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Article

Baseline mapping of Schistosomiasis and Soil Transmitted Helminthiasis in the Northern and Eastern health regions of Gabon, Central Africa: Recommendations for preventive chemotherapy

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Abstract: In order to follow the Preventive Chemotherapy for the transmission control as recommended by WHO, Gabon initiated in 2014 the mapping of Schistosomiasis and Soil Transmitted Helminthiasis (STH). Here we report the results of the Northern and Eastern health regions, representing a third of the land area and 12% of its total population. All the 9 departments of the two regions were surveyed and from each, 5 schools were examined with 50 schoolchildren per school. The parasitological examinations were realized using the filtration method for urine and the Kato-Katz technique for stool samples. Overall 2245 schoolchildren (1116 girls and 1129 boys), mean aged 11.28 ± 0.04 years, were examined. Combined schistosomiasis and STH affected 1270 (56.6%) with variation between regions, departments and schools. For schistosomiasis, prevalence were 1.7% across the two regions, with no significant difference (p>0.05) between the Northern (1.5%) and the Eastern (1.9%). Schistosomiasis is mainly caused by *Schistosoma haematobium* with a prevalence of 1.5%, 1.9% and 1.7%, respectively in the North, East and globally. STH are more common than schistosomiasis, with an overall prevalence of 56.1% significantly different between the Northern (58.1%) and Eastern (53.6%) regions (p=0.034). *Trichuris trichiura* is the most abundant infection with a prevalence of 43.7% followed by *Ascaris lumbricoides* 35.6% and hookworms 1.4%. According to these results, an appropriate mass drug administration strategy is given for the control of each neglected tropical disease group surveyed.

Keywords: schistosomiasis; soil-transmitted-helminthiasis; mapping; preventive chemotherapy; transmission control, Gabon, Central Africa

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1. Introduction

Schistosomiasis and Soil Transmitted Helminthiasis (STH) are the most prevalent infectious diseases in the world. They are the cause of serious global public health problems and impose a great burden on poor populations in the developing world [1]. Indeed, with the exclusion of malaria, the World Health Organization (WHO) further estimated that schistosomiasis and STH were responsible for more than 40% of the disease burden due to tropical diseases [2].

Schistosomiasis is acknowledged to be distributed in Africa, Asia and South America with about 200 million infected people [3]. The WHO regards the disease as a Neglected Tropical Disease (NTD), with an estimated 732 million persons being vulnerable to infection worldwide in renowned transmission areas [4]. The Sub-Sahara African region remains the most affected with still high prevalence with about 192 million people infected [5]. In Gabon, with confirmed occurrence of *Schistosoma guineensis*, formely *S. intercalatum* lower Guinea strain, [6-7] and *S. haematobium*, with some cases of *S. mansoni*, it is estimated at 310,391 the total number of people requiring chemotherapy prevention (PTC) [8].

Soil Transmitted Helminthiasis corresponds to a group of parasitic diseases caused by trematode worms that are transmitted to humans by faecally contaminated soil. The three major human diseases are caused by *Ascaris lumbricoides*, *Trichuris trichiura* and hookworms (*Necator americanus* and *Ancylostoma duodenale*). The latest estimates indicate that more than two billion people are infected by at least one species worldwide and more frequently in areas where sanitation and water supply are insufficient, commonly for a child [9]. Such children have malnutrition, growth stunting, intellectual retardation, and cognitive and educational deficits [10]. It is estimated that over 35.4 million African school-aged children are infected by *A. lumbricoides*, 40.1 million with *T. trichiura* and 41.1 million with hookworms. Since many children have multiple infections, it is estimated that 89.9 million are infected by any STH species [11]. According to the burden of STH per country, WHO African Region, 2009 showed that 145,518 preschool (1-5 years) and 349,386 school-age children (6-14 years) were requiring preventive chemotherapy in Gabon [9]. Indeed, the situation of STH in Gabon remains of concern and the latest local studies that were carried out showed that the prevalence is between low risk in sub-urban area (Melen, Libreville) and moderate risk in rural area (Ekouk, 80 km of Libreville) [12].

Despite the burden that they cause in world public health, schistosomiasis and STH are considered as NTD's. Since the World Health Assembly in 2001, access to essential medicines for schistosomiasis and STH in endemic areas for the treatment of both clinical cases and groups at high risk for morbidity was recommended and endorsed by World Health Assembly resolution WHA54.19. The resolution urges member states to ensure access to essential drugs against schistosomiasis and STH in all health services in endemic areas for the treatment of clinical cases and groups at high risk of morbidity such as women and children; with the declared aim to achieving at last the 75% coverage target of regular administration of anthelminthic drugs and up to 100% of all school-age children at risk of morbidity by 2010 [13]. The strategy adopted by WHO since 2006 advocates integrated preventive chemotherapy using a school-based approach with the concept of coordinated use of anthelminthic medicines again schistosomiasis and STH given the consideration that the diseases are largely co-endemic and that these medicines can safely be co-administered [14]. The 2010 target was not achieved, the current goal is to revitalize the control strategy to eliminate schistosomiasis and STH in school-aged children by 2020 [9]. Preventive chemotherapy with mass drug administration (MDA) for populations at-risk in endemic area was adopted once or twice a year, depending on risk levels, over a 5-year period. Preschool and school-age children in endemic areas were the primary target of PTC interventions. Therefore, the target population was expanded to include all adults in high-risk areas. Indeed, allowing the prevalence of infection, communities can be classified into low-risk (<10% for schistosomiasis and <20% for STH), moderate-risk (≥10% for schistosomiasis and ≥ 20% for STH but <50% for both) and high-risk (≥50% for both) areas and this classification is essential to adapt the frequency of MDA interventions according to the WHO disease specific thresholds [15].

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Thus, the first step for establishing the PTC strategy for schistosomiasis and STH is the knowledge of the geographic distribution of prevalence and the degree of overlap of the diseases in endemic areas [16]. Indeed the distribution of schistosomiasis and STH is particularly sensitive to environmental changes whose heterogeneity reflects numerous human and ecological factors including changes of human origin and focal transmission [17]. For these purposes there is a need to identify restricted areas where infection remains a public health problem for an integrated control identifying the broad scale patterns. A successful role for GIS applications in investigating the spatial epidemiology of the major human helminths was well recognized and helping to this purpose [18]. In 2009, 20 of the 32 African endemic countries had initiated the mapping of schistosomiasis and STH in order to implement the PTC interventions [9]. In Gabon, schistosomiasis and STH are known to occur in many areas [8-9]; however, there has not been any sustained effort to control the diseases, apart the establishment of the National Program for Control of Parasitic Disease in 1999.

