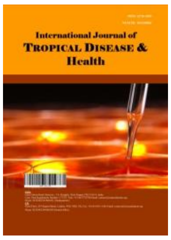

International Journal of TROPICAL DISEASE & Health

43(21): 15-26, 2022; Article no.IJTDH.92937
ISSN: 2278–1005, NLM ID: 101632866

Intestinal Helminthiases among School Children in the Sahelian and Sudanian Zones of Chad: Prevalence and Risk Factors

Kemba Samafou [a,b*], Nack Jacques [c], Oyono Martin Gaël [a,d], Hamit Mahamat Alio [b] and Bilong Bilong Charles Félix [a]

[a] *Laboratory of Parasitology and Ecology, University of Yaoundé I, P.O. Box-812, Yaoundé, Cameroon.*
[b] *Laboratory of Medical Parasitology and Mycology of the Health and Human Sciences, University of N'Djamena, P.O. Box-1117, N'Djamena, Chad.*
[c] *Laboratory of Animal Biology and Physiology, University of Douala, P.O. Box-2701, Douala, Cameroon.*
[d] *Institute of Medical Research and Medicinal Plant Studies, P.O. Box-13033 Yaoundé, Cameroon.*

Authors' contributions

This work was carried out in collaboration among all authors. Author KS conceived and designed the study, collected data in the field and performed data analysis. Author NJ critically revised the manuscript. Author OMG critically revised the manuscript. Author HMA assisted laboratory and field works and reviewed the manuscript. Author BBCF study supervisor, he participated in study design and interpretation of data and critically reviewed the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJTDH/2022/v43i211359

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/92937

Original Research Article

Received 20 August 2022
Accepted 26 October 2022
Published 02 November 2022

ABSTRACT

Aims: The objective of this study was to determine the epidemiological profile of intestinal helminthiases in school children in the Sahelian and Sudanian zones of Chad.
Study Design: Cross-sectional and descriptive.
Place and Duration of Study: September 2021 to February 2022 in two of Chad's three ecological zones: the Sudanian and Sahelian zones.
Methodology: A total of 1408 stool samples were collected from school children (aged from 5 to 18 years) in 19 schools; 13 of which were in the Sudanian zone and 6 in the Sahelian zone. The

*Corresponding author: Email: kembasmaf@gmail.com;

analysis of these samples was carried out by the Kato-Katz method, for the detection and quantification of intestinal helminths eggs.

Results: Analysis of these samples revealed the presence of 9 helminths taxa, with an overall infestation rate of 35.87% in both zones. *Ascaris lumbricoides* (16.41%), *Schistosoma mansoni* (14.00%) and *Hymenolepis nana* (6.53%) were the most common helminths found. Pupils in the Sudanian zone were relatively more infested than those in the Sahelian zone, except for *Taenia saginata* and *Ascaris lumbricoides* which were more often found in the Sahelian zone. With the exception of *Enterobius vermicularis*, no other difference in infestation rates was observed between age groups. By gender, the only significant difference in infestation rates was noted for *Schistosoma mansoni* for which girls were more parasitized.

Conclusion: This study showed a high prevalence of these parasitoses in Chad and that poor hygiene favors the endemicity and persistence of these helminthiases; it also points to the need for a national helminthiases control program.

Keywords: Intestinal helminths; prevalence; Sahelian zone; Sudanian zone; Chad; pupils.

1. INTRODUCTION

Intestinal helminthiases constitute a huge disease burden among young people living in developing countries [1,2]. The persistence of these parasitoses in these countries is directly related to the lack of hygiene, poor climatic conditions, and the great poverty that prevail [3]. These infections are caused by a group of intestinal parasites including *Ascaris lumbricoides*, *Trichuris trichiura*, *Ancylostoma* spp., *Taenia saginata*, *Taenia solium*, *Hymenolepis nana*, *Schistosoma mansoni*, etc. They are transmitted either by faecal contamination of soils, either orally or transcutaneously [4]. They are responsible for much suffering, many deaths, contribute to perpetuate poverty by compromising the intellectual faculties and growth of children, and reducing the work capacity and productivity of adults [5]. According to WHO [2], 1.5 billion people worldwide are affected by geohelminths; *Ascaris lumbricoides*, *Ancylostoma* spp. and *Trichuris trichiura* affect 800 million, 600 million, and 600 million subjects, respectively, including 195,000 deaths each year for *Ascaris lumbricoides* and *Ancylostoma* spp [6]. WHO [2] estimated that 800 million people were at risk of schistosomiasis infection (85% in sub-Saharan Africa), a total of 250 million people were affected in 52 countries around the world, and 800,000 deaths occured per year [1].

In Chad, some patchy epidemiological data reveals the presence of several species of intestinal helminths, which are highly prevalent in the Sudanian and Sahelian zones. For example, Hamit et al. [7] identified eight (8) species of helminths in school children in the Sudanian and Sahelian zones of Chad; a decade early, Brooker et al. [8] noted that 32.7% of the rural population was infested with *Ancylostoma* spp. Due to the lack of a national control program for intestinal helminths, the epidemiological situation of intestinal helminths deserves to be updated in this country for an effective control. The present work aims to determine the prevalence of intestinal helminthiasis in school children in two ecological zones of Chad and to identify the factors associated with this pathology.

2. MATERIALS AND METHODS

2.1 Study Area

Located between the 7th and 24th degrees of the north latitude and between the 13th and 24th degrees of the east longitude, Chad, a central African country, covers an area of 1,284,000 km2. According to Tchana et al. [9], 42% of its population is poor. This country, whose climate is divided into two seasons, a rainy season and a dry season, is subdivided into three ecological zones [10]: the Sudanian, Sahelian and Saharan zones. The present study took place in 19 schools in the Sudanian and Sahelian zones (Fig. 1). These two ecological zones are the rainiest in Chad; the Sudanian zone receives 800 to 1,200 mm of rainfall per year and the Sahelian zone receives 200 to 800 mm of rainfall per year. Due to the presence of a dense hydrographic network, these zones are most often flooded during the rainy season. Average monthly temperatures are 28°C to 42°C during the day, depending on the month, although they can drop to 14°C at night. In the Sahelian zone, temperatures vary from 13°C to 29°C in January and from 25°C to 44°C in May. In the Sudanian zone, on the other hand, temperatures range between 15°C to 34°C in January and between 23°C to 35°C in May [10].

