

Intestinal helminth infection among school-aged children and adolescents in Khammouane province: A neglected public health concern

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ABSTRACT

Intestinal helminth infection in children remains a significant public health concern. In Lao People's Democratic Republic various water (Lao PDR), sanitation and hygiene (WASH) interventions were implemented. This study aims to assess the infection burden of intestinal helminths in children and adolescents and explore association with different WASH levels in Khammouane province.

A cross-sectional study was conducted in 81 villages across three districts with prior WASH interventions in Khammouane province. Stool samples were collected from households members aged 5 - 17 years. Data was collected from parents/caregivers regarding demography, and potential risk factors. Intestinal helminth infections were detected using formalin-ethyl acetate concentration technique (FECT). Random effect logistic regression identified factors associated with infections.

Among 512 participants, 12.5% had multiple intestinal helminth species infections. *Opisthorchis viverrini* was the most prevalent infection (35.4%), followed by hookworm (30.3%) and minute intestinal flukes (11.3%). District of residence, sex and wealth index measurement were significantly associated with intestinal helminth infection, e.g. *O. viverrini* was significantly associated with living in Boualapha (OR = 5.9, 95% CI = 2.2 - 20.9) or Mahaxai district (OR = 12.8, 95%CI = 4.9 - 44.1). WASH levels were not statistically significant predictors of helminth infections.

Children and adolescents in Khammouane province, Lao PDR, have a high burden of intestinal helminth infection, particularly *O. viverrini* and hookworm. Socio-demographics factors (district, sex and wealth measurement) were the most important predictors of helminth infections. Comprehensive control programs, including species-specific strategies such as safe food handling and proper cooking, are essential to reduce infection risk in this vulnerable population.

1. Background

In 2023, globally, an estimated 1.5 billion individuals were infected with intestinal helminths (Ahmed, 2023). >260 million preschool-age children, 654 million school-age, 108 million adolescent girls and 138 million pregnant women require treatment for at least one of the soil-transmitted helminths. These parasite infections disproportionately

affect low-income families, which often lack access to clean and safe water, have poor sanitation and hygiene facilities and practices (Phillips et al., 2022).

Children are the most vulnerable group regarding intestinal helminth infections due to their frequent contact with contaminated environments and limited awareness of hygiene practices (Nanthavong et al., 2017). Chronic infections with intestinal helminths during childhood

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may lead to anaemia, malnutrition, stunted growth and impaired cognitive development, which in turn affect educational performance and long-term health outcomes (Sayasone et al., 2015).

Intestinal helminth infections belong to the neglected diseases. In Lao People's Democratic Republic (Lao PDR), at the national level, intestinal helminth infections remain a significant public health concern. National reports indicate that infections with Hookworm (21.6%), *Opisthorchis viverrini* (18.8%), *Strongyloides stercoralis* (4.8%), *Ascaris lumbricoides* (2.3%) and *Trichuris trichiura* (1.5%) are widely distributed, with prevalence varying substantially by region, age group, and environmental conditions (Phonekeo et al., 2023). *O. viverrini* infection is highly prevalent in certain regions of Lao PDR, particularly in areas where consumption of raw or undercooked freshwater fish is common (Phongluxa et al., 2013).

Poor access to safe water, inadequate sanitation and hygiene facilities and practices are recognized as key risk factors for intestinal helminth transmission (Strunz et al., 2014; Ziegelbauer et al., 2012). Although WASH interventions have been implemented in Lao PDR, their impact on the prevalence of intestinal helminths among young children remains unclear. Information on infection burden of intestinal helminths in children and adolescents are limited. Examining children therefore provides essential insight into both the current burden of infection and has broader implications for community health and development. We therefore aimed to assess the prevalence and identify risk factors for intestinal helminthic infections among children and adolescents aged 5–17 years in three districts of Khammouane Province, Lao PDR, which are characterized by varying levels of water, sanitation, and hygiene (WASH) infrastructure and practices.

2. Methodology

2.1. Ethical consideration

The study was approved by the National Ethics committee for Health Research, Ministry of Health (MoH), Vientiane, Lao PDR (Ref.No.041/2022 NECHR). To conduct the fieldwork, the authorisation was approved by the Ministry of Health, together with the Provincial Health Office of Khammouane province and the District Health Office in Nakay, Boualapha and Mahaxai districts. The parents of the children were informed on the procedure of the study and voluntary participation. Regarding participants under 15 years old, consent was obtained from the parent/guardian and assent was obtained from those aged 15–17 years.

2.2. Study area and population

This study was part of a larger study examining the relationship between viral infection and WASH levels and other exposures (Khounvisith et al., 2025). A cross-sectional study was conducted in 3 districts of Khammouane province from January to April 2023 (Fig. 1). Khammouane Province had a total population of 462,374 in 2025, including Mahaxay (44,097), Nakai (31,430) and Boualapha (40,047) (Lao Statistics Bureau, 2019). Villages were selected using random sampling, targeting 82 of the 174 villages in the study area including 14 villages in Nakay, 34 villages in Mahaxai and 34 villages in Boualapha district. Within each selected village, a list of residents was used to randomly select households, aiming for approximately 30 participants per village between 5 and 17 years (Fig. 2).

The investigator conducted an interview in a convenient place e.g. in a temple. Children aged 5–17 years whose parents provided their