Until early 2014, preventive chemotherapy interventions for schistosomiasis and STHs were not started in Gabon. To be in line of the WHO's target for the control of schistosomiasis and STH, Gabon initiated, in April 2014, the evaluation of the prevalence levels of schistosomiasis and STH throughout its territory. The aim was to report the outcome of schistosomiasis and STH at several levels in order to provide recommendations related to the implementation of preventive chemotherapy interventions according to WHO requirement. The present paper publishes the results regarding the Northern and Eastern health regions of Gabon.

2. Materials and Methods

2.1. Authorization and ethical assessment

Gabon aligns with the NTD coordinated mapping guidelines of WHO. The implementation of the present study will enable the rapid scaling up of national mass treatment interventions and achieve the WHO targets set for 2020. An agreement was obtained for the implementation of this study as a public health exercise assumed for the Ministry of Health. This agreement involve that study was approved by the committee (National Health Direction). Surveys were conducted in schools with the approval of the Ministry of National Education, school inspectors, directors and teachers. Informed consent has been written for the school director and parents or guardians of schoolchildren that will edify about study and objective, with a translation in local language when necessary. No any schoolchildren’s details will be reporting in the manuscript and parents/schoolchildren have been advised that this study will be conducted without any financial, material or moral counterpart. All the schoolchildren involved in the study were registered in a data file containing all the information relating to them and the parasitological examinations were carried out anonymously until the publication of the results. At the end, each schoolchildren infected by schistosomiasis or STH received appropriate treatment, before preventive chemotherapy interventions, according to WHO recommendations.

2.2. Study area

Gabon is part of Central Africa. The Ministry of Public Health divides the country into 10 health regions and 52 departments. The health regions analyzed in this paper represent a third of Gabon land area and include the overall of 9 health departments with 5 (Woleu, Ntem, Haut-Ntem, Haut-Okano and Okano) in the North region and 4 (Ivindo, Lopé and Mvoung and Zadié) in the East region (Figure 1). The General Direction for Statistic (GDS) estimated the total Gabonese population at 1,811,079 inhabitants, of which 34.7% were pre and school-age children, and an urbanization rate of 87% [19]. However, predominantly urban population (87% of total population) live in only 1% of the global space of the country whereas the majority of territory (99% of superficies) is rural and hosts only 13% of the global population. The study area comprises a total population of 218,279 inhabitants (154,986 and 63,293 in the North and East health regions, respectively).

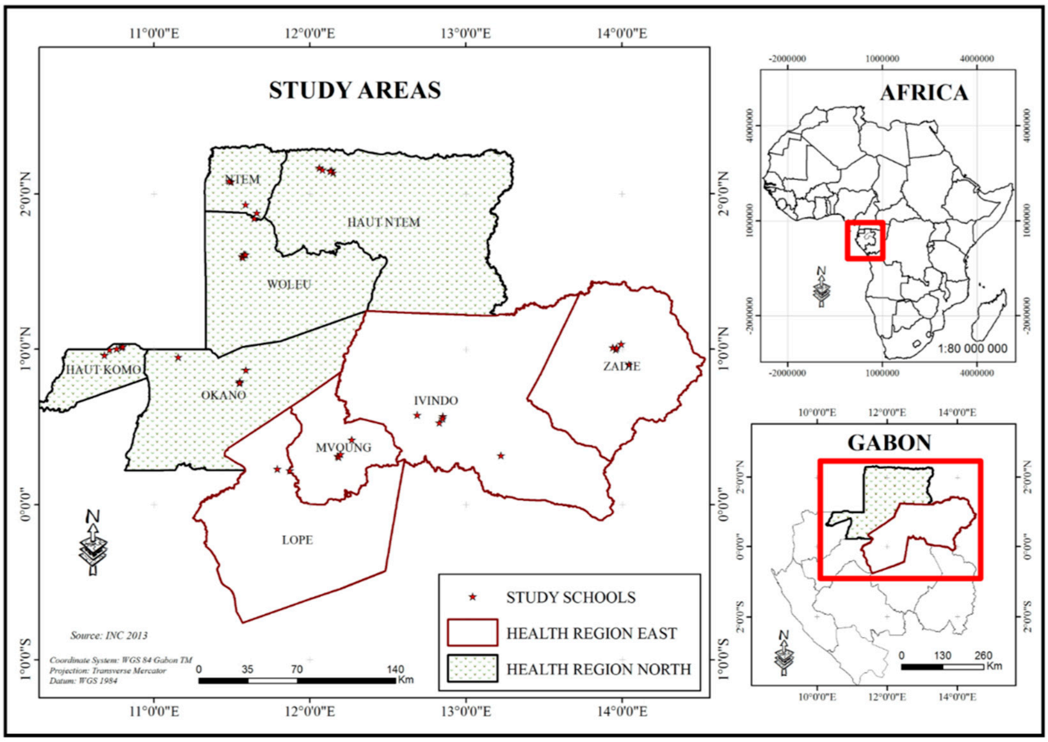

Figure 1. Study area showing the nine departments surveyed: in the Northen region (gray): Woleu, Ntem, Haut-Ntem, Haut-Okano, Okano and in the Eastern region (white): Ivindo, Lopé, Mvoung and Zadié

2.3. Study type, period and population

A cross-sectional prospective study was carried out from January to February 2015. It included both male and female schoolchildren aged 10 to 14 years in priority (where the infection rates will be the highest) in the selected schools.

2.4. Selection and location of schools

Each health department was considered as an ecologically homogeneous area. Five schools were selected according to the proximity of a river, but also of the global repartition of inhabitants. Schools were either urban or rural and either public or private. The geographical coordinates of each school were recorded using a Garmin GPS (Global Positioning System) (Table S1).

2.5. Schoolchildren sampling

In each selected school a mean of 50 schoolchildren (25 girls and 25 boys) aged 10 to 14 years was randomly selected for a total of 250 schoolchildren in each health department. For the random selection, the whole schoolchildren of the interest age group was aligned in two rows according to sex. If the effective is exactly 25 girls and 25 boys, no random selection was done. If the number of girls or boys is deficient (< 25), complete with the age below using a random selection. If the school harboured more than 25 girls or boys aged 10 to 14 years, selection was donned randomly as following. First, calculate the sampling interval that corresponds to the total number of schoolchildren in the rank divided by 25 (the number of schoolchildren to be examined). If the sampling interval is greater than 1, select randomly a number between 1 and the value of sampling interval, which will correspond to the position of the first schoolchildren to be selected in each rank.

