Results of the first mapping of soil-transmitted helminths in Benin: Evidence of countrywide hookworm predominance

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Citation: Ibikounlé M, Onzo-Aboki A, Doritchamou J, Tougué J-J, Boko PM, Savassi BS, et al. (2018) Results of the first mapping of soil-transmitted helminths in Benin: Evidence of countrywide hookworm predominance. PLoS Negl Trop Dis 12(3): e0006241. https://doi.org/10.1371/journal.pntd.0006241

Editor: Serap Aksoy, Yale School of Public Health, UNITED STATES

Received: June 27, 2017
Accepted: January 17, 2018
Published: March 1, 2018

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Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Funding: This study was made possible with funding from the United States Agency for International Development (USAID). USAID support for NTD control in Benin led by RTI International under Cooperative Agreement No 0213210-000-012-003 through the ENVISION project. The contents of this manuscript are the

Abstract

Background
National mapping of soil-transmitted helminth infections (STH) was conducted for the first time in all of the 77 districts of Benin (West Africa) from 2013 to 2015. This mapping aimed to provide basic epidemiological data essential for the implementation of the national strategy against the neglected tropical diseases (NTDs) in the context of achieving the WHO target of controlling these infections by 2020.

Methods
In each district, 5 schools were purposively selected in 5 villages and 50 school-children (25 girls and 25 boys) from ages 8 to 14 years were randomly enrolled in each school. In total, 19,250 stool samples of school children (9,625 girls and 9,625 boys) from 385 schools were examined by Kato-Katz technique.

Results
The three major species of STH (hookworm, Ascaris lumbricoides and Trichuris trichiura) were observed with intra- and inter-specific variations in the prevalence and the intensity of these parasites. Hookworm infection was present in all of the surveyed districts with an average prevalence of 17.14% (95% CI 16.6%-17.6%). Among the infected schoolchildren, at national level, 90.82%, 6.73% and 2.45% of infections were of light, moderate and heavy parasite intensities respectively. A. lumbricoides infection, with a national average prevalence of 5.35% (95% CI 5.00%-5.60%), was the second most prevalent STH, and 84.37%, 14.27% and 1.36% of the infections were of light, moderate and heavy parasite intensities,
respectively. T. trichiura had a national average prevalence of 1.15% (95% CI 0.90%-1.20%) and 80.45%, 13.18% and 6.36% infections were of light, moderate and heavy parasite intensities, respectively. The national cumulative prevalence of the three STH infections was 22.74% (95% CI 22.15%-23.33%), with 58.44% (45/77) of the districts requiring mass treatment according to WHO recommendations. In all of the surveyed districts, multiple infections by STH species were common, and boys seemed more at risk of hookworm and Ascaris infections.

Conclusions
This first national mapping provided an overview of the epidemiological pattern of STH infections and was essential for the implementation of a control strategy with an effective preventive chemotherapy treatment (PCT). Results show that while preventive chemotherapy is not indicated for children in 32/77 districts, 43 require annual deworming and two require twice yearly deworming. If no environmental change occurs, and no mass treatment is delivered, prevalence is likely to remain stable for many years owing to poor hygiene and sanitation.

Author summary
Benin, like other low or moderate-income countries in the African continent, is endemic for several neglected tropical diseases, including soil-transmitted helminthiases. The National Program for Neglected Tropical Diseases of the Ministry of Health has conducted the national STH mapping using the Kato-Katz method to assess the baseline epidemiological status in all 77 districts of Benin, in order to guide implementation of a preventive chemotherapy program using albendazole. The results of the survey showed that infection with at least one of the three targeted species (hookworm, roundworm or whipworm) affected 20% or more of school aged children in 45 out of 77 districts, and which therefore require PCT. Hookworm infection was the most prevalent followed by ascariasis and trichuriasis. Boys were significantly more likely than girls to be infected with hookworm or ascariasis.

Introduction
The soil-transmitted helminthiasis (STH) are one of eighteen groups of diseases termed as Neglected Tropical Diseases by the World Health Organization (WHO) and which have caught the attention of donors following World Health Assembly resolution WHA54.19 in 2001 [1]. Indeed, more than 1.5 billion people, or 24% of the world population, have been estimated to be infected with STH worldwide [2]. Infections are widely distributed in tropical and subtropical areas and affects the poorest and most deprived communities, with the greatest numbers occurring in sub-Saharan Africa, the Americas, China and East Asia [3,4]. These diseases are transmitted by eggs present in human excreta, which contaminate the soil in areas with populations who have limited access to latrines and potable water. The main species of STH that infect humans are nematodes (A. lumbricoides, T. trichiura, Necator americanus and Ancylostoma duodenale) with relatively similar cycles involving the presence of adult worms in the intestine. Infection is caused by larval penetration of the skin (in the case of hookworm) or
ingestion of parasite eggs (for other STH). High to moderate intensity of STH infections have been associated with increased risk of malnutrition, iron-deficiency related anemia and other adverse physical and cognitive morbidities, particularly in children and pregnant women [2,5,6,7]. In sub-Saharan Africa (SSA), the majority of pregnant women are anemic (more than 60% in Benin) [8] and STH infections are among the most significant causes of anemia diagnosed during pregnancy in SSA [9].

In Benin, several studies have highlighted STH infections as a major public health problem and the related associations have been recently demonstrated on a small Beninese cohort [8–11]. Anemia had a negative impact on maternal health but also on newborn health due to significant decrease of the hemoglobin during the first months of life, leading to elevated risk of mortality and morbidity of the young child [8–11]. These studies have been the basis of sporadic preventive chemotherapy according to WHO guidelines. With the London Declaration on NTDs by 2020, the National Communicable Disease Control Program developed a strategy for the control of five NTDs in 2012 (Trachoma, Onchocerciasis and Lymphatic Filariasis, schistosomiasis and STH). Since 2013, the national plan has been funded by USAID through the ENVISION project led by Research Triangle Institute (RTI).

This study aimed to investigate the national epidemiological situation regarding the three major STH infections (hookworm, ascariasis and trichuriasis) as baseline data was essential for implementation of the PCT strategy in Benin.

**Materials and methods**

**Ethical statement**

This study was approved by the Comité National d’Ethique pour la Recherche en Santé (CNERS) under the authorisation reference 009/CNERS-MS from the Ministry of Health in Benin. Informed consent was obtained from the head teacher of each school and sometimes from the chief of the village, parents and teachers associations. In some districts where parents and teachers associations (PTA) exist, the head of the PTA and the head teachers received detailed explanation about the study. Individual parents were informed by the PTA and consents were secured orally. The PTA then provided a formal written approval on behalf of school children and parents. In cases where those that were to give authorisation were unable to read and write, a detailed verbal explanation of the form was given so that informed consent was obtained. Two copies of the written consent form were signed and dated. The person giving consent kept one copy and the second copy was returned to the NTD national control program. During the sampling all school children from whom no consent statement was received were replaced by other volunteers according to inclusion criteria. Participants detected with high intensity of STH or any other intestinal parasite infections were directed to healthcare centres in order to receive appropriate treatment before PCT school-based organized the following year.

