0(117)	69.5(91)
	4	89.1(122)	70.1(96)	56.8(63)	45.5(50)	88.7(118)	72.2(96)
	5	89.5(102)	74.3(84)	66.7(58)	45.9(39)	88.8(95)	74.5(79)
	6	95.5(106)	75.7(84)	63.3(50)	44.4(36)	84.8(89)	65.4(68)
	7	95.5(84)	72.7(64)	67.1(47)	41.4(29)	92.9(78)	63.9(53)
	8	93.4(85)	85.7(78)	62.7(47)	48.0(36)	85.1(74)	73.6(64)
	9	84.6(55)	78.5(51)	66.0(35)	41.5(22)	79.0(49)	82.5(52)
	10	84.4(76)	78.9(71)	62.2(46)	44.6(33)	81.6(71)	65.5(57)
Topographical position of dwelling	*Crest*	87.1(169)	71.1(138)	47.1(82)	31.8(55)	84.5(164)	61.3(119)
	Mid or foot-slope	92.6(225)	76.5(186)	70.2(120)	43.9(76)	86.4(210)	73.7(179)
	Valley bottom	93.0(173)	67.7(126)	63.3(107)	44.4(75)	88.1(163)	75.4(138)
	Flat	87.0(260)	71.5(213)	73.0(157)	52.8(113)	90.3(269)	72.1(214)
Quality of house	*Corrugated iron*	87.2(68)	75.6(59)	72.7(48)	43.9(29)	89.7(70)	77.9(60)
	Cardboard	94.0(63)	79.1(53)	59.6(31)	49.1(26)	82.1(55)	71.6(48)
	Asbestos	90.9(20)	77.3(17)	81.8(18)	40.9(9)	100.0(22)	81.8(18)
	Brick	88.0(198)	74.7(168)	66.2(94)	44.0(62)	87.6(197)	63.1(142)
	Mud	89.7(78)	65.5(57)	39.2(31)	26.9(21)	78.2(68)	64.0(55)

		Ascaris % (n)	*Trichuris* % (n)	*Ascaris* % (n)	*Trichuris* % (n)	*Ascaris* %(n)	*Trichuris* %(n)
	Wooden planks	89.7 (104)	67.8(78)	55.3(52)	39.4(37)	85.3(99)	72.2(83)
	Mixed materials	92.5 (271)	69.6(204)	69.5(169)	48.8(119)	90.0(262)	76.3(222)
Child's origin	*Rural*	90.7 (255)	73.3(206)	62.6(154)	40.2(99)	88.6(249)	72.5(203)
	Township	89.0 (355)	72.9(290)	59.4(203)	42.0(144)	84.1(334)	71.1(281)
	Settlement	90.7 (166)	64.5(118)	79.1(72)	56.7(51)	91.3(167)	61.7(113)
	Urban	84.3(43)	82.4(42)	77.3(34)	50.0(22)	96.1(49)	90.2(46)
Number of rooms per dwelling	1 room	91.2 (134)	73.5(108)	78.1(89)	49.6(58)	92.5(136)	80.3(118)
	2 rooms	90.6 (480)	72.1(382)	71.8(278)	45.7(176)	90.9(480)	70.6(372)
	3 rooms	85.2 (115)	71.9(97)	45.3(58)	36.7(47)	78.5(106)	68.7(92)
	4 rooms	89.0 (81)	71.4(65)	36.9(31)	35.7(30)	73.6(67)	62.6(57)
	5 rooms	85.7 (6)	57.1(4)	66.7(4)	50.0(3)	100.0(7)	71.4(5)
	6 rooms	66.7 (2)	100.0(3)	100(3)	100.0(3)	66.7(2)	100.0(3)
	7 rooms	100.0(2)	20.0(1)	100.0(3)	20.0(1)	100.0(6)	20.0(1)
	8 rooms	100.0(3)	100.0(3)	33.3(2)	100.0(1)	66.7(2)	66.7(2)
Number of inhabitants per dwelling	2	91.3(22)	56.5(14)	84.2(16)	57.9(11)	100.0(24)	87.0(20)
	3	88.8(103)	66.4(77)	77.0(77)	49.5(50)	93.1(108)	75.7(87)
	4	89.1(139)	73.7(115)	61.9(73)	38.8(45)	85.9(134)	64.1(100)
	5	90.3(102)	76.1(86)	50.5(48)	44.8(48)	83.2(94)	66.1(74)
	6	86.8(158)	76.4(139)	65.4(89)	43.1(59)	85.1(154)	73.5(133)
	7	87.7(57)	66.2(43)	68.1(32)	48.9(23)	90.8(59)	73.8(48)

Number of inhabitants per dwelling	8	87.0(67)	72.7(56)	51.4(36)	38.6(27)	81.8(63)	72.7(56)
	9	98.6(71)	69.4(50)	72.5(37)	37.3(19)	91.5(65)	73.2(52)
	10	100 (11)	81.8 (9)	100.0 (9)	55.6 (5)	90.9 (10)	81.8 (9)
	11	90.5(38)	61.9(26)	79.2(19)	62.5(15)	95.2(40)	59.5(25)
	12	94.4(34)	75.0(27)	63.6(21)	45.5(15)	88.9(32)	77.8(28)
	14	100.0(6)	20.0(1)	33.3(2)	20.0(1)	100.0(6)	20.0(1)
	16	84.2(16)	89.5(17)	26.3(5)	21.1(4)	78.9(15)	73.7(14)
Care-giver	*Mother*	91.3(536)	71.0(416)	71.5(338)	46.4(220)	93.0(546)	72.2(423)
	Father	80.0(16)	75.0(15)	100.0(8)	25.0(2)	85.0(17)	60.0(12)
	Granny	89.4(143)	70.6(113)	62.2(74)	44.1(52)	86.2(137)	68.4(108)
	Crèche	83.3(101)	73.3(88)	31.6(31)	35.7(35)	65.3(77)	70.9(83)
Child visits last 6 months	*Rural*	91.8(191)	72.6(151)	68.7(112)	43.2(72)	87.5(182)	73.4(152)
	Settlement	89.5(559)	71.5(444)	62.7(308)	43.9(214)	88.4(547)	69.6(430)
	Urban	100.0(8)	87.5(7)	83.3(5)	50.0(3)	75.0(6)	87.5(7)
	Township	84.3(70)	72.3(60)	62.1(41)	45.5(30)	84.1(69)	74.1(60)
Geophageous parents	*Yes*	92.9(234)	68.5(172)	76.1(162)	49.5(105)	90.0(226)	76.0(190)
	No	88.4(592)	73.3(491)	58.8(301)	41.5(213)	86.4(576)	68.9(458)
Source of soil for parent	*Ground*	89.7(125)	67.4(93)	68.5(79)	46.4(51)	86.7(120)	72.4(97)
	House walls	87.5(17)	56.3(11)	75.0(12)	41.7(5)	93.3(14)	86.7(13)
	Market	89.6(43)	72.9(38)	68.3(28)	39.0(16)	93.8(45)	64.6(31)
How often do you eat soil (parent)	*Daily*	90.2(129)	67.8(97)	70.6(84)	45.4(54)	89.4(127)	74.6(106)

