



Geohelminthiasis in adults working along the rivers of Kinshasa: an analytical cross-sectional study
Géohelminthiase chez les adultes exerçant un métier le long des rivières de Kinshasa : une étude analytique transversale

Eddy Kakiese Laken¹, Samuel Bivula Mambu², Germain Kapour Kieng¹, Solange Mbamvu³, Freddy Kabasele⁴, Christian Divididi Amuganina¹, Hippolyte Situakibanza¹

Auteur correspondant

Eddy Kakiese Laken

Téléphone : (+243) 810787597

Courriel : kakieseaddy@gmail.com

Résumé

Contexte & objectif. Les adultes exerçant des métiers libéraux liés à l'eau le long des rivières de Kinshasa contribuent à la transmission des géohelminthes. La présente étude a donc recherché l'ampleur et les déterminants de géohelminthes afin de lutter contre sa pérennité, en particulier chez les enfants bénéficiaires des campagnes de traitement préventif de masse. *Méthodes.* Il s'agissait d'une étude analytique transversale menée auprès d'adultes exerçant une activité professionnelle le long des rivières de Kinshasa, notamment les creuseurs de sable, conducteurs de pirogues, briquetiers, maraîchers, pêcheurs et vendeurs. Les géohelminthes ont été recherchés à l'aide de la méthode de Kato-Katz et/ou par frottis direct. *Résultats.* Un total de 669 sujets a été inclus dans l'étude. La fréquence de la géohelminthiase était de 47,5 %, avec une prévalence de *Ascaris lumbricoides* de 26,3 %, de *Trichuris trichiura* de 23,3 %, de l'ankylostome de 3,29 % et enfin de *Strongyloides stercoralis* à 0,30 %. Les facteurs associés à la géohelminthiase incluent un niveau d'instruction supérieur au primaire, le fait de travailler le long de la rivière Matete, la défécation dans la rivière, et l'absence de prise de traitement préventif. *Conclusion.* Près de la moitié d'adultes travaillant le long des rivières sont exposés aux géohelminthes et contribuent à la propagation de la maladie dans la communauté. La chimiothérapie préventive, l'amélioration des conditions d'hygiène et la salubrité pourraient jouer un rôle déterminant dans la lutte contre cette maladie.

Mots-clés : géohelminthiase, adultes, profession, rivière, Kinshasa

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Summary

Context & objective. Adults working in water-related informal occupations along the rivers of Kinshasa contribute to the transmission of soil-transmitted helminths. The present study aimed to assess the prevalence of these infections and their associated risk factors in order to curb their persistence, particularly among children who benefit from mass preventive chemotherapy campaigns. *Methods.* This was an analytical cross-sectional study conducted among adults working along the rivers of Kinshasa, including sand diggers, canoe drivers, brickmakers, market gardeners, fishermen, and vendors. Geohelminths were detected using the Kato-Katz method and/or direct stool smears. *Results.* A total of 669 subjects were included in the study. The frequency of geohelminthiasis was 47.5 %, with a prevalence of *Ascaris lumbricoides* of 26.3 %, *Trichuris trichiura* 23.3%, the *Ankylostoma* spp. at 3.29 % and finally *Strongyloides stercoralis* 0.30 %. Factors associated with soil-transmitted helminthiasis included having an educational level higher than primary school, working along the Matete River, defecating in the river, and lacking uptake of preventive chemotherapy. *Conclusion.* Nearly half of adults working along the rivers are exposed to geohelminthes and contribute to the spread of the disease in the community. Preventive chemotherapy, combined with improved hygiene and sanitation conditions, may play a key role in controlling this disease.

Keywords: geohelminthiasis, adults, profession, river, Kinshasa

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1. Department of Tropical Medicine, University of Kinshasa, Kinshasa, Democratic Republic of the Congo
2. Vainqueur Hospital Center Kinshasa, Democratic Republic of the Congo



3. Department of parasitology, Institut National de Recherche Biomédicale, Kinshasa, Democratic Republic of the Congo
4. Institut Supérieur des Techniques médicales, Kinshasa, Democratic Republic of the Congo.