2.2 Study Population and Sampling

This cross-sectional and descriptive study was carried out from September 2021 to February 2022. School children aged 5 to 18 years were randomly recruited from 19 schools in 7 provinces. The protocol implemented was approved by the National Bioethics Committee of Chad. In addition, consent was obtained from the parents or legal guardians of each participant prior to inclusion. With regard to sampling, we carried out random sampling in clusters at three levels. The first stage of sampling consisted of choosing two ecological zones out of the three in Chad. The choice of the two ecological zones (Sudanian zone and Sahelian zone) was made taking into account the ecological, hygienic and climatic conditions, favorable to the transmission, development and persistence of intestinal helminths. The second level of investigation consisted in identifying the provinces within each zone and drawing lots from them by systematic random sampling. The third stage of sampling was to randomly select 1-5 schools from rural areas of each provincial capital. Finally, in each selected school, 2 to 3 classes were drawn by lot before a draw was made there to choose the pupils to be included in the study [11]. For each participant, sociodemographic, hygienic, and environmental information was collected using a survey form. Fresh stool samples were collected in 60-mL hermetically sealed bottles and labeled with anonymous codes. All vials were placed in an insulated cooler (containing ice packs) and transported to the provincial hospital laboratory at each study site for parasitological analysis.

The minimum sample size N was determined using Lorentz's formula:

$$\boldsymbol{N} = \frac{\boldsymbol{t^2 P(1-p)^2}}{\boldsymbol{m^2}} \quad [12]$$

where:

- p is the prevalence of helminthiasis found by Hamit et al. (2013) i.e. 68.4% in the Sudanian zone, and 49.1% in the Sahelian zone in the Sudanian and Sahelian zones of Chad.
- t is a confidence level of the analysis at 95%, ie 1.96;
- m is the margin of error at 5%, or 0.05.

2.3 Parasitological Analysis of Stool Samples

Each stool sample underwent two examinations: a macroscopic examination and a microscopic examination by the quantitative Kato-katz method. The macroscopic examination consisted of looking for the presence of adult worms in the stool and noting its color and consistency. The Kato-katz method was used to concentrate and identify intestinal helminth eggs or larvae. To do this, a portion of sieved stool was used to fill the hole (6 mm diameter by 1.5 mm thick) of the template placed on a clean slide. After removal of the template, the fecal material placed on the slide was covered with a rectangular cellophane film previously soaked (at least 24h) in malachite green. After 30 min, the eggs of *Ancylostoma* spp. were examined and then those of other parasites after sufficient time for clearing [13]. The eggs were searched for using an optical microscope, with a 10X then 40X objectives to better appreciate the contrast of the elements. Helminth eggs were identified using the WHO identification key [13].

2.4 Data Analysis

The results were analyzed using the SPSS version 25 software. The parasite (eggs, larvae and adults) frequencies were determined and the chi-square test was used to compare these frequencies between ecological zones, provinces, schools, genders and age groups. The test was considered statistically significant at a P<0.05 value.

3. RESULTS

3.1 Socio-demographic Characteristics of the Study Population (Table 1)

A total of 1,408 pupils (886 boys, or 62.93%, and 522 girls, or 37.07%) each provided a stool sample. Thus, the sex ratio was 1.70 in favor of males. The mean age of the pupils was 12.17 ± 2.43 years (median 12 years). Participants were divided into 3 age groups: 5 to 9 years, 10 to 14 years, and 15 to 18 years. Pupils in the 10-14 age group represented 75.78% (N_i=1067) of the total working sample; the representation rates for those in the 14-18 and 5-9 age groups were 14.00% (N_i=197) and 10.22% (N_i=144) respectively. The Sudanian and Sahelian zones constituted 66.26% (N_i=933) and 33.73% (N_i=475) of the study population, respectively. The province of N'Djamena provided the highest number of samples (N_i=378, or 26.84%).

Table 1. Distribution of participants according to study areas, provinces and schools

Zone [N_i]	Provinces [N_i]	Schools	Gender		Total per school
			Female	Male	
			N_i (%)	N_i (%)	N_i
	Chari-baguirmi [97]	Marmatodji	18 (1.28)	79 (5.61)	97 (6.89)
Zsa [475]		Gaoui	36 (2.56)	57 (4.05)	93 (6.61)
		Adassakine	5 (0.36)	70 (4.97)	75 (5.33)
	N'Djaména [378]	Boutalwali	33 (2.34)	43 (3.05)	76 (5.40)
		Gardolé	41 (2.91)	38 (2.70)	79 (5.61)
		Zaraf	19 (1.35)	36 (2.56)	55 (3.91)
	Logone occidental [139]	Koutou	10 (0.71)	43 (3.05)	53 (3.76)
		Internant	26 (1.85)	60 (4.26)	86 (6.11)
		Bessama	29 (2.06)	54 (3.84)	83 (5.89)
	Logone oriental [241]	Bedobna	34 (2.41)	37 (2.63)	71 (5,04)
		Nankéssé	26 (1.85)	61 (4.33)	87 (6.18)
Zsu [933]	Mayo kebbi-Est [183]	Djarabou	29 (2.06)	37 (2.63)	66 (4.69)
		Tchinvogo	24 (1.70)	41 (2.91)	65 (4.62)
		Guisédé	6 (0.43)	46 (3.27)	52 (3.69)
	Moyen-chari [86]	Bezo	14 (1.00)	16 (1.14)	30 (2.13)
		Elibongo	24 (1.70)	32 (2.27)	56 (3.98)
		Tchoua	52 (3.70	45 (3.20)	97 (6.89)
	Tandjilé [284]	Tamyo	50 (3.55)	45 (3.20)	95 (6.75)
		Guidjina	46 (3.27)	46 (3.27)	92 (6.53)
Total			**522 (37.07)**	**886 (62.93)**	**1408 (100)**

Zsa: Sahelian zone; Zsu: Sudanian zone; N_i: Number of children examined; ( ): frequencies with respect to the total

