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# Soil-Transmitted Helminth Infections, Re-infection and Anthelmintic Resistance among School-Aged Children: A Review

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## ABSTRACT

Soil-transmitted helminth (STH) infections remain a major public health concern, particularly among school-aged children in tropical and subtropical regions where inadequate sanitation, unsafe water and poor hygiene facilitate transmission. This narrative review examines the epidemiology of STH infections, reinfection following deworming, anthelmintic treatment efficacy and the potential emergence of drug resistance, with particular emphasis on Nigeria. Relevant evidence was obtained from peer-reviewed articles, clinical studies, review papers and World Health Organization publications. The review highlights *Ascaris lumbricoides*, *Trichuris trichiura* and hookworms as the major intestinal STHs affecting children, with *Strongyloides stercoralis* also recognised as an important soil-transmitted parasite with distinct control requirements. Evidence from Nigeria indicates substantial geographical variation in infection prevalence, with persistent transmission reported in some communities despite repeated mass drug administration. Reinfection remains a major challenge because deworming reduces parasite burdens without eliminating environmental sources of infection. Although albendazole and mebendazole are widely used in preventive chemotherapy, their efficacy varies among parasite species, particularly against *T. trichiura*. Furthermore, mathematical modelling suggests that prolonged preventive chemotherapy may create conditions favouring the emergence of anthelmintic resistance; however, widespread clinically confirmed benzimidazole resistance in human STHs has not been established. The review emphasises the importance of distinguishing reinfection from treatment failure through longitudinal monitoring, species-specific therapeutic efficacy assessments and appropriate molecular surveillance. It concludes that sustainable STH control requires an integrated approach combining preventive chemotherapy, improved water, sanitation and hygiene (WASH), health education, sensitive diagnostic methods and strengthened epidemiological surveillance, particularly in underserved Nigerian communities.

**Keywords:** Anthelmintic Resistance, Deworming, Reinfection, School-Aged Children, Soil-Transmitted Helminths.

## Introduction

Soil-transmitted helminth (STH) infections are among the most common neglected tropical diseases worldwide. The World Health Organization (WHO, 2021) estimates that approximately 1.5 billion people or 24% of the global population, are infected. The burden is concentrated in tropical and subtropical regions where poverty, inadequate sanitation and limited access to safe water facilitate transmission (WHO, 2023). The principal STHs affecting humans are *Ascaris lumbricoides*, *Trichuris trichiura* and the hookworms *Necator americanus* and *Ancylostoma duodenale*.

*Strongyloides stercoralis* is also soil-transmitted, but its autoinfective life cycle, diagnostic requirements and control measures differ from those of the three major STH groups (Jourdan et al., 2018; WHO, 2024).

School-aged children are an important risk group because of frequent contact with contaminated soil, outdoor activities and inconsistent hygiene practices. *A. lumbricoides* and *T. trichiura* are usually acquired by ingesting infective eggs from contaminated soil, food, water or hands, whereas hookworm infection occurs mainly when infective larvae penetrate exposed skin.



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The consequences of infection depend on parasite species, worm burden, duration of infection, nutritional status and repeated exposure. Moderate and heavy infections may cause abdominal pain, diarrhoea, intestinal complications, impaired nutritional status and anaemia; hookworm is particularly associated with chronic intestinal blood loss and iron deficiency (Jourdan et al., 2018; WHO, 2023).

Preventive chemotherapy with albendazole or mebendazole is a central component of STH morbidity control. Nevertheless, treatment does not eliminate environmental contamination, and children may become reinfected after returning to contaminated environments. The rapid return of infection following treatment has implications for programme sustainability and should not automatically be interpreted as evidence of drug resistance (Jia et al., 2012).

In addition, regular use of benzimidazole drugs has prompted concern about the possible selection of resistant parasite populations. Modelling predicts that resistance could evolve under sustained preventive chemotherapy, although widespread clinical resistance in human STHs has not yet been demonstrated (Coffeng et al., 2024).

This review synthesizes evidence on STH infections among school-aged children, with particular attention to reinfection and anthelmintic resistance. It also considers the Nigerian epidemiological context and identifies research priorities for strengthening control programmes.