Introduction

Geohelminthiasis is one of the neglected tropical diseases (NTDs) (1), whose global burden exceeds that of malaria or tuberculosis (1). In 2003, schistosomiasis and geohelminthiasis affected more than two billion people worldwide, thus representing a major public health problem (2-3). NTDs, and more particularly geohelminthiasis, represent a human, social and economic burden for many people around the world (4). Geohelminthiasis is caused by various species of worms which are transmitted by eggs present in human excrement, contaminating the soils where the sanitation conditions are insufficient (5-6). The consequences in children are manifest: nutritional and physical disorders; in the infested young girl, blood loss increasing the risk of maternal and infantile mortality as well as hypotrophy of the newborn at birth (5). These infections lead to many deaths and also contribute to perpetuating poverty by compromising the physical and intellectual development of children and reducing the capacity for work and the productivity of adults (5-6). The fight against this disease is based on preventive periodic mass chemotherapy, health education and the improvement of sanitation infrastructure to reduce contamination (5). This treatment consists in administering albendazole or mebendazole to all preschool and school children (5, 7). Since 2021, the ivermectin has been available to fight against *S. Stercoralis* (5, 8). The geohelminthes are roundworms, notably *Ascaris lumbricoides*, *Trichuris trichiura*, and the SSP ankylostomas (*Necator Americanus* and *Ancylostoma Duodenale*). To these four species, we add the *Strongyloides stercoralis* (1, 8). The latter presents particular characteristics: its diagnosis requires specific methods and may escape detection, and is not subject to mass treatment campaigns (5,8). It is therefore necessary to conduct in -depth research to assess the extent of the *Stercoralis* infection in the Democratic Republic of Congo (DRC). However, it is included in this manuscript, because it is

transmitted under conditions similar to those of other geohelminthes and its geographic distribution is almost identical (5). Geohelminthiasis is therefore a group of parasitic diseases caused by helminths whose evolutionary cycle passes through the soil (5,8). It is among the most common infections, affecting more than 4.5 billion people, or about 25% of the world's population (9), with the highest prevalence in sub-Saharan Africa, South America and Asia. Regarding *S. Stercoralis*, it is estimated that there are more than 600 million infections in endemic areas (5,9). Geohelminthiasis is transmitted by eggs present in human faeces, contaminating the soil. Man is infected by ingesting the eggs present in soiled foods or by transcutaneous penetration of the filariform larvae present in the soil, in particular in the water or the mud for the *ankylostoma SSP* and *S. Stercoralis* (5-6). It has also been reported that contamination can occur through other routes, although this is exceptional, for *Ankylostoma spp.* and *S. stercoralis* (6, 11). Here is a high prevalence of geohelminthiasis in children, but the literature on this pathology in adults, particularly those living in Kinshasa, remains insufficiently documented. The few studies available on geohelminthiasis in adults, moreover, reveal that *Ascaris lumbricoides* is the most frequent species, with a prevalence of 12.5%, followed by *Ankylostoma spp.* (7.5%), *Strongyloides stercoralis* (greater than 5%), and *Trichuris trichiura* (1,1%) (11-12). It should be noted that the prevalence among adults in Kinshasa remains unknown. However, adults, particularly those engaged in high-risk activities, represent an important reservoir of infections and reinfections for treated children (13). However, this effort is slowed down by the strong parasitic loads of adults. This study aims to provide updated data on the adult situation, with a view to improving the planning of the fight against geohelminthiasis. The specific objective of this study is to document this disease in adults exercising professional activity along the Kinshasa rivers.



Methodes

Study setting, design and period

This is a cross-sectional analytical study conducted on the hydrographic network of the city of Kinshasa. Kinshasa is crossed by several rivers of varying sizes, which originate in the southern hills and flow northward into the Congo river at the Pool Malebo. Kinshasa is separated from Brazzaville by the Congo river, however, within the city itself, approximately twenty rivers flow. Only the N'Djili and Nsele rivers are navigable by canoe. This study was conducted at multiple sites along the N'Djili, Matete, Funa (Kindibula) and Makelele rivers. The rivers were chosen randomly, selected by simple random sampling. Participants were adults exercising a professional activity along these rivers: sandy cics, canoes operators, brick makers, market gardeners, fishermen and vendors.