**Study area**

The republic of Benin is divided into 12 departments (political subdivisions), which are further divided into 77 districts. A total population is 10,008,749 inhabitants with 29.7% of total population of school age children (5–14 year old). These districts are divided into 545 sub-districts and into 3755 villages. Each sub-district has at least one unit of health and each village has at least one public school. All of the 77 districts were sampled in this study. Rainfall intensifies from the south to the north of the country. In the northern departments (Atacora, Donga, Borgou and Alibori), the annual rainfall varies between 900 mm and 1200 mm with numerous lakes and rivers feeding the region. In the southern departments (Collines, Zou, Atlantic,
Littoral, Mono, Couffo Plateau and Oueme), the annual rainfall varies from 800 mm to 1200 mm [12]. The geographical location of each school surveyed, including altitude and Universal Transverse Mercator coordinates are provided in S1 Table.

**Study design and stool collection**

This study was carried out from 2013 to 2015 in all 77 districts of Benin (S1 Table). In each district, five primary schools were selected as previously described [13]. From each selected school, 50 children (25 girls and 25 boys) aged between 8 and 14 years were randomly selected. The children were given a container to provide stool samples. The containers were distributed by a team of lab technicians and the samples were collected within an hour.

**Detection of STH in stool samples**

The stool samples were analyzed using the Kato-Katz method as previously described [13]. Although the Kato-Katz method has some limitations, especially in terms of sensitivity in settings with low infection intensities [14,15], this technique is the standard approach for highly endemic areas such as Benin [16]. In this study, the kits used were manufactured by Vestergaard Frandsen Group and 41.7 mg of stool was filtered through a nylon mesh and covered with cellophane previously soaked in 50% green-malachite [17]. Only one smear was prepared and examined per stool sample. The slides were observed under microscope by two technicians and their results were validated by a third slide-reader. Especially, hookworm eggs were counted from 20 to 60 minutes after the slide was prepared and other soil-transmitted helminth eggs (A. lumbricoides, T. trichiura) were counted 24 hours later. The presence of infection was recorded; the number of eggs for each parasite was tallied and the intensity of infection was reported as the number of eggs per gram of feces (epg). Egg counts were used to classify the intensity of infection into light (L), moderate (M), or heavy (H) as follows: for *A. duodenale / N. americanus* (not distinguished hookworms) 1–1,999 epg (L), 2,000–3,999 epg (M) and ≥4,000 epg (H); for *A. lumbricoides*, 1–4,999 epg (L), 5,000–49,999 epg (M) and ≥50,000 epg (H); for *T. trichiura*, 1–999 epg (L), 1,000–9,999 epg (M) and ≥10,000 epg (H) [18]. The cumulative prevalence of STH infections reflects the number of individuals infected with any one of the three STH parasites. Cases of co-infection were counted once. For quality control purposes, 10% of the slides prepared on the previous day were examined each day by an independent team of biologists.

**Data analysis**

Data were double entered into Microsoft Excel 2008 (Redmond, Washington, USA). Range and consistency checks were conducted for all non-string variables. Descriptive statistics and prevalence estimates were calculated using Epi-Info 7 (CDC, Atlanta, USA) and all results with a P value of <0.05 were considered significant. The multiple comparison test chi square proportions were used to compare the prevalence by departments. The Fisher exact method of maximum likelihood and calculation of confidence intervals was used to calculate odds ratios by gender in each of the districts.

A Z-test was used to compare prevalence values between two districts and between the gender and Chi square to compare prevalence values between districts of each department. Any district with a prevalence of infection above 50% was defined as a “hotspot” of the corresponding parasite.
Results

In total, stool samples from 19,250 school-children (9,625 boys and 9,625 girls) were screened in 385 schools of the 77 districts of the twelve departments using Kato-Katz technique. The eggs of several helminths (STH, Schistosoma and other) were found but this paper focuses only on STH infection.

Distribution of hookworm infections

Hookworm infection was detected in all the surveyed districts with a prevalence ranging from 0.4% to 60% (Table 1). The national average prevalence of hookworm infection was 17.4% (95% CI: 16.6%-17.6%). The district of Djakotomey in the department of Couffo had the highest prevalence (60%) with hookworm infection detected in 150 children, whereas only one case was detected in the districts of Aguegue and Porto-Novo in the department of Oueme. In two districts (Toffo and Djakotomey), hookworm infection was detected in more than 50% of the surveyed children. The prevalence of hookworm infection was below 10% in 29/77 districts, and in 18 and 28 districts the prevalence ranged from 10% to 19.2% and from 20% to 43.2%, respectively. The intensity of the infection was light in most of the surveyed schools. However, moderate and heavy infections have been detected in different regions of the country with the highest prevalence of heavy infections observed in the districts of Copargo (16.67% of the infections) and Ouake (17.58%), both in the department of Djougou. In these two districts located in the northern part of the country, 33.33% (Copargo) and 27.47% (Ouake) of the hookworm infections were defined as moderate.

Prevalence of *A. lumbricoides* infection

Ascariasis is less widely distributed compared to hookworm and the overall prevalence of infection was 5.35% (95% CI:5.00%-5.60%). No Ascaris infection was detected in 15 districts (Table 2). In the other districts where Ascaris infection was detected, the prevalence ranged from 0.4% to 26.4%. The highest prevalence was observed in Toffo (26.4%), in the department of Atlantique in southern Benin, along with the district of Allada (21.20%) from the same department, and the districts of Bante (22.40%) and Glazoue (23.20%) both from the department of Collines. In these 4 districts, the prevalence of Ascaris infection was ≥20%. In 48/77 districts, the prevalence of Ascaris infection was <10%, whereas 10/77 districts had prevalence values between 10% and 18%. Most of the detected infections had light parasite load. All over the country, Ascaris infections with heavy parasite intensity were detected in only 6 districts, the highest being observed at Ouake (13% of infections) in the department of Djougou (Table 2). Ascaris infections with moderate parasite intensity were found in the 20 districts including the 6 districts with heavy parasite intensity.

