

# Spatial distribution of soil-transmitted helminths, including *Strongyloides stercoralis*, among children in Zanzibar

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**Abstract.** A programme periodically distributing anthelmintic drugs to school-aged children for the control of soil-transmitted helminthiasis was launched in Zanzibar in the early 1990s. We investigated the spatial distribution of soil-transmitted helminth infections, including *Strongyloides stercoralis*, in 336 children from six districts in Unguja, Zanzibar, in 2007. One stool sample per child was examined with the Kato-Katz, Koga agar plate and Baermann methods. The point prevalence of the different helminth infections was compared to the geological characteristics of the study sites. The observed prevalences for *Trichuris trichiura*, *Ascaris lumbricoides*, hookworm and *S. stercoralis* were 35.5%, 12.2%, 11.9% and 2.2%, respectively, with considerable spatial heterogeneity. Whilst *T. trichiura* and hookworm infections were found in all six districts, no *A. lumbricoides* infections were recorded in the urban setting and only a low prevalence (2.2%) was observed in the South district. *S. stercoralis* infections were found in four districts with the highest prevalence (4.0%) in the West district. The prevalence of infection with any soil-transmitted helminth was highest in the North A district (69.6%) and lowest in the urban setting (22.4%). *A. lumbricoides*, hookworm and, with the exception of the North B district, *S. stercoralis* infections were observed to be more prevalent in the settings north of Zanzibar Town, which are characterized by alluvial clayey soils, moist forest regions and a higher precipitation. After a decade of large-scale administration of anthelmintic drugs, the prevalence of soil-transmitted helminth infections across Unguja is still considerable. Hence, additional measures, such as improving access to adequate sanitation and clean water and continued health education, are warranted to successfully control soil-transmitted helminthiasis in Zanzibar.

**Keywords:** soil-transmitted helminths, *Strongyloides stercoralis*, spatial distribution, soil type, Zanzibar.

## Introduction

Unguja and Pemba, the two islands belonging to the Zanzibar archipelago offshore Tanzania in East

Africa, are highly endemic for worm infections (Albonico et al., 1997; Mohammed et al., 2008; Stothard et al., 2008). Indeed, filaria (*Wuchereria bancrofti*), schistosomes (*Schistosoma haematobium*) and the common soil-transmitted helminths (i.e. *Ascaris lumbricoides*, hookworm and *Trichuris trichiura*) co-exist and multiple infections of different helminth species are common (Mohammed et al., 2008; Rudge et al., 2008). Additionally, *Strongyloides stercoralis*, the most

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neglected of the soil-transmitted helminths (Bethony et al., 2006; Steinmann et al., 2007), is also endemic (Marti et al., 1996; Stoltzfus et al., 1997; Knopp et al., 2008).

The tropical climate of the Zanzibar archipelago and the poor hygienic conditions under which the socio-economically deprived rural dwellers live facilitate the development and transmission of these helminth infections. Whilst lymphatic filariasis and soil-transmitted helminthiasis are endemic across Unguja (Mohammed et al., 2008), urinary schistosomiasis is geographically restricted. The focalicity of urinary schistosomiasis is governed by the distribution of its intermediate host, i.e. *Bulinus globosus* (Stothard and Rollinson, 1997). This snail species, and hence urinary schistosomiasis, is absent in the south of the island (Stothard et al., 2002). New research has revealed that soil-transmitted helminth infections also show considerable spatial heterogeneity; indeed an elevated prevalence of *A. lumbricoides* and *T. trichiura* has been reported in the northern parts of Unguja (Stothard et al., 2008). One possible explanation is that the eggs of these soil-transmitted helminths remain infective for a long period of time in the alluvium and clayey sands that are the predominant soil type in North Unguja (Stothard et al., 2008). Clayey sands can be considered as a composite matrix of coarse and fine grains where the interaction between coarser and finer grain matrices affects the overall stress-strain behaviour of the soil (Monkul and Ozden, 2007). For the transmission of hookworm, a poverty-related lifestyle in combination with environmental factors such as a sandy soil type with a high moisture content, a suitable temperature, rainfall and sun exposure are key factors (Brooker et al., 2004; Saathoff et al., 2005b; Hotez, 2008). The ecological and epidemiological features that might explain the spatial heterogeneity of hookworm and *S. stercoralis* distribution in Unguja, however, remain to be investigated.