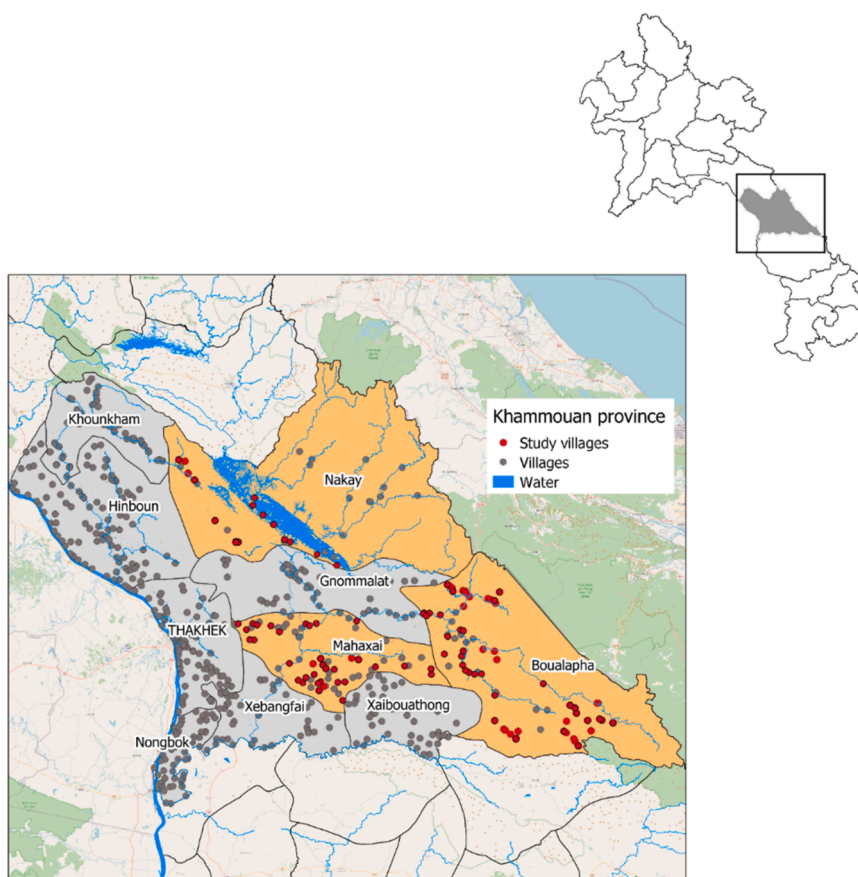


Figure 1. Map of Khammouane province showing the study area and villages in Nakay, Mahaxai and Boualapha districts (orange color).

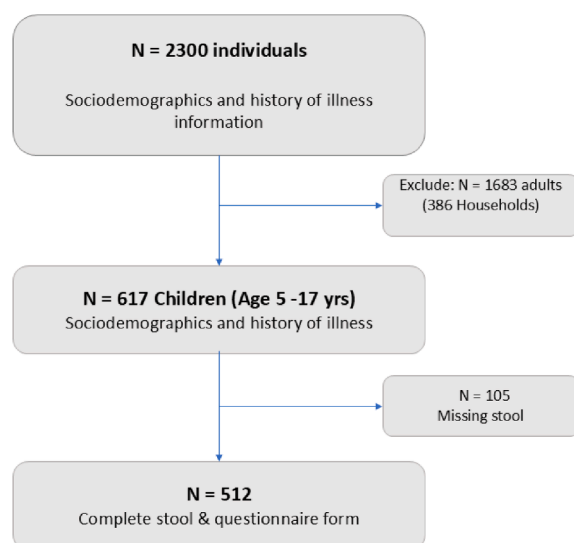


Figure 2. Flowchart of participant recruitment.

consent, who had no fever and who voluntarily agreed to participate and to provide a stool sample were included.

The questionnaire form included socio-demographic characteristics (location, age, sex, ethnicity, level of education, etc.) and the history of illness within 6 months was also captured based on self-reported any health problem or episodes of illness experienced during that period.

2.3. Field and laboratory procedure

The stool containers were labelled with the name of the children and dispensed together with the stool collection guidelines to the parent/guardian. The following day, the stool containers were collected at the same time as administering the questionnaires.

A single stool sample was collected from each participant. From each stool sample, 2 g were fixed with 10 ml sodium acetated acetic-acid formalin and transferred into 15 ml centrifuge tubes. The preserved stool samples were stored at room temperature in the district hospital and subsequently transferred to the Lao Tropical and Public Health Institute in Vientiane capital. The formalin-ethyl acetate concentration technique (FECT) was used for the concentration and microscopic detection of intestinal helminth eggs in stool samples. All slides were examined under the microscope, with egg count and identification of helminth species. In case of any discrepancy, the laboratory technicians and laboratory expert reviewed the slides and results together to reach a conclusion.

Data collection Kobo toolbox was used to collect the data in the field on electronic tablets. The analysis was performed using STATA software, version 16.0. The wealth index measurement (WIM) of the population was assessed using a household-based asset approach (Fry et al., 2014). The information was obtained from the parent interviewed e.g. socio-demographics, WASH assessment levels etc. The participants were grouped into three tertiles according to the WIM status into (a) poor, (b) middle, and (c) high. The WIM was classified on a range of household assets, housing characteristics (materials used for the roof, floor and walls), access to electricity, and ownership of various items, including televisions, radios, refrigerators, cars, bicycles, and motorcycles. Additionally, land use and livestock ownership of buffalo, cows, pigs, goats, and poultry were included in the analysis to provide a comprehensive assessment of household wealth and socio-economic status.

2.4. Statistical analysis

The descriptive analysis was conducted on all variables, including

district, age group, sex, ethnicity, education and socio-economic status. Bivariate and multivariable analysis were performed between socio-demographics and intestinal helminth infection.

WASH levels scores were based on UNICEF/WHO guidelines (WHO and UNICEF, 2017). The classification allowed to simplify the analysis and improve statistical analysis. This approach also facilitated comparison across households with varying levels of WASH access and practices. Data were collected through interviews using a structured questionnaire administered to the head of each household. The resulting scores were subsequently categorized into levels based on the criteria presented in Table 1.

Legend: Water source service levels: 1). Surface water: drinking water directly from a river, dam, lake, pond, stream, canal or irrigation canal; 2). Unimproved: drinking water from an unprotected dug well or unprotected spring; 3). Improved limited: drinking water from an improved source that requires a journey of >30 min round trip, including queuing; 4). Improved basic: <30 min including queuing; 5). Improved safely managed: water source located on the premises, available when needed, free from faecal and priority chemical contamination. **Sanitation service levels:** 1). Open defecation; 2). Unimproved: Use of pit latrines without a slab or platform, hanging latrines or bucket latrines; 3). Improved limited: use of improved facilities shared between two or more households; 4). Improved basic: not shared with other households; 5). Improved safely managed: not shared with other households and excreta are safely disposed of in situ or transported and treated offsite. **Hygiene service levels:** 1). No facility: No hand-washing facility on premises; 2). Limited: Availability of handwashing facility lacking soap and/or water at home; 3). Basic: Availability of a handwashing facility on premises with soap and water. For statistical analysis of water and sanitation levels, the classification of “improved” levels grouped “limited”, “basic” and “safely managed” together.