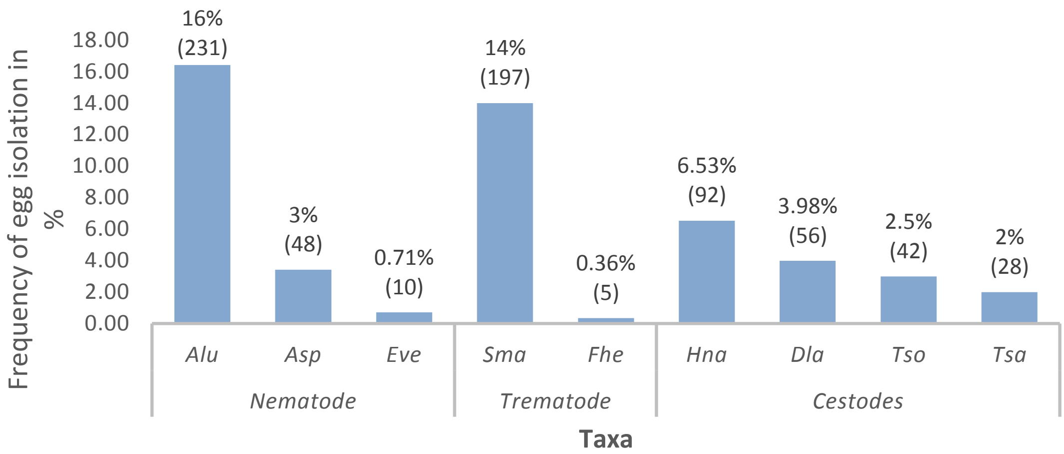

Fig. 1. Specific parasite prevalence

Alu: Ascaris lumbricoides; Asp: Ancylostoma spp.; Dla: Diphyllobotrium latum; Eve: Enterobius vermicularis; Fhe: Fasciola hepatica; Hna: Hymenolepis nana; Sma: Schistosoma mansoni; Tsa: Taenia saginata; Tso: Taenia solium; ( ): individuals infested by the parasitic species

3.2 Prevalence and Frequency of Parasite Species Found

A total of 505 pupils out of the 1408 sampled were carriers of at least one species of intestinal helminth, for an overall prevalence of 35.87%. The nine (9) helminths species found belonged to three classes (Fig. 1): 3 nematodes (*Ascaris lumbricoides, Ancylostoma* spp. and *Enterobius vermicularis*); 2 trematodes (*Schistosoma mansoni* and *Fasciola hepatica*), and 4 cestodes (*Hymenolepis nana, Diphyllobothrium latum, Taenia solium and Taenia saginata*). Eggs of *A. lumbricoides* and *S. mansoni* were isolated most often, from 16.41% and 14% of pupils respectively. The prevalence rates of other parasite species were: *H. nana* (6.53%), D. latum (3.98%), *Ancylostoma* spp. (3.41%), *T. solium* (2.98%), *T. saginata* (2.00%), *E. vermicularis* (0.71%) and *F. hepatica* (0.36%).

3.3 Parasitism According to Ecological Zones, Age Groups and Gender

Fasciola hepatica species was found in only five (5) children in the Sudanian zone. The infestation rates of the other species were comparable between the two ecological zones, except for *Schistosoma mansoni* (P=0.003), *Hymenolepis nana* (P=0.02) and *Taenia saginata* (P=0.0001). In general, prevalence was always relatively higher in the Sudanian zone, except for *T. saginata* and *A. lumbricoides*. The prevalence rate of the latter species was also found to be higher (16.42%) than that of the other species. The infestation rates of the isolated parasites were statistically similar between genders, except for *S. mansoni* which was diagnosed more in girls (17.62% vs. 11.85% in boys). While the prevalence appeared relatively higher in boys for *F. hepatica* and *T. saginata,* the opposite was true for all other parasitic taxa. Regarding infestation by age group, *T. saginata* and *E. vermicularis* were not diagnosed in students aged 15 to 18 years, nor was *F. hepatica* diagnosed in children aged 10 to 14 years. The prevalence rate varied between age groups only for *E. vermicularis* (P=0.0002); it was higher (4.17%) in the youngest school children (5-9 years) than the 0.37% in those aged 10-14 years. Except for *Ancylostoma* spp., *H. nana*, and *F. hepatica*, which were more frequently found in 15 to 18-year-olds, younger school children (5 to 9-year-olds) were relatively (P≥0.05) more frequently infested with the other parasites (Table 2).

3.4 Parasite Species Infestation Rates by Province (Intrazonal Analysis)

Of the nine (9) intestinal parasite helminth species identified (Table 3), only three (03) were hardly encountered among pupils in one or four provinces. These were *T. saginata* (not diagnosed in Mayo-kebbi-Est), *E. vermicularis* (not found in N'Djaména), and *F. hepatica* (not observed in stool samples from Chari-baguirmi, N'Djaména, Logone Oriental and Tandjilé). Between the two provinces of the Sahelian zone, the prevalence rate varied (P=0.006) only for *S. mansoni*, being higher in Chari-baguirmi (14.43% versus 8.20% in N'Djamena). In the Sudanian zone (Table 3), the differences in parasite prevalences between provinces were statistically significant for: *S. mansoni* (P<0.0001) whose prevalence was higher in Moyen-Chari (56.98%) and lower in Logone Oriental (7.88%) and Logone Occidental (7.19%); *A. lumbricoides* (P=0.001) with a higher prevalence in Tandjilé (21. 83%) and lower in Logone Oriental (8.71%); *H. nana* (P=0.003), and *Ancylostoma* spp. (P=0.01), with higher prevalences (10.47%) in Moyen-Chari than in the other provinces.

3.5 Infestation Rates of Parasite Species by School (Intrazonal Analysis)

In the Sahelian zone (Table 4), no child emitted *F. hepatica* eggs; *E. vermicularis* eggs were only isolated from the stools of two children attending school in Marmatodji. No carrier of *D. latum* eggs was identified in Gaoui; no carrier of *Ancylostoma* spp. in Gardolé, and none of *H. nana* in Adassakine or Zaraf was identified. Inter-school differences in infestation rates were noted for *S. mansoni* (P=0.01), *A. lumbricoides* (P=0.001), *H. nana* (P=0.01) and *T. saginata* (P=0.003). In the Sudanian zone (Table 4), only a few stool samples were positive for *F. hepatica*: 2 (2.33%), 2 (3.03%) and 1 (3.33%) in Internant, Djarabou and Elibongo respectively. In addition, neither *D. latum* nor *T. solium* were diagnosed in Guisédé, nor *E. vermicularis* in Bezo, Guidjina, Guisédé, Internant, Nankéssé and Tchinvogo, nor finally *T. saginata* in Bedobna, Bessama, Djarabou, Guidjina, Guisédé, Internant, Tamyo and Tchinvogo. Differences in parasite prevalence between schools were found for *S. mansoni* (P <0.0001), *A. lumbricoides* (P=0.001) and *H. nana* (P=0.00). In both ecological zones (particularly in Gaoui, Marmatodji in the Sahelian zone, Bezo, Djarabou, Guidjina, Guisédé and especially Elibongo in the Sudanian zone), these three (3) parasite species stood out with higher prevalences compared to those of the other species.