Due to the high prevalence of *S. haematobium* and soil-transmitted helminth infections in Zanzibar and their negative health impacts, especially among children, a national control programme was initiated

by the Zanzibar Ministry of Health in the early 1990s (Renganathan et al., 1995). Since 1994, single-dose oral praziquantel (40 mg/kg) against schistosomiasis, and single-dose oral mebendazole (500 mg) against soil-transmitted helminthiasis, were administered, mainly through the existing education sector (Mohammed et al., 2008). From 2003 onwards, mebendazole has been replaced by single-dose oral albendazole (400 mg) (Stothard et al., 2008). In 2001, a programme to eliminate lymphatic filariasis was established, distributing once yearly single-dose oral albendazole (400 mg) plus ivermectin (200 µg/kg) to the whole eligible population of Unguja (Mohammed et al., 2006). Ivermectin is not only effective against filaria and *A. lumbricoides*, but is also the drug of choice to treat *S. stercoralis* infections (Gann et al., 1994), and hence is likely to have an ancillary effect against strongyloidiasis.

Despite *S. stercoralis* being endemic in Unguja and Pemba (Marti et al., 1996; Stoltzfus et al., 1997), only one of the recently published articles discussing different aspects of soil-transmitted helminthiasis focussed on *S. stercoralis* (Knopp et al., 2008). The aim of the present study was to assess the prevalence and intensity of infection of soil-transmitted helminth infections, placing particular emphasis on *S. stercoralis*, among children from selected “madrassas” (Koran-schools) and primary schools in the six districts of Unguja. Finally, the spatial distribution of soil-transmitted helminth infections was considered in relation to known geological features.

## Materials and methods

### Study area

This study was carried out in Unguja, the main island of Zanzibar, in June 2007. Unguja has two annual wet seasons: the “Masika rains” from the south, lasting usually from mid-March to mid-June, and the “Vuli rains” from north-east, occurring during November and December. The average annual

rainfalls for north Unguja are 1,800 mm and for South Unguja 1,500 mm (MDG-Centre, 2007). The average annual temperature in Unguja is 27°C. The pedology of Unguja soils range from alluvium to clayey sands with subordinate limestone (Kent et al., 1971). In the north-east of Unguja various soil-types constitute the ground whereas, at the western coast-line and in the south, coral limestone areas are predominant (Calton et al., 1955; Hettige, 1990).

### *Study population*

Stool samples were obtained from children visiting the “madrassas” of five villages, namely Banda-Maji, Mahonda, Kitumba, Dole and Pete. These villages are situated in the North A, North B, Central, West and South districts, respectively, and were geographically localized using Google™-Earth 2008. All villages are quite remote, have a similar socio-economic status with houses usually built with clayey walls and thatched coconut leaves. The majority of houses have no access to the power grid.

Additionally, stool samples were collected from children visiting five peri-urban primary schools (i.e. Nyerere, Rahaleo, Fuoni, Mwenge and Regeza Mwendo) belonging to the Urban district around Zanzibar Town. All surveyed villages were located between 5 and 40 km from Zanzibar Town.

### *Field and laboratory procedures*

One day before visiting the Koran-schools, the respective “shehas” (heads) of the communities were informed about the purpose and procedures of the study and asked for permission. Stool containers, a marker-pen and a pre-numbered form to fill in the name, sex and age of the children attending school were given to the teachers who were instructed to ask each child, attending the afternoon class, to write down his/her name on the pre-numbered list and to record his/her unique identification number on the designated stool collection container. The containers were handed out to the children and they were invited to return the containers with a lime-

sized sample of their next morning stool.

To minimize the risk of sample mix-up, a member of the Helminth Control Laboratory Unguja (HCLU) visited the Koran-schools early in the morning and called each child by name and compared the number on their filled container with the number on the list. The stool samples were transferred to the HCLU in Mianzini, Zanzibar Town. A similar stool collection procedure was implemented in the five urban primary schools, readily integrated in the so-called 24-school-survey, as part of an ongoing study on the epidemiology and control of soil-transmitted helminthiasis and urinary schistosomiasis (French et al., 2007).