*T. trichiura* infections in Benin

*T. trichiura* had the lowest prevalence at district and national level. The overall prevalence was 1.15% (Table 3). Trichuris infection was absent in 40/77 districts and most of the infections were detected at prevalence <10% in the other 37 districts. In these districts, the prevalence of Trichuris infection varied between 0.4% and 9.6%. Districts of Dassa-Zoume and Dogbo in the departments of Collines and Couffo respectively, had the highest (9.6%) prevalence of Trichuris infections. Along with these two districts, the districts of Materi in the department of Atacora, and Glazoue in the department of Collines were the only 4 districts with prevalence >5%. As for the other parasites screened in this study, the intensity of the Trichuris
| Department | District | Infected/Examined | Prevalence [95% CI] | Light n (%) | Moderate n (%) | Heavy n (%) |
|------------|----------|-------------------|---------------------|-------------|--------------|------------|
|            |          |                   |                     | 1–1999 epg  | 2000–3999 epg | ≥4000 epg  |
| ATACORA    | COBLI    | 76/250            | 30.40 [24.7–36.1]   | 72 (94.74)  | 4 (5.26)     | 0          |
|            | BOUKOUMBE| 33/250            | 13.20 [9.0–17.4]    | 31 (93.94)  | 2 (6.06)     | 0          |
|            | MATERI   | 27/250            | 10.80 [6.9–14.6]    | 27 (100.00) | 0            | 0          |
|            | KOUANDE  | 54/250            | 21.60 [16.5–26.7]   | 52 (96.30)  | 2 (3.70)     | 0          |
|            | TOUKOUMANNA | 11/250   | 4.40 [1.8–6.9]     | 11 (100.00) | 0            | 0          |
|            | TANGUIETTA | 26/250   | 10.40 [6.6–14.1]   | 26 (100.00) | 0            | 0          |
|            | NAITITINGOU | 15/250   | 6.00 [3.0–8.9]     | 15 (100.00) | 0            | 0          |
|            | KEROU    | 37/250            | 15.00 [10.6–19.4]   | 25 (67.57)  | 12 (32.43)   | 0          |
|            | PEHUNCO  | 15/250            | 6.00 [3.0–8.9]     | 10 (66.67)  | 5 (33.33)    | 0          |
| DONGA      | BASSILA  | 108/250           | 43.20 [37.0–49.3]   | 102 (94.44) | 2 (1.85)     | 4 (3.70)   |
|            | DJOUGOU  | 16/250            | 6.40 [3.4–9.4]     | 16 (100.00) | 0            | 0          |
|            | COPARGO  | 90/250            | 36.00 [30.0–41.9]   | 45 (50.00)  | 30 (33.33)   | 15 (16.67) |
|            | OUAKE    | 91/250            | 36.40 [30.4–42.4]   | 50 (54.95)  | 25 (27.47)   | 16 (17.58) |
| BORGOU     | NIKKI    | 18/250            | 7.20 [4.0–10.4]    | 17 (94.44)  | 1 (5.56)     | 0          |
|            | PERERE   | 44/250            | 17.60 [12.9–22.3]   | 43 (97.73)  | 1 (2.27)     | 0          |
|            | TCHAOUROU | 48/250   | 19.20 [14.3–24.1]  | 48 (100.00) | 0            | 0          |
|            | PARAKOU  | 53/250            | 21.20 [16.1–26.3]  | 52 (98.11)  | 1 (1.89)     | 0          |
|            | SINENDE  | 14/250            | 5.60 [2.7–8.4]     | 14 (100.00) | 0            | 0          |
|            | BEMBEREKE | 15/250   | 6.00 [3.0–8.9]     | 15 (100.00) | 0            | 0          |
|            | N’DALI   | 57/250            | 23.00 [17.8–28.2]   | 30 (52.63)  | 20 (35.09)   | 7 (12.28)  |
|            | KALALE   | 65/250            | 26.00 [20.6–31.4]   | 32 (49.23)  | 25 (38.46)   | 8 (12.31)  |
| ALIBORI    | BANIKOARA | 19/250   | 7.60 [4.3–10.9]    | 19 (100.00) | 0            | 0          |
|            | GOGOUNOU | 26/250            | 10.40 [6.6–14.2]   | 26 (100.00) | 0            | 0          |
|            | MALANVILLE | 7/250   | 2.80 [0.7–4.8]     | 7 (100.00)  | 0            | 0          |
|            | KARIMAMA | 3/250            | 1.20 [0–2.5]       | 3 (100.00)  | 0            | 0          |
|            | SEGABANA | 35/250            | 14.00 [9.7–18.3]   | 35 (100.00) | 0            | 0          |
|            | KANDI    | 12/250            | 4.80 [2.1–7.4]     | 12 (100.00) | 0            | 0          |
| COLLINES   | DASSA-ZOUME | 76/250   | 30.40 [24.7–36.1]  | 74 (97.36)  | 1 (1.32)     | 1 (1.32)   |
|            | OUESSE   | 74/250            | 29.60 [23.9–35.2]  | 70 (94.60)  | 3 (4.05)     | 1 (1.35)   |
|            | SAVÈ     | 73/250            | 29.20 [23.6–34.8]  | 67 (91.78)  | 1 (1.37)     | 5 (6.85)   |
|            | BANTE    | 61/250            | 24.40 [19.1–29.7]  | 60 (98.36)  | 1 (1.64)     | 0          |
|            | GLAZOUZE | 61/250            | 24.40 [19.1–29.7]  | 61 (100.00) | 0            | 0          |
|            | SAVALOU  | 42/250            | 16.80 [12.2–21.4]  | 36 (85.71)  | 6 (14.29)    | 0          |
| ZOU        | ABOMEY   | 15/250            | 6.00 [3.0–8.9]     | 14 (93.33)  | 0            | 1 (6.67)   |
|            | AGBANGNIZOUN | 55/250  | 22.00 [16.9–27.1]  | 53 (96.36)  | 1 (1.82)     | 1 (1.82)   |
|            | BOHICON  | 23/250            | 9.20 [5.6–12.8]    | 23 (100.00) | 0            | 0          |
|            | COVE     | 70/250            | 28.00 [22.4–33.6]  | 63 (90.00)  | 6 (8.57)     | 1 (1.43)   |
|            | DJIDJA   | 45/250            | 18.00 [13.2–22.8]  | 43 (95.56)  | 2 (4.44)     | 0          |
|            | OUINHI   | 30/250            | 12.00 [8.0–16]     | 29 (96.67)  | 1 (3.33)     | 0          |
|            | ZAKPOTA  | 58/250            | 23.20 [18.0–28.4]  | 55 (94.83)  | 1 (1.72)     | 2 (3.45)   |
|            | ZOGBODOMEY | 77/250  | 30.20 [24.5–35.9]  | 77 (100.00) | 0            | 0          |
|            | ZAGNANADO | 24/250   | 9.60 [5.9–13.2]    | 21 (87.50)  | 2 (8.33)     | 1 (4.17)   |

(Continued)
Infections was light, whereas moderate and heavy infections were observed in 12 and 4 districts, respectively. In the district of Dassa-zoume, heavy infection (41.67%; 95% CI: 35.56%-47.78%) was more prevalent as compared to moderate (20.83%; 95% CI: 15.79%-25.86%) and light (35.50%; 95% CI: 29.57%-41.43%) infections.