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The following schoolchildren will be selected by adding each time the value of the sampling interval to the position of the previous schoolchildren.

2.6. Data collection

Collection was done from 9 to 11 am. The selected schoolchildren were made aware of the need to provide both stool and urine, otherwise they would be excluded from the survey. Small cakes have been distributed to encourage them. Those who did not provide both samples despite any efforts were replaced for another selected according to schoolchildren sampling protocol. For schools with fewer than 50 schoolchildren, enrollment is completed among the other schools selected in the same district.

For each selected schoolchildren, the urine and stool samples were collected, along with information on sex and age. The collected urine and stool samples were forwarded and examined in the laboratories equipped for the circumstance at the department level. Urine was analyzed for presence and number of schistosomiasis eggs, using a slightly modified Nucleopore syringe urine filtration method [20], filtering a10 ml unique aliquot from each urine sample [21]. When the volume of the sample was less than 10 ml, it was measured before filtration and the number of eggs per 10 ml was calculated. Intensity of *S. haematobium* infection was expressed as the number of eggs per 10 ml of urine (eggs/10 ml). Stool samples were examined for presence and number of both soil transmitted helminth and eggs of intestinal *Schistosoma* using the Kato-Katz technique [22]. A single thick smear equivalent to 41.7 mg of stool was analyzed for each stool sample. The method used is that described in the Kato-Katz kit (VESTERGAARD FRANDSEN). Eggs were immediately examined and counted by microscopy so as not missing hookworm and individual intensity of infection was expressed as eggs per gram of feces (epg).

2.7. Data analysis

All the collected data: age, sex, parasitological results, were reported on an Excel sheet for checking. Prevalence of infection (percentage of infected schoolchildren among those examined) was calculated for each parasite, for each parasite group: schistosomiasis (including all three species) and STH (including all three species) and for the combined schistosomiasis and STH, at the overall, regional, departmental, school, school category (public/private), school location (urban/rural) and sex levels. The 95% confidence intervals (CI) for prevalence were calculated using the exact method in the software R version 3.2.2. Arithmetic mean intensities of infection (number of egg per infested schoolchildren) with standard deviations (SD) for each parasite specie were estimated including only the positives schoolchildren [23]. The Chi squared or Fisher exact tests were used to compare the prevalence differences in relation to the region, sex, school category (private/public), school area (urban/rural) while the non-parametric Wilcoxon or Man-Whitney rank sum test was use to compare differences in mean intensities of infection using R version 3.2.2 or SPSS 10.0 for Windows software. The significance of tests was defined at p <0.05. Prevalence generated in each department were used to produce the prevalence maps of distribution for each species using software ArcGis version 10.1.

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3. Results

3.1. Characteristics of sampling

A total of 45 schools were examined, 25 for North and 20 for East region, 27 for urban versus 18 for rural area and 27 for public versus 18 for private category. A total of 2,245 schoolchildren (1,116 girls and 1,129 boys) and the mean number of schoolchildren per school was 49.9 ± 3.9. The number of examined schoolchildren is 1,236 (632 girls and 604 boys) in the North region and 1,009 (484 girls and 525 boys) in the East region. 1754 schoolchildren were from urban versus 491 from rural area and 1420 public versus 825 private. Age of schoolchildren ranged from 4 to 17 years with median age of

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11 years. The average ages of examined schoolchildren were 11.28 ± 0.04 at global level; 11.39 ± 0.05 in the Northern and 11.26 ± 0.09 in the Eastern region.

3.2. Prevalence

3.2.1. Combined schistosomiasis and Soil Transmitted Helminthiasis

Of the 2245 schoolchildren surveyed, 1270 (56.57%; 95% CI 54.49-58.63%) were affected by schistosomiasis (at least one species) and/or STH (at least one species) (Table 1). Schoolchildren from the North region: 723 (58.50%; 95% CI 55.3-60.9%) were significantly more infected than those from the East region: 548 (54.31%; 95% CI 50.5-56.7%), (X-squared=4.5129, df = 1; p=0.04169). At the department level, prevalence was from 44.4% (WLE department) to 73.6% (HKO department) in the Northern region and from 46.56% (LPE department) to 67.45% (ZAD department) in the Eastern. Prevalence was significantly different between departments (X-squared = 84.672, df = 8, p<0.0001). All the schools were infected with prevalence ranging from 28.6% at school 3 of WLE to 92.9% at school 3 of NTM in the North region and from 8.3% at school 4 of MVG department to 88.2% at school 4 of IVD in the East region (Table S2).There were significant differences between schools (X-squared = 325.31, df = 44, p<0.0001). Sex and school category had no influence on prevalence of schistosomiasis and/or STH (p>0.05) while rural schoolchildren (72.10%; 95% CI 67.90-76.02%) were most prevalent than urban schoolchildren (51.60; 95% CI 49.23-53.96%) (X-squared = 64.633, df = 1, p< 0.00001).

Of the total 1270 affected schoolchildren, 718 had one species, 537 two species, 15 three species and no schoolchildren had four, five or six parasites concomitantly. For those affected for schistosomiasis only one had two species, and for those with STH, 528 had two species, 8 had three species and the rest had one species (Table 2).

Table 1. Percentage of infected schoolchildren (prevalence) [95% confidence intervals], at overall level, at regional level, according to sex, school area and school category. SCH = combined Schistosomiasis (including all three species); STH = combined Soil Transmitted Helminthiasis (including all three species). SCH-STH = presence at least one Schistosomiasis and/or Soil Transmitted Helminthiasis.