3. Results

3.1. Socio-demographics

Overall, 512 children and adolescents from the study area had a completed questionnaire and examined stool samples, and were therefore included in the analysis (Fig. 2). Of these participants, 11.2% were from Nakay, 44.4% from Mahaxai, and 44.5% from Boualapha. Just over half of the participants were female (276, 53.9%). About half were aged 10–14 years (51.0%), with a mean age of 11.6 years. Most participants were enrolled in primary education (314, 61.3%). There was a relatively equal number of low, medium and high WIM households. The majority of participants were Lao-Loum ethnicity (268, 52.5%). Furthermore, 65.6% of participants had not reported any illness during the six months preceding the survey (Table 2).

3.2. Water and sanitation status of the households

Overall, 57.0% of the participants used safely managed water services, 21.5% relied on limited water services and 14.0% depended on surface water sources. For sanitation, 38.1% had access to safely managed facilities, 12.4% to basic facilities, while 26.3% still practiced open defecation. Regarding hygiene, 66.0% of the participants practiced basic handwashing with soap, whereas about 11.1% had no hygiene facilities at home (Table 3).

3.3. Intestinal helminth infections

Opisthorchis viverrini (*O.viverrini*), minute intestinal flukes (MIF) and hookworm were the most frequently diagnosed helminth species (Fig. 3). *O. viverrini* was the most frequently diagnosed infection with 35.4%, with Mahaxai district (47.6%) and the age group 15–17 years old (46.7%) being the most affected. MIF was detected in 11.3% of the participants. Hookworm had a prevalence of 30.3%, with the highest

Table 1

WASH levels scores base on UNICEF/WHO(WHO and UNICEF, 2017).

Variables	WASH levels scores				
	1	2	3	4	5
Water source service level	Surface water	Unimproved	Improved: Limited	Improved: Basic	Improved: Safely managed
Sanitation service levels	Open defecation	Unimproved	Improved: Limited	Improved: Basic	Improved: Safely managed
Hygiene service levels	No facilities	Limited	Basic	N/A	N/A

Table 2

Socio-demographic characteristics of study participants, n = 512.

Variable	N (n = 512)	Percentage
District		
Nakay	57	11.1
Mahaxai	227	44.4
Boulapha	228	44.5
Sex		
Male	236	46.1
Female	276	53.9
Age (years), mean (SD)		11.6 ± 3.1
Age group (years)		
5 to 9	146	28.5
10 to 14	261	51.0
15 to 17	105	20.5
Ethnicity		
Lao-Loum (Lao-Tai)	269	52.5
Non-Lao-Loum (Mong-Khmer)	243	47.5
Education		
No schooling	14	2.7
Primary	314	61.3
Lower 2nd school	154	30.1
Upper 2nd school	30	5.9
Wealth Index Measurement, (n = 494)		
Poor	178	36.0
Middle	147	29.8
High	169	34.2
History of illness		
Being ill in the last 6 months		
No	336	65.6
Yes	176	34.4
if yes, symptoms		
Symptoms not related to GI*	119	67.6
GI* symptoms	57	32.4

* GI: gastrointestinal tract.

Table 3

Water, sanitation and hygiene levels assessment of the household, n = 494.

Variables	Total N = 494 (%)
Water assessment level	
Surface water	69 (14.0)
Unimproved	16 (3.2)
Improved (Limited/Basic/Safely managed)	409 (82.8)
Sanitation assessment level	
Open defecation	130 (26.3)
Unimproved	0 (0)
Improved (Limited/Basic/Safely managed)	364 (73.7)
Hygiene assessment level	
No facility	55 (11.1)
Limited	113 (22.9)
Basic	326 (66.0)

rates in Mahaxai (35.2%) and the age group 15–17 years (43.8%) being the most affected. Moreover, *Trichuris trichiura* was found in 39 participants (7.6%), with Boulapha (15.8%) and females (9.8%) showing the highest prevalence. *Ascaris Lumbricoides* demonstrated a low prevalence of 2.2% (Annex, Table A1).

Infection with multiple helminth species was very frequent. Double and >2 types of intestinal helminth co-infection occurred in 15.8%, and

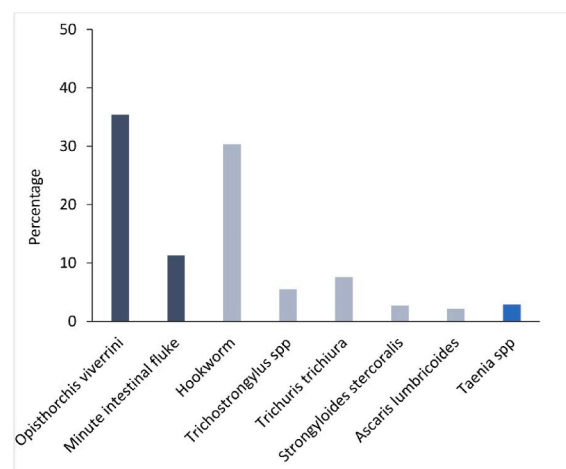


Figure 3. Prevalence of intestinal helminth infection. Dark grey represented trematodes, light grey represented nematodes and blue represented cestodes (n=512).

12.5% of participants, respectively, while 38.1% had a single helminth species infection, and 39.8% had no infection. Mahaxai and Boulapha district demonstrated a higher prevalence of multiple infections compare to Nakay district (Fig. 4, Annex Table A1).

In the youngest age group (5–9 years), a high prevalence of helminth infections was observed. *O. viverrini* was the most common infection (26.7%), followed by hookworm (15.8%) and MIF (9.6%). Multiple infections were also frequently detected in this age group, with 17.8% presenting double infections (Fig. 3).

3.4. Risk factors

We identified significant predictors for intestinal helminth infections (Fig. 5, Annex Table A2). Age was the most important predictor. Infection with *O. viverrini* (15 to 17 age group vs younger age: OR = 2.3; 95% CI: 1.3–4.2; p = 0.004) (Fig. 5, Annex Table A2), MIF (15 to 17 age group vs younger age: OR = 3.4; 95% CI: 1.5–7.7; p = 0.004) (Fig. 6, Annex

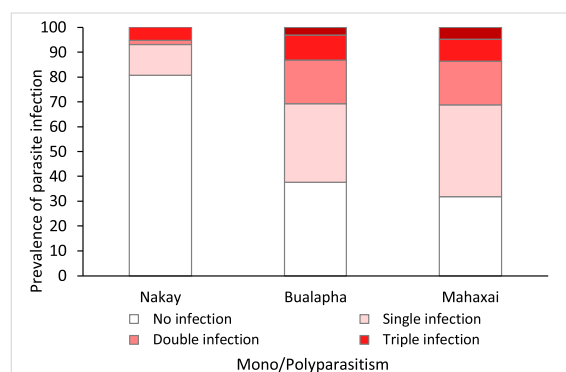


Figure 4. Multiple helminth infections in three districts of Khamouane province 2024, n=512.