Participants were recruited from lists established by site managers. The selected sample size was 669 volunteers. The sample size was calculated using the formula:

$$N = \frac{z^2 \cdot x \cdot p \cdot q}{d^2}$$

where:

- p: represents the disease prevalence (50%); this prevalence was assumed due to the lack of available data on the prevalence of geohelminthiasis among adults in our setting.
- q: 1 - p
- d: margin of error
- Z α : confidence coefficient

The minimum calculated sample size was 192 individuals. However, the actual sample collected, based on field availability, consisted of 669 adults.

This study was conducted from September 05, 2019 to January 21, 2020.

The inclusion criteria were engaging in a professional activity along the selected river, having worked there for at least six months, being at least 18 years old, providing informed consent, and submitting a stool sample. Sociodemographic and etiological variables were collected. Data collection involved interviews,

sample collection, and processing prior to slide examination.

The Kato-Katz technique was used for formed stools, while the direct smear technique has been applied for soft or liquid stools (14).

Operational definition:

- Egg load or parasite density: the number of parasite eggs observed on the slide.
- Disease intensity: the severity of infection based on egg load; it can be classified as light, moderate, or heavy.

Statistical analysis

Analyses were performed using EPI Info 7 software. The proportions were calculated with their corresponding confidence intervals. The median was used instead of the mean because the numerical variables did not follow a normal distribution.

Logistics regression was applied to identify the factors associated with geohelminthiasis and to measure this strength of the association. A significantness threshold of $\alpha = 0.05$ was applied.

Rigor in participant inclusion, clarity of questionnaires, and the experience of investigators and laboratory technicians, helped minimize potential bias.

All ethical considerations were respected. The study was approved by the National Ethics Committee under number 123/CNES/BN/PMMF/2016.

Results

General characteristics

A total of 669 volunteers provided stool samples, with a median age of 33 years (EIQ = 27), with extremes from 18 to 85 years. Men represented 70.5 % of the sample. The majority of participants had a primary education level (68.9 %). Sand diggers also constituted the majority group (56 %). Participants resided mainly in the following districts: FUNA (33.0 %), Mont Amba (31.3 %), Tshangu (23.4 %) and Lukunga (12.1 %). Only 22.2% of participants used latrines for defecation during working hours. Moreover, only 8.5% of individuals had received preventive treatment against helminths (figure 1).

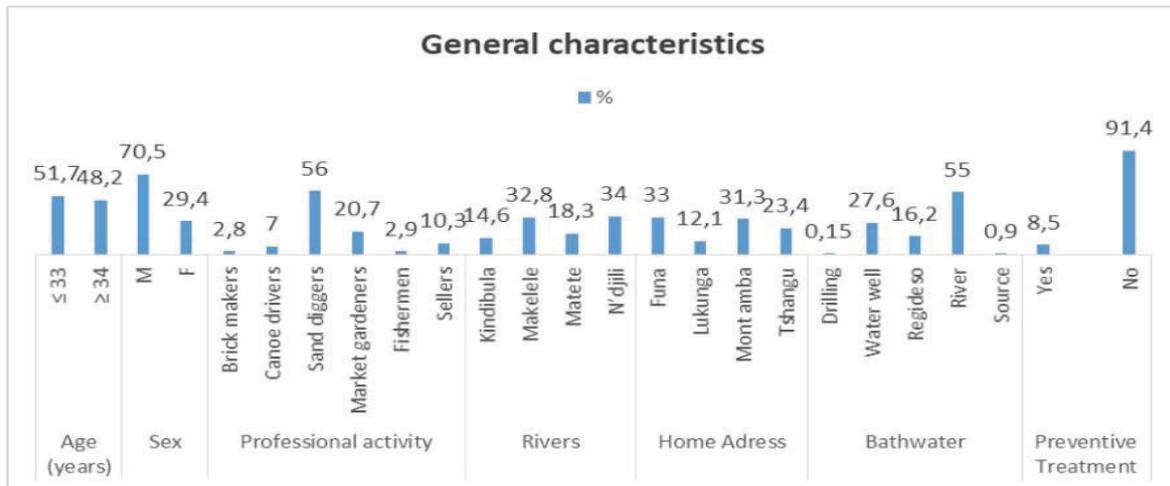


Figure 1. General characteristics of study population

Frequency, ovular load, infection intensity and geohelminthes species

The overall prevalence of geohelminthiasis was 47.5% (figure 2), with the following species distribution: *A. lumbricoides* 26.3%, *T. trichiura* 23.3%, *A. duodenale* 3.29% and *S. stercoralis* 0.30%.