### Table 1. (Continued)

| Department | District       | Infected/Examined | Prevalence [95% CI] | Light n (%) | Moderate n (%) | Heavy n (%) |
|------------|----------------|-------------------|---------------------|-------------|---------------|-------------|
|            |                |                   |                     | 1–1999 epg  | 2000–3999 epg | ≥4000 epg   |
| OUÈME      | ADJARRA        | 19/250            | 7.60 [4.3–10.9]     | 19 (100.00) | 0             | 0           |
|            | Adiohou        | 33/250            | 13.20 [9.0–17.4]    | 32 (96.97)  | 0             | 1 (3.03)    |
|            | AGUEGUE       | 1/250             | 0.40 [0–1.2]        | 1 (100.00)  | 0             | 0           |
|            | AKPRO-MISERETE| 50/250            | 20.00 [15.0–24.9]   | 48 (96.00)  | 1 (2.00)      | 1 (2.00)    |
|            | AVRANKOU       | 22/250            | 8.80 [5.3–12.3]     | 22 (100.00) | 0             | 0           |
|            | BONOU          | 15/250            | 6.00 [3.0–8.9]      | 15 (100.00) | 0             | 0           |
|            | DANGBO         | 12/250            | 4.80 [2.1–7.4]      | 12 (100.00) | 0             | 0           |
|            | PORTO-NOVO     | 1/250             | 0.40 [0–1.2]        | 1 (100.00)  | 0             | 0           |
|            | SÈME-KPODJJI   | 14/250            | 5.60 [2.7–8.4]      | 14 (100.00) | 0             | 0           |
| PLATEAU    | ADJA-OUERE     | 34/250            | 13.60 [9.3–17.8]    | 32 (94.12)  | 1 (2.94)      | 1 (2.94)    |
|            | IFANJNÈ        | 80/250            | 32.00 [26.2–37.8]   | 70 (87.50)  | 6 (7.50)      | 4 (5.00)    |
|            | POBE           | 66/250            | 26.40 [20.9–31.9]   | 63 (95.45)  | 2 (3.03)      | 1 (1.52)    |
|            | KETOU          | 70/250            | 28.00 [22.4–33.6]   | 64 (91.43)  | 5 (7.14)      | 1 (1.43)    |
|            | SAKÈTÈ         | 66/250            | 26.40 [20.9–31.9]   | 63 (95.45)  | 3 (4.55)      | 0           |
| ATLANTIQUE | ABOIMEY-CAVALI | 25/250            | 10.00 [6.2–13.7]    | 18 (72.00)  | 6 (24.00)     | 1 (4.00)    |
|            | ALLADA         | 27/250            | 10.80 [6.9–14.6]    | 26 (96.30)  | 1 (3.70)      | 0           |
|            | KPOMASSE       | 12/250            | 4.80 [2.1–7.4]      | 11 (91.67)  | 0             | 1 (8.33)    |
|            | OUIDAH         | 24/250            | 9.60 [5.9–13.2]     | 24 (100.00) | 0             | 0           |
|            | SÔ-AVA         | 5/250             | 2.00 [0.3–3.7]      | 5 (100.00)  | 0             | 0           |
|            | TOFFO          | 125/250           | 50.00 [43.8–56.2]   | 121 (96.80) | 4 (3.20)      | 0           |
|            | TÔRI-BISSÔTO   | 80/250            | 32.00 [26.2–37.8]   | 78 (97.50)  | 2 (2.50)      | 0           |
|            | ZE             | 69/250            | 27.60 [22.0–33.1]   | 67 (97.10)  | 2 (2.90)      | 0           |
| LITTORAL   | COTONOU        | 6/250             | 2.40 [0.5–4.3]      | 6 (100.00)  | 0             | 0           |
| COUFFO     | APLAHOU        | 81/250            | 32.40 [26.6–38.2]   | 81 (100.00) | 0             | 0           |
|            | DIJAKOTOMEY    | 150/250           | 60.00 [53.9–66.0]   | 142 (94.67) | 6 (4.00)      | 2 (1.33)    |
|            | DOBO           | 3/250             | 1.20 [0.0–2.5]      | 3 (100.00)  | 0             | 0           |
|            | KLOUEKAME      | 96/250            | 38.40 [32.3–44.4]   | 94 (97.92)  | 2 (2.08)      | 0           |
|            | LALO           | 73/250            | 29.20 [23.5–34.8]   | 58 (79.45)  | 12 (16.44)    | 3 (4.11)    |
|            | TOVIKLIN       | 46/250            | 18.40 [13.5–23.2]   | 45 (97.83)  | 1 (2.17)      | 0           |
| MONO       | ATHIÈME        | 30/250            | 12.00 [8.0–16.0]    | 25 (83.33)  | 5 (16.67)     | 0           |
|            | BOPA           | 22/250            | 8.80 [5.3–12.3]     | 22 (100.00) | 0             | 0           |
|            | COME           | 10/250            | 4.00 [1.6–6.4]      | 9 (90.00)   | 1 (10.00)     | 0           |
|            | GRAND POPO     | 20/250            | 8.00 [4.6–11.3]     | 18 (90.00)  | 2 (10.00)     | 0           |
|            | HOUEYOGBE      | 38/250            | 15.20 [10.7–19.6]   | 36 (94.74)  | 2 (5.26)      | 0           |
|            | LOKOSSA        | 76/250            | 30.40 [24.7–36.1]   | 71 (93.42)  | 4 (5.26)      | 1 (1.32)    |
| SYNTHESIÈS | 3300/19250     | 17.14 [16.6–17.6]  | 2997 (90.82)        | 222 (6.73)  | 21 (2.45)     |            |

https://doi.org/10.1371/journal.pntd.0006241.t001
Table 2. Prevalence (%) and intensity of *A. lumbricoides* infections.