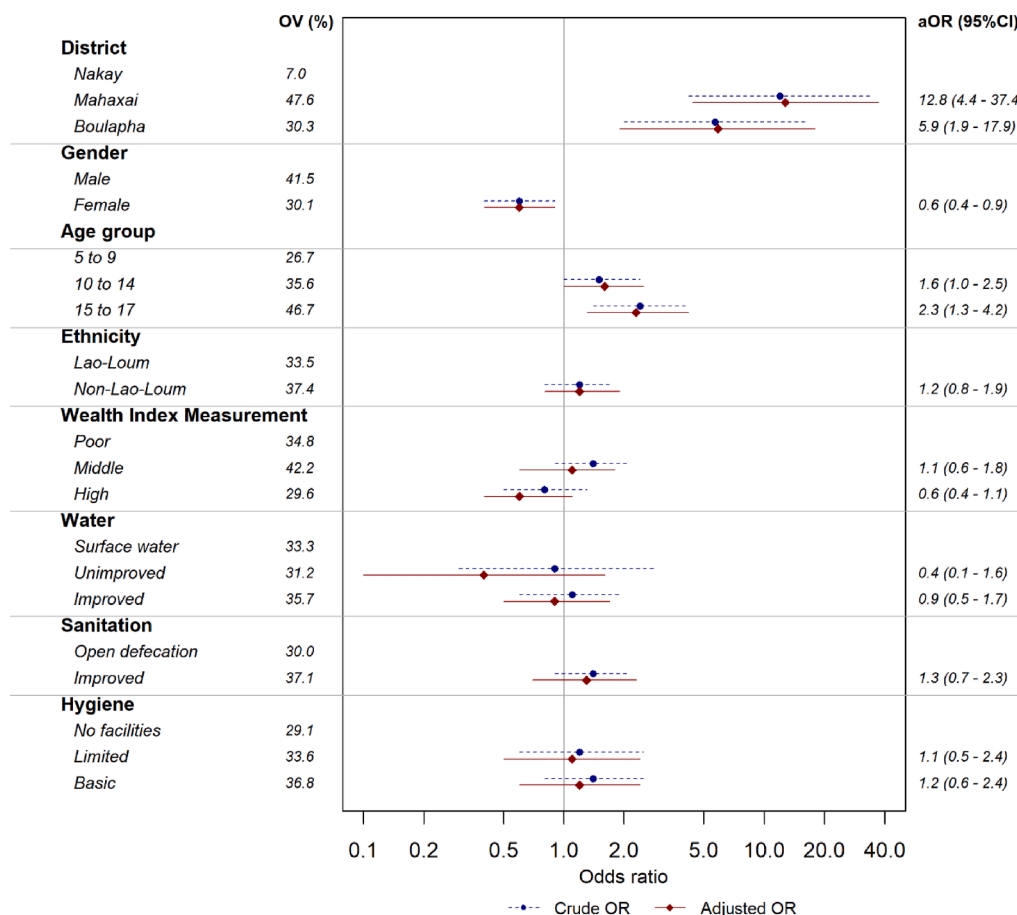


Figure 5. Socio-demographics and water, sanitation and hygiene risk factors associated with *Opisthorchis viverrini* (Ov) infection among children, n=512. Blue dotted line: bivariable analysis with crude odds ratio; Red solid line: multivariable analysis with adjusted odds ratio; 1.0 reference.

Table A3) and hookworm (15 to 17 age group vs younger age: OR = 4.7; 95% CI: 2.5–9.1; $p < 0.001$) (Fig. 7, Annex Table A4) were associated with older age of participants. Furthermore, *O. viverrini* infection was significantly less frequent in female compared to male study participants (OR = 0.6; 95% CI: 0.4–0.9; $p = 0.01$) (Fig. 5, Annex Table A2) and MIF infections were significantly less frequent in households with high WIM (OR = 0.4; 95% CI: 0.2–0.9; $p = 0.03$) (Fig. 6, Annex Table A3).

Furthermore, the highest infection risk was observed in residents of Mahaxai district, followed by Boulapha compared to Nakay district. For example, *O. viverrini* infection risk was significantly higher residents from Mahaxai district (OR = 12.8; 95% CI: 4.4–37.4; $p < 0.001$) and Boulapha (OR = 5.9; 95% CI: 1.9–17.9; $p = 0.002$) compared to Nakay district (Fig. 5, Annex Table A2). Equally, hookworm infection was significantly higher among participants living in Mahaxai (OR = 6.0; 95% CI: 2.2–16.3; $p < 0.001$) and Boulapha districts (OR = 4.3; 95% CI: 1.5–12.0; $p = 0.005$) compared to Nakay district (Fig. 7, Annex Table A4).

Overall, no statistically significant associations were identified between WASH levels and any of the three main helminth infections in our study population. E.g., *O. viverrini* infection was not associated with improved sanitation (aOR = 1.3; 95% CI = 0.7–2.3; $p = 0.41$) and the presence of a basic sanitary facility at home (OR = 1.2; 95% CI = 0.6–2.4; $p = 0.68$) (Fig. 5–7). Furthermore, hookworm infection was not associated with improved water facility (aOR = 1.0; 95% CI: 0.5–1.9; $p = 0.96$) and sanitation facility (aOR = 0.6; 95% CI = 0.3–1.1; $p = 0.08$), respectively.