Figure 2. Prevalence of geohelminthiasis

The specific prevalence is illustrated in figure 3.

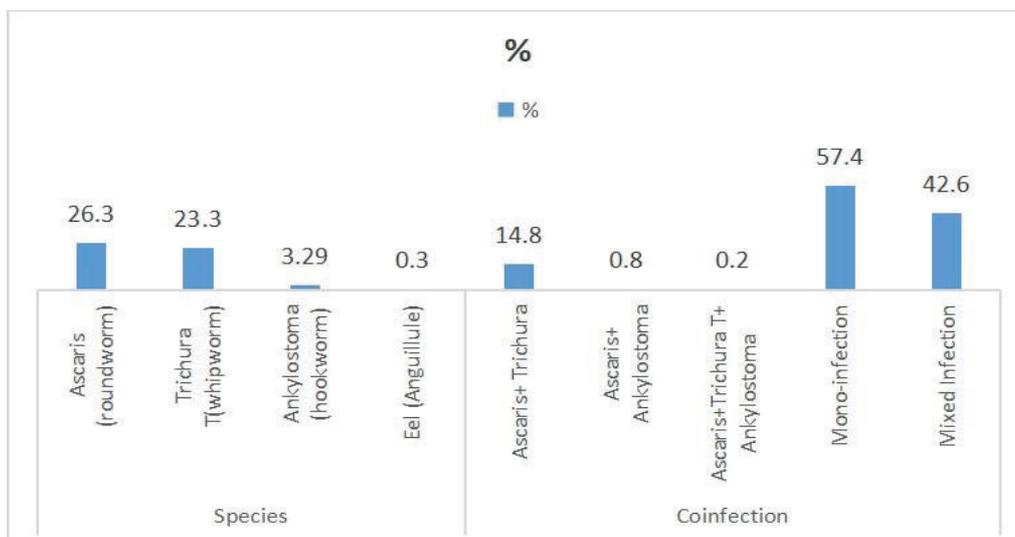


Figure 3. Specific prevalence by parasite and co-infection



The median egg density was: 6543 OPG (Eggs per gram of stool) for *A. lumbricoides*; 1059 OPG for *T.trichiura* (whipworm) and 42 OPG for *ankylostoma*. The maximum egg density recorded was 91,248 OPG of the stools for the *lumbricoides Ascaris*.

Only participants infected with ascariasis or trichuriasis presented all three levels of infection intensity mild, moderate, and severe. Hookworm infection and strongyloidiasis were observed at low levels.

Table 1. Frequency of the geohelminthiasis

Variables	N	Positives	% (95% CI)
Geohelminthes	669	318	47,5 (43,7 – 51,3)
Species			
<i>Ascaris</i> (roundworm)	669	176	26,3 (23,1 – 29,7)
<i>Trichura T</i> (whipworm)	669	156	23,3 (20,2–26,6)
<i>Ankylostoma</i> (hookworm)	669	22	3,29 (2,18–4,93)
Eel (Anguillule)	669	2	0,30 (0,08 –1,08)
Coinfection			
<i>Ascaris+ Trichura</i>	669	99	14,8 (12,3 - 17,69)
<i>Ascaris+ Ankylostoma</i>	669	5	0,8 (0,3 - 1,7)
<i>Ascaris+Trichura T+ Ankylostoma</i>	669	1	0,2 (0,03 - 0,84)
<i>Mono-infection</i>	244	140	57,4 (50,9 – 63,7)
<i>Mixed Infection</i>	244	104	42,6 (36,3 – 49,1)

Men showed a prevalence of Geohelminthiasis, particularly for *T.tricur*a and *S. stercoralis*, whereas the prevalence of *e A.lumbricoides* and hookworm was similar between sexes.

Participants with a post primary level of study were mainly infected with at least one geohelminthe, by *A. Lumbricoides* and *T. Tichura*.