Once the stool samples reached HCLU, they were promptly processed and examined by an experienced laboratory technician. In brief, stool samples of sufficient quantity were examined with three different methods according to the following priorities. First, a Kato-Katz thick smear was prepared using 41.7 mg templates (Katz et al., 1972). Second, a groundnut-sized portion of each stool sample (~1 g) was subjected to the Koga agar plate method (Koga et al., 1990). Third and finally, the Baermann technique was performed (García and Bruckner, 2001). Further details pertaining to these three methods for helminth diagnosis have been presented elsewhere (Steinmann et al., 2007; Knopp et al., 2008).

Kato-Katz thick smears were examined quantitatively, i.e. the number of eggs for each helminth species was counted and recorded separately. The Koga agar plate was used to determine the presence, or absence, of larvae of *S. stercoralis* and hookworm. The Baermann method was used for diagnosis of *S. stercoralis* larvae. For quality control purposes, random samples amounting to 5% of the Kato-Katz thick smears, were re-examined by a senior laboratory technician.

### *Data management and analysis*

Data were double-entered in Microsoft Excel version 10.0 and checked for consistency using EpiData version 3.1 (EpiData Association, Odense,

Table 1. Thresholds issued by the WHO for distinguishing light, moderate and heavy infection intensities (Montresor et al., 1998).

| Infection intensity | Thresholds for each soil-transmitted helminth (EPG <sup>a</sup> ) |                     |             |
|---------------------|---|---------------------|-------------|
|                     | <i>A. lumbricoides</i>  | <i>T. trichiura</i> | Hookworm    |
| Light               | 1-4,999   | 1-999               | 1-1,999     |
| Moderate            | 5,000-49,999  | 1,000-9,999         | 2,000-3,999 |
| Heavy               | ≥50,000   | ≥10,000             | ≥4,000      |

<sup>a</sup> EPG = eggs per gram of stool

Denmark). Statistical analyses were made with STATA version 9.2 (StataCorp., College Station, USA). The number of eggs per gram of stool (EPG) was obtained by multiplying the species-specific egg-count in a single Kato-Katz thick smear by 24. We used thresholds issued by the World Health Organization (WHO) for distinguishing light, moderate and heavy infection intensities (Montresor et al., 1998), as showed in Table 1.

The geometric mean EPG was calculated for the children in the respective settings, using the following formula:  $\exp(\sum \log(\text{EPG} + 1) / n) - 1$ .

#### *Ethical considerations and treatment*

One part of this study was embedded in the island-wide parasitological surveys that are carried out in Unguja by the HCLU as part of their routine activities. Moreover, two schools were part of the 24-school survey that have been conducted once every year, starting in 2004, as a collaborative activity between the HCLU and the Natural History Museum (London, UK).

The institutional research commission of the Swiss Tropical Institute (Basel, Switzerland) and the institutional review board of the National Health Service Local Research Ethics Committee (application 03.36) of St. Mary's Hospital (London, UK), on behalf of the Natural History Museum/Imperial College, approved the study. The WHO (Geneva, Switzerland), and the Ministry of Health and Social Welfare (Stone Town, Zanzibar) cleared the study protocol.

Detailed information about the study was provid-

ed to the “shehas” of the villages, the teachers of the Koran-schools and the headmasters of the urban primary schools. A member of the HCLU explained the study to the children. Written informed consent to all anticipated medical interventions, including parasitological surveys done at schools, was given by parents and/or legal guardians upon enrolment of their children at school. At the end of the study, children were treated regardless of their infection status with a single oral dose of albendazole (400 mg). Those children found positive for *S. stercoralis* were also treated with a single oral dose of ivermectin (200 µg/kg).

#### **Results**

##### *Study compliance*

In total, 336 children from the six districts of Unguja submitted one stool sample each. The samples were subjected to three different methods for helminth diagnosis. Age and/or sex were not available for all children; sex was recorded for 309 (92.0%) children out of which 51.8% were girls and 48.2% were boys, and age was recorded from 244 (72.6%) children. The median age was 11 years with a range from 3 to 19 years. Hookworm diagnosis was performed on 334 (99.4%) stool samples examined either with the Kato-Katz, or the Koga agar plate, or both methods. Results for *A. lumbricoides* and *T. trichiura* were available for 327 (97.3%) children who had their stool samples examined with the Kato-Katz method. Finally, 319 (94.9%) stool samples were subjected both to the

Baermann and the Koga agar plate method for diagnosis of *S. stercoralis*.