Table 2. Parasite prevalence by ecological zone, age group and gender of pupils

Parasite species	N_i	Ecological zones			Age groups				Gender		
		Zsu (N=933)	Zsa (N=475)	P	5-9 ans (N=144)	10-14 ans (N=1067)	15 -18ans (N=197)	P	Female (N=522)	Male (N=886)	P
		n_i (%)	n_i (%)		n_i (%)	n_i (%)	n_i (%)		n_i (%)	n_i (%)	
Alu	231	153 (16.40)^{a}	78 (16.42)^{a}	0.99	25 (17.36)^{a}	176 (16.49)^{a}	30 (15.23)^{a}	0.9	91 (17.43)^{a}	140 (15.80)^{a}	0.50
Sma	197	152 (16.29)^{a}	45 (9.47)^{b}	0.003	22 (15.28)^{a}	150 (14.06)^{a}	25 (12.69)^{a}	0.85	92 (17.62)^{a}	105 (11.85)^{b}	0.01
Hna	91	71 (7.61)^{a}	20 (4.21)^{b}	0.02	10 (6.94)^{a}	65 (6.09)^{a}	16 (8.12)^{a}	0.60	39 (7.47)^{a}	52 (5.87)^{a}	0.31
Dla	56	39 (4.18)^{a}	17 (3.58)^{a}	0.66	8 (5.56)^{a}	40 (3.75)^{a}	8 (4.06)^{a}	0.61	23 (4.41)^{a}	33 (3.72)^{a}	0.56
Asp	48	36 (3.86)^{a}	12 (2.53)^{a}	0.22	5 (3.47)^{a}	33 (3.09)^{a}	10 (5.08)^{a}	0.40	21 (4.02)^{a}	27 (3.05)^{a}	0.35
Tso	42	29 (3.11)^{a}	13 (2.74)^{a}	0.73	7 (4.86)^{a}	27 (2.53)^{a}	8 (4.06)^{a}	0.23	16 (3.07)^{a}	26 (2.93)^{a}	0.89
Tsa	28	7 (0.75)^{b}	21 (4.42)^{a}	0.0001	5 (3.47)^{a}	23 (2.16)^{a}	/	0.36	9 (1.72)^{a}	19 (2.14)^{a}	0.69
Eve	10	8 (0.86)^{a}	2 (0.42)^{a}	0.5	6 (4.17)^{a}	4 (0.37)^{b}	/	0.0009	5 (0.96)^{a}	5 (0.56)^{a}	0.50
Fhe	5	5 (0.54)	/	/	2 (1.39)^{a}	/	3 (1.52)^{a}	0.9	1 (0.19)^{a}	4 (0.45)^{a}	0.65

Zsa: Sahelian zone; Zsu: Sudanian zone; Alu: Ascaris lumbricoides; Asp: Ancylostoma spp.; Dla: Diphyllobotriumlatum; Eve: Enterobius vermicularis; Fhe: Fasciola hépatica; Hna: Hymenolepis nana; Sma: Schistosoma mansoni; Tsa: Taeniasaginata; Tso: Taenia solium; n_i : number of pupils carriers; F: female; M: male; Flagged percentages of the same letter on the same line are not statistically significant; N: number of pupils examined; N_i: number of infested children; n_i: number of infested children per ecology zone, age group and gender

Table 3. Parasite prevalence by province: intrazonal analysis

Ecol. zones	Provinces	Infested children	Diagnosed parasite species								
			Sma	*Alu*	*Hna*	*Tsa*	*Tso*	*Asp*	*Eve*	*Dla*	*Fhe*
	(N)	N_i (%)	n_i (%)	n_i (%)	n_i (%)	n_i (%)	n_i (%)	n_i (%)	n_i (%)	n_i (%)	n_i (%)
Zsa	ChBa (97)	32 (32.99)^{a}	14 (14.43)^{a}	21 (21.65)^{a}	3 (3.09)^{a}	4 (4.12)^{a}	2 (2.06)^{a}	3 (3.09)^{a}	2 (2.06)	2 (2.06)^{a}	/
	NDja (378)	122 (32.28)^{a}	23 (8.20)^{b}	57 (15.08)^{a}	17 (4.50)^{a}	17 (4.50)^{a}	11 (2.91)^{a}	9 (2.38)^{a}	/	14 (3.70)^{a}	/
	P-value	**0.89**	**0.006**	**0.11**	**0.53**	**0.87**	**0.65**	**0.69**	**/**	**0.42**	/
	Locc (139)	42 (30.22)^{bc}	10 (7.19)^{c}	21 (15.11)^{ab}	8 (5.76)^{ab}	3 (2.16)^{a}	4 (2.88)^{a}	5 (3.60)^{b}	1 (0.55)^{a}	4 (2.88)^{a}	2 (1.44.)^{a}
	Lori (241)	58 (24.06)^{c}	19 (7.88)^{c}	21 (8.71)^{b}	13 (5.39)^{b}	1 (0.41)^{a}	6 (2.49)^{a}	9 (3.73)^{b}	2 (0.83)^{a}	7 (2.90)^{a}	/
Zsu	MaKE (183)	73 (39.90)^{b}	34 (18.58)^{b}	32 (17.49)^{a}	22 (12.02)^{a}	/	6 (3.28)^{a}	6 (3.28)^{b}	1 (0.55)^{a}	7 (3.83)^{a}	2 (1.09)^{a}
	Mcha (86)	67 (77.91)^{a}	49 (56.98)^{a}	17 (19.77)^{a}	14 (16.28)^{a}	2 (2.33)^{a}	3 (3.49)^{a}	9 (10.47)^{a}	1 (1.16)^{a}	4 (3.09)^{a}	1 (1.16)^{a}
	Tand (284)	111 (39.08)^{b}	40 (14.08)^{bc}	62 (21.83)^{a}	14 (4.93)^{b}	1 (0.41)^{a}	10 (3.52)^{a}	7 (2.42)^{b}	3 (1.06)^{a}	17 (5.99)^{a}	/
	P-value	**<0.0001**	**<0.0001**	**0.001**	**0.003**	**0.12**	**0.96**	**0.01**	**0.97**	**0.40**	**0.96**

Ecol. zones: Ecological zones; Zsa: Sahelian zone; Zsu: Sudanian zone; ChBa: Chari-baguirmi; LOcc: Logone occidental; LOri: Logone oriental; MaKE: Mayo Kebbi-Est; MCha: Moyen-chari; NDja: N'Djaména; Tand: Tandjilé; Alu: Ascaris lumbricoides; Asp: Ancylostoma spp.; Dla: Diphyllobotrium latum; Eve: Enterobius vermicularis; Fhe: Fasciola hépatica; Hna: Hymenolepis nana; Sma: Schistosoma mansoni; Tsa: Taenia saginata; Tso: Taenia solium; N_i: Children infested by province; N: Children screened by province; n_i: individuals infested by a parasite; Flagged percentages of the same letter on the same line are not statistically significant