	Weekly	90.0(54)	70.0(42)	74.0(37)	48.0(24)	88.1(52)	72.9(43)
	When she is pregnant	100.0(5)	25.0(1)	40.0(2)	25.0(1)	100.0(5)	25.0(1)
Mother's level of education	*None*	81.8(9)	81.8(9)	42.9(3)	33.3(2)	90.9(10)	63.6(7)
	Primary	90.5(439)	72.2(350)	(67.4)265	44.1(173)	88.2(425)	70.5(339)
	Secondary	89.1(368)	71.1(293)	61.2(194)	44.5(142)	86.9(358)	72.0(295)
	Tertiary	100.0(1)	100.0(1)	0.0(0)	0.0(0)	100.0(1)	100.0(1)
Father's level of education	*None*	88.2(67)	82.9(63)	58.0(29)	44.9(22)	80.0(60)	74.7(56)
	Primary	91.3(438)	71.8(344)	74.2(273)	43.0(159)	92.1(441)	70.2(335)
	Secondary	87.5(232)	72.5(192)	53.5(122)	46.3(105)	82.2(217)	71.1(187)
	Tertiary	100.0(1)	100.0(1)	0.0(0)	0.0(0)	100.0(1)	100.0(1)
Guardian's level of education	*None*	86.7(13)	80.0(12)	57.1(8)	50.0(7)	93.3(14)	73.7(11)
	Primary	88.4(61)	72.5(50)	62.5(35)	48.2(27)	94.2(65)	68.1(47)
	Secondary	88.9(16)	88.9(16)	37.5(6)	31.3(5)	77.8(14)	55.6(10)
	Tertiary	0.0(0)	0.0(0)	0.0(0)	0.0(0)	0.0(0)	0.0(0)
Mother's level of employment	*Not employed*	90.5(313)	74.6(258)	69.5(196)	45.1(128)	87.0(301)	75.1(260)
	Formal	86.4(38)	63.6(28)	48.8(20)	29.3(12)	90.9(40)	59.1(26)
Father's level of employment	*Informal*	89.8(465)	70.8(366)	62.1(244)	45.0(176)	87.7(451)	69.3(354)
	Not employed	85.1(166)	74.7(145)	64.1(93)	40.3(58)	88.7(172)	64.6(124)
	Formal	88.5(46)	69.2(36)	72.3(34)	53.2(25)	94.2(49)	82.7(43)
	Informal	91.3(526)	72.9(420)	65.8(300)	44.6(204)	86.9(499)	72.1(413)

Guardian's level of employment	*Not employed*	90.9(90)	76.8(76)	58.1(50)	44.2(38)	89.9(89)	67.7(67)
	Formal	100.0(1)	100.0(1)	100.0(1)	100.0(1)	100.0(1)	100.0(1)
	Informal	25.0(1)	75.3(3)	0.0(0)	0.0(0)	100.0(4)	25.0(1)
Mother's income	*<R200.99*	89.7(367)	66.7(272)	64.0(192)	45.3(135)	88.9(362)	67.4(273)
	R300.00 – R999.99	88.6(124)	77.9(109)	53.3(65)	39.3(48)	84.1(116)	70.1(96)
	>R1000.00	94.1(16)	88.2(15)	37.5(6)	25.0(4)	88.2(15)	64.7(11)
Father's income	*<R200.99*	91.0(274)	66.8(201)	78.8(182)	48.1(112)	92.0(277)	73.1(220)
	R300.00 – R999.99	89.8(298)	76.2(253)	58.8(161)	44.3(121)	83.9(277)	72.3(238)
	>R1000.00	92.9(13)	92.9(13)	28.6(4)	35.7(5)	85.7(12)	78.6(11)
Guardian's income	*<R200.99*	76.5(13)	88.2(15)	43.8(7)	43.8(7)	94.1(16)	52.9(9)
	R300.00 – R999.99	85.7(42)	77.6(38)	48.6(18)	27.0(10)	85.7(42)	55.1(27)
	>R1000.00	100.0(1)	100.0(1)	100.0(1)	100.0(0)	100.0(1)	100.0(1)
Distance between house and water source	*< 500metres*	88.5(531)	70.3(421)	49.9(235)	38.9(182)	82.9(494)	64.1(380)
	>500metres	91.0(284)	75.0(234)	89.7(234)	52.3(138)	98.4(304)	84.8(262)
Water source	*Tap in the house*	91.0(131)	71.5(103)	69.0(29)	61.9(26)	85.4(123)	51.4(74)
	Rain-tank	100.0(1)	100.0(1)	0.0(0)	0.0(0)	0.0(0)	100.0(0)
	River	100.0(36)	55.6(20)	75.0(3)	50.0(2)	100.0(36)	66.7(24)
	Purchase from standpipe	89.6(583)	72.8(473)	69.9(421)	44.9(270)	90.5(584)	76.6(492)
	Tap in the yard	83.3(80)	71.9(69)	18.8(16)	25.9(22)	67.7(65)	61.5(59)
Cooking facility	*Wood*	100.0 (2)	100.0(2)	0.0(0)	0.0(0)	100.0(2)	0.0(0)
	Paraffin	96.5(647)	82.1(516)	64.7(386)	66.7(254)	92.9(627)	73.9(516)

	Gas	100.0(3)	79.7(55)	52.9(27)	45.1(23)	84.1(58)	71.0(49)
	Electricity	90.2(119)	72.0(95)	83.6(56)	61.2(41)	90.9(120)	63.6(84)
Use of household bleach	*Yes*	60.0(3)	80.0(4)	50.0(1)	50.0(1)	80.0(4)	60.0(3)
	No	89.8(834)	72.0(668)	63.9(468)	43.6(319)	87.4(805)	70.7(649)
Boil water before use	*Yes*	0.0(0)	0.0(0)	0.0(0)	0.0(0)	0.0(0)	0.0(0)
	No	89.6 (836)	72.0(671)	64.0(469)	43.5(319)	87.4(808)	70.6(651)
	Unsafe	89.6(318)	76.9(273)	85.2(253)	52.7(158)	95.4(335)	83.5(293)
Distance between house and toilet	*<500metres*	88.5(525)	73.0(432)	()	()	()	()
	>500metres	89.2(74)	74.7(62)	()	()	()	()
Girls sanitation habit during the day	*Safe*	88.8(442)	67.6(336)	46.4(168)	35.9(129)	82.3(405)	59.7(293)
	Unsafe	90.3(391)	76.7(332)	81.3(300)	51.3(191)	93.5(402)	83.9(359)
Boys sanitation habit during the day	*Safe*	89.0(453)	67.9(345)	45.3(169)	35.4(131)	81.5(410)	59.7(299)
	Unsafe	90.0(378)	76.9(323)	83.7(298)	51.8(186)	94.7(395)	83.9(349)
Girls sanitation habit at night	*Safe*	87.7(342)	68.1(265)	45.7(122)	34.8(92)	85.3(330)	55.4(214)
	Unsafe	90.8(491)	74.5(403)	74.6(346)	48.8(228)	89.2(477)	82.2(438)
Boys sanitation habit at night	*Safe*	87.7(343)	68.2(266)	45.5(122)	34.3(91)	85.3(331)	55.0(213)
	Unsafe	90.7(488)	74.7(402)	74.8(345)	48.7(226)	89.1(474)	82.1(435)
At what age do mothers teach your children to use a toilet	*3*	88.4(220)	75.9(189)	51.6(95)	34.8(64)	76.7(191)	65.5(163)
	4	87.7(307)	68.2(238)	64.5(178)	46.7(129)	90.2(314)	70.8(245)
	5	92.9(287)	72.5(224)	69.6(176)	44.3(112)	92.8(284)	73.4(224)
	6	83.3(10)	83.3(10)	100.0(12)	91.7(11)	100.0(12)	100.0(12)