	N	**Schistosomiasis**			**Soil Transmittted Helminthiasis**			SCH	STH	SCH-STH
		S. haematobium	*S. mansoni*	*S. guineensis*	*A. lumbricoides*	*T. trichiura*	Hookworms			
Overall	2245	1.65 [1.16-2.27]	0.04 [0.0-0.25]	0.04 [0.0-0.25]	35.59 [33.61-37.59]	43.74 [41.68-45.82]	1.43 [0.98-2.01]	1.69 [1.2-2.32]	56.08 [54.0-58.15]	56.57 [54.49-58.63]
By region										
Northern	1236	1.46 [0.87-2.29]	0.08 [0.0-0.45]	0.08 [0.0-0.45]	29.13* [26.60-31.75]	52.83* [50.0-55.65]	1.62 [0.99-2.49]	1.54 [0.93-2.39]	58.09* [55.29-60.86]	58.5* [55.69-61.26]
Eastern	1009	1.88 [1.14-2.93]	0.00 [0.0-0.37]	0.00 [0.0-0.37]	43.51 [40.42-46.63]	32.61 [29.72-35.60]	1.19 [0.62-2.07]	1.88 [1.14-2.93]	53.62 [50.48-56.73]	54.2 [51.08-57.32]
By Sex										
Girl	1116	1.25 [0.69-2.1]	0.00 [0.0-0.33]	0.09 [0.0-0.5]	34.14 [31.36-37.01]	42.47[39.55-45.43]	0.81[0.37-1.53]	1.34[0.75-2.2]	54.84 [51.87-57.79]	55.11 [52.13-58.05]
Boy	1129	2.04[1.30-3.04]	0.09[0.0-0.49]	0.00[0.0-0.49]	37.02[34.20-39.92]	45.00[42.07-47.95]	2.04* [1.30-3.04]	2.04[1.30-3.04]	57.31[54.36-60.21]	58.02[55.08-60.91]
By school area										
urban	1754	1.48 [0.97-2.16]	0.06 [0.0-0.32]	0.06 [0.0-0.32]	30.84 [28.69-33.06]*	40.59 [38.28-42.93]*	1.37 [0.88-2.03]	1.54 [1.02-2.23]	51.60 [49.23-53.96]*	52.17 [49.80-54.48]*

rural	491	2.24 [1.12-3.97]	0.00 0.75]	[0.0-	0.00 [0.0-0.75]	52.55 57.04]	[48.02-	54.99 59.45]	[50.47-	1.63 3.19]	[0.71-	2.24 [11.24-3.97]	72.10 [67.90-76.02]	72.51 [68.33-76.41]
By school category														
Public	1420	1.97 [1.31-2.84]	0.07 0.39]	[0.0-	0.07 [0.0-0.39]	36.76 39.33]	[34.25-	45.35 47.98]*	[43.74-	1.62 2.42]	[1.03-	2.04 [1.37-2.92]	57.61 [54.99-60.19]	58.24 [55.62-60.82]*
Private	825	1.09 [0.50-2.06]	0.00 0.45]	[0.0-	0.00 [0.0-0.45]	33.58 36.91]	[30.36-	40.97 44.41]	[37.59-	1.09 2.06]	[0.50-	1.09 [0.50-2.06]	53.46 [49.98-56.90]	53.82 [50.35-57.26]

*p<0.05 (Chi squared test)

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Table 2. Proportion of polyparasitism for schistosomiaisis, Soil Transmitted Helminthiasis (STH) and combined (Schistosomiais-STH).

Number of species	N	Schistosomiasis	STH	Schistosomiasis-STH
0		2238	986	975
1		36	723	718
2		1	528	537
3	2245	0	8	15
4		0	0	0
5		0	0	0
6		0	0	0

3.2.2. Combined Schistosomiasis

Including all three species**,** overall 38 cases (1.7%) were positive for schistosomiasis (all three species) in 21 schools of the 45 surveyed, with no significant difference (p>0.05) between the North, 19 cases (1.5%; 95% CI 0.9-2.4%) and the East region, 19 cases (1.88%; 95% CI 1.1-2.9%), (Table 1).Sex, school area and school category had no influence on prevalence of the combined schistosomiasis (p>0.05). At the department level, prevalence was all <10%. It varied from 0.8% at WLE to 2.6% at HKO department in the North region (p>0.05) and from 0.0% at ZAD to 4.4% at MVG department in the East region (X- squared = 22.032, df = 8, p = 0.004857). At school level, prevalence was all < 10% (0% in 25 schools), with the exception of school 5 in MVG department it was 15.8% (X-squared = 84.762, df = 44, p = 0.0002171).

3.2.3. Schistosomiasis *haematobium*

It is the most frequent schistosomiasis which was found prevalent in 20 schools from the 45 studied (Table S2). In overall, *S. haematobium* affected 37 (1.45%; 95% CI 1.16-2.27%) schoolchildren with 18 (1.46%. 95% CI 0.87-2.29%) in the North and 19 (1.88%; 95% CI 1.14-2.93%) in the East region (p>0.05).Sex, school area and school category had no influence on prevalence of *S. haematobium* (p>0.05). At the department level (Figure 2), prevalence of *S. haematobium* was all <10%, from 0.8% (HNT department) to 2.4% (NTM department) in the North region and from 0% (ZAD department) to 4.36% (MVG department) in the East region, (X-squared = 21.741, df = 8, p = 0.00542). At school level, prevalence varied from 0 (in 25 schools) to15.8% (6 cases in school 5 in the MVG department) (X-squared = 85.959, df = 44, p = 0.0001583).

3.2.4. Other schistosomiasis

S. guineensis and *S. mansoni* are very unusual, only one case of each respectively was listed in the North region. The *S. mansoni* case was encountered in school 4 of NTM department while the *S. guineensis* case was in school 1 of HKO department (Table S2). All the distribution map of schistosomiasis are presented in the Figure 2.