| Department | District | Infected/Examined | Prevalence [95% IC] | Parasite load |
|------------|---------|-------------------|----------------------|--------------|
|            |         |                   |                      | Light n (%)  | Moderate n (%) | Heavy n (%) |
|            |         |                   |                      | 1–4999 epg   | 5000–49999 epg | ≥50000 epg |
| ATACORA    | COBLI   | 13/250            | 5.20 [2.4–7.9]       | 13 (100)     | 0             | 0           |
|            | BOUKOUMBE | 32/250         | 12.80 [8.6–16.9]     | 32 (100)     | 0             | 0           |
|            | MATERI  | 32/250            | 12.80 [8.6–16.9]     | 30 (93.75)   | 2 (6.25)      | 0           |
|            | KOUANDE | 16/250            | 6.40 [3.4–9.4]       | 15 (93.75)   | 1 (6.25)      | 0           |
|            | TOUKOUNTOUNA | 15/250      | 6.00 [3.0–8.9]       | 15 (100)     | 0             | 0           |
|            | TANGUIETA | 12/250         | 4.80 [2.1–7.4]       | 12 (100)     | 0             | 0           |
|            | NATITINGOU | 0/250         | 0                   | 0            | 0             | 0           |
|            | KEROU   | 7/250             | 3.00 [0.9–5.1]       | 7 (100)      | 0             | 0           |
|            | PEHUNCO | 0/250             | 0                   | 0            | 0             | 0           |
| DONGA      | BASSILA | 0/250             | 0                   | 0            | 0             | 0           |
|            | DJOUGOU | 0/250             | 0                   | 0            | 0             | 0           |
|            | COPARGO | 9/250             | 4.00 [1.6–6.4]       | 9 (100)      | 0             | 0           |
|            | OUAKE   | 45/250            | 18.00 [13.2–22.8]    | 30 (66.67)   | 9 (20.00)     | 6 (13.33)  |
| BORGOU     | NIKKI   | 0/250             | 0                   | 0            | 0             | 0           |
|            | PERERE  | 0/250             | 0                   | 0            | 0             | 0           |
|            | TCHAOUROU | 14/250        | 5.60 [2.7–8.4]       | 14 (100)     | 0             | 0           |
|            | PARAKOU | 17/250            | 6.80 [3.7–9.9]       | 17 (100)     | 0             | 0           |
|            | SINENDE | 8/250             | 3.20 [1.0–5.4]       | 8 (100)      | 0             | 0           |
|            | BEMBEREKE | 7/250          | 3.00 [0.9–5.1]       | 6 (85.7)     | 1 (14.3)      | 0           |
|            | NDALI   | 0/250             | 0                   | 0            | 0             | 0           |
|            | KALALE  | 0/250             | 0                   | 0            | 0             | 0           |
| ALIBORI    | BANIKOARA | 25/250         | 10.00 [6.3–13.7]     | 25 (100)     | 0             | 0           |
|            | GOGOUNOU | 14/250         | 5.60 [2.7–8.4]       | 14 (100)     | 0             | 0           |
|            | MALANVILLE | 15/250        | 6.00 [3.0–8.9]       | 15 (100)     | 0             | 0           |
|            | KARIMAMA | 6/250             | 2.40 [0.5–4.3]       | 6 (100)      | 0             | 0           |
|            | SEGBAHA | 33/250            | 13.20 [9.0–17.4]     | 33 (100)     | 0             | 0           |
|            | KANDI   | 9/250             | 3.60 [1.3–5.9]       | 9 (100)      | 0             | 0           |
| COLLINES   | DASSA-ZOUME | 1/250          | 0.40 [0–1.2]         | 1 (100.00)   | 0             | 0           |
|            | OUESSE  | 0/250             | 0                   | 0            | 0             | 0           |
|            | SAVÈ    | 3/250             | 1.20 [0–2.5]         | 3 (100.00)   | 0             | 0           |
|            | BANTE   | 56/250            | 22.40 [17.2–27.6]    | 56 (100)     | 0             | 0           |
|            | GLAZOUE | 58/250            | 23.20 [18.0–28.4]    | 58 (100)     | 0             | 0           |
|            | SAVALOU | 11/250            | 4.40 [1.8–6.9]       | 11 (100)     | 0             | 0           |
| ZOU        | ABOIMEY | 1/250             | 0.40 [0–1.2]         | 1 (100.00)   | 0             | 0           |
|            | AGBANGNIZOUN | 2/250        | 0.80 [0–1.9]         | 2 (100.00)   | 0             | 0           |
|            | BOHICON   | 2/250            | 0.80 [0–1.9]         | 2 (100.00)   | 0             | 0           |
|            | COVÈ    | 0/250             | 0                   | 0            | 0             | 0           |
|            | DJIDJA  | 0/250             | 0                   | 0            | 0             | 0           |
|            | OUINHI  | 36/250            | 14.40 [10–18.7]      | 18 (50.00)   | 18 (50.00)    | 0           |
|            | ZAKPOTA | 5/250             | 2.00 [0.3–3.7]       | 5 (100.00)   | 0             | 0           |
|            | ZOGBODOMEY | 8/250          | 3.20 [1.0–5.4]       | 8 (100.00)   | 0             | 0           |
|            | ZAGNANADO | 3/250           | 1.20 [0–2.5]         | 3 (100.00)   | 0             | 0           |

(Continued)
Soil-transmitted helminthiasis endemicity and preventive chemotherapy strategy

Cumulative prevalence of the surveyed STH parasites was analyzed by combining the determined prevalence of hookworm, Ascaris and Trichuris infections (Table 4). At least one of the three species of the targeted STH was found in all 77 surveyed districts. The average cumulative prevalence of STH infection was 22.74% (95% CI 22.15%-23.33%) and 58.44% (45/77) of

Table 2. (Continued)