House with their own toilet	*Yes*	88.5(544)	69.7(428)	53.4(254)	36.4(172)	85.0(520)	65.2(398)
	No	91.7(287)	76.0(238)	83.2(213)	56.5(147)	92.6(288)	81.6(253)
How do you dispose of your child's nappies	*Unsafe*	92.1(314)	76.5(260)	84.4(238)	54.9(156)	94.1(319)	83.3(280)
	Safe	88.5(484)	68.7(376)	49.3(204)	37.4(154)	82.9(450)	62.8(341)
Hygiene condition of toilet	*Good*	100.0(5)	60.0(3)	100.0(1)	0.0(0)	80.0(4)	40.0(2)
	Satisfactory	85.7(233)	70.1(190)	32.8(60)	32.0(58)	77.5(210)	54.1(146)
	Functional	89.9(178)	73.7(146)	68.5(124)	40.9(74)	89.8(176)	74.5(146)
	Bad	89.3(150)	72.0(121)	63.9(94)	41.5(61)	87.5(147)	72.9(121)
	Full	91.8(145)	74.7(118)	78.5(84)	43.6(48)	92.9(145)	76.9(120)
	No toilet/bush	96.0(119)	71.8(89)	93.7(104)	71.8(79)	99.2(122)	91.9(113)
With soap and water	*Never*	82.9(580)	70.6(458)	70.7(357)	45.1(228)	91.8(595)	72.0(465)
	Always	91.0(172)	77.2(146)	43.9(72)	39.0(64)	72.0(136)	68.6(129)
	Occasionally	92.5(62)	74.6(50)	73.9(34)	54.3(25)	92.5(62)	74.6(50)
With water only	*Never*	93.3(166)	67.4(120)	60.9(96)	42.7(67)	95.5(170)	65.7(117)
	Always	88.9(567)	73.2(467)	63.4(306)	43.1(208)	84.8(540)	70.6(448)
	Occasionally	89.9(79)	75.9(66)	81.1(60)	57.5(42)	93.1(81)	87.2(75)
After playing	*Never*	90.2 (687)	71.7(546)	65.6(394)	44.1(265)	89.1(677)	71.5(543)
	Always	87.0(107)	74.8(92)	61.5(59)	44.8(43)	78.9(97)	71.3(87)
	Occasionally	95.7(22)	78.3(18)	57.9(11)	47.4(9)	91.3(21)	63.6(14)
Before eating	*Never*	89.5(488)	69.5(378)	67.6(290)	44.7(192)	91.0(494)	71.6(388)
	Always	93.9(169)	73.3(132)	68.8(97)	45.7(64)	90.6(163)	71.5(128)

	Occasionally	86.7(157)	72.3(654)	52.1(75)	42.4(61)	75.1(136)	70.0(126)
After defecation	*Never*	89.9(491)	69.5(379)	68.1(291)	45.2(194)	90.8(494)	72.0(391)
	Always	91.9(124)	71.1(96)	76.2(80)	74.1(49)	94.8(128)	71.9(97)
	Occasionally	88.5(201)	79.7(181)	50.5(93)	40.4(74)	76.2(173)	69.3(156)
Before going to bed	*Never*	88.7(425)	74.1 (354)	69.4(250)	47.2(170)	88.7(423)	72.0(342)
	Always	88.6(124)	67.1(94)	41.6(52)	35.5(44)	74.3(104)	66.2(92)
	Occasionally	92.4(267)	72.0(208)	70.1(162)	44.4(103)	92.7(268)	72.7(210)
In the morning when s/he wakes up	*Never*	89.8(292)	74.4(241)	72.8(163)	45.8(103)	88.9(288)	69.9(225)
	Always	89.9(177)	69.9(270)	58.0(184)	42.6(135)	84.7(326)	72.9(280)
	Occasionally	89.8(177)	73.6(145)	66.9(117)	45.4(79)	91.9(181)	70.6(139)
Cut and clean the nails	*Never*	90.4(517)	72.0(411)	60.3(290)	41.9(201)	88.4(505)	70.4(400)
	Always	87.3(233)	72.3(193)	72.1(145)	51.2(103)	86.1(229)	74.8(199)
	Occasionally	95.7(66)	75.4(52)	85.3(29)	37.1(13)	88.4(61)	65.2(45)
Does the child use hands while eating	*Never*	92.1(117)	79.5(101)	59.6(59)	35.6(36)	85.0(108)	66.7(84)
	Always	90.1(246)	76.8(209)	64.5(136)	47.1(98)	83.5(228)	71.2(193)
	Occasionally	89.2(453)	68.1(346)	66.3(269)	45.0(183)	90.7(459)	72.5(367)
Where do you get your fruits and vegetables	*Garden*	100.0 (1)	100.0(1)	0.0(0)	0.0(0)	100.0(1)	0.0(0)
	Street vendors	88.2(75)	57.6(51)	71.5(258)	42.5(36)	94.1(82)	71.8(63)
	Supermarkets or shops	89.8(431)	80.0(359)	80.0(262)	48.8(177)	88.7(428)	80.0(346)
	Rubbish dump	89.1(213)	74.1(177)	63.3(131)	41.3(89)	85.4(204)	76.2(182)
Do you feed the child leftovers	*No*	88.5 23()	80.8(21)	68.4(13)	52.6(10)	88.5(23)	73.1(19)

	Yes	89.9(815)	72.0(634)	64.8(451)	44.0(306)	87.8(772)	71.1(623)
Food storage	*Fridge*	87.1(135)	67.1(104)	54.3(72)	42.3(55)	85.2(132)	63.9(99)
	Cupboard	88.8(381)	73.1(313)	67.2(215)	45.8(147)	86.9(376)	72.8(314)
	Bucket	97.3(197)	81.8(165)	77.8(178)	53.7(116)	97.5(288)	78.5(156)
Where do you normally have your meals	*Indoor*	89.9(764)	72.2(611)	64.5(428)	44.6(298)	87.5(738)	71.3(599)
	Outdoor	90.0(36)	75.0(30)	67.7(21)	32.3(10)	92.5(37)	62.5(25)
	Indoor or outdoor	88.2(17)	70.6(13)	86.7(15)	60.0(10)	100.0(19)	82.4(16)
How do you prepare your food	*Fry*	90.2(339)	71.9(263)	67.9(195)	45.6(131)	89.6(329)	73.7(269)
	Boil	88.1(52)	74.6(44)	62.5(25)	36.6(15)	86.4(51)	54.2(32)
Child eats soil	*No*	86.3(515)	71.5(427)	53.3(244)	37.8(173)	84.9(500)	66.6(391)
	Yes	95.3(323)	72.2(244)	81.3(226)	53.2(148)	92.0(309)	77.6(260)
Child source of soil	*Ground*	94.6(106)	70.3(78)	81.0(68)	48.2(40)	91.1(102)	67.6(75)
	Walls of the house	97.5(39)	72.5(29)	81.1(31)	54.1(20)	87.5(35)	85.0(34)
	From friends	100.0(36)	88.9(32)	87.1(27)	61.3(19)	100.0(36)	80.6(29)
	From mom	100.0(6)	75.0(3)	75.0(3)	50.0(2)	100.0(4)	100.0(4)
Frequency of child soil eating	*Daily*	96.1(195)	73.4(149)	83.8(134)	57.1(92)	91.0(183)	79.6(160)
	Weekly	95.3(122)	72.4(92)	75.7(84)	46.4(51)	93.0(119)	73.2(93)
Why does a child eat soil	*Its nice*	94.9(166)	74.9(131)	81.0(111)	52.2(72)	89.1(156)	74.3(130)
	Imitates mom	97.6(40)	55.0(22)	85.3(29)	57.6(19)	95.1(39)	80.0(32)
	Imitates friends	97.1(102)	76.2(80)	80.0(72)	51.1(46)	95.1(98)	80.6(83)
	Suppresses hunger	100.0(11)	72.7(8)	63.6(7)	54.5(6)	90.9(10)	81.8(9)