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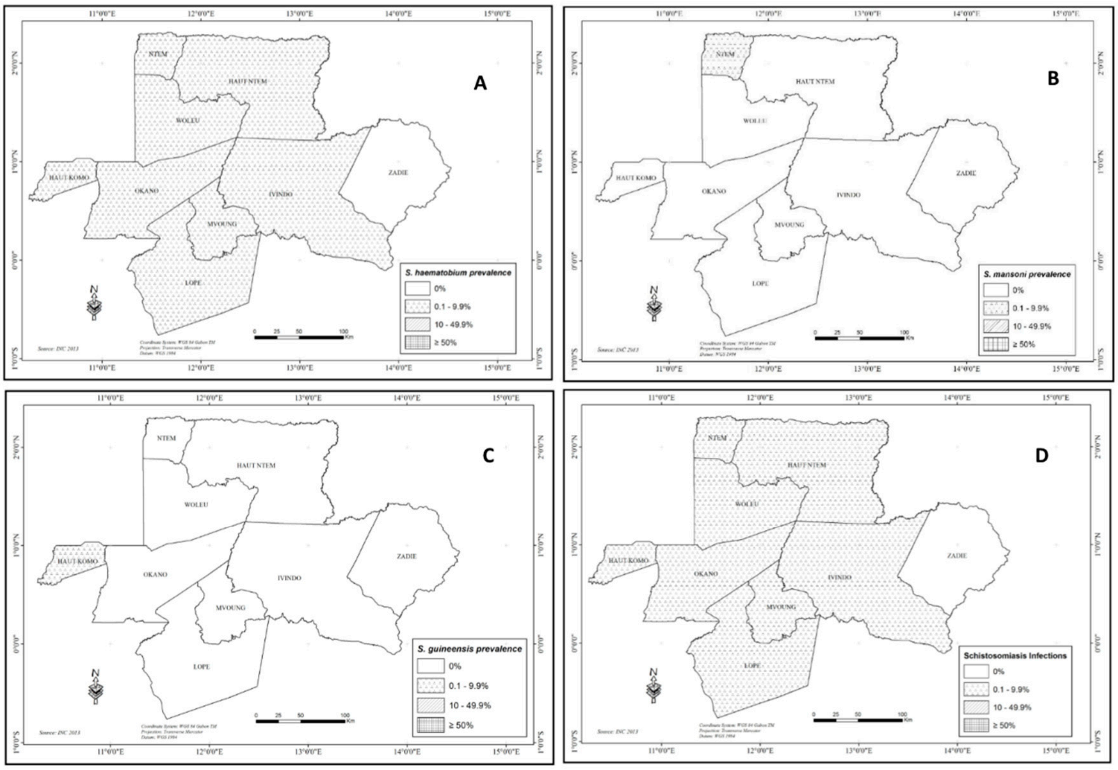

Figure 2. Map of prevalence levels for Schistosomiasis at department scale: (A) *Schistosoma haematobium*; (B) *S. mansoni*; (C) *S. guineensis* and (D) Combined schistosomiasis

3.2.5. Combined Soil Transmitted Helminthiasis (STH)

Including all three species, a total of 1259 (56.08%; 95% CI 54.0-58.15%) schoolchildren were affected by STH (Table 1). At the regional level, North health region (58.09%; 95% CI 55.29-60.86%) was more affected than Eastern (53.62%; 95% CI 50.48-56.73%), (X-squared = 4.3331, df = 1, *p* = 0.03738). At the department level, significant differences were found (X-squared = 85.435, df = 8, *p*<0.0001). Prevalence varied from 44.736% (WLE department) to 73.16% (HKO department) in the North and from 46.56% (LPE department) to 67.45% (LPE department) in the East region. At the school level, there were heterogeneity between schools (X-squared = 326.25, df = 44, *p*<0.00001). One school had a prevalence of STH<20%, 14 schools had a prevalence ≤20% but <50% and 29 had a prevalence ≥50% (Table S2). Sex and school category had no influence on overall prevalence of STH (*p*>0.05) while according to school area: schoolchildren of rural schools (72.1% [67.90-76.02]) were more affected than those of urban schools (51.6%; 95% CI 49.23-53.96%), X-squared = 64.633, df = 1, *p*<0.0001.

3.2.6. *Ascaris lumbricoides*

It was prevalent in 44 schools of the 45 schools studied for a total of 799 (35.59% (95% CI 33.61-37.59%)) schoolchildren affected (Table 1). According to health region, East (43.51% (95% CI 40.42-46.63%)) was more affected than North (29.13% (95% CI 26.60-31.75%)), (X-squared = 50.126, df = 1, *p*< 0.0001). Sex and school category had no influence on overall prevalence of *A. lumbricoides* (*p*>0.05) while rural schools (52.55% (95% CI 48.02-57.04%)) were more affected by *A. lumbricoides* than urban schools (30.84% (95% CI 28.69-33.06%)) (X-squared = 77.872, df = 1, *p*<0.0001). At the department level (Figure 3), prevalence was comprised from 12.9% in WLE department to 58.04% in ZAD, (X-squared = 160.82, df = 8, *p*<0.0001). Significant heterogeneity (X-squared = 382.81, df = 44, *p*<0.0001) existed

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between schools: 10 schools had a low prevalence (<20%), 19 had a moderate prevalence (≤20% but <50%) and 16 had a high prevalence (≥50%) (Table S2).

3.2.7. *Trichuris trichiura*

It was prevalent in all schools surveyed and was the more frequently species with a total of 982 (43.7% (95% CI 41.68-45.8%)) affected schoolchildren. According to health region, North (52.8% (95% CI 50-55.7%)) was more affected than East (32.6% (95% CI 29.7-35.6%)), (X-squared = 91.521, df = 1, p< 0.0001). There was a significant difference between rural schools (55%; 95% CI 50.5-59.5%) and urban schools (40.6%; 95% CI 38.3-42.9%),(X-squared = 31.729, df = 1, p< 0.0001)); and between public (45.4%; 95% CI 43.7-48%) and private (41%; 95% CI 37.6-44.4%) schools (X-squared = 3.8965, df = 1, p< 0.0001) for the overall prevalence of *T. trichiura*. There was no significant difference of overall prevalence of *T. trichiura* according to sex (p>0.05). At the department level, (Figure 3) prevalence of *T trichiura* varied from 27.13% in LPE to 67.53% in HKO department with significant heterogeneity (X-squared = 142.85, df = 8, p< 0.0001). At the school level, six schools had a prevalence of *T trichiura* <20%, 21 schools had a prevalence ≤20% but <50% and 18 had a prevalence ≥50% (S2 Table). There was a significant difference in the distribution of *T trichiura* among schools (X-squared = 340.14, df = 44, p< 0.0001).

3.2.8. Hookworms

Hookworms were present uniquely in 12 of the 45 studied schools with an overall prevalence of 1.43% (95% CI 1-2%): 1.6% (95% CI 0.99-2.49%) in the North region, 1.2% (95% CI 0.6-2.1%) in the East region. There was no significance difference between regions, school areas and school categories (p>0.05), while there was a significant difference in overall prevalence of hookworm between girls (1.3%; 95% CI: 0.8-2.2%) and boys (2%; 95% CI: 1.3-3%) (X-squared = 5.2061, df = 1, p = 0.02251). At the department level (Fig 3), prevalence was from 0 (for 3 departments) to a maximum of 6% in the WLE department with significant difference between departments (X-squared = 53.552, df = 8, p<0.0001). Prevalence of hookworm in schools ranged from 0% (30 of the 45 schools surveyed) to 14.3% (Table S2). There was significant differences between schools (X-squared = 159.25, df = 44, p<0.0001). All the distribution map of STH are presented in the Figure 3.