### Helminth infections

Table 2 shows that helminth infections are still prevalent among children in Unguja. With regard to the three common soil-transmitted helminths, *A. lumbricoides* was the only species that was absent in one of the surveyed settings, namely in the Urban district. *S. stercoralis* was the least common helminth infection. It was found in four of the six districts with an overall prevalence of 2.2% according to combined results from the Koga agar plate and the Baermann methods. The highest prevalence (4.0%) was observed in Dole in the West district. Larval counts were usually low; the two highest counts (i.e. 4 and 9 larvae) were observed in stool samples from the two infected children in Dole in the West district.

In Banda-Maji village in North A district, more than two-thirds of the children were infected with at least one helminth species (69.6%). The second highest prevalence of helminth infection was observed in Kitumba village located in Central district (52.0%). Considerably lower prevalences were found in Mahonda village in North B district (40.0%), in Pete village in South district (39.1%), in

Dole village in West district (30.8%) and, finally, in the primary schools surveyed in the Urban district (22.4%). Taken together, almost half of the children surveyed were infected with at least one helminth (166/336, overall prevalence: 49.4%). Moreover, 47 (28.3%) children harboured two or more helminth species concurrently.

*T. trichiura* was the predominant helminth with an overall prevalence of 35.5% as assessed by a single Kato-Katz thick smear per child. The infection prevalence ranged from 16.1% (Urban district) to 55.2% (North A district). The large majority of infections (111/116, 95.7%) were of light intensity with EPGs below 1,000 (Table 3). The remaining five children (4.3%) had a moderate infection intensity and attended the "madrassas" of either Pete (n = 3) or Banda-Maji (n = 2). The overall prevalence of *A. lumbricoides* infection was 12.2% according to the Kato-Katz method with the highest prevalence (40.4%) observed in Banda-Maji in North A district. Most infections (32/40, 80%) were of light intensity with EPGs below 5,000. The remaining eight children (20.0%) had a moderate infection intensity and they were diagnosed either in Banda-Maji in North A district (n = 6) or in Dole in West district (n = 2). The combined results from the Kato-Katz and the Koga agar plate methods revealed an overall hookworm prevalence of 11.9%, ranging

Table 2. Prevalence (number of children positive/number of children examined) of soil-transmitted helminth infections in 336 children from the six districts of Zanzibar, Tanzania.

| Village    | District | Parasite (method)                             |  |  |  |
|------------|----------|---|--|--|--|
|            |          | <i>A. lumbricoides</i><br>(K-K <sup>a</sup> ) | <i>T. trichiura</i><br>(K-K <sup>a</sup> ) | Hookworm<br>(K-K <sup>a</sup> , KAP <sup>b</sup> ) | <i>S. stercoralis</i><br>(KAP <sup>b</sup> , BM <sup>c</sup> ) |
| Banda-Maji | North A  | 40.3 (27/67)                                  | 55.2 (37/67)                               | 14.5 (10/69)                                       | 2.9 (2/68)   |
| Mahonda    | North B  | 8.3 (2/24)                                    | 29.2 (7/24)                                | 16.0 (4/25)  | 0 (0/21)   |
| Kitumba    | Central  | 9.1 (7/77)                                    | 44.2 (34/77)                               | 11.7 (9/77)  | 2.8 (2/74)   |
| Dole       | West     | 5.9 (3/51)                                    | 19.6 (10/51)                               | 15.4 (8/52)  | 4.0 (2/50)   |
| Pete       | South    | 2.2 (1/46)                                    | 39.1 (18/46)                               | 6.5 (3/46)   | 0 (0/39)   |
| —          | Urban    | 0 (0/62)                                      | 16.1 (10/62)                               | 7.7 (5/65)   | 1.5 (1/67)   |
| Total      |          | 12.2 (40/327)                                 | 35.5 (116/327)                             | 11.9 (39/334)                                      | 2.2 (7/319)  |

<sup>a</sup> K-K = Kato-Katz thick smear; <sup>b</sup> KAP = Koga agar plate; <sup>c</sup> BM = Baermann

Table 3. Characteristics of the three common soil-transmitted helminth infections among the 327 school-aged children from Unguja who had one stool sample quantitatively examined by the Kato-Katz method.