What kind of soil a child prefer	*Clay*	98.6(73)	74.3(55)	82.0(50)	65.6(40)	94.6(70)	85.1(63)
	Sandy	95.0(249)	72.8(190)	80.4(172)	49.1(105)	91.2(237)	75.3(195)
Silica 1	*No silica*	-	-	43.4(128)	31.0(91)	82.6(246)	68.1(203)
	Occasional	-	-	53.7(36)	37.9(25)	85.1(57)	80p.6(54)
	Scanty	-	-	77.3(51)	40.9(27)	97.0(64)	67.7(44)
	+	-	-	77.6(118)	59.6(90)	95.4(144)	78.7(118)
	++	-	-	89.3(108)	56.6(69)	95.5(117)	88.5(108)
	+++	-	-	95.1(39)	68.3(28)	95.1(39)	95.1(39)
Silica 2	*No silica*	-	-	43.0(49)	30.4(34)	76.9(103)	60.2(80)
	Occasional	-	-	55.4(31)	35.1(20)	76.8(53)	71.0(49)
	Scanty	-	-	65.0(67)	47.6(49)	90.7(107)	74.4(87)
	+	-	-	61.1(129)	44.5(94)	91.2(250)	68.9(188)
	++	-	-	79.1(151)	50.5(97)	90.5(229)	73.9(187)
	+++	-	-	78.8(52)	57.6(38)	88.4(76)	87.2(75)

Table 10. Total number of *Ascaris lumbricoides* and *Trichuris trichiura* eggs voided to the environment at baseline and follow-up 2 in the 10 study slums.

Slums	**Total *A. lumbricoides* & *T. trichiura* (e.p.g.) at baseline**	**Baseline *Ascaris lumbricoides* intensities**				**Total *A. lumbricoides* & *T. trichiura* (e.p.g.) at follow-up 2**	**Follow-up 2 *Ascaris lumbricoides* intensities**			
		Light	Moderate	Heavy	Very heavy		Light	Moderate	Heavy	Very heavy
1.Bottlebrush	**5 005 597** **324 483**	61 939 (1.24)	2 049 783 (40.95)	2 013 480 (40.22)	880 395 (17.59)	**1 884 895** **185 725**	469 333 (24.91)	874 315 (46.41)	224 445 (24.02)	87 895 (4.66)
2. Kennedy Lower	**2 613 190** **64 655**	44 005 (1.68)	1 544 550 (59.11)	924 120 (35.36)	100 515 (3.85)	**2 854 128** **40 218**	330 385 (11.57)	1 945 970 (68.18)	432 568 (20.01)	6 750 (0.24)
3. Lusaka	**2 028 300** **83 558**	7 665 (0.33)	993 010 (48.97)	916 245 (45.20)	111 380 (5.50)	**890 370** **93 678**	40 780 (4.58)	538 705 (60.50)	232 880 (34.24)	6 125 (0.68)
4. Pemary Ridge	**2 361 232** **98 048**	18 390 (0.78)	678 632 (28.74)	1 121 475 (47.5)	542 735 (22.98)	**3 681 403** **428 245**	505 470 (13.73)	1 947 318 (52.90)	1 015 685 (30.17)	117 955 (3.20)
5. Quarry Road West	**4 916 325** **93 193**	2 700 (0.05)	879 025 (17.88)	2 452 685 (49.89)	1 581 915 (32.18)	**4 227 715** **552 475**	61 950 (1.46)	1 719 423 (40.67)	1 935 875 (48.82)	382 458 (9.05)
6. Simplace	**4 726 317** **235 560**	28 255 (0.60)	1 537 087 (32.52)	2 386 212 (50.48)	774 763 (16.40)	**6 645 175** **529 185**	973 925 (14.66)	3 120 320 (46.96)	1 660 480 (32.63)	318 835 (5.75)
7. Briardene	**3 551 370** **137 073**	29 360 (0.68)	1 400 270 (39.43)	1 621 875 (45.79)	499 865 (14.10)	**4 430 353** **613 865**	720 695 (16.27)	1 873 263 (42.28)	1 057 680 (37.75)	164 065 (3.70)
8. Smithfield	**486 515** **39 278**	8 860 (1.82)	418 770 (86.1)	58 885 (12.10)	0 (0.00)	**27 655** **99 855**	5 705 (20.63)	21 555 (77.94)	0 (0.0)	0 (0.00)
9. Park Station	**1 190 183** **35 760**	20 543 (1.73)	838 520 (70.45)	331 120 (27.82)	0 (0.00)	**1 362 905** **369 990**	321 535 (23.60)	642 085 (47.11)	100 725 (29.29)	0 (0.00)
10. Canaan	**4 825 760** **70 750**	40 860 (0.87)	1 554 780 (32.20)	2 203 120 (45.65)	1 027 000 (21.28)	**2 140 058** **235 095**	141 228 (6.69)	1 029 355 (48.10)	739 030 (39.24)	127 845 (5.97)
TOTAL	**31 704 789** **1 182 355**	**262 577** **(0.83)**	**11 894 428** **(37.52)**	**14 029 217** **(44.25)**	**5 518 568** **(17.40)**	**28 143 793** **3 148 330**	**262 577** **(0.93)**	**11 894 428** **(42.26)**	**14 029 217** **(49.85)**	**5 518 568** **(6.96)**