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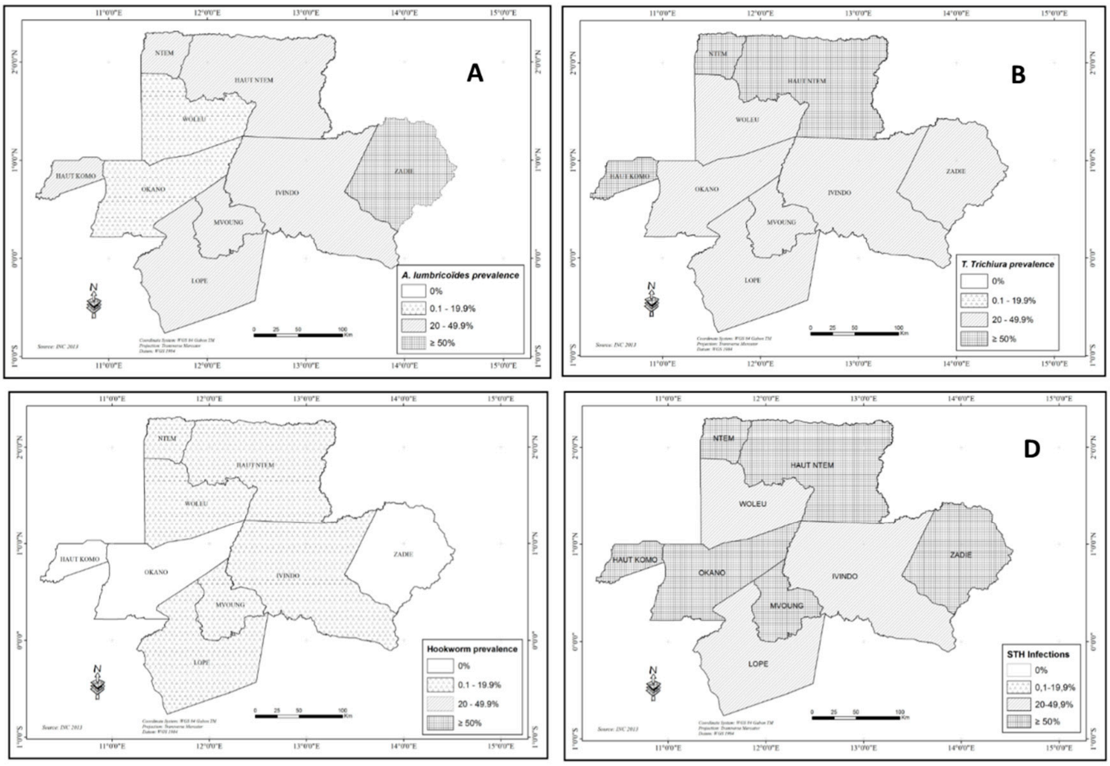

Figure 3. Map of prevalence levels for Soil Transmitted Helminthiasis at the department scale: (A) *Ascaris lumbrocoides*; (B) *Trichurus trichuira*; (C) Hookworm and (D) Combined STH.

3.3. Intensity of infection

3.3.1. Schistosomiasis

For the 37 schoolchildren infected with *S. haematobium*, the mean intensity of infections was 101.9 ± 41.1 eggs per 10 ml of urine with a significant difference between the North (18.3±8.2 epg) and the East region (181.1±85.6 epg), (W = 246, p = 0.02176) (Table 3). On the 20 schools prevalent with *S. haematobium*, light-intensity infections (<50eggs/10ml) occurred in 12 schools (11 in the North region and 1 in the East Region) and heavy-intensity infections (≥50 eggs/10ml) occurred in 8 schools (1 in the North region and 7 in the East Region) (Table S3). The maximum individual egg counts was 1534 eggs/10ml of urine; 73% of infected schoolchildren had low-intensity infections and 27% had heavy-intensity infections. Overall, sex, school area and school category have not influence on the *S. haematobium* intensity of infection of (p>0.05).

Intensity of infections was 72 epg for the only case of *S. mansoni* and 240 epg for the only case of *S. guineensis* (Table 3).

3.3.2. *Ascaris lumbricoides*

Overall mean intensity of infection was moderate: 9586.6±618.3 epg and different between the two regions: 11433.6±1061.7 epg for the North and 8071.9±707.3 epg for the East region (W = 69804, p = 0.004523). On the 44 schools prevalent with *A. lumbricoides*, light intensity infections (1-4999 epg) occurred in 10 schools (4 in the North region and 6 in the East region), moderate-intensity infections (5000–49,999 epg) occurred in 33 schools (20 in the North region and 13 in the East region) and heavy-intensity infections (≥50,000 epg) occurred in 1 school (in the North region) (Table S3). The maximum individual egg counts was 176,640, whereas 59.1% of infected schoolchildren had low-intensity infections, 37.5% with moderate-intensity infection and 3.4% with heavy-intensity infections. Overall,

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sex, school area and school category had no influence on the *A. lumbricoides* intensity of infection (p>0.05).

3.3.3. *Trichuris trichiura*

The overall mean intensity of infection was moderate: 1143.2±97 with significant difference between the North (1395.2±126.6 epg) and the East region (642.9±140.2 epg), (W = 76502, p = 1.551e-13) (Table 3). Intensities of infection were classified in the light-intensity infections class (1-999 epg) for 30 schools (13 in the North region and 17 in the East region), in the moderate-intensity infections class (1000-9999) for15 schools (12 in the North region and 3 in the East region). No school had the heavy-intensity infections (≥10000 epg) (S3 Table). The maximum individual egg count was 37,440; 77.8% of the infected schoolchildren had low-intensity infections, 20.1% moderate-intensity infections and 2.1% heavy-intensity infections. Overall, sex and school area had no influence on the *T. trichiura* intensity of infection (p>0.05) while intensities of infection were higher in public schools (1193.5±113.1 epg) than in private schools (1047.3±182.1 epg) (W = 98024, p-value = 0.01032) in the same class of intensity.

3.3.4. Hookworm

The overall mean intensity of infection was light: 618.0± 499.6 epg; 130.8±31.1 epg in the North region and 1430.0±1369.1 epg in the East region (Table 3). No significant difference was found between regions, sex, school areas and school categories. The maximum individual egg count was 15,840 eggs and 96.9% of the schoolchildren had light-intensity infections (Table S3).