| Characteristics                 | Parasite            |                        |              |
|---------------------------------|---------------------|------------------------|--------------|
|                                 | <i>T. trichiura</i> | <i>A. lumbricoides</i> | Hookworm     |
| Number (%) of children infected | 116 (35.5%)         | 40 (12.2%)             | 32 (9.8%)    |
| Infection intensity             |                     |                        |              |
| Light                           | 111 (95.7%)         | 32 (80.0%)             | 32 (100%)    |
| Moderate                        | 5 (4.3%)            | 8 (20.0%)              | 0            |
| Heavy                           | 0                   | 0                      | 0            |
| Geometric mean EPG (95% CI)     | 1,326 (962-1,829)   | 104 (86-125)           | 143 (98-207) |

CI = confidence interval; EPG = eggs per gram of stool

between 6.5% (Pete, South district) and 16.0% (Mahonda, North B district). According to the quantitative Kato-Katz thick smear results, all infections were of light intensity with EPGs below 2,000.

The geometric mean EPGs of the three common soil-transmitted helminths are summarised in Table 3.

#### *Geological features and soil types*

The geographical location of the six sites where the study was carried out were superimposed onto a Google™-Earth satellite image of Unguja (Fig. 1B) and juxtaposed to the underground composition and predominant soil types of the island (Fig. 1A), according to geological investigations published by Kent and colleagues in the early 1970s (Kent et al., 1971). The geographical coordinates of the study sites are as follows: Banda-Maji (5° 57' 0" S longitude and 39° 19' 0" E latitude); Mahonda (5° 59' 0" S, 39° 15' 0" E); Kitumba (6° 07' 0" S, 39° 17' 0" E); Dole (6° 06' 0" S, 39° 14' 0" E); and Pete (6° 17' 0" S, 39° 25' 0" E). The urban area is located in Zanzibar Town (6° 09' 0" S, 39° 12' 0" E).

The ground in Banda-Maji in North A district and in Kitumba in Central district consists of fossiliferous limestone and marly sand lithology. In Mahonda in North B district and in Dole in West district, the ground is characterized by clayey sands with subordinate limestone. In Pete in South district, reefal limestone constitutes the ground. In the

urban area around Zanzibar Town, the ground consists primarily of limestone and soft sandstone or alluvium.

#### **Discussion**

Despite considerable efforts to control helminth infections on the islands of Unguja and Pemba over the past decade (Renganathan et al., 1995; Mohammed et al., 2008), surprisingly little is known about the spatial distribution of different helminth species, including underlying demographic, environmental and socio-economic factors. Our study sheds light on the distribution of helminth infections (among children) in the six districts of Unguja, five of them characterized as rural and the sixth in Zanzibar Town being urban. Emphasis is placed on the geological composition and soil types of the study locations, since these environmental factors have been shown to play an important role in the transmission of soil-transmitted helminthiasis (Brooker et al., 2004; Saathoff et al., 2005a). Particular consideration was given to *S. stercoralis* because this helminth species is often neglected in epidemiological investigations, which is partially explained by the need of particular diagnostic methods that are seldom used (Steinmann et al., 2007; Knopp et al., 2008).

In the present study, we screened over 300 children from six environmentally-distinct settings and subjected a single stool sample per child to the Kato-