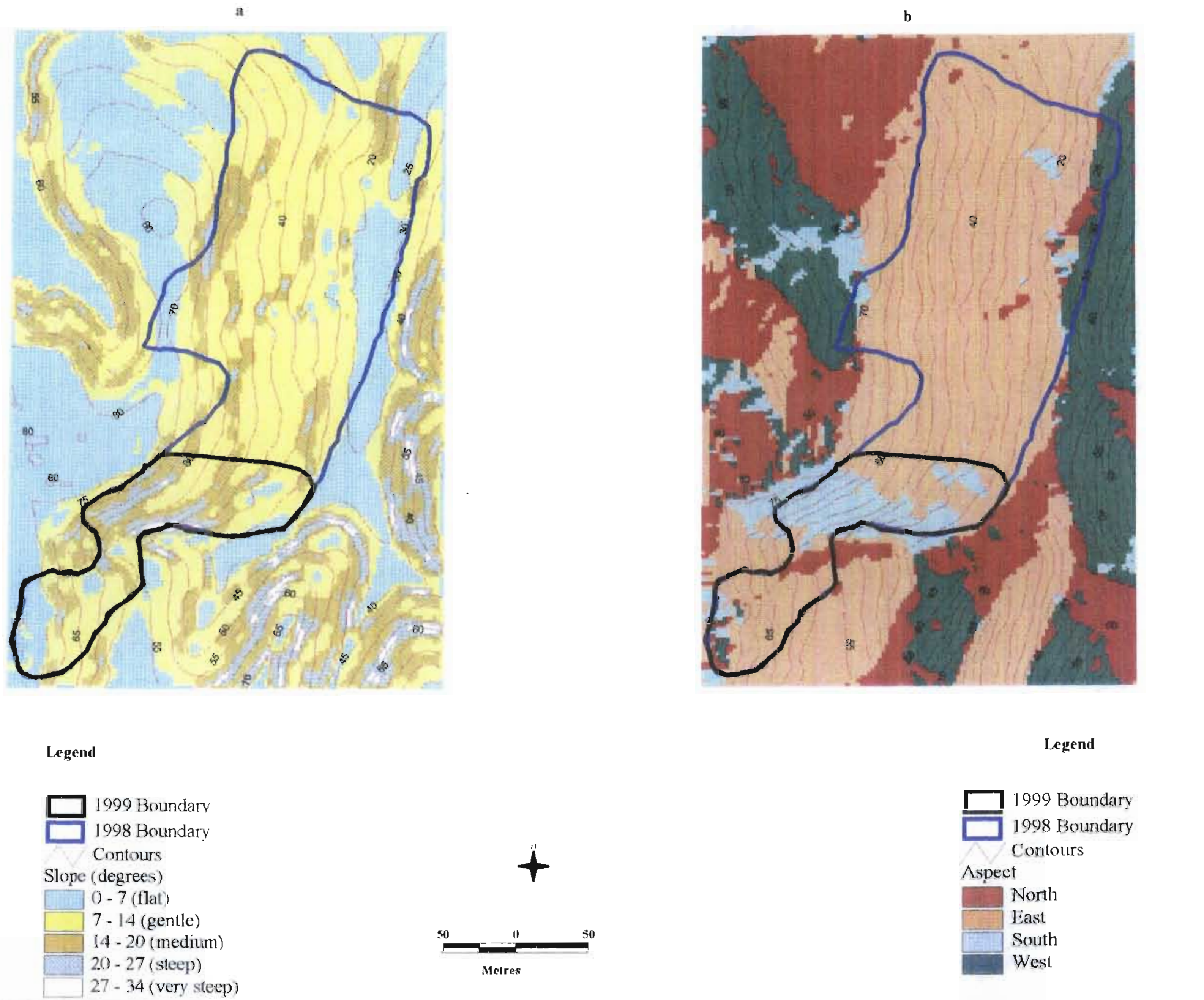


Figure3.9 GIS map of Canaan showing 1998 and 1999 boundaries, altitudinal contours and (a)slope gradients and (b) aspect.

bile duct leads to back-flow of bile causing the patient to produce bile-stained (yellow) vomitus with live worms. Adult worms may emerge from the nostrils, mouth or anus.

Statistics from clinics run by the Durban City Health Department in urban slums in the Durban Unicity, show that in the year from July 1st 1998 to June 30th 1999, 6029 patients reported with worm infections, i.e. morbidity due to ascariasis; 8061 with anaemia and 11928 for nutritional disorders. During the next year, July 1st 1999 to June 30th 2000, there were 8944 worm infections, 11335 anaemia cases and 13732 nutritional disorders.

Clinical trichuriasis is not often reported. Fisher & Cremin (1970) and Bowie *et al.*(1978) recorded it in Cape Town while in Durban the case rate for the most severe form of the disease was estimated at 1-20 per 5 000 population (Winship & Hennesy, 1959). These authors reported an infection rate of 30% among newly arrived rural migrants in Durban's Cato Crest area but this rose to 60% in those who had stayed there for more than two years. Clinical trichuriasis was clearly common in Durban's urban slums some 40 years ago but it is seldom reported today (Elsdon-Dew & Freeman, 1952). The reason for this is not known but the parasite is still very common. There are no records of hookworm disease and pathology in KwaZulu-Natal hospitals.

1.2 PATHOLOGY OF GEOHE LMINTH INFECTIONS

1.2.1 Ascariasis

The most serious consequences of ascariasis are those complications requiring surgical intervention. These include obstruction of the hepatic and pancreatic ducts, appendicitis, volvulus (twisting of a loop of the intestine causing obstruction), intussusception (prolapse of one part of the intestine into the lumen of an immediately adjacent part), intestinal perforation and obstruction due to worm boluses (Shah & Desai, 1969; Okumura *et al.*, 1974; Blumenthal & Schultz, 1975; Guyatt & Bundy, 1991; Medley *et al.*, 1993). Otu (1991) followed 3550 patients in three hospitals in Calabar, Nigeria, and found that intussusception caused obstruction in 18 adults and 26 children. The most common cause of death was late presentation at hospital resulting in late and ineffective treatment. Rathi *et al.* (1981) reported intestinal obstruction in a 45 day-old child, which was probably infected in its first couple of days of life!

When *A. lumbricoides* larvae break out of the lung capillaries during their migration, they cause haemorrhage, eosinophilia and an accompanying accumulation of blood and dead cells in the lung tissue, which leads to congestion and focal pneumonitis. Subsequent inflammatory

Table.3.3 Summary of the conditions inside the individual slums at the start (1998) and end of the study (2000).

Slum	Land owner	Year	Area Size (m^2)	Perimeter (Km)	No. of dwellings	Water source	Sanitation	Drainage	Soil conditions	Electricity
1. Bottlebrush	Council	1998	397916.0	3.411	800	DC standpipes	836 pit-privies	No developments in drainage lines (40m)	Stable	Grid supply
		2000	397916.0	3.411	1011	Standpipes & low pressure tanks	836 VIP privies			
2. Kennedy Lower	Council, private and unregistered	1998	44466.4	1.446	290	HDC standpipe	170 VIP privies	No objections	Potentially unstable	Credit meters pre-payment and street lights
		2000	44466.4	1.446	550	DC Standpipe	170 VIP privies 70% full			
3. Lusaka	State	1998	82982.6	1.400	164	1 DC standpipe	Bush & 60 pit-latrines	No objections	Stable	Credit meters
		2000	147329.0	2.07719	300	Taps installed in houses	Flush toilets			
4. Pemary Ridge	Private	1998	8435.8	0.358	56	Purchased from neighbours	4 latrines & bush	Slum falls within 1:50yr flood-plain	Stable	No supply
		2000	8435.8	0.358	62	HDC standpipe	3 latrines Bush			
5. Quarry Road West	Private	1998	35065.0	1.275	220	HDC installed on the road verge	27 latrines & bush	Slum falls within 1:50yr flood-plain	Stable	No supply
		2000	35065.0	1.275	600	HDC installed on the road verge	27 pit latrines & bush			
6. Simplace	State	1998	104129.0	1.519	420	HDC standpipe	20 latrines & bush	No objections	Potentially unstable	No supply
		2000	115544.0	1.608	925	HDC standpipe	20 latrines & bush			
7. Briardene	Council	1998	17160.7	0.584	216	HDC standpipe	22 chemical toilets	No objections	Partially unstable	No supply
		2000	43885.8	1.240	234	Water reticulation system to be installed	22 chemical toilets			
8. Smithfield	Private	1998	55837.0	1.019	65	Obtained from No 31 Triumph Road - purchased for 29c/25l	50 pit-latrines	No objections	Potentially unstable	No supply
		2000	59784.6	1.040	116	Same as above	50 pit latrines			
9. Park Station	Private	1998	17615.1	0.551	147	1 DC standpipe	10 pit latrines & bush	No objections	Potentially unstable	No supply
		2000	17615.1	0.551		Same as above	10 latrines & bush			
10. Canaan	Private & State	1998	193249.0	2.643	2500	2 DC standpipes	200 latrines	No objections	Potentially unstable	No supply
		2000	51959.2	1.275	330	Water reticulation system to be installed				

reactions produce *A. lumbricoides*-pneumonia (Jones, 1976). Some migratory larvae get lost and die in ectopic (abnormal) locations such as the brain, spleen, liver and bile duct where they induce inflammatory responses which can be confused with other conditions such as malnutrition or pneumonia (Cremin & Fisher, 1976).