## Methodology

This study adopted a narrative literature review approach to examine soil-transmitted helminth (STH) infections, re-infection, and anthelmintic resistance among school-aged children.

Relevant information was obtained from peer-reviewed journal articles, review papers, clinical studies, and World Health Organization publications focusing on STH epidemiology, particularly in Nigeria, treatment outcomes, diagnostic methods, re-infection, drug resistance, and water, sanitation, and hygiene (WASH).

Literature was selected based on its relevance to human STH infections and the study objectives. Information on prevalence, parasite species, treatment efficacy, re-infection rates, and resistance patterns was extracted and organised into thematic areas. The findings were synthesised descriptively to identify major trends, research gaps, and public health implications. No statistical pooling or meta-analysis was conducted because of the narrative nature of the review and variations in study designs, populations, and reported outcomes.

### Major Soil-Transmitted Helminths and Transmission

#### *Ascaris lumbricoides*

*A. lumbricoides* is a large intestinal nematode whose adult stages inhabit the small intestine. Infection follows ingestion of embryonated eggs from contaminated soil, food, water or hands. The eggs have a resistant shell and can remain viable in suitable environmental conditions, helping to maintain transmission where sanitation is inadequate. Light infections may be asymptomatic, whereas heavy infections can cause abdominal symptoms, nutritional impairment and, occasionally, intestinal obstruction (Jourdan et al., 2018; Leung et al., 2020).

#### *Trichuris trichiura*

*T. trichiura*, commonly called whipworm, is acquired by ingestion of embryonated eggs. Adult worms inhabit the caecum and colon. Light infections are often asymptomatic, but heavy infections may cause abdominal pain, chronic diarrhoea, intestinal inflammation, rectal prolapse and impaired growth. Single-dose albendazole and mebendazole generally have lower efficacy against *T. trichiura* than against *A. lumbricoides*, making species-specific assessment of treatment response important (Jourdan et al., 2018; Moser et al., 2017).

### Hookworms

Human hookworm infection is caused mainly by *N. americanus* and *A. duodenale*. Eggs passed in faeces hatch in suitable soil, and larvae develop into infective filariform stages. These larvae penetrate human skin, commonly through bare feet, migrate through the



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circulation and lungs, are swallowed and mature in the small intestine. Adult worms attach to the intestinal mucosa and feed on blood; chronic or heavy infection can therefore contribute to iron-deficiency anaemia (Jourdan et al., 2018; Caldrer et al., 2022).

***Strongyloides stercoralis***

*S. stercoralis* is an additional soil-transmitted nematode with a distinct life cycle that includes free-living stages and autoinfection within the human host. Autoinfection can allow untreated infection to persist for many years. In immunosuppressed individuals, hyperinfection or disseminated strongyloidiasis can be life-threatening. WHO issued a separate 2024 guideline recommending consideration of ivermectin preventive chemotherapy in endemic settings where *S. stercoralis* prevalence is at least 5%; this recommendation should not be conflated with routine albendazole- or mebendazole-based programmes for the classical STHs (WHO, 2024).

Transmission of the classical STHs is sustained when faeces contaminate soil in settings without adequate sanitation. Children may ingest infective eggs through contaminated hands, food or water, or acquire hookworm through skin contact with contaminated soil. Environmental conditions, sanitation infrastructure, footwear, handwashing, food preparation and access to safe water all influence exposure (Jourdan et al., 2018; WHO, 2023).

**Epidemiology and Public-Health Effects among Children**

STH infections are concentrated in communities where poverty, inadequate sanitation, unsafe water and limited access to hygiene facilities increase exposure. Children are a priority group for preventive chemotherapy because infection can occur early in life and repeated exposure may lead to persistent or recurrent infection. The health effects are strongly associated with infection intensity: moderate and heavy infections are more likely to cause clinically important morbidity than light infections (WHO, 2023).

