

Residual Soil-Transmitted Helminth Infection Among School-Aged Children in an Urban Informal Settlement of Nairobi, Kenya: Prevalence, Species Distribution, and Associated Factors

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Abstract

Soil-transmitted helminths (STH) remain an important public health challenge across sub-Saharan Africa, particularly for school-aged children, and transmission may continue in crowded urban informal settlements despite Kenya's school-based deworming programme. This study set out to establish the current prevalence and species composition of STH infection and to examine the sociodemographic and water, sanitation, and hygiene (WASH) factors associated with infection among school-aged children in Pumwani, Nairobi. A descriptive cross-sectional survey enrolled 372 children aged 5–11 years, selected through two-stage cluster sampling from three public primary schools. A single Kato-Katz thick smear was used to examine each stool specimen, and structured questionnaires captured sociodemographic details, household WASH conditions, and deworming history. Associations were tested using Pearson's chi-square and Fisher's exact tests. The overall prevalence of STH infection was 19.4%, with *Ascaris lumbricoides* most common (15.6%), followed by *Trichuris trichiura* (4.3%); no hookworm was detected. Younger age ($p = 0.0014$) and lower grade level ($p = 0.0024$) were significantly associated with infection, whereas sex, parental education, WASH indicators, and deworming history were not. STH infection, therefore, persists in this informal settlement despite reported deworming coverage, with the heaviest burden among the youngest children. Sustained control is likely to require an integrated approach combining preventive chemotherapy with WASH improvements and school health education, and further work using multivariable analysis and more sensitive parasitological methods is recommended.

Keywords: *Soil-transmitted helminths, Ascaris lumbricoides, Trichuris trichiura, Urban informal settlement, School-aged children*

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1.0 Introduction

Soil-transmitted helminths (STH), chiefly *Ascaris lumbricoides*, *Trichuris trichiura*, and the hookworms (*Necator americanus* and *Ancylostoma duodenale*), are among the most widespread parasitic infections of humans, affecting an estimated 1.5 billion people, or close to a quarter of the world's population (Pullan et al., 2014; World Health Organization [WHO], 2023). Infection concentrates in low- and middle-income tropical and subtropical regions, where poverty, poor sanitation, and unsafe water sustain the transmission cycle. Children of school age carry the greatest morbidity, and chronic infection is linked to undernutrition, anaemia, growth faltering, and poorer cognitive and educational outcomes that can constrain later productivity (Hotez et al., 2008; Jourdan et al., 2018).

A large share of this burden falls on sub-Saharan Africa (Karagiannis-Voules et al., 2015). Kenya's National School-Based Deworming Programme has delivered mass drug administration (MDA) to millions of at-risk children and reduced infection intensity in many endemic districts (Mwandawiro et al., 2013). Even so, infection persists in both rural and urban communities, indicating that chemotherapy alone cannot interrupt transmission where overcrowding, inadequate sanitation, and weak hygiene infrastructure persist (Brooker et al., 2006; Campbell et al., 2016). WHO therefore advocates pairing deworming with water, sanitation, and hygiene (WASH) measures and health education.

Conditions in urban informal settlements are especially conducive to ongoing transmission. Pumwani, among the oldest of Nairobi's informal settlements, is characterized by high population density, poor sewerage, and heavy reliance on shared latrines (Mitullah, 2003). Earlier work in

Nairobi's slums documented STH prevalence of roughly 40%, dominated by *A. lumbricoides* and *T. trichiura* (Suchdev et al., 2014). Pumwani was purposively selected for the present study because, as one of Nairobi's oldest and most densely populated urban informal settlements, it typifies the crowded and poorly serviced conditions under which STH transmission is most likely to persist. Although the settlement had featured in earlier Nairobi slum surveys, no recent school-based data specific to Pumwani were available despite recurrent MDA. Given the several rounds of mass deworming delivered since those earlier studies, a lower residual prevalence than the historical figure of about 40% was anticipated; the magnitude of any such decline, the current species distribution, and the factors sustaining transmission in this particular setting nonetheless remained unknown.

Against this background, the present study sought to determine the prevalence and species distribution of soil-transmitted helminth (STH) infections and to identify the sociodemographic and water, sanitation, and hygiene (WASH)-related factors associated with infection among children aged 5–11 years attending public primary schools in Pumwani, Nairobi. Pumwani was selected because of its distinct demographic, socioeconomic, and environmental characteristics, including high population density, urban informal settlements, and a diverse population, which may influence the transmission and distribution of STH infections. Generating evidence from this setting provides context-

specific data that can inform targeted control and prevention strategies.