| Department    | District       | Infected/Examined | Prevalence [95% IC] | Parasite load |
|---------------|----------------|-------------------|---------------------|---------------|
|               |                |                   | Light n (%) 1| Moderate n (%) 5000–49999 epg | Heavy n (%) ≥50000 epg |
|               |                |                   | 1–4999 epg 5000 |                  |               |
| OUÉME         | ADJARRA        | 6/250              | 2.40 [0.5–4.3] | 6 (100.00) | 0            | 0          |
|               | ADJOHOUN       | 0/250              | 0                 | 0             | 0            | 0          |
|               | AGUEGUE        | 12/250             | 4.80 [2.1–7.4] | 12 (100.00) | 0            | 0          |
|               | AKPRO-MISSERET| 4/250              | 1.60 [0.04–3.1] | 4 (100.00) | 0            | 0          |
|               | AVRANKOU       | 0/250              | 0                 | 0             | 0            | 0          |
|               | BONOU          | 0/250              | 0                 | 0             | 0            | 0          |
|               | DANGBO         | 3/250              | 1.20 [0–2.5] | 3 (100.00) | 0            | 0          |
|               | PORTO-NOVO     | 1/250              | 0.40 [0–1.2] | 1 (100.00) | 0            | 0          |
|               | SEME-KPODJI    | 18/250             | 7.20 [4.0–10.4] | 12 (66.67) | 6 (33.33) | 0          |
| PLATEAU       | ADJA OUERE     | 37/250             | 14.80 [10.4–19.2] | 29 (78.38) | 8 (21.62) | 0          |
|               | IFANGNI        | 18/250             | 7.20 [4.0–10.4] | 8 (44.44) | 9 (50.00) | 1 (5.56) |
|               | POBE           | 34/250             | 13.60 [9.5–17.8] | 17 (50.00) | 17 (50.00) | 0          |
|               | KETOU          | 1/250              | 0.40 [0–1.2] | 1 (100.00) | 0            | 0          |
|               | SAKÉTÉ         | 9/250              | 3.60 [1.3–5.9] | 9 (100.00) | 0            | 0          |
| ATLANTIQUE    | ABOMEY-CALAVI  | 7/250              | 2.80 [0.7–4.8] | 7 (100.00) | 0            | 0          |
|               | ALLADA         | 53/250             | 21.20 [16.1–26.2] | 30 (56.60) | 23 (43.40) | 0          |
|               | KPOMASSE       | 2/250              | 0.80 [0–1.9] | 2 (100.00) | 0            | 0          |
|               | OUIDAH         | 4/250              | 1.60 [0.4–3.1] | 4 (100.00) | 0            | 0          |
|               | SÔ-AVA         | 15/250             | 6.00 [3.0–8.9] | 10 (66.67) | 5 (33.33) | 0          |
|               | TOFFO          | 66/250             | 26.40 [20.9–31.9] | 49 (74.24) | 16 (24.24) | 1 (1.52) |
|               | TORI-BOSSITO   | 0/250              | 0                 | 0             | 0            | 0          |
|               | ZE             | 23/250             | 9.20 [5.6–12.8] | 19 (82.61) | 4 (17.39) | 0          |
| LITTORAL      | COTONOU        | 7/250              | 2.80 [0.7–4.8] | 7 (100.00) | 0            | 0          |
| COUFFO        | APLAHOUJ       | 41/250             | 16.40 [11.8–20.9] | 41 (100) | 0            | 0          |
|               | DJAKOTOMEY     | 21/250             | 8.40 [5.0–11.8] | 17 (80.95) | 3 (14.29) | 1 (4.76) |
|               | DOGBO          | 8/250              | 3.20 [1.0–5.4] | 8 (100) | 0            | 0          |
|               | KLOUEKAME      | 6/250              | 2.40 [0.5–4.3] | 4 (66.67) | 2 (33.33) | 0          |
|               | LALO           | 17/250             | 6.80 [3.7–9.9] | 7 (41.18) | 6 (35.29) | 4 (23.53) |
|               | TOVIKLIN       | 21/250             | 8.40 [5.0–11.8] | 17 (80.95) | 3 (14.29) | 1 (4.76) |
| MONO          | ATHIEME        | 4/250              | 1.60 [0.4–3.1] | 3 (75.00) | 1 (25.00) | 0          |
|               | BOPA           | 7/250              | 2.80 [0.7–4.8] | 7 (100) | 0            | 0          |
|               | COME           | 39/250             | 15.60 [11.1–20.1] | 27 (69.23) | 12 (30.77) | 0          |
|               | GRAND POPO     | 1/250              | 0.40 [0–1.2] | 1 (100) | 0            | 0          |
|               | HOUEYOGBE      | 13/250             | 5.20 [2.4–7.9] | 13 (100) | 0            | 0          |
|               | LOKOSSA        | 17/250             | 6.80 [3.7–9.9] | 16 (94.12) | 1 (5.88) | 0          |
| SYNTHESIS     | 1030/19250     | 5.35 [5.0–5.6] | 869 (84.37) | 147 (14.27) | 14 (1.36) | 0          |

https://doi.org/10.1371/journal.pntd.0006241.t002
| Department | District     | Infected/Examined | Prevalence [95% IC] | Parasites Load |   |
|------------|-------------|-------------------|---------------------|----------------|---|
|            |             |                   |                     | Light n (%)    |   |
|            |             |                   |                     | Moderate n (%) |   |
|            |             |                   |                     | Heavy n (%)    |   |
|            |             |                   |                     | 1–999 epg      | 1000–9999 epg | ≥10000 epg |
| ATACORA    | COBLI       | 0/250              | 0                   | 0              | 0 |
|            | BOUKOUMBE   | 6/250              | 2.40 [0.5–4.3]      | 6 (100)        | 0 |
|            | MATERI      | 23/250             | 9.20 [5.6–12.8]     | 20 (86.96)     | 3 (13.04) |
|            | KOUANDE     | 0/250              | 0                   | 0              | 0 |
|            | TOUKOUNTOUNA| 0/250              | 0                   | 0              | 0 |
|            | TANGUITIA   | 0/250              | 0                   | 0              | 0 |
|            | NATITINGOU  | 0/250              | 0                   | 0              | 0 |
|            | KEROU       | 0/250              | 0                   | 0              | 0 |
|            | PEHUNCO     | 0/250              | 0                   | 0              | 0 |
| DONGA      | BASSILA     | 0/250              | 0                   | 0              | 0 |
|            | DIOUGOU     | 0/250              | 0                   | 0              | 0 |
|            | COPARGO     | 0/250              | 0                   | 0              | 0 |
|            | KEROU       | 0/250              | 0                   | 0              | 0 |
| BORGOU     | NIKKI       | 1/250              | 0.40 [0–1.2]        | 1 (100.00)     | 0 |
|            | PERÈRE      | 0/250              | 0                   | 0              | 0 |
|            | TCHAOUROU   | 8/250              | 3.20 [1–5.4]        | 6 (75.00)      | 2 (25.00) |
|            | PARAKOU     | 2/250              | 0.80 [0–1.9]        | 2 (100)        | 0 |
|            | SINENDE     | 0/250              | 0                   | 0              | 0 |
|            | BEMBEREKE   | 0/250              | 0                   | 0              | 0 |
|            | N’DALI      | 0/250              | 0                   | 0              | 0 |
|            | KALALE      | 0/250              | 0                   | 0              | 0 |
| ALIBORI    | BANIKOARA   | 3/250              | 1.20 [0–2.5]        | 3 (100)        | 0 |
|            | GOGOUNOU    | 0/250              | 0                   | 0              | 0 |
|            | MALANVILLE  | 0/250              | 0                   | 0              | 0 |
|            | KARIMAMA    | 0/250              | 0                   | 0              | 0 |
|            | SEGĐANA     | 4/250              | 1.60 [0.04–3.1]     | 4 (100)        | 0 |
|            | KANDI       | 0/250              | 0                   | 0              | 0 |
| COLLINES   | DASSA-ZOUMÈ | 24/250             | 9.60 [5.9–13.2]     | 9 (37.50)      | 5 (20.83) |
|            | OUÉSSÉ      | 4/250              | 1.60 [0.04–3.1]     | 3 (75.00)      | 0 (0.00) |
|            | SAVÈ        | 4/250              | 1.60 [0.04–3.1]     | 4 (100.00)     | 0 |
|            | BANTE       | 0/250              | 0                   | 0              | 0 |
|            | GLAZOUJE    | 21/250             | 8.40 [5–11.8]       | 21 (100)       | 0 |
|            | SAVALOU     | 5/250              | 2.00 [0.3–3.7]      | 5 (100)        | 0 |
| ZOU        | ABOMÉY      | 1/250              | 0.40 [0–1.2]        | 1 (100.00)     | 0 |
|            | AGBANGNIZOUN| 1/250              | 0.40 [0–1.2]        | 1 (100.00)     | 0 |
|            | BOHICON     | 3/250              | 1.20 [0–2.5]        | 3 (100.00)     | 0 |
|            | COVÈ        | 5/250              | 2.00 [0.3–3.7]      | 2 (40.00)      | 1 (20.00) |
|            | DJIDJA      | 5/250              | 2.00 [0.3–3.7]      | 2 (40.00)      | 1 (20.00) |
|            | OUINHI      | 1/250              | 0.40 [0–1.2]        | 0              | 1 (100.00) |
|            | ZAKPOTA     | 10/250             | 4.00 [1.6–6.4]      | 7 (70.00)      | 3 (30.00) |
|            | ZOGBODOMEY  | 1/250              | 0.40 [0–1.2]        | 1 (100.00)     | 0 |
|            | ZAGNANADO   | 3/250              | 1.20 [0–2.5]        | 3 (100.00)     | 0 |