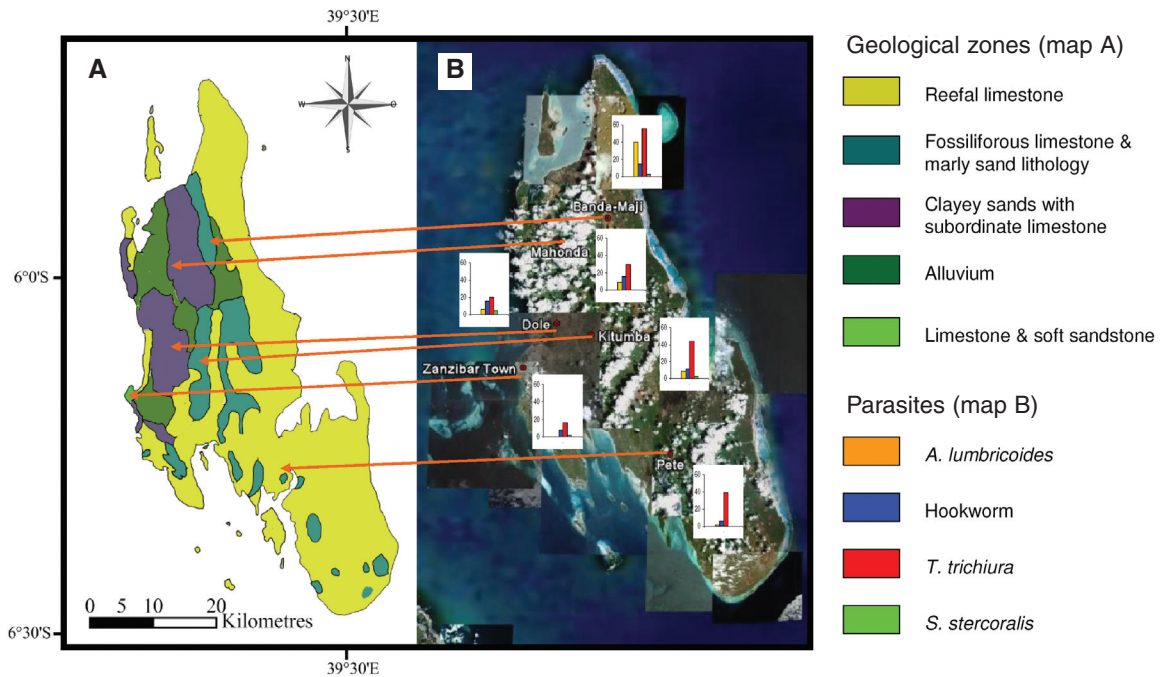


Fig. 1. Map showing the geological zones of Zanzibar (adapted from Kent et al., 1971; A) and satellite image of Zanzibar from Google™-Earth (B) indicating the surveyed settings.

Katz, Koga agar plate and Baermann methods. We achieved a reasonable compliance; more than 77% (259/336) of the children supplied stool samples of sufficient quantity to perform all three tests. Our findings underscore the feasibility and efficiency of epidemiological studies carried out in school environments, which in turn further strengthen the collaborative links between the health and education sectors (Lengeler et al., 2002). Approximately half of the children were infected with at least one helminth species with *T. trichiura* being the predominant one. Importantly, helminth infections were primarily of light intensity according to WHO thresholds (Montresor et al., 1998), which show the ability of a rigorously implemented national helminth control programme to reduce morbidity. Whilst *T. trichiura* and hookworm infections were observed in children from all six districts, no *A. lumbricoides* infections were diagnosed in the urban setting, and *S. stercoralis* infections were not detected in Mahonda in North B district and Pete in South district. However,

the latter findings have to be interpreted with care, as the sample sizes in Mahonda and Pete were small (21 and 39 children, respectively) and only one stool sample per child was examined. Of note, *A. lumbricoides* and hookworm infections were considerably more often diagnosed in the northern part of Unguja than in the South.

We speculate that the high point-prevalence of *T. trichiura* infections in all districts (i.e. 16-55%) is, at least partially, explained by the low efficacy of the anthelmintics albendazole and ivermectin against this parasite (Marti et al., 1996; Keiser and Utzinger, 2008). The national control programme, emphasising repeated administration of anthelmintic drugs to school-aged children and other high-risk groups in Unguja, might therefore only have a limited effect on the transmission of trichuriasis. Moreover, it is likely that rapid re-infection occurs as long as sanitation on Unguja remains inadequate, or other treatment regimens (e.g. triple dose) or more efficacious drugs against trichuriasis

have been developed and used in the national helminth control programme.