Table 4. Specific parasite prevalence by school guideline for reporting *P* values

Ecological zones	Schools	Infested children	Diagnosed parasitic species								
			Sma	***Alu***	***Hna***	***Tsa***	***Tso***	***Asp***	***Eve***	***Dla***	***Fhe***
	(N)	**(N_i)**	**n_i (%)**	**n_i (%)**	**n_i (%)**	**n_i (%)**	**n_i (%)**	**n_i (%)**	**n_i (%)**	**n_i (%)**	**n_i (%)**
	Adassakine (75)	24 (32.00) ^{a}	7 (9.33) ^{ab}	12 (16.00) ^{ab}	/	7 (9,33) ^{ab}	1 (1.33) ^{a}	5 (6.67) ^{a}	/	3 (4.00) ^{a}	/
	Boutalwali (76)	26 (34.21) ^{a}	6 (7.89 ^{ab}	14 (18.42) ^{a}	6 (7.89) ^{ab}	1 (1,32) ^{b}	2 (2.63) ^{a}	1 (1.32) ^{a}	/	3 (3.95) ^{a}	/
	Gaoui (93)	36 (38.70) ^{a}	10 (10.75 ^{ab}	16 (17.20) ^{a}	10 (10.75) ^{a}	2 (2,15) ^{ab}	3 (3.23) ^{a}	1 (1.08) ^{a}	/	/	/
Zsa	Gardolé (79)	22 (27.84) ^{a}	7 (8.86) ^{ab}	12 (15.19) ^{ab}	1 (1.27) ^{b}	1 (1,27) ^{b}	2 (2.53) ^{a}	/	/	5 (6.33) ^{a}	/
	Marmatodji (97)	32 (32.98) ^{a}	14 (14.43) ^{a}	21 (21.65) ^{a}	3 (3.09)^{ab}	4 (4,12) ^{ab}	2 (2.06) ^{a}	3 (3.09) ^{a}	2 (2.06)	3 (3.09) ^{a}	/
	Zaraf (55)	14 (25.45) ^{a}	1 (1.82) ^{b}	3 (5.45) ^{b}	/	6 (10,91)^{a}	3 (5.45) ^{a}	2 (3.64) ^{a}	/	3 (5.45) ^{a}	/
	P-value	**0.86**	**0.01**	**0.001**	**0.01**	**0.003**	**0.80**	**0.17**	**/**	**0.87**	**/**
	Bedobna (71)	17 (23.94) ^{cd}	7 (9.86)^{bd}	4 (5.63) ^{c}	3 (4.23) ^{b}	/	3 (4.23)^{a}	2 (2.82) ^{a}	1 (1.41) ^{a}	3 (4.23) ^{a}	/
	Bessama (83)	21 (25.30) ^{cd}	8 (9.64) ^{c}	8 (9.64)^{bc}	7 (8.43) ^{ab}	/	1 (1.20) ^{a}	2 (2.41) ^{a}	1 (1.20) ^{a}	3 (3.61) ^{a}	/
	Bezo (30)	15 (50.00)^{bc}	4 (13.33)^{bd}	5 (16.67) ^{ac}	3 (10.00) ^{ab}	1 (3.33) ^{a}	2 (6.67) ^{a}	3 (10.00) ^{a}	/	1 (3.33) ^{a}	/
	Djarabou (66)	20 (30.30) ^{cd}	12 (18.18)^{bc}	6 (9.09)^{bc}	6 (9.09) ^{ab}	/	4 (6.06) ^{a}	2 (3.03) ^{a}	1 (1.52) ^{a}	4 (6.06) ^{a}	2 (3.03) ^{a}
	Elibongo (56)	52 (92.85) ^{a}	45 (80.36) ^{a}	12 (21.43) ^{ab}	11 (19.64) ^{a}	1 (1.79) ^{a}	1 (1.79) ^{a}	6 (10.71) ^{a}	1 (1.79) ^{a}	3 (5.36) ^{a}	1 (3.33) ^{a}
	Guidjina (92)	35 (38.04)^{bc}	15 (16.30)^{bc}	12 (13.04)^{bc}	5 (5.43) ^{b}	/	7 (7.61) ^{a}	2 (2.17) ^{a}	/	5 (5.43) ^{a}	/
Zsu	Guisédé (52)	28 (53.85) ^{b}	8 (15.38)^{bc}	12 (23.08) ^{ab}	9 (17.31) ^{a}	/	/	2 (3.85) ^{a}	/	/	/
	Koutou (53)	17 (32.07) ^{cd}	3 (5.66) ^{c}	8 (15.09)^{bc}	3 (5.66) ^{b}	3 (5.66) ^{a}	1 (1.89) ^{a}	1 (1.89) ^{a}	1 (1.89) ^{a}	1 (1.89) ^{a}	/
	Nankéssé (87)	20 (22.98) ^{d}	4 (4.60) ^{d}	9 (10.34)^{bc}	3 (3.45) ^{b}	1 (1.15) ^{a}	2 (2.30) ^{a}	5 (5.75) ^{a}	/	1 (1.15) ^{a}	/
	Orphanage(86)	25 (29.07) ^{cd}	7 (8.14) ^{c}	13 (15.12) ^{b}	5 (5.81) ^{b}	/	3 (3.49) ^{a}	4 (4.65) ^{a}	/	3 (3.49) ^{a}	2 (2.33) ^{a}
	Tamyo (95)	40 (42.10)^{bc}	11 (11.58)^{bd}	27 (28.42) ^{a}	6 (6.32) ^{b}	/	2 (2.11) ^{a}	3 (3.16) ^{a}	2 (2.11) ^{a}	7 (7.37) ^{a}	/
	Tchinvogo (65)	25 (38.46)^{bc}	14 (21.54) ^{b}	14 (21.54)^{bc}	7 (10.77) ^{ab}	/	2 (3.08) ^{a}	2 (3.08) ^{a}	/	3 (4.62) ^{a}	/
	Tchoua (97)	36 (37.11) ^{c}	14 (14.43)^{bc}	23 (23.71) ^{ab}	3 (3,09) ^{b}	1 (1.03)^{a}	1 (1.03) ^{a}	2 (2.06) ^{a}	1 (1.03) ^{a}	5 (5.15) ^{a}	/
	P-value	**<0.0001**	**<0.0001**	**0.001**	**0.001**	**0.36**	**0.33**	**0.28**	**0.98**	**0.85**	**0.90**