All occupational groups were similar affected by at least one type of geohelminthiasis except *S. stercoralis* which was only observed among sand diggers. The prevalence of geohelminth infections was similar across participants working along all rivers except in Makelele, where a higher prevalence of *A. lumbricoides* and *T. Trichur* was observed. No cases of *T.trichura* were found in Matete (Mont-Amba), and *S. stercoralis* was detected only in Kindibula (Funu).

Factors associated with geohelminthiasis

In multivariate analysis, post-primary level of education, working along the Matete River, defecation in the river, and lack of preventive treatment were independently associated with geohelminthiasis. Participants with a post-primary level of education had a significantly

Co-infections

A total of 99 individuals (14.8 %) were co-infected with two parasites including *Ascaris lumbricoides* (roundworm) + *Trichuristrichura* (whipworm). Five individuals (0,8%) were co-infected with *A. lumbricoides* + *Ancylostoma duodenale* (hookworm) and one individual (0,2%) harbored three species of soil-transmitted helminths (STH): *Ascaris lumbricoides*+ *T.trichura Ancylostoma duodenale* (table 1).

higher likelihood of infection compared with those with a primary level (adjusted OR = 1.66; 95% CI: 1.13–2.42; p = 0.009).

Regarding river exposure, no significant association was observed for the Makelele River after adjustment (adjusted OR = 0.53; 95% CI: 0.24–1.15; p = 0.109), whereas exposure to the Matete River was associated with a significantly lower risk of geohelminthiasis (adjusted OR = 0.26; 95% CI: 0.09–0.72; p = 0.010), corresponding to a 74% reduction in odds compared with the Kindibula River. No significant association was found for the N'djili River (adjusted OR = 1.06; 95% CI: 0.34–3.31; p = 0.926). With respect to sanitation practices, open defecation in nature was not associated with geohelminthiasis (adjusted OR = 0.69; 95% CI: 0.39–1.22; p = 0.203), whereas defecation in the river was significantly associated with infection (adjusted OR = 0.56; 95% CI: 0.34–0.93; p = 0.024). Lack of preventive treatment showed the strongest association with geohelminthiasis (adjusted OR = 0.21; 95% CI: 0.10–0.44; p < 0.001), identifying preventive treatment as the main protective factor (table 2).



Table 2. Factors associated with geohelminthiasis

Variables	U OR	CI 95 %	P value	adjusted	OR CI 95 %	P value
Level of Education						
Primary	1					
Post Primary	1,863	1,337 - 2,596	< 0,0001	1,6567	1,133 - 2,422	0,009
River						
Kindibula	1					
Makelele	1,078	0,665 - 1,749	0,758	0,528	0,241 - 1,154	0,109
Matete	0,274	0,156 - 0,482	<0,0001	0,256	0,090 - 0,722	0,010
N'djili	0,513	0,317 - 0,830	0,006	1,055	0,336 - 3,310	0,926
Defecation						
Latrine	1					
Nature	0,8759	0,526 - 1,457	0,609	0,693	0,393 - 1,219	0,203
River	0,5358	0,367 - 0,782	0,001	0,558	0,336 - 0,927	0,024
Preventive treatment						
Yes	1					
No	0,2376	0,120 - 0,467	<0,0001	0,210	0,101 - 0,435	<0,0001

Discussion

The aim of this study was to document the prevalence of geohelminthiasis among adults working along the rivers of Kinshasa. Several studies have reported a high prevalence of infection in adults who are not included in the control programs (15–16).

Main epidemiological aspects

The results of this study provide an epidemiological profile of geohelminths among adults working along Kinshasa's rivers. Adults who are not treated against geohelminthiasis may serve as a reservoir for the contamination of children targeted by mass treatment campaigns (13). The median age of participants was 33 years, is similar to other studies (17-18). In Kenya, most participants were under 30 years, and in Kwilu and Tanzania, the median age was 30 years (15-18). Male predominated sex was predominant (70.5 %), whereas both sexes were equally represented in Kwilu (18). This difference likely reflects the nature of riverine occupations, which are mostly performed by men and require significant physical effort, except for market gardeners and vendors. This male predominance contrasts with the household sex structure in the DRC, where the male-to-female ratio is 93:100, indicating a relative under-representation of men. By comparison, in Kenya, the proportions of men and women were similar (17). The majority of participants worked along the N'Djili and Makelele rivers, likely due to the high number of activities there, including sand extraction sites, large marshes, and navigation (N'djili), which attract labor. Participants

primarily came from the districts of Funa, Mont-Amba, and Tshangu, although all districts have residents engaged in these occupations. This distribution may be influenced by the advanced socioeconomic precariousness of Kinshasa's population, which compels many to engage in occupations exposing them to waterborne diseases (19).