2.0 Materials and Methods

Study Design and Setting

A descriptive cross-sectional design was used, with data gathered over a single field period at three public primary schools in Pumwani Division, Nairobi County, Kenya (1°17'S, 36°49'E). Located east of Nairobi's central business district, Pumwani is a densely settled informal area characterized by semi-permanent housing, limited access to piped water, and widespread use of shared sanitation. Its residents are predominantly Muslim and largely dependent on the informal economy. Contaminated water sources, poor solid-waste management, and communal toilets together create an environment well-suited to STH transmission.

Study Population, Sampling, and Eligibility

The study targeted all children aged 5–11 years enrolled in Pumwani's public primary schools. The minimum sample size was derived from the Cochran (1977) formula for proportions, assuming a baseline prevalence of 40.7% (based on Suchdev et al., 2014), a 95% confidence level ($z = 1.96$), and 5% precision, which produced a minimum of 372 participants. Sampling proceeded in two stages: three schools were first drawn at random from a full list of schools in the area, after which pupils in Grades 1 to 5 were drawn from class registers with computer-generated random numbers, and allocation across schools and grade strata was made proportional to enrolment size. Children qualified for inclusion if they were 5–11 years old, enrolled at a participating school, and provided assent together with written parental or guardian consent. Those who were acutely ill, unable to provide a stool

specimen, or currently taking anthelmintic medication were excluded.

“This study shows that STH infection remains a substantial public health problem in Pumwani, an urban informal settlement of Nairobi, with an overall prevalence of 19.4%”

Parasitological Assessment

Each child received a labelled container and standardized verbal instructions for specimen collection. For each fresh stool specimen, one thick Kato-Katz smear was prepared in accordance with WHO procedures (World Health Organization [WHO], 1991) and examined under $\times 10$ magnification by a trained laboratory technician to identify and speciate STH eggs. The primary outcome, STH infection status, was defined as the presence of one or more STH species eggs on examination, irrespective of species or egg count. For quality control, a randomly selected 10% of prepared slides was re-read by an experienced microscopist blinded to the first reading. Specimens were discarded in accordance with established biosafety and laboratory waste protocols, and every infected child was treated with a single 400 mg dose of albendazole, consistent with WHO guidance on surveillance-linked care.

Questionnaire Administration

A pretested, structured questionnaire was administered to each participant by the principal investigator or a trained research assistant. It

captured sociodemographic details (age, sex, grade, religion, parental marital status, and parental education), household WASH characteristics (main water source, water-treatment practice, and toilet type), and anthelmintic treatment history.

Variable Definitions

Age was captured in completed years and treated both as a continuous variable and in single-year categories across the 5–11 range. Grade was analysed in five categories (Grades 1–5). Parental education was grouped as primary incomplete, secondary incomplete, secondary complete, college, and university. The main water source was classified as piped, well/borehole, tanker truck, or cart vendor, and toilet type as modern flush/pour-flush, ventilated improved pit (VIP) latrine, or traditional pit latrine. Deworming history was based on the parent or child self-report.

Statistical Analysis

Data were entered in Microsoft Excel and analysed in SPSS version 22.0 (IBM Corp., Armonk, NY, USA). The study population and species-specific prevalence were summarised using descriptive statistics. Associations between infection status and categorical predictors were examined using Pearson's chi-square test, and Fisher's exact test was used when expected cell counts were below 5. Statistical significance was set at $p < 0.05$. Unadjusted odds ratios with 95% confidence intervals were computed for variables significantly associated with infection, and age- and grade-specific prevalence trends were described.

Ethical Considerations

Ethical clearance was granted by the Kenya Methodist University Institutional Scientific and

Ethics Review Committee (ISERC), with additional approval from the Sub-County Director of Education and the head teachers of the participating schools. Registration was completed with the National Commission for Science, Technology, and Innovation (NACOSTI). Parents or legal guardians gave written informed consent, and children provided verbal assent. Participation was voluntary; withdrawal was permitted at any time without penalty; and all data were anonymised and stored securely, with access restricted to the research team.