Zsa: Sahelian zone; Zsu: Sudanian zone; Alu: Ascaris lumbricoides; Asp: Ancylostoma spp.; Dla: Diphyllobotrium latum; Eve: Enterobius vermicularis; Fhe: Fasciola hépatica; Hna: Hymenolepis nana; Sma: Schistosoma mansoni; Tsa: Taenia saginata; Tso: Taenia solium; n_i: individuals infested by a parasite; N_i: Children infested by school; N: Children screened by school; The flagged percentages of the same letter in the same column are not statistically significant

4. DISCUSSION

The present study aimed to determine the prevalence of intestinal helminthiases among school children in two ecological zones (Sudanian and Sahelian zones) of Chad and to identify factors associated with these pathologies. A total of 1408 pupils were recruited in the study. The Sudanian zone provided the most samples, 933 (66.26%), compared to 475 (33.74%) in the Sahelian zone. This disparity can be explained by the fact that the Sudanian zone consists of 5 provinces compared to 2 in the Sahelian zone. Male participants represented 62.93% of the total sample size compared to 37.07% for female participants. This result is similar to those of Hamit et al*.* [6] in N'Djaména (Chad) and even by Nkengazong et al*.* [14] in southwest Cameroon where there is a different climate; however, it differs from those obtained by Ould et al*.* [15] in Mauritania (male : 43% ; female : 57%) and Savadogo et al*.* [16] in Burkina Faso (male: 50.1%; female: 49.9%). In the Chadian context, this could be explained by a lower school enrolment rate for girls than for boys (43% compared to a national average of 65.6%) on the one hand [17] and, on the other hand, by the reluctance of girls to give their stool during sample collection. This could be due to a cultural problem. The 10 to 14-year-old age group constituted 75.75% of the total sample. This observation is similar to the 61.07% (10-14 year) and 72.35% (9 – 14 year) reported in Chad by Hamit et al*.* [7] and in Morocco by Tagajdid et al*.* [18] respectively. This is thought to be a consequence of the delay in the schooling of Chadian children in rural areas [19].

During this study, 505 pupils out of 1408 sampled were found to be carriers of at least one species of intestinal helminth, for an overall infestation rate of 35.87%. This prevalence is comparable to 36.7% obtained by Dankoni et al*.* [20] in Kékem in West Cameroon. It is much lower than the prevalences (60% and 57.1%) previously obtained in Chad by Béchir et al. [21] and by Hamit et al*.* [7] respectively. This decrease in the infestation rate would be linked to the awareness of the population on the one hand, and to the recent sporadic distribution of antihelminthic drugs by the Ministry of Public Health on the other hand. In total, the infesting forms of nine (09) helminth taxa were found during this study, including three (3) Nematodes (*Ascaris lumbricoides, Ancylostoma* spp. *and Enterobius vermicularis*), two (2) trematodes (*Schistosoma mansoni* and *Fasciola hepatica*), and four (4) cestodes (*Hymenolepis nana, Diphillobotrium latum, Taenia saginata and Taenia solium*). This species richness is similar than that published by other studies conducted in various sub-Saharan African countries; this is the case of the study conducted by Awono-Ambene et al*.* [22] in Yaoundé, who identified 6 of the 9 helminth taxa found in the present study, but also the work of Hamit et al*.* [7] in Chad and Kouassi et al*.* [23] in Côte d'Ivoire, who respectively diagnosed 6 and 5 of the 9 species identified in this study. These observations confirm that in sub-Saharan Africa, environmental, hygienic and climatic conditions, as well as population impoverishment, are favorable elements for the transmission, development and persistence of several species of intestinal helminths [8]. Three parasite species were predominantly diagnosed in pupils, namely *Ascaris lumbricoides* (16.41%), *Schistosoma mansoni* (14%), and *Hymenolepis nana* (6.53%). This observation was also made for the first species by, among others, Goodman et al*.* [24] in Zanzibar, Hamit et al*.* [25,26] in N'Djaména, Zephania et al*.* [27] in Cameroon, Oyono et al*.* [28] in the central Cameroon region, and Leta et al*.* [29] in Ethiopia. This high infestation rate of *Ascaris lumbricoides* in our study confirms that it is one of the most widespread intestinal helminths in the world [3,5,7]. Similarly, Lehman et al*.* [30] noted that in Njombé, Cameroon, *S. mansoni* and *A. lumbricoides* were more prevalent among isolated helminths. Except for *S. mansoni* for which girls were significantly more often infested than boys, no other significant gender difference was found for the other parasites. This result is similar to those of Daryani et al*.* [31] in Northern Iran, Nxasana et al*.* [32] in South Africa, and Dankoni et al*.* [20] in Cameroon, differs from those of Traoré et al*.* [33] in Côte d'Ivoire, Ould et al*.* [15] in Mauritania, and Hamit et al*.* [7] in Chad, who noted gender differences in infestations. The absence in this study of a significant association for a given sex for almost all parasites would be essentially due to the failure of all to respect basic hygiene rules and the frequentation of the same playgrounds by children of both sexes; they are thus subject to the same exposure factors to infestation by these intestinal helminths. Regarding *S. mansoni*, the same finding was made in Morocco by Tagajdid et al*.* [18] and in Benin by Ibikounlé et al*.* [34], but contrary to those made by Dankoni et al*.* [20] and Hamit et al*.* [6] in Kékem (West Cameroon) and N'Djaména (Chad) respectively. Indeed, due to the lack of certain essential infrastructures (improved wells, toilets, drinking water distribution network, etc.) in almost all the localities studied, children of both sexes resort to water from wells and or streams soiled with helminth and cercarial eggs for drinking and bathing; which constitutes a high risk of infestation [35]. In addition, girls are more exposed to schistosomiasis than boys, as they are culturally responsible for performing certain household tasks (laundry, washing dishes, etc.) in ponds where they become infested. Pupils in the 5–9-year age group were relatively more often infested than those that were 10 years and older for *E. vermicularis*. This difference was significant and therefore age-related in the younger age group (5-9 years). This result corroborates those of Narayan et al*.* [36] in Nepal, Nxasana et al*.* [32] in South Africa, and Saotoing et al*.* [37] in Northern Cameroon. The tendency for geophagy to be more common in children, as well as the progressive acquisition of immunity with age would explain this observation [23]. Indeed, the humoral immunity acquired gradually by the host significantly destroys young larvae or eggs of the helminths present in the host [38]. The significant relationship found only for *E. vermicularis* confirms a predilection of this parasite for smaller children [39].