Table 3. Mean intensity of infection ± standard deviation at overall, by region, sex, school area and school category. (N)

	Schistosomiasis			**SoilTransmitttedHelminthiasis**		
	S. haematobium	*S. mansoni*	*S. guineensis*	*A. lumbricoides*	*T. trichiura*	Hookworms
Overall	101.9±45.1 (37)	72 (1)	240 (1)	9586.6±618.3 (799)	1143.2±97.0 (982)	618.0±499.6 (32)
By region						
North	18.3±8.2 (18)	72 (1)	240 (1)	11433.6±1061.7 (360)	1395.2±126.6 (653)	130.8±31.1 (20)
East	181.1±85.6 (19)	-	-	8071.9±707.3 (439)	642.9±140.2 (329)	1430.0±1369.1 (12)
By sex						
Girl	65.3±32.4 (14)	-	240 (1)	10131.3±1053.6 (381)	1152.6±147.4 (474)	1861.3±1853.7 (9)
Boy	124.2±70.9 (23)	72 (1)	-	9018.1±688.7 (418)	1130.1±127.7 (508)	131.5±35.0 (23)
By school area						
urban	109.5±61.0 (26)	72 (1)	240 (1)	9144.6±665.8 (541)	1139.9±113.9 (712)	791.0±669.2 (24)
rural	174.7±55.3 (11)	-	-	10513.4±1313.1 (258)	1151.7±185.9 (270)	99.0±46.9 (8)
By school category						
Public	73.3±26.3 (28)	72 (1)	240 (1)	8874.4±624.4 (522)	1193.5±113.1 (644)	97.0±18.9 (23)
Private	504.9±178.5 (9)	-	-	10928.7±1340.5 (277)	1047.3±182.1 (338)	1949.3±1843.5 (9)

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3.4. Community diagnosis and recommended treatment strategies

According to our results on the prevalence and the intensity of infection, the recommended treatment strategies by department were summarized in Table 4.

Table 4. Department diagnosis and recommended treatment strategies. PTC= preventive chemotherapy, MDA= mass drug administration

Department	Category	MDA interventions in schools (enrolled and non-enrolled)	Drug
Schistosomiasis infections			
Woleu Ntem Haut-Ntem Haut-Okano Okano Ivindo Lopé Mvoung	Low prevalence	MDA of school-age children twice during primary schooling (once on entry, again on leaving)	Praziquantel
Zadié	Not endemic	No required PTC. Treatment of individual confirmed cases	
Soil Transmitted Helminthiasis infections			
Woleu	Moderate prevalence and moderate intensity	Annual MDA	Mebendazole + Levamisole
Ntem Haut-Ntem Haut-Komo Okano	High prevalence	Biannual MDA	
Ivindo Lopé	Moderate prevalence and moderate intensity	Annual MDA	
Mvoung Zadié	High prevalence	Biannual MDA	

Discussion

Our study showed that schistosomiasis and Soil Transmitted Helminthiasis (STH) remain common in schoolchildren of both North and East health regions of Gabon with heterogenic proportions. Indeed on the all 2245 examined school children, 1270 (56.6%) were affected by at least one schistosomiasis and/or STH. Infection was influenced by both regions and school area. Indeed schoolchildren in the North region (58.5%) were most prevalent than those in the East region (54.2%) and rural schoolchildren (72.10%) were most affected than urban schoolchildren (51.6%). Sex

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(girl/boy) and school category (public/private) had no influence on the burden of schistosomiasis and STH. Burden was most supported by STH than by schistosomiasis that is very low.

For schistosomiasis, the present study indicates that the infection is low endemic in the surveyed area, prevalence was 1.7% (all three species). Exhaustive results indicate that distribution of schistosomiasis is heterogeneous with an overall low endemicity for all the three species in the whole of the study area. Schistosomiasis *haematobium* was the most frequent and was diagnosed with at least one case in 20 schools from the 45 studied and from these 20 schools only one school was moderately endemic with a prevalence at 15.8%. Overall infection of *S haematobium* was low (1.7%) in both the North (1.5%) and the East regions (1.9%). At the departmental level, prevalence was from 0.8% to 2.4% in the North region and from 0 to 4.4% in the Eastern region. Schistosomiasis *mansoni* and *guineensis* were endangered in the surveyed areas with only 1 case of *S. mansoni* and *S. guineensis* respectively from the total schoolchildren examined. Data obtained here contrast with the results available for other areas and for the overall estimations in Gabon. Indeed, Mintsa *et al*. reported prevalence for *S. haematobium* at 17% and 26% in Melen, Libreville and Ekouk (80 km to Libreville), respectively [24], Gabon. Even wider, the estimation of prevalence of schistosomiasis in Gabon was about 45% [3]. Outside Gabon, in Central Africa, prevalence of schistosomiasis is generally high. For instance, in Cameroon, some localities in the East, West and Central regions had prevalence between 20 and 50% and for some of them > 50% [25]. In the Littoral, North-West and South-West Cameroon regions [26], prevalence were also much higher than those recorded in our study. This contrast confirms the patching distribution of schistosomiasis. Some parameters can explain the patching distribution of schistosomiasis and they include human and ecological factors [27], temperature and rainfall [28]. Finding of using GIS for epidemiological survey in Tanzania showed that schistosomiasis was not endemic in areas where the temperature was below 20° C [18; 29]. By contrast, in Cameroon, prevalence is > 10% for the areas where temperature is > 40 °C and precipitation <1500 mm [30]. These differences can be attributed to both distribution of the intermediate snail host species in Africa [31] and their optimal conditions for development in West Africa [32]. Besides temperature and rainfall, relief [33], demography and living conditions [34] can also play a role in the distribution of schistosomiasis.