Although light and moderate, infections are usually asymptomatic. Heavy intensities, co-infection with other parasites like *T. trichiura,* hookworms, *Schistosoma mansoni*, bacteria and viruses are evident in most patients (Spillman, 1975). These conditions present as colicky cramps, abdominal pain, distended abdomen, rashes, insomnia, restlessness, lethargy and tiredness related to hunger and loss of appetite. Even a single adult *A. lumbricoides* has the potential to cause serious or perhaps fatal disease (Pawlowski & Davis, 1989). This might occur when the larval worms migrate and enter the nasal meatus via the nasopharynx and exit via a nostril, a worm in the oropharynx may enter the eustachian tube and penetrate the middle ear and tympanic membrane to the external auditory meatus. Rarely, an immature worm may enter the lachrymal duct and attempt to move into the eye (Roche, 1971).

Paediatricians often report that ascariasis is the main cause of pancreatitis (Coovadia & Wittenburg, 1998). Such pancreatitis can occur in various ways, e.g. by direct invasion of the bile and pancreatic ducts causing abdominal and back pain, nausea, worms in vomitus, fever, jaundice, tender hepatomegaly; worms entering the liver cortex, dying there and forming "worm nests" (Dr S. Ramjii, pers. comm.). It may also cause acute appendicitis (Dorfman, 1995), vitamin A deficiency (Mahalanabis *et al.*, 1976) and impair lactose digestion in pre-school children (Carerra *et al.*, 1983).

1.2.1 Trichuriasis

Most people infected with *T. trichiura* experience neither signs nor symptoms. This is because the clinical picture produced by the worm in the human host depends largely on the intensity of infection (worm burden). When signs are visible however, they are seldom specific, depending on the duration of infection, the age and nutritional status of the host (Gilman *et al.*, 1983; Cooper & Bundy, 1993). Heavy intensities can cause chronic bloody mucoid diarrhoea. The mucosa may be oedematous and friable, tenesmus (straining at stool) is common, anal sphincter tone is lost, the rectum tends to prolapse and the patient may have finger-clubbing and oedema of the legs (Gilman *et al.*, 1976). This often causes bleeding and iron-deficiency anaemia, which may be severe in heavy infections and lead to cardiac failure if left unattended (Layrisse *et al.*, 1967). Nokes *et al.*, (1991, 1992) and Nokes & Bundy (1993, 1994) found that *Trichuris trichiura* heavy infections affects' children mental processing, cognitive development.

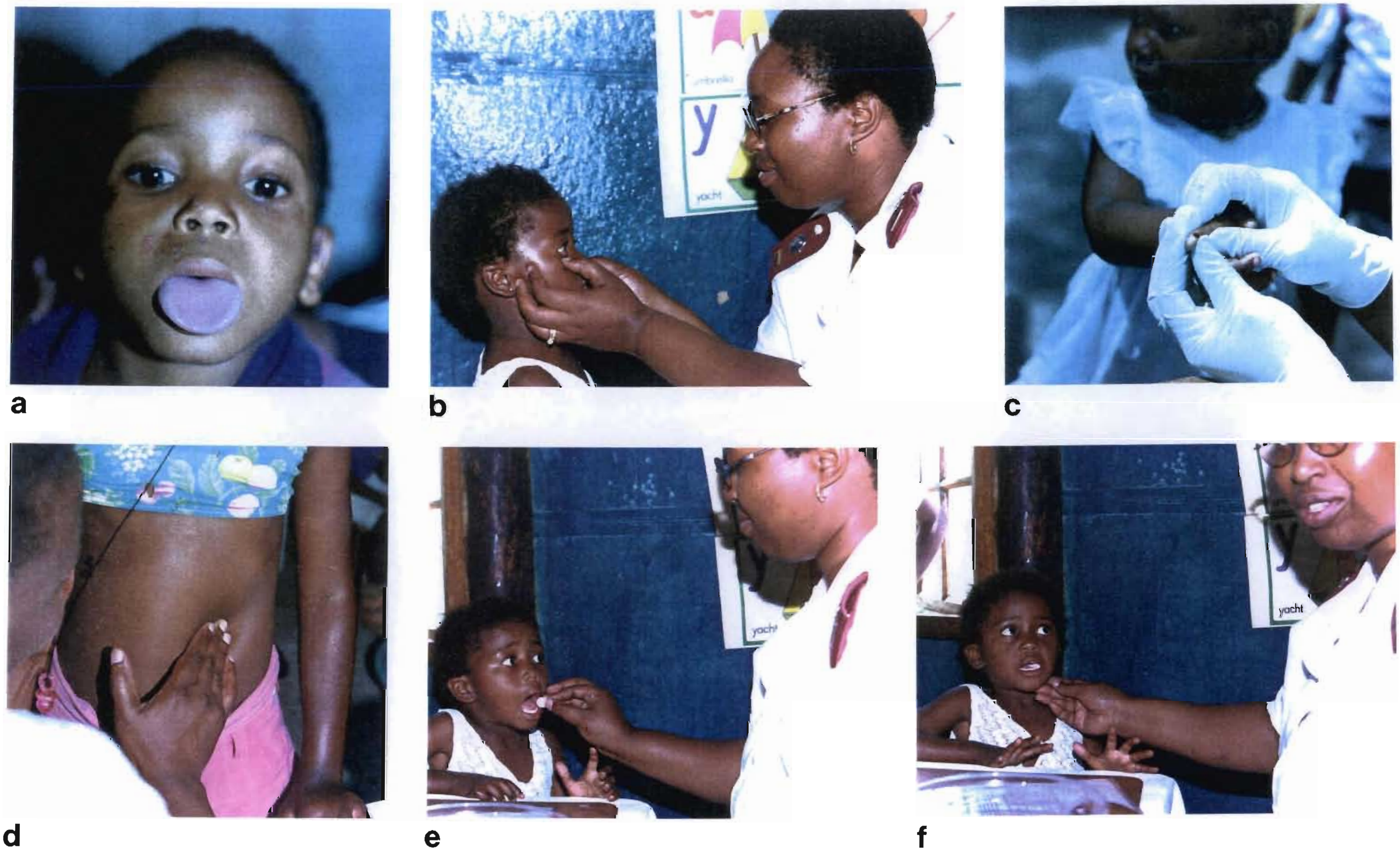
educational achievement and affect school attendance. Some malnourished children with heavy *T. trichiura* infections fail to thrive and become emaciated (Coovadia & Wittenberg, 1998). Following anthelmintic treatment, rural pre-school children in the Machakos district of Kenya gained weight and developed a greater triceps skinfold thickness (Kamath, 1973; Stephenson, 1980; Elkins *et al.*, 1988). The pathology of trichuriasis is rather enigmatic – the key may be an appreciation of the pathophysiology of the human colon, but this is currently not well-understood (Cooper & Bundy, 1987, 1993).