(Continued)
the surveyed districts needed preventive chemotherapy (Table 4), as defined by WHO (STH prevalence ≥20%). Two rounds of PCT per year was needed in the districts of Toffo and Djakotomey where the detected STH prevalence was >50% (Table 4) using WHO guidelines [15]. Boys were significantly more likely to be infected compared to girls (S2 Table), with both hookworm and Ascaris, with average prevalence of 20.31% v. 14.03% (Z = 11.53; p < 0.00001).

| Department | District | Infected/Examined | Prevalence[95% IC] | Parasites Load | Light n (%) | Moderate n (%) | Heavy n (%) |
|------------|----------|------------------|-------------------|---------------|-------------|---------------|-------------|
|            |          |                  |                   |               | 1–999 epg   | 1000–9999 epg | ≥10000 epg   |
| OUEME      | ADJARRA  | 4/250            | 1.60[0.04–3.1]    | 4 (100.00)    | 0           | 0             |
|            | ADJOHOUN | 0/250            | 0                 | 0             | 0           | 0             |
|            | AGUÉGUÉ | 0/250            | 0                 | 0             | 0           | 0             |
|            | AKPRO-MISSÉRÉTÉ | 0/250 | 0 | 0 | 0 | 0 |
|            | AVRANKOU | 1/250            | 0.40[0–1.2]       | 1 (100.00)    | 0           | 0             |
|            | BONOU    | 1/250            | 0.40[0–1.2]       | 0             | 1 (100.00)  | 0             |
|            | DANGBO   | 2/250            | 0.80[0–1.9]       | 2 (100.00)    | 0           | 0             |
|            | PORTO-NOVO | 3/250 | 1.20[0–2.5]     | 3 (100.00)    | 0           | 0             |
|            | SÉMÉ-KPODJI | 3/250 | 1.20[0–2.5]     | 3 (100.00)    | 0           | 0             |
| PLATEAU    | ADJA OUÉRÈ | 1/250 | 0.40[0–1.2]     | 1 (100.00)    | 0           | 0             |
|            | IFANGNI  | 2/250            | 0.80[0–1.9]       | 2 (100.00)    | 0           | 0             |
|            | POBÉ     | 0/250            | 0                 | 0             | 0           | 0             |
|            | KÉTOU    | 0/250            | 0                 | 0             | 0           | 0             |
|            | SAKÉTÉ   | 0/250            | 0                 | 0             | 0           | 0             |
| ATLANTIQUE | ABOIMEY-CALAVI | 0/250 | 0 | 0 | 0 | 0 |
|            | ALLADA   | 0/250            | 0                 | 0             | 0           | 0             |
|            | KPMASSE  | 0/250            | 0                 | 0             | 0           | 0             |
|            | OUIDAH   | 3/250            | 1.20[0–2.5]       | 3 (100.00)    | 0           | 0             |
|            | SÔ-AVA   | 0/250            | 0                 | 0             | 0           | 0             |
|            | TOFFO    | 2/250            | 0.80[0–0.19]      | 1 (50.00)     | 1 (50.00)   | 0             |
|            | TORI-BOSSITO | 0/250 | 0 | 0 | 0 | 0 |
|            | ZÈ       | 2/250            | 0.80[0–0.19]      | 1 (50.00)     | 1 (50.00)   | 0             |
| LITTORAL   | COTONOU  | 10/250           | 4.00[1.6–6.4]     | 2 (20.00)     | 8 (80.00)   | 0             |
| COUFO      | APLAHOUÉ | 7/250            | 2.80[0.7–4.8]     | 7 (100)       | 0           | 0             |
|            | DJAKOTOMEY | 0/250 | 0 | 0 | 0 | 0 |
|            | DOGBO    | 24/250           | 9.60[5.9–13.2]    | 22 (91.67)    | 1 (4.17)    | 0             |
|            | KLOUEKAME | 0/250 | 0 | 0 | 0 | 0 |
|            | LALO     | 0/250            | 0                 | 0             | 0           | 0             |
|            | TOVIKLIN | 0/250            | 0                 | 0             | 0           | 0             |
| MONO       | ATHIEME  | 0/250            | 0                 | 0             | 0           | 0             |
|            | BOPA     | 0/250            | 0                 | 0             | 0           | 0             |
|            | COME     | 12/250           | 4.80[2.1–7.4]     | 12 (100)      | 0           | 0             |
|            | GRAND POPO | 0/250 | 0 | 0 | 0 | 0 |
|            | HOUEYOGBE | 9/250 | 3.60[1.3–5.9]   | 9 (100)       | 0           | 0             |
|            | LOKOSA   | 0/250            | 0                 | 0             | 0           | 0             |
| SYNTHESIS  |          | 221/19250        | 1.15[0.9–1.2]     | 177 (80.45)   | 29 (13.18)  | 14 (6.36)    |

https://doi.org/10.1371/journal.pntd.0006241.t003
Table 4. Cumulative STH (hookworms, Ascaris and Trichuris) prevalence and PCT strategy (n: Schoolchildren co-infected by at least two STH species; schoolchildren co-infected were counted once; n1: Number of schoolchildren infected per department; PCT: Preventive chemotherapy; SAC: School age children).