4. Discussion

Our results demonstrated a high burden of intestinal helminth infections in children and adolescents in the three rural study districts of Khammouane province. *O. viverrini* infection was the most prevalent (35.4%) followed by hookworm (30.3%) and MIF (11.3%). Since 2005, preventive chemotherapy against soil-transmitted helminths (STH) has been implemented in school-aged children and pregnant women in Lao PDR. The aim was to reduce the infection and morbidity burden due to STH in these high-risk groups. Mass-drug administration (MDA) campaigns distributing anti-helminthic medication (i.e., mebendazole, albendazole) combined with information, education and communication were implemented (Phommasack et al., 2008). Our findings indicate that despite these MDA interventions, many participants were infected with hookworm. Therefore, these interventions were not sufficient to reduce the STH infection burden, perhaps due to reinfection, low treatment coverage, or low adherence to medication. The medicines used in MDA campaigns are not active against trematode infections and could thus not reduce the infection burden with *O. viverrini* and other trematodes. In Lao PDR, MDA using praziquantel effective against trematodes has been implemented only in two districts of Champasack province where *Schistosoma mekongi* is endemic and co-infection with *O. viverrini* is very frequent (Sayasone et al., 2024). In other *O. viverrini* endemic provinces such as Khammouane, praziquantel MDAs have been implemented only occasionally.

In the present study, no statistically significant association was observed between WASH conditions and intestinal helminth infections. These results were surprising as WASH facilities and practices are recognized as important risk factors. In our study area, we could also

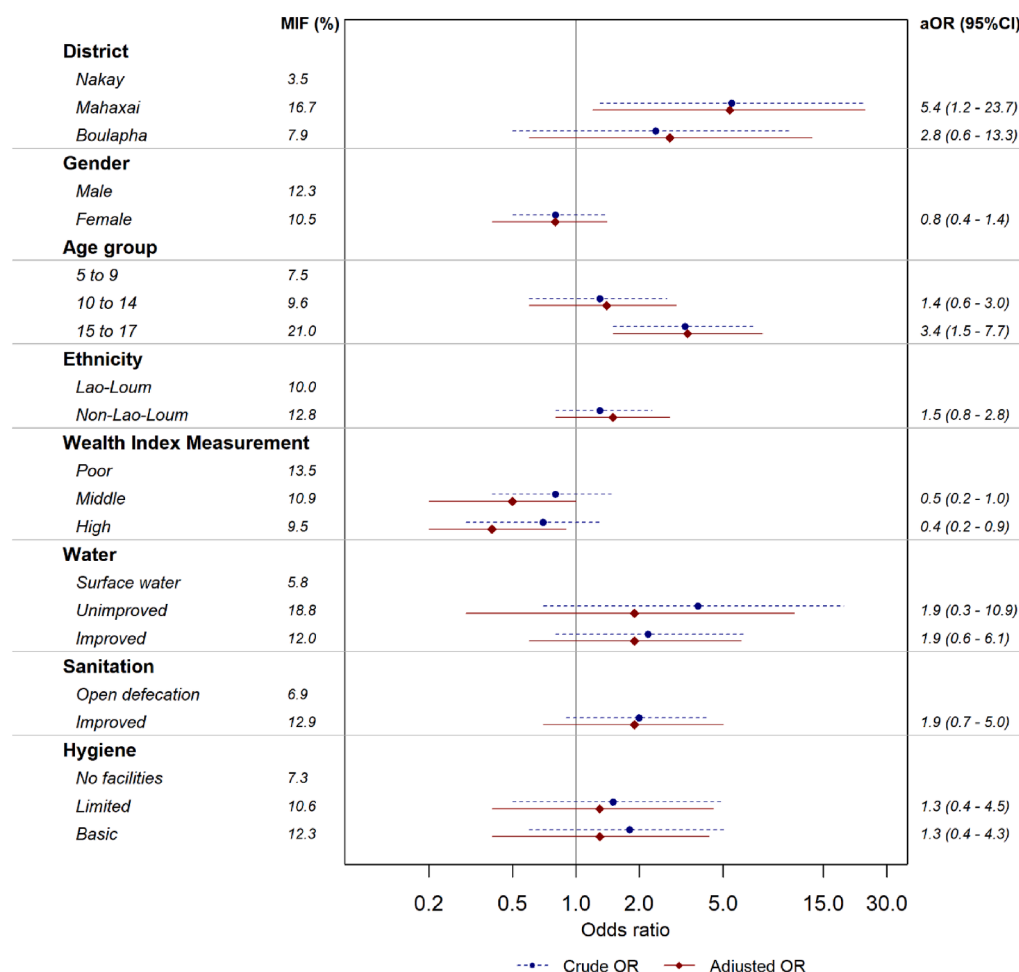


Figure 6. Socio-demographics and water, sanitation and hygiene risk factors associated with minute intestinal flukes (MIF) infection among children, n=512. Blue dotted line: bivariable analysis with crude odds ratio; Red solid line: multivariable analysis with adjusted odds ratio; 1.0 reference.

observe that WASH levels varied considerably between villages and households. The persistence of intestinal helminth infections despite reported WASH improvements may indicate the influence of other contributing factors, such as location, environmental contamination and behavioural practices. Moreover, the effect of WASH improvement may take time to translate into measurable reductions in infection prevalence, especially in highly endemic areas and the self-reported of WASH data may also have contributed to the absence of statistically significant associations. Additional measures such as regular anti-helminthic treatment may be required so that the influence of WASH becomes visible or measurable. Lastly, because the WASH intervention was not implemented with MDA targeting all intestinal helminths, preexisting infections may have persisted in the community although the WASH level has changed. This may have limited our ability to detect the full potential impact of WASH improvements on transmission.

Our findings demonstrate the challenges associated with the documentation of impact of WASH improvements on intestinal helminth infections. They are consistent with those of a study conducted in adults from the same area (Khounvisith et al., 2026), which similarly demonstrated a significant age-related increase in *O. viverrini*, MIF and hookworm infections, indicating progressive cumulative exposure over time. However, the overall prevalence observed in our study was lower than that reported in a previous study conducted in southern Lao PDR among children aged 6 months to 12 years, where hookworm and *O. viverrini* were reported at high prevalences of 51.0% and 43.3%, respectively (Sayasone et al., 2015). These differences may reflect geographic variability, differences in transmission intensity, environmental conditions,

time and local sanitation practices.

In contrast to our findings demonstrating a very high burden of intestinal helminth infections already in very young age groups, a study conducted in neighboring Thailand has reported substantially lower prevalences and different parasite profiles. That study among school-aged children in Thailand in 2016 reported a low overall infection prevalence, with single and multiple infections observed in only 15.6% and 6.5% of children, respectively, and *Strongyloides stercoralis* (1.5%) and *O. viverrini* (0.4%) being the most commonly detected species (Assavapongpaiboon et al., 2018). This possibly results from more risk practices in Laos, such as consumption of raw fish, under-cooked meat and other behaviours.