In addition to the low prevalence recorded in this study, schistosomiasis was characterized by low intensity of infections. Indeed, 73% of schoolchildren infected by *S. haematobium* had a light (<50 eggs/10 ml urine) intensity of infection, and 27% a heavy one (≥ 50 eggs/10 ml urine). These results are lower than those recorded at baseline results in the Barombi Kotto focus, Cameroon [23] and in the Sahel region, Burkina Faso [35]. The intensity of infection to *Schistosoma* is often correlated to the morbidity in school-aged children and other susceptible groups [36-37] and plays an important role for the estimation of prevalence with consequences for the treatment strategy in PCT [38]. Although the microscopic techniques used in our study (urine filtration for *S. haematobium* diagnosis and Kato-Katz for *S. mansoni* and *S. guineensis* diagnosis) are the most recommended by WHO [39] and the most widely used diagnostic approaches in epidemiological surveys, their sensitivity is very discussed in foci with low intensity of infection because of day to day egg variations [40]. Hence, multiple Kato-Katz thick smears are required to enhance sensitivity [41], but this poses operational challenges and strains financial resources. As an alternative to these conventional diagnostic methods, novel tools showing a very high diagnostic accuracy have recently been developed. They include detection of monoclonal antibody-based circulating antigens CCA and CAA [42] and the molecular approaches [43]. For example, it has been shown that estimation of prevalence with Kato-Katz technique underestimates the prevalence of active *S. japonicum* infections in China by a factor of 10 compared with the UCP-LF CAA assay [44]. Similarly, estimation of *S. haematobium* prevalence was several-fold higher with UCP-LF CAA assay than the one detected with a single urine filtration [45]. Since 2008, a more sophisticated Point-Of-Care (POC) test detecting *Schistosoma* CCA in urine has been developed and is now commercially available and recommended by the authors for *S mansoni* diagnosis [46; 47]. POC-CCA test revealed higher sensitivity than triplicate Kato-Katz, and produced similar prevalence as nine Kato-Katz in many field survey evaluation [21; 48].

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Our results showed that Soil Transmitted Helminthiasis (STH) were highly endemic. Overall, 56.1% of the school children examined were affected by the combined STH (all three species: *Ascaris lumbricoides*, *Trichuris trichiura* and Hookworms). This confirms the important level of STH in Central Africa, as in Cameroun [49]. Factors that may explain high levels of STH infections include lacks of sanitation and access to drinking water [9]. Our results indicate that the North region (58.1%) was most prevalent that the East (53.1%) and schoolchildren from rural schools (72.1%) were more affected than those from urban schools (51.6%).Various factors, such as genetics, poly-parasitism, demography, and urbanization, may explain these differences [11].The most common STH was *T. trichiura* (43.7%) followed by *A. lumbricoides* (35.6%), with heterogeneous distributions between departments (Fig 3) and between schools. Indeed, *T. trichiura* and *A. lumbricoides* were moderately prevalent (≥ 20 and <50%) in 21 and 19 schools, respectively, and both were very highly prevalent (≥ 50%) in 16 schools. In contrast to the high prevalence of *A. lumbricoides* and *T. trichiura*, prevalence of hookworm was low, 1.4% at overall, 1.6% in the North and 1.2% in the East region. These results confirm the well documented observation that prevalence of *T. trichiura* and *A. lumbricoides* were always higher than prevalence of hookworms [12, 25, 26]. Besides prevalence, intensity of infection is a good indicator for epidemiology of STH. Indeed most of the morbidity is accounted for by infected individuals who are the most heavily infected [50]. Our results showed a moderate-intensity infections for *T. trichiura*. (1143.2 epg overall) and *A. lumbricoides* (overall 9586.6 epg) and light-intensity infection for hookworms (overall 618 epg). However, 2.1% and 3.4% of schoolchildren had heavy-intensity of infections for *T. trichiura* and *A. lumbricoides*, respectively, attesting the burden of these STH in the surveyed foci.

One of the objectives of our study was to address recommendations for SCH and STH preventive chemotherapy in Gabon. Following WHO guidelines, beside on prevalence and intensity of infections, the program is classifying communities according to three strategies: (1) a high prevalence (≥50% for both Schistosomiasis and STH) or heavy-intensity infections, schoolchildren are treated every year, and high risk groups, such as fishermen, are treated; (2) a moderate prevalence(≥10% for Schistosomiasis and ≥20% for STH but <50% for both schistosomiasis and STH) and light-intensity infections, schoolchildren are treated once every two years; and (3) a low prevalence (<10% for Schistosomiasis and <20% for STH) and light-intensity infections, chemotherapy is made available in health facilities for treatment of suspected cases [15]. For schistosomiasis, considering the low prevalence recorded in our study, we recommend MDA of school-age children twice during primary schooling (once on entry, again on leaving) for 8 departments and individual treatment for the confirmed cases in the Zadié department. We also recommend the diagnosis of other communities at high risk (such as pre-school children, pregnant women and special occupation groups) and chemotherapy will be made available in health facilities for treatment of suspected cases according to OMS guidelines [15]. WHO recommended the drug Praziquantel (PZQ) with a dosage of 40mg/Kg for the treatment of schistosomiasis in PTC. Impact of treatment varies according to region and treatment strategy. An annual treatment strategy has significantly reduced prevalence of schistosomiasis 1, 2 and 3 years post-treatment in West Africa, i.e. Burkina Faso [35], Niger [51], Ghana [52]; East Africa i.e. Uganda [53], and in Central Africa, i.e. Cameroun [23, 26]. For STH, we recommend a biannual MDA strategy including pre and school age children, women of child bearing age including pregnant women in the 2nd and 3rd trimesters and lactating women and adults at high risk in certain occupations (e.g. tea-pickers and miners) for the 6 departments (Ntem, Haut-Ntem, Haut-Komo, Okano, Mvoung and Zadié) where the prevalence was high (≥50%) and an annual MDA strategy for the 3 departments (Woleu, Ivindo, Lopé) with moderate prevalence. Four anthelminthics are currently on the WHO model list of essential medicines for the treatment and control of STH: albendazole, mebendazole, levamisole, and pyrantel-pamoate [15]. Impact of these different drugs on STH are discussed by Keizer and Utzinger [54]. For these authors, oral single-doses of these drugs show high cure rates against *A. lumbricoides*, but not always against *T trichiura* and hookworms. Combination of mebendazole and levamisole shows the best cure rate against all three species [55]. Furthermore, considering the global costs per child treated against schistosomiasis and STH, including drug and delivery, US$ 0.32 in Burkina Faso [35], the MDA should integrate and progress with both schistosomiasis and STH.

Supplementary Materials: The following are available as attached files, Table S1: list of schools surveyed per region and department with their respective geographical position. Non-italic = public school; italics = private school. In bold = urban school; normal = rural school, Table S2: Number of infected school children (prevalence in %) for each parasite according to school and department investigated. N is the number of school children examined. *p<0.05 (Fisher-Exact-test); * is followed by school number or by department name with a significant difference, Table S3: Intensity of infection (mean ± standard deviation) for each parasite according to school and department investigated. N is the number of schoolchildren examined. *p<0.05 (Mann-Whitney test); * is followed by the school number or department code with significant difference. $^{L, M \text{ and } H}$ indicate class intensity of infection. L= light-intensity infection, M= moderate-intensity infections, H= heavy-intensity infections according to each species.

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