3.0 Results and Discussion

Participant Characteristics

Of the 372 children aged 5–11 years enrolled, 220 (59.1%) were male, and 152 (40.9%) were female, a male-to-female ratio of about 1.4:1. Mean age was 8.4 years (median 9; range 5–11). Enrolment was spread across five grades, the largest being Grade 4 (108; 29.0%) and Grade 2 (80; 21.5%). Almost all children were Muslim (362; 97.3%), and most came from monogamous households (358; 96.2%). These characteristics are summarised in Table 1. Parental education was strikingly uneven: 366 mothers (98.4%) had not completed primary school, whereas 347 fathers (93.3%) had completed secondary education. For household WASH, piped water served 210 households (56.5%) and 181 (48.7%) treated their water before use. Most households used modern flush or pour-flush toilets (210; 56.5%), with the remainder relying on VIP latrines (126; 33.9%) or traditional pit latrines (36; 9.7%). Although 318 children (85.5%) had been dewormed in the previous year, only 143 (38.4%) had received treatment within the previous three months, revealing a wide gap between annual and recent coverage.

Table 1

Sociodemographic Characteristics of Study Participants (N = 372)

Variable / Category	N	%
Sex		
Male	220	59.1
Female	152	40.9
Age group (years)		
5	40	10.8
6	32	8.6
7	48	12.9
8	56	15.1
9	74	19.9
10	54	14.5
11	68	18.3
Grade level		
Grade 1	51	13.7
Grade 2	80	21.5
Grade 3	65	17.5
Grade 4	108	29.0
Grade 5	68	18.3
Religion		
Islam	362	97.3
Christianity	10	2.7
Parental marital status		
Married, monogamous	358	96.2
Married, polygamous	14	3.8
Separated/divorced/widowed	0	0.0

STH Prevalence and Species Distribution

Overall STH prevalence was 19.4% (72/372). Infection intensities were uniformly light to moderate, and no heavy-intensity cases were recorded. *A. lumbricoides* was the leading species, found in 58 children (15.6%), followed

by *T. trichiura* in 16 children (4.3%); no hookworm was identified in any participant. Two children (0.5%) harboured both *A. lumbricoides* and *T. trichiura*, so single-species infection clearly predominated (Table 2).

Table 2

Prevalence and Species Distribution of STH Infections (N = 372)

Helminth species / outcome	Infected (n)	Not infected (n)	Prevalence (%)
Any STH infection	72	300	19.4
<i>Ascaris lumbricoides</i>	58	314	15.6
<i>Trichuris trichiura</i>	16	356	4.3
Hookworm spp.	0	372	0.0
Co-infection (<i>Ascaris</i> + <i>Trichuris</i>)	2	370	0.5

Note. Species names *Ascaris lumbricoides* and *Trichuris trichiura* are italicised. Co-infected children are counted under each contributing species.

STH Infection by Age and Grade

A clear inverse relationship between age and infection was evident across all seven age groups (Table 3). Prevalence peaked among 6-year-olds (34.4%) and 7-year-olds (31.3%), followed by 8-year-olds (26.8%) and 5-year-olds (25.0%), and then fell sharply from age 9 onwards (9.5% at 9 years, 9.3% at 10 years, and 13.2% at 11 years).

This gradient was statistically significant ($\chi^2 = 21.574$, $df = 6$, $p = 0.0014$). Grade level followed the same pattern: Grade 1 recorded the highest prevalence (33.3%; 17/51), ahead of Grade 3 (24.6%; 16/65) and Grade 2 (23.8%; 19/80), with markedly lower figures in Grade 4 (9.3%; 10/108) and Grade 5 (14.7%; 10/68); this gradient was also significant ($\chi^2 = 16.521$, $df = 4$, $p = 0.0024$).

Table 3

STH Infection Prevalence by Age Group and Grade Level

Category	Infected (n)	Not infected (n)	Total (n)	Prevalence (%)
Age group (years)				
5	10	30	40	25.0
6	11	21	32	34.4
7	15	33	48	31.3
8	15	41	56	26.8
9	7	67	74	9.5
10	5	49	54	9.3
11	9	59	68	13.2
Grade level				
Grade 1	17	34	51	33.3
Grade 2	19	61	80	23.8
Grade 3	16	49	65	24.6
Grade 4	10	98	108	9.3
Grade 5	10	58	68	14.7

Note. $\chi^2 = 21.574$, $df = 6$, $p = 0.0014$ (age group); $\chi^2 = 16.521$, $df = 4$, $p = 0.0024$ (grade level).