Mahaxai and Boulapha district showed a high prevalence with *O. viverrini*, MIF and hookworm. The reason for the lower infection burden in Nakay could result from previous health interventions in connection with the Nam Theun 2 hydropower dam. These interventions included strengthening of local health services, improved water and sanitation infrastructure, health education and ongoing community support aimed at improving living conditions and well-being (Erlanger et al., 2008).

The prevalence of *O. viverrini* infection was higher in males compared to female participants. In many rural areas, traditional dishes are made from raw or undercooked fish for the whole family including children (Phongluxa et al., 2013). The difference observed between male and female participants may reflect sex-related differences in food consumption behaviors. Cultural practices within households may also play an important role in sustaining the transmission of soil-transmitted

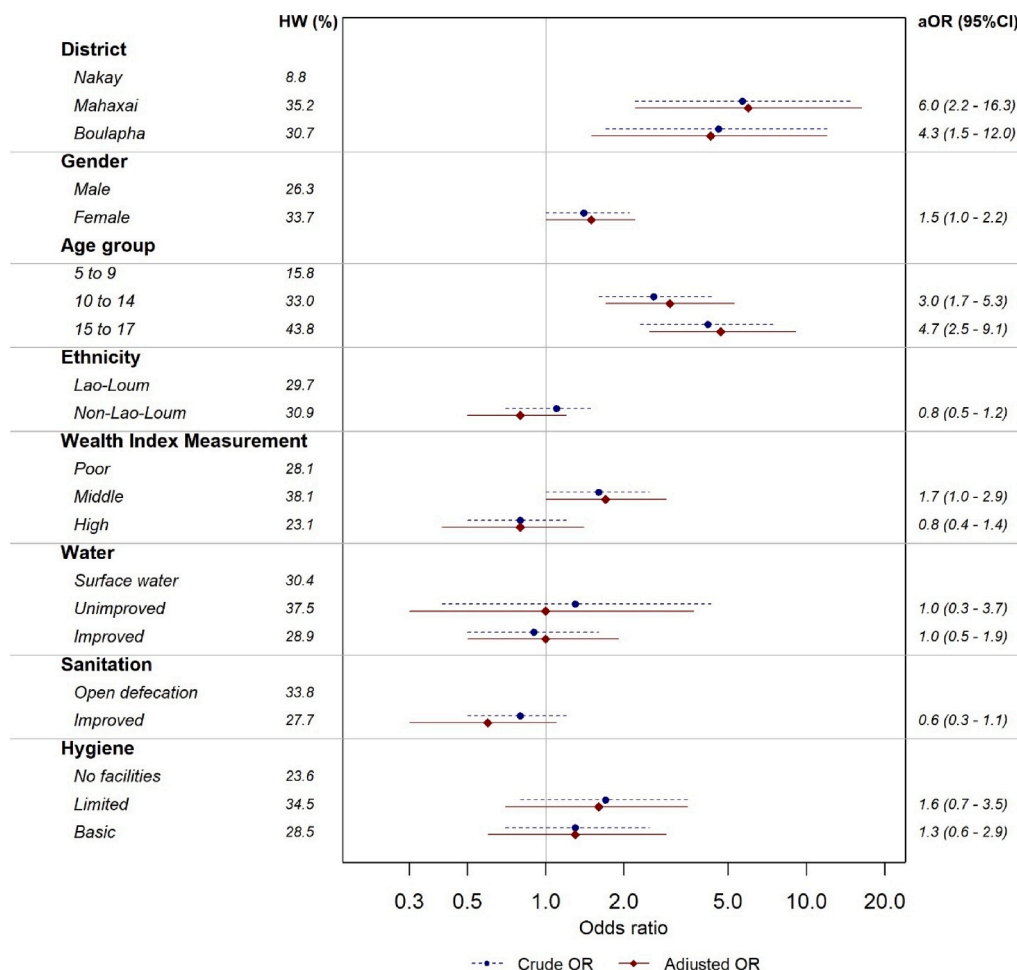


Figure 7. Socio-demographics and water, sanitation and hygiene risk factors associated with hookworm (HW) infection among children, n=512. Blue dotted line: bivariable analysis with crude odds ratio; Red solid line: multivariable analysis with adjusted odds ratio; 1.0 reference.

helminths among children, and gender-linked practices may explain the higher prevalence of hookworm in females. Future research should focus on investigating the behavioural and cultural factors that influence transmission. We found higher WIM significantly associated with lower MIF infection. This association is likely due to the fact that wealthier families generally have better access to safe food preparation, better hygiene and sanitation and have increased awareness. Similar trends have been reported in Thailand where lower socio-economic status is consistently linked to *O. viverrini* infection (Subdistrict and Patumthani, 2014). In our study, there was also a trend towards higher *O. viverrini* in lower socio-economic groups, although this did not reach statistical significance.

The higher occurrence of *Taenia* spp. infections in Boulapha district may reflect local ecological and behavioural factors that facilitate transmission. Although *Taenia solium* transmission is partly related to inadequate sanitation and poor hygiene practices, it is also strongly influenced by pig-rearing practices, free-roaming pigs and insufficient meat inspection and food safety practice (Tritz et al., 2018). Therefore, the observed clustering of *Taenia* spp. cases in this district may indicate a combination of environmental contamination and local animal husbandry practices that favour ongoing transmission within the community.

4.1. Limitations

This study has some limitations. First, data were collected from only three districts, that had previous WASH interventions. Therefore, the

findings regarding the infection prevalence were not representative for the rest of the province and other rural areas, where no interventions took place. However, our study results reflect the prevailing WASH facilities and practices in the areas. Second, only a single stool sample was collected from each participant, which may have led to an underestimation of the true prevalence of infections, particularly those with low infection intensity. However, the study still provides valuable baseline data on the epidemiology of infections in children, and future studies should collect multiple stool samples from each participant to improve the sensitivity of parasite detection. Third, WASH assessment relied on household survey data rather than the observation, which may have introduced reporting bias. Nevertheless, the data collection provided important insights into household WASH conditions within the study area. Fourth, the grouping of WASH levels into three categories may have reduced the variability and detail of individual WASH indicators. Despite this classification improved analytical feasibility and standardized comparisons based on internationally recognized Joint Monitoring Program definitions. Fifth, WASH assessment focused mainly on infrastructure and access indicators, without detailed data on WASH-related practices and behaviours (e.g. latrine use, footwear, school exposures etc.). As behavioural adherence may influence intestinal helminth infection risk, this may have affected the observed association. Besides this, WASH assessment focused on access and infrastructure rather than hygiene-related behaviours. Potential re-infection from school-related exposures was also not assessed and schooling may not necessarily reflect improved hygiene practices in settings with continued environmental contamination. Finally, the questionnaire primarily captured

sociodemographic information and did not include other behavioral or environmental risk factors specifically for children, such as wearing shoes. Consequently, some important risk factors might not have been assessed and included in the analysis. However, key risk factors were well documented.