Pupils in the Sudanian zone were relatively more infested by the parasites diagnosed than those in the Sahelian zone, with the exception of *T. saginata* and *A. lumbricoides*, which were more often found in the Sahelian zone. However, between these two zones, the specific prevalence rates varied significantly only for *S. mansoni* (P=0.003) and H. nana (P=0.02), which were more often found in the Sudanian zone, and *T. saginata* (P=0.0001), which was more frequently identified in the Sahelian zone. These observations had already been made in these two ecological zones a decade ago by Hamit et al*.* [7]; they are also related to the different ecological or environmental conditions between these two zones. Indeed, the Sudanian zone has a more humid climate and a denser hydrographic network, favorable to the persistence and dissemination of helminth eggs or larvae in general, and to the development of intermediate host mollusks of *S. mansoni* in particular [40]. With regard to *T. saginata*, its preponderance in the Sahelian zone would be essentially due to culinary habits centered on the consumption of beef (undercooked) in this part of the country, known to be a cattle breeding area par excellence [10].

Intra-zonal analysis revealed only one significant variation in prevalence between provinces in the Sahelian zone for *S. mansoni* (P= 0.006); pupils in the Chari-baguirmi province were more often infested (14.43%) than those in N'Djamena (8.20%). Similarly, differences in prevalence were obtained between schools in this zone for *S. mansoni, A. lumbricoides, H. nana* and *T. saginata*. In the Sudanian zone, the infestation rates of *S. mansoni*, *A. lumbricoides* and *H. nana* varied significantly between provinces and between schools in this zone, with the exception of *Ancylostoma* spp., whose prevalence varied significantly only between provinces. These intra-zonal disparities were due, on the one hand, to the geographical location of the localities studied and, on the other hand, to the anarchic chemoprevention campaigns organized in Chad due to the lack of a national helminthiases control program [1]. In fact, in Chad, there are localities or schools that do not benefit from chemoprevention, while others benefit regularly. However, Oyono et al*.* [28] recommend that strategies to control these diseases by deworming children in schools be regular and targeted.

Our study experienced a number of infrastructural, financial and cultural difficulties. Given the problem of accessibility in the Sahelian zone, and the inadequacy of our resources, it was not easy to carry out the study in a large number of provinces of this ecological zone. In addition, female pupils were reluctant to give their sample; which did not make it possible to have a balanced sample by gender.

5. CONCLUSION

This study shows that intestinal helminthiasis still remains a major public health problem in Chad, particularly in poor and rural communities. The present study identified 9 species of intestinal helminths with uneven distribution in the Sudanian and Sahelian zones. The Sudanian zone is more prone to geohelminthiases. Given the persistence of these parasitoses in Chad, we recommend the establishment of a national program to control intestinal helminthiasis.

ETHICAL APPROVAL AND CONSENT

All authors hereby declare that the protocol implemented was approved by the national bioethics committee of chad under number 014/PR/MESRI/DGM/CNBT/SG/2021. In addition, written informed consent was obtained from the parents or legal guardians of each participant prior to inclusion in the study.

ACKNOWLEDGEMENTS

The authors are grateful to the academic authorities of the University of Yaoundé I, the Ministries of Public Health and National Education of Chad, as well as the provincial hospitals, provincial education delegations, school principals, parents and pupils for their collaboration throughout this study. This work is based on research supported in part by technical and material contributions from members of the Laboratory of Parasitology and Ecology of the University of Yaoundé I and the Laboratory of Parasitology and Mycology of the Faculty of Human Health Sciences of the University of N'Djamena.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. World Health Organization. Schistosomiase et géohelminthiases : Prévention et lutte. Rapport d'un Comité d'experts de l'OMS. Série de Rapports Techniques, n°912. 2004;77.
2. World Health Organization. Lutte contre les helminthiases chez les enfants d'âge scolaire. Guide à l'intention des responsables des programmes de lutte. WHO/CDS/CPC/SIP/. 2012;89.
3. Tchuem Tchuenté LA, Romuald IKN, Sumo L, Ngassam P, Calvine DN, Deguy DLN et al. Mapping of schistosomiasis and soil-transmitted helminthiasis in the regions of centre, East and West Cameroon. Plos Negl. Trop. Dis. 2012;6(3): e1553.
4. World Health Oragnization. Schistoso-miasis and soil-transmitted helminthiases: Numbers of people treated in 2017. 2018; 93:681–692.
   Available:http://www.who.int/wer
5. Montresor A, Crompton DWT, Bundy DAP, Hall A, et Savioli L. Guidelines for the evaluation of soil-transmitted helminthiasis and schistosomiasis at community level. WHO/CTD/SIP/. 1998;1: 49.
6. Hamit MA, Fombotioh N, Issa RA, Samafou S. Epidemiological profile of urinary schistosomiasis in three primary schools in the city of N'Djamena (Chad). European J Biomed Pharm Sci. 2020;7: 242-246.
7. Hamit MA, Abdelsalam T, Brahim BO, Mahamat TT, Bilong Bilong CF. An epidemiological assessment of the infectious forms of intestinal helminths in school children from Chad. J Biol L Sci. 2013;4(2):341.
8. Brooker S, Beasley M, Ndinaromtan M, Madjiouroum E, Baboguel M, Djenguinabe E, Hay S, Bundy D. Use of remote sensing and a geographical information system in a national helminth control programme in Chad. Bull Word Health Organ. 2002;80: 783-789.
9. Tchana TF, Aboudrahyme S, Temgoua CN. Perspectives économiques et pauvreté au Tchad en 10 graphiques, Africa can end poverty, Banque mondiale-Blogs; 2021.
   Accessed 15 August 2022.
   Available:https://blogs.worldbank.org/fr/africacan/perspectives-economiques-et-pauvrete-au-tchad-en-10-graphiques
10. Ministère de l'Agriculture et de l'Irrigation du Tchad. Plan quinquennal de développement de l'agriculture au Tchad. 2013;58.
11. Magnani R. Guide d'échantillonnage. Food and Nutrition Technique Assistance Project. 2001; 57.
    Available:http://www.fantaproject.org
12. Zineb S, Karima B, Ahmed BA, Mohammed BO. Methodological sheet n°1: How to calculate the size of a sample for an observational study? Tunis Med. 2020;98(01):7.
13. World Health Organization. Planches pour le diagnostic des parasites intestinaux. WHO/CDS/CPE/SMT/. 1994;23.
14. NKengazong L, Njiokou F, Wandji S, Teukeng F, Enyosng P, Asonganyi P. Prevalence of soil transmitted helminths and impact of albendazole on parasitic indices in Kottobarombi and Marumba II villages (South-West Cameroon). Afr J Environ Sci. Technol. 2010;4(3):115-121.
15. Ould ASCB, Bent A, Ousmane B, Koita M, Dem E, Hamidou S, Mohamed OA, Baidy L. Prévalence des parasitoses intestinales chez les écoliers dans les Wilayas du Gorgol, Guidimagha et Brakna (Mauritanie). Rev Francoph des Lab N °440. 2012;75-78.
16. Savadogo B, Bengaly MD, Sorgho H, Zongo D, Zeba AN, Lanou H et al. Statut nutritionnel et parasitoses (intestinales et urinaires) chez les enfants d'âges scolaire au Burkina Faso : Cas des écoles de