Bivariate Analysis of Sociodemographic and WASH Factors

Table 4 presents the bivariate associations between the examined variables and overall STH infection status. Sex was not related to infection (males 18.2%, 40/220; females 21.1%, 32/152; $\chi^2 = 0.309$, $p = 0.579$). Religion could not be meaningfully assessed because of near-complete homogeneity (97.3% Muslim). Parental marital status (Fisher's exact $p = 0.486$), maternal

education ($\chi^2 = 2.25$, $p = 0.522$), and paternal education ($\chi^2 = 1.60$, $p = 0.884$) showed no association. WASH indicators were likewise non-significant: main water source ($\chi^2 = 0.31$, $p = 0.579$), water treatment ($\chi^2 = 0.00$, $p = 1.000$), and toilet type ($\chi^2 = 0.29$, $p = 0.864$). Neither annual deworming ($\chi^2 = 0.005$, $p = 0.942$) nor deworming within three months ($\chi^2 = 2.32$, $p = 0.128$) was associated with infection. Age and grade were thus the only significant predictors in the bivariate analysis.

Table 4

Bivariate Analysis of the Association Between Sociodemographic and WASH Variables and STH Infection

Variable	χ^2	df	p-value	Significant
Age group	21.574	6	0.0014	Yes
Grade level	16.521	4	0.0024	Yes
Sex	0.309	1	0.579	No
Parental marital status ^a	—	—	0.486	No
Maternal education	2.25	3	0.522	No
Paternal education	1.60	4	0.884	No
Main water source	0.31	1	0.579	No
Water treatment	0.00	1	1.000	No
Toilet facility type	0.29	2	0.864	No
Deworming (past year)	0.005	1	0.942	No
Deworming (past 3 months)	2.32	1	0.128	No

Note. df = degrees of freedom. p-values < 0.05 indicate statistical significance. ^aFisher's exact test was applied owing to sparse cell counts.

Residual STH Burden Despite Reported Deworming Coverage

The headline finding is that nearly one in five children (19.4%) in Pumwani were infected despite a reported 85.5% annual deworming coverage. This is direct evidence of continuing STH transmission in an urban informal settlement after repeated preventive chemotherapy and supports the view that MDA alone cannot interrupt transmission where soil and water remain heavily contaminated (Campbell et al.,

2016). The observed prevalence exceeds the 10% threshold at which the WHO regards STH as a significant public health problem among school-aged children, justifying the sustained and strengthened interventions here (World Health Organization [WHO] 2012). It is nonetheless lower than the approximately 40% reported about a decade earlier in Nairobi's informal settlements (Suchdev et al., 2014), a decline that may partly reflect the cumulative benefit of successive MDA rounds. Because a single Kato-Katz smear was

used, a method known to underestimate the true prevalence compared with duplicate or triplicate examinations (Khurana et al., 2021), the actual residual burden may exceed 19.4%. The species pattern, with *A. lumbricoides* (15.6%) predominating over *T. trichiura* (4.3%) and hookworm entirely absent, is characteristic of warm, humid settings in which *Ascaris* eggs readily survive and embryonate in the soil (Karagiannis-Voules et al., 2015). The lack of hookworm mirrors other urban Kenyan findings and may reflect local soil drainage conditions, together with routine footwear use, which limits transcutaneous larval entry (Riesel et al., 2010).

Age and Grade as Principal Determinants

Age and grade were the only significant predictors, and the effect was pronounced: children aged 5–8 years were infected at rates of 25–34%, more than twice those of children aged 9–11 years (9.5–13.2%). This inverse age gradient is one of the most consistent observations in STH epidemiology and has been reported widely across sub-Saharan Africa and beyond (Andereck et al., 2014; Shumbej et al., 2015). Several overlapping mechanisms plausibly account for it. Younger children have more frequent contact with contaminated soil through hand-to-mouth behaviour and ground-level play, and they adhere less consistently to hygiene practices. Partial immunity also accumulates with repeated exposure and treatment, with regulatory and antibody responses strengthening over time to limit worm establishment and egg output (Hotez et al., 2008). In addition, older pupils in higher grades have accumulated more MDA rounds and benefited from more school-delivered health education, both of which reduce worm burden. These findings carry a clear programmatic message: an annual deworming cycle may be insufficient for

the youngest pupils. WHO recommends biannual MDA where prevalence exceeds 50%, and although overall prevalence here was 19.4%, the figures for Grade 1 (33.3%) and children aged 6–7 years (31–34%) approach that level within specific strata, supporting more frequent treatment for Grades 1–3. Because the design was cross-sectional, however, these interpretations are associational rather than causal, and the proposed mechanisms remain plausible hypotheses.