1.2.3 Hookworm disease

Anaemia is the most prominent feature of hookworm infection. The degree of anaemia varies from slight to severe and, like trichuriasis, may lead to cardiac failure. It is caused mainly by two factors: bleeding from the sites of worm attachment and nutritional deficiency due to a decreased appetite. Adult hookworms attach to the intestinal mucosa with their cutting plates or "teeth", damaging it as they do so. As they move from one site to another, the old sites continue to bleed after detachment, probably because of the action of anti-coagulants introduced with the saliva (Crompton & Stephenson, 1990). As a result, patients may present with black-coloured stool due to digested haemoglobin (Migasena & Gilles, 1987). Various symptoms may accompany anaemia, e.g. depleted iron status, dietary iron intake (Stephenson & Holland, 1987; Pritchard *et al.*, 1991; Robertson *et al.*, 1992a; Geissler *et al.*, 1998b; Olsen *et al.*, 2000) lassitude, palpitations, shortness of breath on exertion, tinnitus, mental apathy, fainting, swelling of the legs, loss of normal skin colour, anorexia and impotence (Migasena & Gilles, 1987).

The loss of red blood cells (RBC) into the gut is proportional to the worm burden and has been estimated for *N. americanus* at 0.02-0.07 millilitres of blood per worm per day (Stephenson & Holland, 1987; Gilles, 1996). Bleeding usually stops immediately after de-worming (Gilles & Ball, 1997) but it takes 15-20 months for haemoglobin levels to return to normal (Roche & Layrisse, 1966).

The assessment of the pathological significance of hookworm infection is complicated by the fact that in areas where it is endemic, other diseases which cause blood loss are common too, e.g. schistosomiasis, malaria, dysentry and heavy *T. trichiura* infections (WHO, 1964; Schad & Warren, 1990). It is therefore difficult to determine how much is attributable to hookworm.



Drug administration: (a-c) Checking for signs of anaemia (tongue pallor, optical anaemia and taking blood sample for haemoglobin assay, **(d)** checking for signs of abdominal distension, **(e)** giving Albendazole 400mg and **(f)** checking that the tablet has been swallowed.

1.3 GEOHELMINTHS AND MALNUTRITION

The global distribution of malnutrition coincides closely with those of *A. lumbricoides* and *T. trichiura* (Powers *et al.*, 1960; Ruttar & Beer, 1975; Crompton, 1985; Hagel *et al.*, 1995). Chronic infections, especially of *A. lumbricoides*, contribute to long-term protein energy malnutrition (PEM) and children aged 6 months to 6 years appear to be most vulnerable (Freij et al., 1979; Sawaya, *et al.*, 1985; Chan *et al.*, 1992; Fincham, *et al.*, 1996). Histological examination of the mucosa of *A. lumbricoides*-infected children showed the presence of a broadening and shortening of the villi, elongation of the crypts and a cellular infiltration of the lamina propria (Tripathy *et al.*, 1971a). Marked remission was observed in this mucosal histology in the same children three weeks after anthelmintic treatment. The same authors (Tripathy *et al*, 1971b) showed that in another group of children, ascariasis was associated with steatorrhoea (excess fat in the stool due to disturbed fat digestion), malabsorption of D-xylose (impaired carbohydrate absorption) and impaired nitrogen retention. These defects generally returned to normal after treatment.

For ethical reasons, many studies on the role of chronic ascariasis in malnutrition have been helped by experiments using pigs or mice infected with *A. suum*. The pig-*A. suum* relationship is similar to that between man and *A. lumbricoides* (Nesheim, 1989) and unequivocal results have shown that *A. suum*-infected pigs eat less food and gain less weight than uninfected controls (Forsum *et al.*, 1981). The presence of *A. suum* in the small intestine was accompanied by significant reductions in the pig's ability to digest nitrogen and fat, the quantities of which were related to intensity of infection. *In vitro* measurements on preparations of the intestinal mucosa showed lactose activity to be almost halved in infected pigs. These pigs also gave evidence of impaired lactose digestion (Forsum *et al.*, 1981; Carrera *et al.*, 1983).

Malnutrition is also associated with heavy *T. trichiura* infections, especially in children. If a heavy infection is allowed to persist, the child loses weight or fails to gain weight (Elkins *et al.*, 1988; Robertson *et al.*, 1992b; Coovadia & Wittenberg, 1998). Indices of nutrition such as the weight: height ratio improved following the expulsion of heavy burdens of *T. trichiura* (Gillman *et al.*, 1976; Gillman *et al.*, 1983; Bundy, 1985) suggesting that this specific infection had been a prime determinant of malnutrition. Cooper & Bundy (1986, 1993) and Walker *et al.* (1992) showed that stunting (long-standing process resulting in short stature for age) was correlated with heavy *T. trichiura* burdens but not with *A. lumbricoides* infections. There was however no relationship between trichuriasis and wasting (a relatively acute process resulting in low weight for achieved height), implying that the chronic colitis typical of trichuriasis had simply inhibited growth over a number of months.

The pathogenesis of the anaemia caused by hookworm disease is aggravated by three factors: the iron content of the diet, the state of the body's iron reserves and the intensity and duration of the infection. For example, in Nigeria where iron intake is high (21-31mg daily), people whose only pathological source of bleeding is hookworm infection show no evidence of iron depletion, viz. a reduced serum iron concentration or an iron deficiency anaemia, unless they harboured 800 or more worms (Migasena & Gilles *et al.*, 1987). However, in areas where the total iron content of food is low, moderate hookworm burdens (less than 400 eggs per gram of stool – Renganathan *et al.*, (1995), will cause sufficient blood loss to precipitate anaemia (Pawlowski, 1987).

1.4 ROUTES OF INFECTION

Ascaris lumbricoides and *Trichuris trichiura* infections occur passively via the faecal-oral and hand-to-mouth routes, entering the mouth with contaminated food, water and soil, as well as from all sorts of domestic surfaces, including linen and banknotes (Crompton *et al.*, 1989; Huttly, 1990). These may however be combined with mechanical transmission by muscid flies (e.g. *Musca domestica* and *M. vicina*) and with geophagy. Domestic flies are able to transfer helminth eggs from place to place on their mouthparts or by regurgitation with ingested food (Dipeolu, 1977, 1982). Geophagy (soil eating) is another potentially important source of infection (Halsted, 1968; Wong *et al.*, 1991; Geissler *et al.*, 1998), and this behaviour is common in South Africa, e.g. in Maputaland, north-eastern KwaZulu-Natal (Saathoff, 2001) and confirmed by this study. There may be a link between geophagy, growth retardation in people due to zinc deficiency and heavy *T. trichiura* infections (Halsted, 1968; Bundy & Golden, 1987).