Frequency of geohelminthiasis, ovular load and the intensity of the infection

The frequency of geohelminthiasis among adults in the present study (47.5 %) is markedly high. In contrast, much lower frequencies have been reported in East Africa. In Kenya, a prevalence of 5.6% was observed among adult women in a study assessing risk factors and the burden of co-infection with *S. haematobium*, soil-transmitted helminths (STH) and *Plasmodium* (17), while in Tanzania the reported prevalence was 9.1% in a study focusing on the prevalence and associated risk factors of geohelminthiasis in adults (16). Our finding remains lower than that reported in Swat, Pakistan, where a prevalence of 73.2% was recorded among farmers, teachers, shepherds and their children. This high frequency was attributed to poor hygienic conditions and might have been even higher if diagnostic methods other than the direct smear technique had been used (20). Kinshasa faces similar challenges related to poor environmental sanitation, including inadequate waste management, illegal dumping sites and the discharge of wastewater into rivers, particularly after rainfall. Most households located along riverbanks directly release wastewater into nearby rivers, creating favorable conditions for



the transmission of geohelminths (19-20). Male participants were more frequently infected, which may be explained by their higher representation in the study population, as reported in several other studies (20). Geohelminthiasis prevalence was comparable across age groups and occupational categories. Current WHO control strategies mainly target children through periodic mass drug administration, in line with World Health Assembly resolution 54.19 of 2001, with no specific guidelines for adults (11). This approach contributes to the persistence of infection in adults and facilitates reinfection among treated children. In this study, *A. lumbricoides* and *T. trichiura* were the most prevalent species, whereas hookworms and *S. stercoralis* were less common, indicating a distribution pattern different from that reported in Kwilu and Kenya (17-18). Based on prevalence at district and river levels, all study sites were classified as low-risk areas for hookworms and *S. stercoralis*, but as high-risk areas for *A. lumbricoides* and *T. trichiura*. Overall, these findings highlight the need to include adults in geohelminth control and treatment programs in order to reduce infection persistence and limit reinfection in children.

Ascariidiasis

In the present study, *A. lumbricoides* was the predominant parasite, with a prevalence of 26.3%. This species remains one of the three most common intestinal helminths in tropical regions, owing to its very high fecundity (up to 200,000 eggs per day), long survival, and strong adaptation to environmental conditions (5-8,12). The prevalence observed in our study is lower than that reported in Pakistan, where a prevalence of 53.0% was documented (20). In contrast, several other studies have reported comparatively lower prevalence rates than those observed in the present work (16). The particularly high prevalence reported in Pakistan may be explained by differences in environmental sanitation, hygiene practices, and diagnostic approaches (15,20). The median egg load was 696 eggs per gram (EPG) (IQR 4056), with values ranging from 24 to 91,248 EPG. At such intensities, infected individuals may develop significant physiological and mechanical complications, including intestinal obstruction, which in severe cases may require surgical intervention (21). In Kenya, a gradual decline in the mean intensity of *A. lumbricoides* infection has been observed over time among children, but not among adults,

underscoring the close relationship between infection prevalence, intensity, and hygiene practices, as well as the limited impact of control strategies that do not target adults (17). Three levels of infection intensity were identified among infected individuals. Unlike findings from Kwilu, where most infections were of low intensity, our results reveal a more heterogeneous distribution of infection intensities (18). While low-intensity infections are often asymptomatic, moderate to high-intensity infections are associated with increased morbidity. Spatially, ascariasis was more frequent in the Funa and Lukunga districts, with fewer cases recorded in other districts. This distribution pattern is consistent with findings from other studies conducted in the Democratic Republic of the Congo (18).