The relationship between STH infection and nutrition is complex. Heavy infections may contribute to poor appetite, impaired nutrient absorption, intestinal blood loss and anaemia, while pre-existing undernutrition may increase vulnerability to adverse health outcomes. Hookworm is particularly relevant to iron deficiency because of chronic blood loss. Evidence linking STH infection to cognition and educational outcomes is mixed and varies by study design, infection intensity and setting; therefore, causal claims should be made cautiously (Caldrer et al., 2022; Pabalan et al., 2018).

Mass deworming is intended primarily to reduce worm burden and prevent morbidity in populations at risk. It should not be assumed that periodic treatment alone will consistently improve every nutritional, cognitive or educational outcome across all settings. A Cochrane review concluded that public-health deworming programmes do not appear to produce consistent average improvements in height, haemoglobin, cognition, school performance or mortality across the populations studied, although treatment remains important for reducing morbidity among infected individuals and in endemic control programmes (Taylor-Robinson et al., 2019).

**Soil-Transmitted Helminth Infections in Nigeria**

The epidemiology of STH infection in Nigeria is geographically heterogeneous. Karshima (2018), in a systematic review and meta-analysis of studies published between 1980 and 2015, estimated a pooled prevalence of 54.8% among Nigerian children and 54.9% among school-aged children. *A. lumbricoides* had a pooled prevalence of 44.6% and was the most frequently reported species in the included studies. These estimates describe the studies and period included in that review; they should not be interpreted as a current national prevalence without updated, representative surveillance.

Evidence from north-central Nigeria demonstrates that residual STH infection may remain detectable after repeated mass drug administration (MDA). Griswold et al. (2022) assessed school-aged children in Nasarawa and Plateau States before and after three to five rounds of MDA.

Overall STH prevalence changed from 10.8% in 2013 to 9.4% in 2018, illustrating that infection can persist despite repeated treatment and that programme impact should be interpreted alongside local transmission conditions and WASH access.



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A more recent impact assessment in Akwa Ibom State examined 6,431 school-aged children across 26 local government areas after five effective rounds of preventive chemotherapy. Opara et al. (2026) reported an overall STH prevalence of 27.62%, with marked variation between local government areas (4.92%–71.65%). Hookworm and *A. lumbricoides* were the principal species reported. These findings emphasize that statewide averages can conceal local hotspots and that treatment frequency and complementary interventions should be guided by local epidemiological assessment.

The Nigerian evidence base remains unevenly distributed geographically. Local surveys are therefore needed in underrepresented northern, rural, peri-urban and riverine communities. Such studies should report species-specific prevalence, infection intensity, diagnostic methods, age groups, treatment history and WASH indicators so that findings can be compared and used for programme planning.

### Re-infection Following Deworming

Reinfection refers to the acquisition of a new infection after successful treatment or substantial clearance of the original infection. It differs from treatment failure, in which infection persists because treatment has not adequately cleared the parasites. Positive stool examination months after treatment cannot, by itself, distinguish reinfection from persistent infection, incomplete adherence, inadequate dosing, reduced drug efficacy or diagnostic error. This distinction is essential when interpreting programme outcomes and suspected resistance.

Jia et al. (2012), in a systematic review and meta-analysis of 51 studies, estimated that prevalence of *A. lumbricoides* returned to approximately 26%, 68% and 94% of pretreatment levels at 3, 6 and 12 months after treatment, respectively. The corresponding estimates were 36%, 67% and 82% for *T. trichiura* and 30%, 55% and 57% for hookworm. These percentages represent the proportion of pretreatment prevalence levels reached during follow-up, not the proportion of treated individuals who necessarily became reinfected. The review also found that reinfection prevalence and intensity were positively associated with pretreatment infection status.

The principal driver of reinfection is continued exposure to infective stages in contaminated environments. Anthelmintic drugs act on parasites within the host but do not remove eggs and larvae already present in soil or prevent subsequent exposure. Open defecation, inadequate toilets, unsafe water, poor hand hygiene, contaminated produce and barefoot exposure in hookworm-endemic settings can therefore sustain transmission after treatment (Jia et al., 2012; WHO, 2023).