Distinct spatial patterns were observed for the other helminth species. From a north-south perspective (not considering the Urban district in the centre), children visiting the “madrassas” in the northern part of the island had a higher risk to be infected with *A. lumbricoides* (odds ratio (OR) = 9.75) and hookworm (OR = 2.31) but a similar risk to be infected with *T. trichiura* (OR = 1.05) compared to the children from the “madrassa” in Pete in South district. However, these findings might be biased by the small sample size in Pete ( $n = 39$ ) and should hence be interpreted with care. Regarding the individual study-settings, the prevalence of *A. lumbricoides* in Banda-Maji in North A district (40.3%) was 4.4 to 20-fold higher than in the other districts. This observation confirms that Banda-Maji has an elevated risk for soil-transmitted helminthiasis (Mohammed et al., 2008; Stothard et al., 2008). The high *A. lumbricoides* prevalence in Banda-Maji gives rise to concerns about whether in this area school-aged children had indeed been treated regularly with anthelmintic drugs and, if so, whether our findings might be an early sign of albendazole resistance development. Interestingly, a recent study carried out in this setting reported a low cure rate (42%) when *A. lumbricoides*-infected individuals were given single oral dose of albendazole (Stothard et al., 2008). On the other hand, the fact that no or only very few *A. lumbricoides* infections were observed in Pete in South district and among children attending peri-urban schools might be explained by the predominant soil types (i.e. limestone and sandstone) in those areas. It is conceivable that these soil types do not provide conducive microenvironments for sustaining the longevity of *A. lumbricoides* eggs, and that transmission of this infection is hence compromised. In addition, hookworm infections were less prevalent in these two settings. Indeed, the infective larval stages of hookworm require appropriate warmth, humidity and UV protection (e.g. facilitated by

vegetation coverage providing sufficient shade and moisture of the soil) for their survival, and hence transmission (Brooker et al., 2004; Saathoff et al., 2005b; Hotez, 2008). Thus, the environment in the Unguja’s South district might be less suitable for their development and survival when compared to the districts further north. The predominant geological formation in the southern part of Unguja is reefal limestone with dry and sunlight-exposed savannah, whereas the areas studied north of Zanzibar Town consist of alluvium, marly and clayey sands, have higher annual precipitation and include lots of streams and shady forests, which provide more suitable conditions for hookworm larval development and survival. However, the absence of *A. lumbricoides* infections and the low hookworm prevalences in the Urban district are likely also a result of improved socio-economic status leading to behavioural changes (e.g. wearing shoes) and improved hygienic conditions, and hence a reduced risk of infection. Of note, the stool samples obtained in the Urban district were provided by children attending primary schools, which are regularly subjected to screenings and anthelmintic drug distributions conducted by the national helminth control team. The stool samples obtained from the other districts of Unguja stemmed from children visiting “madrassas” which are not specifically part of the periodic school-based mass-drug administrations as children also visit public schools and anthelmintics are additionally distributed to the whole eligible island population in the frame of the programme to eliminate lymphatic filariasis. However, confounding factors such as lower coverage of treatment in the respective study population cannot be excluded.

The highest prevalence of *S. stercoralis* was found in Dole in West district (4.0%), but infections were absent in Mahonda in North B district and Pete in South district. Bearing in mind that the absence of an infection might be explained by the low sample sizes there, an additional factor to note is that, in Pete, the environment is drier than elsewhere, which might



therefore be less suitable for the development of infective *S. stercoralis* larvae or free-living adult stages. However, one has to keep in mind that autoinfection can perpetuate *S. stercoralis* transmission for an extended period of time (Keiser and Nutman, 2004; Vadlamudi et al., 2006). It follows that this helminth is less closely linked to environmental factors than, for example, hookworm larvae. Autoinfection of *S. stercoralis* also imposes a considerable problem on copro-diagnostics. As larvae are not necessarily excreted in the stool, it is exceedingly difficult to identify infected individuals. Our recent work, focussing on the diagnosis of *S. stercoralis* among schoolchildren in Unguja, showed that the observed prevalence of this worm was more than double when three instead of a single stool sample were examined with a combination of the Koga agar plate and Baermann method (Knopp et al., 2008). Hence, the “true” overall prevalence of *S. stercoralis* in the present study might well be 4% or even higher.

We conclude that soil-transmitted helminth infections are still prevalent across Unguja, but infection intensities are generally low, demonstrating the positive effect of the national control programme on morbidity. *T. trichiura* infections seem to be hardest to reduce with the current single-dose anthelmintic treatment campaigns. Although the observed prevalence of *S. stercoralis* was low, the “true” prevalence might be considerably higher were more sensitive diagnostic approaches employed, and hence this parasite should not be neglected. Our findings call for continuation of the national control programme especially in the rural areas, but chemotherapy should be complemented by improved access to clean water and adequate sanitation, coupled with sound health education.

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