Trichuriasis (Trichocephalosis)

Trichuriasis was the second most prevalent geohelminth infection in the study population, with an overall prevalence of 23.3%. This prevalence is comparable to that reported in some studies, but remains markedly higher than in others (15,20). In contrast, substantially lower prevalences have been reported in East Africa, notably 0.6% in Kenya (17) and 0.72% in Tanzania for *Trichuris trichiura* infection (16).

The intensity of infection, expressed as eggs per gram of feces (EPG), ranged from 24 to 38,400 EPG, with a mean intensity of 168 EPG (interquartile range [IQR]: 348). These egg counts exceed those reported in several previous studies, in which lower parasite burdens were observed (7).

Trichuriasis-associated morbidity includes dysentery, chronic blood and iron loss, and iron-deficiency anemia. At the infection intensities observed in the present study, a proportion of infected individuals may develop Trichuris-associated dysenteric syndrome, a condition that often requires repeated rounds of anthelmintic treatment to achieve effective parasite clearance (22,24).

Infections were classified into three intensity levels, whereas in other studies, infections were generally mild (17,24). Notably, in Kenya, no reduction trend for *T. trichiura* was observed in adults during drug follow-up (7).

Regarding spatial distribution, the Makelele River area recorded the highest number of trichuriasis cases, followed by Kindibula and N'Djili, while no cases were detected among participants working along the Matete River.



Ankylostoma sp

Ankylostomiasis was the third most frequent geohelminthiasis, with a prevalence of 3.3 % in this study. This frequency is similar to that reported in some studies (15,22) but lower than in others; in Tanzania, a prevalence of 7.43% was reported (16). By contrast, the study conducted in Kwilu reported a much higher prevalence of 20.8 % (18), likely because it involved the general population rather than a specific occupational group (15). The median egg count was 24 eggs per gram (EPG) (IQR 24), with a minimum of 24 and a maximum of 144 EPG. This density is lower than that reported in Kenya (17). Even at this level, the infection increases the risk of anemia, as ankylostomes exacerbate iron-deficiency anemia, reducing work capacity and productivity (5-6, 15). In this study, ankylostomiasis was exclusively of low intensity, similar to findings reported elsewhere (17). Infection intensity remains an important parameter for assessing the impact of community-wide mass deworming programs targeting geohelminthiasis (6). Moderate to high-intensity infections may lead to severe morbidity and an increased risk of hospitalization. However, the relationship between infection intensity and morbidity is not fully understood, as even light infections can sometimes result in significant clinical manifestations (17). Unfortunately, morbidity and clinical criteria were not assessed in the present study.

No ankylostome eggs were detected among sellers, brickmakers, and fishermen, whereas infections were observed among piroguers, market gardeners, and sand diggers, reflecting their greater exposure to muddy environments.

Ankylostomiasis was identified along the Kindibula, Makelele, and N'Djili rivers, but not along the Matete River, possibly due to the absence of extensive muddy areas along its riverbed.

The infection was present in all districts in relatively similar proportions. Environmental sanitation and effective fecal waste management can therefore play a crucial role in reducing the population's ankylostome burden.

Strongyloidosis

Strongyloides stercoralis, is a marker of immunodepression, and may cause severe or malignant forms in immunocompromised individuals (8,11). In this fortuitous cross-sectional study, *S. stercoralis* was detected with a prevalence of 0.30%. This frequency is lower

than that reported by other authors (23). It should be noted that the available literature is limited, as many studies conducted in Africa appear to have been neglected or underreported (8,11,23).

The number of rhabditoid larvae observed microscopically averaged four, with a minimum of one and a maximum of four larvae. Only men were affected by strongyloidiasis. All infected individuals were sand diggers, suggesting a strong occupational exposure. All cases of strongyloidiasis were detected along the Kindibula River, and the infected individuals resided in the Funa district.

It is possible that the diagnostic technique used in this study underestimated both the prevalence and the larval burden of strongyloidiasis. Indeed, direct stool examination may yield up to 90% false-negative results. Alternative methods, such as the Baermann or Harada-Mori techniques, could improve diagnostic sensitivity (11,14,23).