Other factors influencing reinfection include baseline infection intensity, household crowding, age-related behaviour, local climate, soil conditions, treatment coverage and the interval between treatment rounds. A cross-sectional survey conducted after deworming may identify residual infection but cannot reliably establish whether each positive case represents reinfection or treatment failure. Longitudinal studies with pretreatment, early post-treatment and later follow-up assessments are more informative.

## Anthelmintic Treatment and Resistance

### Preventive Chemotherapy and Drug Efficacy

Albendazole and mebendazole are the principal drugs used in preventive chemotherapy programmes targeting *A. lumbricoides*, *T. trichiura* and hookworm. WHO recommends albendazole 400 mg or mebendazole 500 mg in appropriate endemic settings, with treatment frequency determined by the prevalence and intensity of infection in the target population (WHO, 2023). Preventive chemotherapy is intended to reduce infection intensity and morbidity; it does not, on its own, interrupt environmental transmission. Drug efficacy differs by parasite species. *A. lumbricoides* generally responds well to single-dose benzimidazole treatment, whereas efficacy against *T. trichiura* is often lower. A systematic review and network meta-analysis by Moser et al. (2017) demonstrated important species-specific differences in cure and egg-reduction rates. Combination regimens, including albendazole with ivermectin, have shown improved efficacy against *T. trichiura* in clinical trials, although outcomes vary across geographical settings (Hürlimann et al., 2022). These findings support monitoring treatment response by parasite species rather than relying only on overall prevalence.



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**Understanding Anthelmintic Resistance**

Anthelmintic resistance is an inherited reduction in parasite susceptibility to a drug that was previously effective. Resistance is well documented in veterinary gastrointestinal nematodes following repeated exposure to anthelmintic drugs. In human STHs, however, widespread clinically confirmed benzimidazole resistance has not been established. Suboptimal efficacy may arise from several causes, including species-specific drug response, high baseline infection intensity, poor adherence, incorrect dosing, inadequate drug quality, diagnostic limitations or rapid reinfection.

The β-tubulin gene is investigated because particular amino-acid substitutions at codons 167, 198 and 200 are associated with benzimidazole resistance in several nematodes. Molecular assays have been developed to detect putative resistance-associated variants in human STHs, but detection of a variant alone does not prove that a parasite population is clinically resistant. Molecular findings should be interpreted alongside standardized therapeutic efficacy data, including cure rate and egg-reduction rate (Diawara et al., 2013).

Coffeng et al. (2024) used mathematical modelling to examine the evolution of benzimidazole resistance under preventive chemotherapy. Their model predicted that resistance could potentially evolve within a decade under some treatment scenarios, particularly with more intensive population-wide treatment. This is a model-based projection, not evidence that widespread clinical resistance has already emerged. The authors highlighted that the absence of systematic drug-efficacy monitoring makes early detection difficult. Continued surveillance is therefore justified, but claims of confirmed resistance require robust parasitological and molecular evidence.

**Diagnosis and Monitoring of Treatment Efficacy**

Diagnosis of classical STH infections commonly relies on detecting eggs in stool samples. The Kato–Katz thick-smear technique is widely used in epidemiological surveys because it identifies parasite eggs and provides a quantitative estimate of eggs per gram of faeces. However, its sensitivity declines in low-intensity infections, and a single stool sample or slide may underestimate prevalence. Repeated samples or multiple slides can improve detection. Hookworm eggs should be examined promptly because they may become difficult to identify as the preparation clears (WHO, 2019; Nikolay et al., 2014).

More sensitive methods, including FLOTAC and molecular assays such as PCR, may detect infections missed by conventional microscopy, particularly in low-transmission settings. Their use may be limited by cost, equipment, technical expertise and the need for standardized protocols. Diagnostic choice should therefore reflect the objective of the study, available resources and expected infection intensity (Nikolay et al., 2014).

Anthelmintic efficacy monitoring should include standardized parasitological assessments before and after treatment. The cure rate is the proportion of initially infected individuals who become egg-negative after treatment; whereas the egg-reduction rate measures the percentage reduction in egg counts. These indicators should be interpreted by parasite species and with attention to diagnostic sensitivity, sample timing and treatment adherence. Molecular surveillance can complement, but should not replace, therapeutic efficacy assessment (Diawara et al., 2013; WHO, 2019).