Yamtenga, Koubri et Daguilma. Sci Tech. 2014;37:45-56.

17. Ministère de la Fonction Publique, du Travail et l'Emploi. Politique Nationale de l'Emploi et de la Formation Professionnelle au Tchad. 2014;78.
18. Tagajdid R, Lemkhente Z, Errami M, El Mellouki W et Lmimouni B. Portage parasitaire intestinal chez l'enfant scolarisé à Salé, Maroc. Bull Soc Pathol Exot. 2012;105:40-45.
19. Salé Hagam. Développement de l'éducation en Afrique subsaharienne (exemple du Tchad). Edition Harmattan. 2012;304.
20. Dankoni EN, TchuemTchuenté LA. Epidemiology of schistosomiasis and soil-transmitted helminthiasis in the sub-division of Kékem (West-Cameroon). Int J Innov Appl Stud. 2014;8(4): 1782-1790.
21. Bechir M, Schelling E, Hamit MA, Tanner M, Zinsstag J. Parasitic infections, anemia and malnutrition among rural settled and mobile pastoralist mothers and their children in Chad. Eco Health. 2012;9(2): 122–131.
22. Awono-Ambene HP, Njieyap LD, Akono NP, Etang JD, Antonio-Nkondjio C, Ndo C et al. Soil-transmitted protozoans and helminths from market gardening sites of Yaounde, Cameroon. J Environ Sci Public Health. 2020;4:61-70.
23. Kouassi WYR, Perrotey S, Bassa KF, N'goran K. Parasites gastro-intestinaux des population humaines du parc national de tai, Cote d'Ivoire. Eur Sci J. 2019; 15(36):27-44.
24. Goodman D, Haji HJ, Bickle QD. A comparison of methods for detecting the eggs of Ascaris, Trichuris and hookworm in infant stool and the epidemiology of infection in Zanzibari infants. Am J Trop Med Hyg. 2007;76(4):725-31.
25. Hamit MA, Tidjani MT, Bilong Bilong CF. Recent data on the prevalence of intestinal parasites in N'Djamena, Chad Republic. Afr J Environ Sci Technol. 2008;2(12): 407-411.
26. Hamit MA, Abdelsalam T, Brahim BO, Mahamat B, Bilong Bilong CF. Prevalence of intestinal worms among, schoolchildren in Chad : Importance of highlighting the concentration method in fecal examination. Eur J Biomed Pharm Sci. 2017;4(1):52-59.
27. Zephania NF, Ndifor FC. Tropical city milieux and disease infection: The case of Douala, Cameroon. J Hum Ecol. 2017;30 (2):123-130.
28. Oyono MG, Lehman LG, Bilong BCF. Multiparasitism among school children of Akonolinga, Nyong and Mfoumou Division, Centre Region of Cameroon. J Biol L Sci. 2019;10(2):90-105.
29. Leta GT, Kalkidan M, Yonas W, Abeba G, Heven S, Sindew M et al. National mapping of soil-transmitted helminth and schistosome infections in Ethiopia. Parasit Vectors. 2020;13(1):437.
30. Lehman LG, Kouodjip LN, Bilong Bilong CF. Diagnostic des parasitoses intestinales à l'aide de la microscopie à fluorescence. Med Afr Noire. 2012;59(7): 378-385.
31. Daryani AM, Nasrolahei M, Khalilian A, Mohammadi A, Barzega G. Epidemiological survey of the prevalence of intestinal parasites among schoolchildren in Sari, northern Iran. R Soc Trop Med Hyg. 2012;106(8):455-9.
32. Nxasana N, Baba K, Bhat V, Vasaikar SD. Prevalence of intestinal parasites in primary school children of mthatha, Eastern Cape Province, South Africa. Ann Med Health Sci Res. 2013;3(4): 511-516.
33. Traoré SG, Odermatt P, Bonfoh B, Utzinger J, Aka ND, Adoubryn KD et al. No *Paragonimus* in high-risk groups in Cote d'Ivoire, but considerable prevalence of helminths and intestinal protozoon infections. Parasit vectors. 2011;4:96.
34. Ibikounlé M, Satoguina J, Fachinan R, Tokplonou L, Batcho W, Kindé-Gazard D et al. Épidémiologie de la bilharziose urinaire et des géohelminthiases chez les jeunes scolaires des zones lacustres de la commune de So-Ava, sud-Bénin. J Appl Biosci. 2013;70:5632-5639.
35. Aubry P, Gauzère BA. Schistosomoses ou bilharzioses. Med Trop. 2021;10.
36. Narayan G, Ritu A, Hari PN. Intestinal parasitosis in school going children of Dharan municipality, Nepal. Trop Gastroenterol. 2009;30:145-147.
37. Saotoing P, Wadoube Z, Njan Nlôga AM. Epidemiological survey of urinary and intestinal schistosomiasis in Mayo-Louti Division, Northern Region Cameroon. J Appl Biosci. 2014; 81:7233-7240.
38. Auriault C, Pancré V, Wolowczuk I, Asseman C, Ferru I, Verwaerde C. Immunité cellulaire et pathologie de la schistosomiase. Parasit. 1996;3:199–208.

39. *Anofel*. Oxyurose. Université Médicale Virtuelle Francophone. 2014;5.
40. Gbocho YF, Diakité NR, Akotto OF, N'Goran KE. Dynamique des populations de mollusques hôtes intermédiaires de *Schistosoma haematobium* et *Schistosoma mansoni de* Taabo- village (sud Côte d'Ivoire). J Anim Plant Sci. 2015; 25(3): 3939-3953.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/92937