Non-Significant Predictors in a Uniformly Contaminated Environment

No significant associations emerged for sex, parental education, WASH characteristics, or deworming history. Where the settlement environment is uniformly contaminated, the effect of household- or individual-level differences may be muted, making it harder to detect links between infection and WASH or sex reported elsewhere in dense, heavily contaminated settings (Strunz et al., 2014). Poor area-level sanitation, inadequate waste disposal, and shared facilities may also limit the protective value of household WASH improvements (Freeman et al., 2017). The absence of any link between deworming history and current infection is consistent with rapid reinfection after treatment and reinforces the conclusion that MDA alone cannot interrupt transmission. The 19.4% prevalence is comparable to that reported in other Kenyan settings after repeated deworming (Kepha et al., 2015; Ngonjo et al., 2016; Mutungi et al., 2019), pointing to persistent residual transmission where WASH infrastructure and integrated control remain inadequate (Bisanzio et al., 2014; Gunawardena et al., 2011).

Limitations

Several limitations should be considered. The cross-sectional design cannot establish causal

direction or exclude confounding. Reliance on a single Kato-Katz smear likely underestimates true prevalence, especially for *T. trichiura*, which sheds eggs variably; duplicate or repeat smears on consecutive days would improve accuracy. A repeat smear was not undertaken in this study because of limited financial resources and the time constraints of the single field period, a constraint that should be borne in mind when interpreting the prevalence estimates reported here. Conducting the study in three schools within a single division limits generalizability to other settlements or ecological settings. Data on key behavioral exposures, including handwashing, nail hygiene, footwear use, and soil contact, were limited, constraining the aetiological analysis. Because deworming history was based on self- or parent-report, it may be affected by recall bias. The two-stage cluster design produced clustering effects that were not statistically adjusted for, potentially reducing the precision of the prevalence estimates. Finally, the absence of a multivariable model restricts the identification of independent predictors and the adjustment for confounding.

4.0 Conclusion

This study shows that STH infection remains a substantial public health problem in Pumwani, an urban informal settlement of Nairobi, with an overall prevalence of 19.4% despite reportedly high annual deworming coverage. *A. lumbricoides* is the dominant species, and the burden falls disproportionately on younger children in Grades 1–3, particularly those aged 5–8 years. The lack of any significant association with sex, parental education, WASH indicators, or prior deworming reflects the uniformly high environmental contamination in this settlement and argues for universal rather than targeted school-based prevention. The persistence of

infection at this level after repeated MDA provides strong evidence that chemotherapy alone cannot interrupt transmission in this setting.

5.0 Recommendations

Building on these findings, an integrated control strategy is recommended for Pumwani and comparable urban informal settlements. First, preventive chemotherapy should be intensified to a biannual schedule for children in Grades 1–3, who carry the highest burden, rather than relying on a single annual round. Second, deworming should be coupled with targeted improvements in water, sanitation, and hygiene infrastructure, since chemotherapy alone does not prevent the rapid reinfection observed here (Campbell et al., 2016; Strunz et al., 2014). Third, school-based health education promoting handwashing, footwear use, and safe sanitation should be strengthened and sustained, drawing on approaches shown to improve hygiene behavior and support helminth control (Asaolu & Ofoezie, 2003; Makata et al., 2020; Watson et al., 2020). Fourth, these measures should be embedded within the wider neglected tropical disease agenda and national road map to sustain gains (World Health Organization [WHO], 2020).

The value and implications of this work are threefold. For programme managers, it provides current, settlement-specific evidence that the youngest primary school children are underserved by an annual deworming cycle and should be prioritised for more frequent treatment. For policymakers, it demonstrates that durable STH control in urban informal settlements depends on combining chemotherapy with WASH investment rather than on MDA in isolation. For researchers, it signals the need for future studies that apply multivariable models, examine duplicate stool specimens, and systematically

measure hygiene behaviours to characterise the drivers of residual transmission and guide the efficient use of limited control resources.

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