Co-infections

Only 99 individuals (14.8%) were co-infected with two geohelminths, namely *Ascaris* spp and *Tricocephalus* (*Trichuris trichiura*). Five individuals (0.8%) were co-infected with *Ascaris* spp. and *Ankylostoma* spp; while only one individual (0.2%) harbored all three helminth species: *Ascaris* spp., *Tricocephalus* spp and *Ankylostoma* spp. Multiple and diverse associations of geohelminths have been reported in several studies (5, 17, 22).

The most frequent co-infection observed was the association between *Ascaris* spp. and *T. trichiura*. Some evidence suggests that co-infections involving hookworms (*Ankylostoma* spp.), *T. trichiura*, and *Ascaris* spp. may exacerbate anemia. All these infections are strongly associated with poor fecal hygiene and inadequate sanitation (5, 6, 17, 22-24).

Factors Associated with Geohelminthiasis

Multivariate analysis identified several factors associated with the occurrence of geohelminthiasis in the studied population, including the river where activities were carried out, defecation practices, prior anthelmintic treatment, and educational level.

Riverine Activity Site

Individuals working along the Matete River had a slightly higher risk of infection (OR = 1.055) compared to those working along other rivers. Although this increase is moderate, it may reflect greater exposure to wet soils and fecally contaminated environments that favor the survival and maturation of geohelminth eggs (5-



6). The odds ratio (OR) being close to 1 suggests that the influence of the effect of the river itself is limited, and that other individual or behavioral factors - such as personal hygiene, footwear use, and deworming practices - likely contribute to infection risk.

Defecation Practices

Participants who reported defecating directly into the river had a significantly lower risk of infection (adjusted OR = 0.558; 95% CI = 0.336–0.927; $p = 0.024$) compared with those using latrines. Although this finding appears paradoxical, it may be explained by the rapid removal of fecal matter by river currents, which could reduce soil contamination and limit direct contact with parasite eggs or larvae (5-6). In contrast, defecation in open areas was not significantly associated with infection (adjusted OR = 0.693; $p = 0.203$), suggesting that additional environmental or behavioral factors may influence the risk of geohelminth transmission.

Preventive Anthelmintic Treatment

Individuals who had not received preventive anthelmintic treatment appeared to have a lower risk of infection (adjusted OR = 0.210; 95% CI = 0.101–0.435; $p < 0.001$). This counter-intuitive result may reflect a selection bias, as deworming campaigns are often implemented in the most highly endemic areas where exposure remains high despite treatment.

Educational Level

Participants with an educational level above primary school had a 1.66-fold higher risk of infection (adjusted OR = 1.6567). This result contrasts with the literature, where higher education is generally considered protective, promoting better hygiene practices and greater knowledge of preventive measures. This observation may reflect context-specific factors in the studied population, such as proximity to high-risk areas or certain occupational habits (15).

Implications

Overall, these findings confirm the multifactorial nature of geohelminth transmission, involving environmental, behavioral, and socio-economic determinants.

Strengthening health education and community therefore appears to be key strategy for improving hygiene behaviors and reducing exposure to geohelminth eggs and larvae.

Weaknesses and Strengths

The limitations of this study include the absence of an unexposed control group and the restriction of the survey to four rivers in Kinshasa, which may affect the external validity of the findings. Nevertheless, this study stands out for its focus on the adult population, which is often neglected in control strategies despite its key role in transmission. In addition, it adopts a multidisciplinary approach integrating tropical medicine, public health, and occupational medicine.

Conclusion

Adults working along rivers expose themselves to helminths. All the geohelminths were isolated from workers employed along the rivers in the city of Kinshasa. It is necessary to extend chemoprevention to the entire community, including adults. The promotion of improved hygiene and sanitation should also be encouraged in the fight against geohelminthiasis.

Conflict of interest

The authors declare no conflict of interest.

Contribution of authors

Conceptualization: EKL ; HS ; Methodology: EKL ; SBM ; GKK.; SM Investigation: EKL ; SM ; CDA ; FK ; Data curation: E.K.L; CDA; FK; Formal analysis: C.DA., E.K.L; SBM ; GKK.; Writing—original draft: EKL ; HS ; C.DA;SM .; Writing—review and editing: G.KK ;C.DA., E.K.L; HS ; SM ; Supervision: HS; E.K.L.All authors have read and agreed to the published version of the manuscript.

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