5. Conclusion

Despite WASH interventions in the 3 studied districts of Khammouane province, high intestinal helminth infection prevalences were found in children and adolescents in this area. Our study highlighted that *O. viverrini*, hookworm and MIF were predominant. Place of residence, sex and wealth were identified as important predictors for intestinal helminth infections while no association was found with WASH levels. Effective control of intestinal helminths requires a comprehensive programme, including tailored measures such as promoting safe cooking practices and limiting raw food consumption among these populations.

List of abbreviations

CIs = Confidence Intervals.
EPG = Eggs per grams.
FECT = Formalin-ethyl acetate concentration technique.
MOH = Ministry of Health.
NECHR = National Ethics Committee for Health Research.
OR = Odds ratio.
PCA = Principal component analysis.
SD = Standard deviation.
WASH = Water, Sanitation and Hygiene.
WHO = World Health Organisation.
WIM = Wealth Index Measurement.

Ethics approval and consent to participate

Ethics approval was obtained from the Lao National Ethics Committee for Health Research (NECHR), Ministry of Health (MoH), Vientiane, Lao PDR (Ref. no. #041/2022 NECHR).

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Competing interests

The authors declare no competing interests or personal relationships that could have appeared to influence the work reported to this paper. The authors confirm that they have no conflicts of interest related to this study or its publication.

CRediT authorship contribution statement

Vilaysone Khounvisith: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Siriphone Virachith:** Investigation. **Nouna Innoula:** Investigation. **Bounta Vongphachanh:** Investigation. **Latdavone Khenkha:** Investigation. **Somphou Sayasone:** Investigation. **Jan Hattendorf:** Methodology, Formal analysis. **Judith M. Hübschen:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Antony P. Black:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization. **Peter Odermatt:** Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Conceptualization.

Declaration of competing interest

To the Editorial Office of Acta Tropica, On behalf of all authors, I hereby declare that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in the manuscript entitled "Intestinal helminth infection among school-aged children and adolescents in Khammouane province: A neglected public health concern".

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Annex

Table A1

Intestinal helminth infection prevalence by district, sex and age, $n = 512$.

Parasites	n (%) ($n = 512$)	District			Sex		Age groups (years)		
		Nakay ($n = 57$)	Mahaxai ($n = 227$)	Boualapha ($n = 228$)	Male ($n = 236$)	Female ($n = 276$)	5 to 9 ($n = 146$)	10 to 14 ($n = 261$)	15 to 17 ($n = 105$)
Trematodes									
<i>Opisthorchis viverrini</i>	181 (35.4)	4 (7.0)	108 (47.6)	69 (30.3)	98 (41.5)	83 (30.1)	39 (26.7)	93 (35.6)	49 (46.7)
Minute intestinal fluke	58 (11.3)	2 (3.5)	38 (16.7)	18 (7.9)	29 (12.3)	29 (10.5)	11 (7.5)	25 (9.6)	22 (21.0)
Large trematode eggs	5 (1.0)	1 (1.8)	0 (0.0)	4 (1.8)	4 (1.7)	1 (0.4)	1 (0.7)	3 (1.2)	1 (1.0)
Nematodes									
Hookworm	155 (30.3)	5 (8.8)	80 (35.2)	70 (30.7)	62 (26.3)	93 (33.7)	23 (15.8)	86 (33.0)	46 (43.8)
<i>Ascaris lumbricoides</i>	11 (2.2)	0 (0.0)	0 (0.0)	11 (4.8)	5 (2.1)	6 (2.2)	6 (4.1)	4 (1.5)	1 (1.0)
<i>Trichuris trichiura</i>	39 (7.6)	0 (0.0)	3 (1.3)	36 (15.8)	12 (5.1)	27 (9.8)	11 (7.5)	22 (8.4)	6 (5.7)
<i>Strongyloides stercoralis</i>	14 (2.7)	3 (5.3)	3 (1.3)	8 (3.5)	9 (3.8)	5 (1.8)	2 (1.4)	9 (3.5)	3 (2.9)
<i>Enterobius vermicularis</i>	3 (0.6)	0 (0.0)	0 (0.0)	3 (1.3)	2 (0.9)	1 (0.4)	0 (0.0)	2 (0.8)	1 (1.0)
<i>Trichostrongylus</i> spp.	28 (5.5)	2 (3.5)	14 (6.2)	12 (5.3)	12 (5.1)	16 (5.8)	2 (1.4)	15 (5.8)	11 (10.5)
Cestodes									
<i>Taenia</i> spp.	15 (2.9)	0 (0.0)	6 (2.6)	9 (4.0)	9 (3.8)	6 (2.2)	2 (1.4)	7 (2.7)	6 (5.7)

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Table A1 (continued)

Mono/polyparasitism									
No infection	204 (39.8)	46 (80.7)	72 (31.8)	86 (37.7)	93 (39.4)	111 (40.2)	78 (53.4)	96 (36.8)	30 (28.6)
Single infection	163 (31.8)	7 (12.3)	84 (37.0)	72 (31.6)	78 (33.1)	85 (30.8)	41 (28.1)	91 (34.9)	31 (29.5)
Double infection	81 (15.8)	1 (1.8)	40 (17.6)	40 (17.5)	32 (13.6)	49 (17.8)	20 (13.7)	43 (16.5)	18 (17.1)
>2 types of infection	64 (12.5)	3 (5.3)	31 (13.7)	30 (13.2)	33 (14.0)	31 (11.2)	7 (4.8)	31 (11.9)	26 (24.8)

Table A2Univariate and multivariable analysis of *Opisthorchis viverrini* prevalence in children.