To distinguish treatment failure from re-infection, a useful study design includes baseline stool examination, documented or observed treatment, an early post-treatment assessment to evaluate clearance, and follow-up at later intervals such as 3, 6 and 12 months. Environmental and behavioural data should be collected concurrently.

A recurrence detected only at later follow-up is not sufficient evidence of resistance without evidence that initial treatment failed.

**Integrated Control: Preventive Chemotherapy and WASH**

Sustainable STH control requires preventive chemotherapy to be combined with measures that reduce environmental contamination and human exposure. WHO identifies periodic deworming, health education and improved sanitation as complementary elements of control (WHO, 2023).



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Access to safe water supports handwashing and food hygiene, while functional toilets reduce the release of parasite eggs into the environment.

Handwashing with soap, washing or peeling produce, safe food preparation and consistent footwear can reduce exposure through ingestion or skin penetration, depending on the parasite species.

Systematic reviews have found associations between improved WASH access or practices and lower odds of STH infection. Ziegelbauer et al. (2012) reported protective associations between sanitation and STH infection, while Strunz et al. (2014) found that treated water, sanitation, footwear and handwashing practices were associated with reduced odds of infection. These findings support integrated interventions, although much of the evidence is observational; and the effect of a specific intervention depends on coverage, sustained use and local transmission conditions.

In Nigeria, the persistence of infection after multiple rounds of MDA reinforces the importance of school and household WASH infrastructure. Griswold et al. (2022) documented limited availability of school latrines and handwashing facilities in their north-central Nigerian assessment. Drug delivery without improvements in sanitation and hygiene leaves the environmental reservoir largely unchanged. WASH should therefore complement, not replace, preventive chemotherapy.

### Research Gaps and Future Directions

Several research priorities emerge from the evidence. First, more longitudinal studies are needed to measure species-specific reinfection after treatment and to distinguish persistent infection from new infection. Studies should include baseline, early post-treatment and repeated follow-up assessments, alongside household and school-level WASH data.

Second, human STH anthelmintic efficacy requires systematic monitoring. Therapeutic efficacy studies should use standardized protocols, adequate sample sizes, appropriate timing and species-specific cure and egg-reduction rates. Molecular investigations of β-tubulin variants should be conducted where justified, but genetic findings should not be described as clinical resistance without supporting phenotypic evidence.

Third, diagnostic surveillance should be strengthened in areas where infection intensity is low. Comparative studies of Kato–Katz, FLOTAC and molecular methods can help determine the most appropriate and cost-effective tools for routine monitoring. Fourth, Nigerian research should address geographical gaps by generating district- and local-government-level data, particularly in underserved communities. Fifth, studies should evaluate integrated MDA–WASH programmes, including their implementation, sustainability, cost-effectiveness and effects on reinfection.

Finally, research should examine the relationship between STH infection intensity, anaemia, nutritional status and school outcomes while controlling for confounding factors such as diet, malaria, socioeconomic status and other infections. Such studies would provide a stronger evidence base for integrated child-health interventions.

## Conclusion

Soil-transmitted helminth infections remain an important public-health concern among school-aged children, particularly in communities affected by inadequate sanitation, unsafe water and poor hygiene. Preventive chemotherapy with albendazole or mebendazole reduces worm burden and morbidity, but reinfection can occur when environmental exposure continues. The rapid return of infection after treatment must be distinguished from treatment failure and should not automatically be interpreted as anthelmintic resistance.

Although concern about benzimidazole resistance is justified by extensive use of these drugs and modelling predictions, widespread clinically confirmed resistance in human STHs has not been established. Monitoring should therefore combine standardized therapeutic efficacy assessments with cautious molecular surveillance.

In Nigeria, substantial geographical variation and residual infection after repeated MDA demonstrate the need for local surveillance and stronger school and community WASH services. Sustainable progress will depend on an integrated approach that combines preventive chemotherapy, safe water, sanitation, hygiene education, sensitive diagnostics and longitudinal monitoring.



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