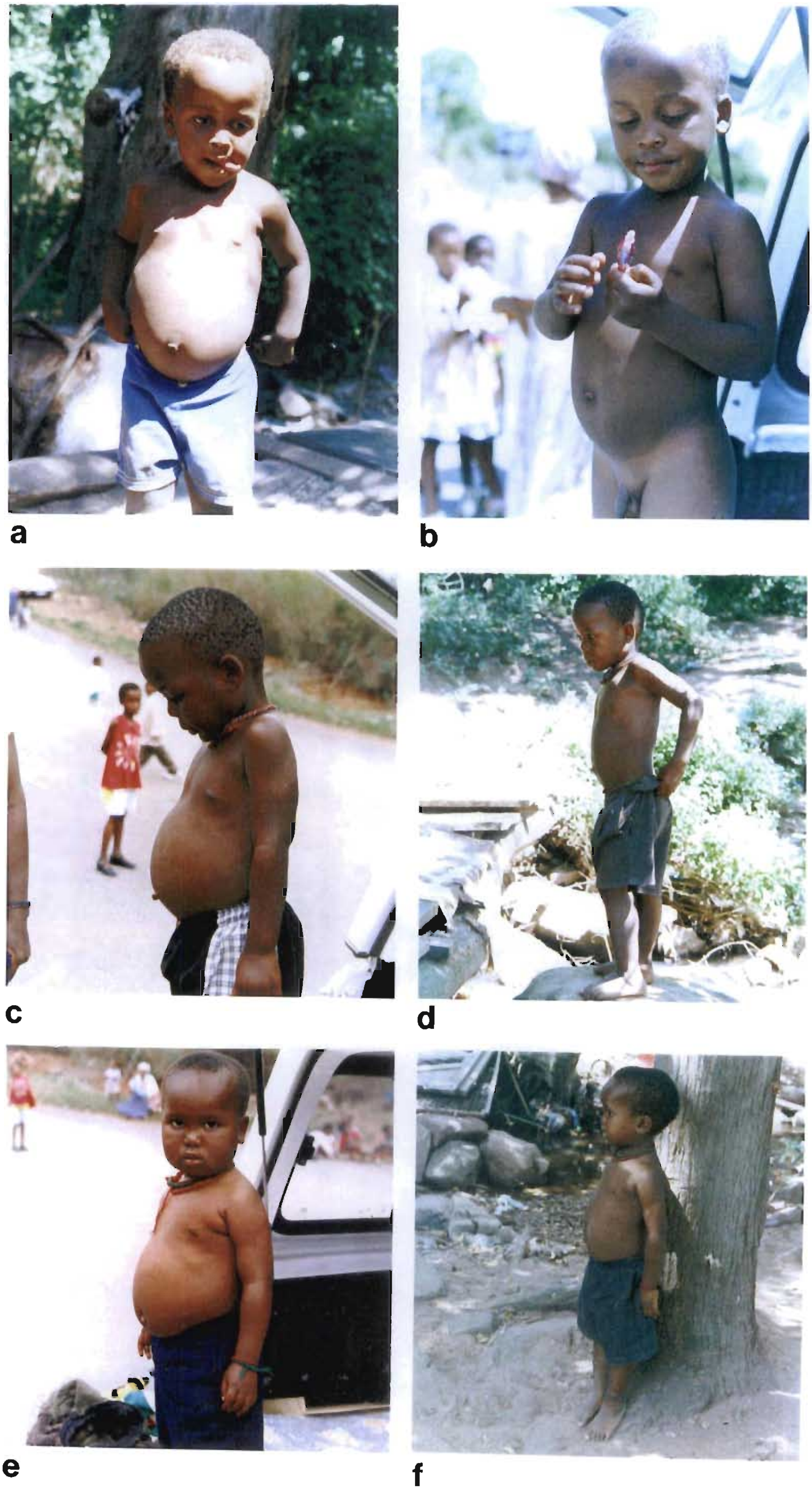
Hookworm infects people via active penetration of the skin by filariform (L_3) larvae living in the soil but, as demonstrated by Mabaso (1999), transmission only occurs from sandy soils with a low clay content.

1.5 DETERMINANTS OF TRANSMISSION

Geohelminth transmission rates depend on a combination of biological, environmental, cultural and socio-economic variables (Mata, 1982; Ashford *et al.*, 1993; Cooper *et al.*, 1993; Appleton & Gouws, 1996), and the best way to measure transmission is to examine as many of these as

CHAPTER 5

Demonstration of the effect of treatment on abdominal distension: (a, c, e) before treatment and **(b, d, f)** after treatment in the same children.



possible. Risk factors associated with *A. lumbricoides, T. trichiura* and *N. americanus* transmission fall into several categories: poor sanitation, poor housing, lack of personal and environmental hygiene (Kilama, 1989; Crompton *et al.*, 1989; Ittiravivongs *et al.*, 1992; Sorenson *et al.*, 1994; Olsen *et al.*, 1998; Olsen, 1999); contaminated water supplies and high population and housing densities (Forrester *et al.*, 1988; Haswell-Elkins *et al.*, 1988; Ramesh *et al.*, 1991); water use, beliefs and taboos (Almedom, 1996); maternal education (Tshikuka *et al.*, 1995) and agricultural practices (Ghadirian *et al.*, 1979; Chandiwana *et al.*, 1989).

Generally, geohelminth transmission is associated with overcrowding and a low level or lack of sanitation in which food and water are easily contaminated with faeces, factors which together with the type of excreta disposal facility were found by Henry (1988) to be useful predictors of reinfection by *A. lumbricoides* and *T. trichiura*. In contrast, Muller *et al.* (1989) found in Mozambique that the type of latrine used was not associated with either *A. lumbricoides* infection or the presence of the parasite's eggs in the soil. Rather they concluded that behavioural factors determined the extent of transmission. In other words, use of a latrine was more important than the presence of a latrine. Predictors of infection probably vary from one area to another and from one study to another.

1.6 BASIC EPIDEMIOLOGY OF GEOHELMINTH INFECTIONS

Five important aspects of geohelminth epidemiology need to be described:

1. The distribution of geohelminth infections in the community generally follows the negative binomial pattern. This highly aggregated distribution means that only a few individuals are likely to have heavy worm burdens (and thus contribute the most eggs to transmission) while the majority will harbour light infections. Thus, severe morbidity due to these helminths is usually restricted to a small fraction of the infected population – the "wormy people" (Jones, 1976; Croll & Ghandirian, 1981; Anderson & Schad, 1985; Bundy *et al.*, 1987a & 1987b; Chan *et al.*, 1992 & 1994; Anderson & May, 1992). The reason(s) for such individual predisposition remain obscure but a variety of biological, environmental, behavioural, social, cultural, nutritional and genetic factors may be involved (Bloch *et al.*, 1985)

2. Worm fecundity appears to decline as the *A. lumbricoides* or *T. trichiura* burden per individual increases; this does not happen with hookworm (Schad & Anderson, 1985).

3. Changes in the average intensity of infection with age tend to be convex in form for *A. lumbricoides* and *T. trichiura* but less so for hookworm; peak intensities usually lie in the 5-10 year age class. The reasons for this may be ecological or immunological, or a combination of both, or genetic (Anderson & May, 1985).

4. In endemic areas, changes in prevalence with age are less convex in form than those observed following reinfection after treatment (Anderson & Medley, 1985).

5. Polyparasitism is common, particularly in those individuals with heavy *A. lumbricoides* infections. These individuals seem predisposed to carry heavy infections of *T. trichiura,* hookworm and *E. vermicularis* as well. This may be the result of the combined effect of behavioural factors and acquired immunity (Butterworth, 1984, Cooper *et al.*, 1993). Polyparasitism complicates the clinical picture, preventing an accurate assessment of the individual roles played by these helminths.

1.7 RESEARCH QUESTIONS

The aim of this study was to review the literature on geohelminth transmission in urban slums in South Africa and to measure the status of these parasites in selected slums in the city of Durban. This would involve measuring geohelminth infection status (i.e. identifying the species present and measuring their prevalences and intensities) as well as reinfection rates after chemotherapy and identifying risk factors for transmission. Little parasitological research has focussed on the collection of basic epidemiological data or geohelminth-induced morbidity from slums in this country or on community-based interventions. The slums to be investigated in this study should be representative of the many in the sub-tropical Durban Unicity and could perhaps serve as a model for those in other parts of South Africa and even further afield. This study would be unique because the development of these slums can be attributed both to the rural-urban migration so characteristic of third world countries and to creating political advantage for urban communities where parasites are endemic.

Finally, this study should recommend appropriate control measures for incorporation into the Parasite Control Programme currently operating in KwaZulu-Natal and advise the Durban City Health Department and Durban Metro Housing Development on the suitability of their "urban renewal/upgrading" programme with respect to reducing helminth morbidity and transmission.