<i>Opisthorchis viverrini</i>		Crude OR (95% CI)	P-value	Adjusted OR (95% CI)	p-value
District	Nakay	Ref		Ref	
	Mahaxai	12.0 (4.2 - 34.3)	<0.001	12.8 (4.4 - 37.4)	<0.001
	Boualapha	5.7 (2.0 - 16.5)		5.9 (1.9 - 17.9)	0.002
			0.001		
Sex	Male	Ref		Ref	
	Female	0.6 (0.4 - 0.9)	0.007	0.6 (0.4 - 0.9)	0.012
Age group	5 to 9	Ref		Ref	
	10 to 14	1.5 (1.0 - 2.4)	0.066	1.6 (1.0 - 2.5)	0.063
	15 to 17	2.4 (1.4 - 4.1)	0.001	2.3 (1.3 - 4.2)	0.004
Ethnicity	Lao Loum	Ref		Ref	
	Non-Lao-Loum	1.2 (0.8 - 1.7)	0.346	1.2 (0.8 - 1.9)	0.418
Wealth Index Measurement	Poor	Ref		Ref	
	Middle	1.4 (0.9 - 2.1)	0.175	1.1 (0.6 - 1.8)	0.747
	High	0.8 (0.5 - 1.3)	0.297	0.6 (0.4 - 1.1)	0.108
Water assessment levels	Surface water	Ref		Ref	
	Unimproved	0.9 (0.3 - 2.9)	0.873	0.4 (0.1 - 1.6)	0.212
	Improved	1.1 (0.6 - 1.9)	0.704	0.9 (0.5 - 1.7)	0.748
Sanitation assessment levels	Open defecation	Ref		Ref	
	Improved	1.4 (0.9 - 2.1)	0.147	1.3 (0.7 - 2.3)	0.411
Hygiene assessment levels	No facilities	Ref		Ref	
	Limited	1.2 (0.6 - 2.5)	0.555	1.1 (0.5 - 2.4)	0.763
	Basic	1.4 (0.8 - 2.6)	0.271	1.2 (0.6 - 2.4)	0.681

Table A3

Univariate and multivariable analysis of MIF prevalence in children.

Minute Intestinal Fluke		Crude OR (95% CI)	P-value	Adjusted OR (95% CI)	p-value
District	Nakay	Ref		Ref	
	Mahaxai	5.5 (1.3 - 23.6)	0.021	5.4 (1.2 - 23.7)	0.03
	Boualapha	2.4 (0.5 - 10.5)	0.260	2.8 (0.6 - 13.3)	0.2
Sex	Male	Ref		Ref	
	Female	0.8 (0.5 - 1.4)	0.527	0.8 (0.4 - 1.4)	0.38
Age group	5 to 9	Ref		Ref	
	10 to 14	1.3 (0.6 - 2.7)	0.487	1.4 (0.6 - 3.0)	0.42
	15 to 17	3.3 (1.5 - 7.1)	0.003	3.4 (1.5 - 7.7)	0.004
Ethnicity	Lao-Loum	Ref		Ref	
	Non-Lao-Loum	1.3 (0.8 - 2.3)	0.333	1.5 (0.8 - 2.8)	0.21
Wealth Index Measurement	Poor	Ref		Ref	
	Middle	0.8 (0.4 - 1.5)	0.479	0.5 (0.2 - 1.0)	0.055
	High	0.7 (0.3 - 1.3)	0.244	0.4 (0.2 - 0.9)	0.029
Water assessment levels	Surface water	Ref		Ref	
	Unimproved	3.8 (0.7 - 18.8)	0.108	1.9 (0.3 - 10.9)	0.49
	Improved	2.2 (0.8 - 6.3)	0.139	1.9 (0.6 - 6.1)	0.29
Sanitation assessment levels	Open defecation	Ref		Ref	

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Table A3 (continued)

Minute Intestinal Fluke		Crude OR (95% CI)	P-value	Adjusted OR (95% CI)	p-value
Hygiene assessment levels	Improved	2.0 (0.9 - 4.2)	0.069	1.9 (0.7 - 5.0)	0.19
	No facilities	Ref		Ref	
	Limited	1.5 (0.5 - 4.9)	0.491	1.3 (0.4 - 4.5)	0.68
	Basic	1.8 (0.6 - 5.2)	0.289	1.3 (0.4 - 4.3)	0.7

Table A4

Univariate and multivariable analysis of Hookworm prevalence in children.

Hookworm		Crude OR (95% CI)	P-value	Adjusted OR (95% CI)	p-value
District					
	Nakay	Ref		Ref	
	Mahaxai	5.7 (2.2 - 14.7)	<0.001	6.0 (2.2 - 16.3)	<0.001
	Boualapha	4.6 (1.7 - 12.0)	0.005	4.3 (1.5 - 12.0)	0.005
Sex					
	Male	Ref		Ref	
	Female	1.4 (1.0 - 2.1)	0.08	1.5 (1.0 - 2.2)	0.075
Age group					
	5 to 9	Ref		Ref	
	10 to 14	2.6 (1.6 - 4.4)	<0.001	3.0 (1.7 - 5.3)	<0.001
	15 to 17	4.2 (2.3 - 7.5)	<0.001	4.7 (2.5 - 9.1)	<0.001
Ethnicity					
	Lao-Loum	Ref		Ref	
	Non-Lao-Loum	1.1 (0.7 - 1.5)	0.31	0.8 (0.5 - 1.2)	0.31
Wealth Index Measurement					
	Poor	Ref		Ref	
	Middle	1.6 (1.0 - 2.5)	0.064	1.7 (1.0 - 2.9)	0.06
	High	0.8 (0.5 - 1.2)	0.39	0.8 (0.4 - 1.4)	0.39
Water assessment levels					
	Surface water	Ref		Ref	
	Unimproved	1.3 (0.4 - 4.3)	0.96	1.0 (0.3 - 3.7)	0.96
	Improved	0.9 (0.5 - 1.6)	0.96	1.0 (0.5 - 1.9)	0.96
Sanitation assessment levels					
	Open defecation	Ref		Ref	
	Improved	0.8 (0.5 - 1.2)	0.08	0.6 (0.3 - 1.1)	0.08
Hygiene assessment levels					
	No facilities	Ref		Ref	
	Limited	1.7 (0.8 - 3.5)	0.24	1.6 (0.7 - 3.5)	0.24
	Basic	1.3 (0.7 - 2.5)	0.46	1.3 (0.6 - 2.9)	0.46

Data availability

Data will be made available on request.

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