| Department | District | Parasitological data | STH Prevalence[95% CI] | X2 p-Value n1 (%) | PCT strategy |
|------------|---------|----------------------|------------------------|-------------------|--------------|
| ATACORA    | COBLI   | 76/250               | 30.40[24.7–36.1]       | X2 = 134.031 p<0.00001 453 (20.13) | 1PCT/Year for SAC |
|            | BOUKOUMBE | 71/250             | 28.40[22.8–34.0]       |                   | 1PCT/Year for SAC |
|            | MATERI   | 76/250               | 30.40[24.7–36.1]       |                   | 1PCT/Year for SAC |
|            | KOUANDE   | 70/250               | 28.00[22.4–33.6]       |                   | No PCT |
|            | TOUKOUNTOUNA | 26/250           | 10.40[6.6–14.2]        |                   | No PCT |
|            | TANGUIETTA | 61/250              | 24.40[19.1–29.7]       |                   | No PCT |
|            | NATITINGOU | 15/250              | 6.00[3.0–8.9]          |                   | No PCT |
|            | KEROU    | 43/250               | 17.20[12.5–21.9]       |                   | No PCT |
|            | PEHUNCO   | 15/250               | 6.00[3.0–8.9]          |                   | No PCT |
|            |          |                      |                        |                   |              |
| DONGA      | BASSILA  | 108/250              | 43.20[37.0–49.3]       | X2 = 86.630 p<0.00001 318 (31.80) | 1PCT/Year for SAC |
|            | DJOUGOU  | 21/250               | 8.40[5.0–11.8]         |                   | No PCT |
|            | COPARGO  | 92/250               | 36.80[30.8–42.8]       |                   | 1PCT/Year for SAC |
|            | OUAKE    | 97/250               | 38.80[32.7–44.8]       |                   | 1PCT/Year for SAC |
|            |          |                      |                        |                   |              |
| BORGOU     | NIKKI    | 21/250               | 8.40[5.0–11.8]         | X2 = 73.691 p<0.00001 411 (20.55) | No PCT |
|            | PERERE   | 51/250               | 20.40[15.4–25.4]       |                   | 1PCT/Year for SAC |
|            | TCHAOUROU | 71/250              | 28.40[22.8–34.0]       |                   | 1PCT/Year for SAC |
|            | PARAKOU  | 69/250               | 27.60[22.0–33.1]       |                   | 1PCT/Year for SAC |
|            | SINEDE   | 59/250               | 23.60[18.3–28.9]       |                   | 1PCT/Year for SAC |
|            | BEMBEREKE | 18/250              | 7.20[4.0–10.4]         |                   | No PCT |
|            | NDALI    | 57/250               | 22.80[17.6–28.0]       |                   | 1PCT/Year for SAC |
|            | KALALE   | 65/250               | 26.00[20.6–31.4]       |                   | 1PCT/Year for SAC |
|            |          |                      |                        |                   |              |
| ALIBORI    | BANIKOARA | 44/250              | 17.60[12.9–22.3]       | X2 = 43.091 p<0.00001 313 (20.87) | No PCT |
|            | GOGOUNOU | 57/250               | 22.80[17.6–28.0]       |                   | No PCT |
|            | MALANVILLE | 36/250            | 14.40[10.0–18.7]       |                   | 1PCT/Year for SAC |
|            | KARIMAMA  | 33/250               | 13.20[9.0–17.4]        |                   | 1PCT/Year for SAC |
|            | SEGIBANA  | 84/250               | 33.60[27.7–39.4]       |                   | 1PCT/Year for SAC |
|            | KANDI    | 59/250               | 23.60[18.3–28.9]       |                   | 1PCT/Year for SAC |
|            |          |                      |                        |                   |              |
| COLLINES   | DASSA-ZOUME | 90/250             | 36.00[30.0–41.9]       | X2 = 32.903 p<0.00001 512 (34.13) | 1PCT/Year for SAC |
|            | OUESSE   | 75/250               | 30.00[24.3–35.7]       |                   | 1PCT/Year for SAC |
|            | SAVÈ     | 87/250               | 34.80[28.9–40.7]       |                   | 1PCT/Year for SAC |
|            | BANTE    | 106/250              | 42.40[36.3–48.5]       |                   | 1PCT/Year for SAC |
|            | GLAZOUE  | 101/250              | 40.40[34.3–46.5]       |                   | 1PCT/Year for SAC |
|            | SAVALOU  | 53/250               | 21.20[16.1–26.3]       |                   | 1PCT/Year for SAC |
|            |          |                      |                        |                   |              |
| ZOU        | ABOMEY   | 20/250               | 8.00[4.6–11.4]         | X2 = 103.427 p<0.00001 476 (21.16) | No PCT |
|            | AGBANGNIZOUN | 57/250             | 22.80[17.6–28.0]       |                   | 1PCT/Year for SAC |
|            | BOHICON  | 31/250               | 12.40[8.3–16.5]        |                   | No PCT |
|            | COVÈ     | 71/250               | 28.40[22.8–34.0]       |                   | 1PCT/Year for SAC |
|            | DJIDJA   | 47/250               | 18.80[13.9–23.6]       |                   | No PCT |
|            | OUINHI   | 62/250               | 24.80[19.4–30.1]       |                   | 1PCT/Year for SAC |
|            | ZAKPOTA  | 70/250               | 28.00[22.4–33.6]       |                   | 1PCT/Year for SAC |
|            | ZOGBOTOMEY | 90/250             | 36.00[30.0–41.9]       |                   | No PCT |
|            | ZAGNANADO | 28/250              | 11.20[7.3–15.1]        |                   | No PCT |

(Continued)
and 5.79% v. 4.91% (Z = 2.68; p = 0.01), respectively. This difference was not observed with Trichuris infections. In all the surveyed districts, multiple infections by STH species was common in school age children as determined by the prevalence of co-infections with the highest number of cases (prevalence >10%) being found in the districts of Toffo (18.00%), Glazoue (16.50%), Bante and Lalo (14.40%), Djakotomey (14.00%) and Lokossa (10.80%).

Table 4. (Continued)

| Department | District | Parasitological data | STH Prevalence [95% CI] | X² p-Value | PCT strategy |
|------------|----------|----------------------|-------------------------|-----------|--------------|
|            |          | Infected / Examined  |                          |           |              |
| OUÉME (9)  | ADJARRA  | 26/250               | 10.40 [6.6–14.2]         | X² = 69.827 p < 0.0001 |
|            | ADJOHOUN | 33/250               | 13.20 [9.0–17.4]         | No PCT    |              |
|            | AGUEGUE  | 13/250               | 5.20 [2.4–7.9]           | No PCT    |              |
|            | AKPRO-MISSETE | 52/250         | 20.80 [15.8–25.8]        | 1 PCT/Year for SAC |
|            | AVRANKOU | 23/250               | 9.20 [5.6–12.8]          | No PCT    |              |
|            | BONOU    | 15/250               | 6.00 [3.0–8.9]           | No PCT    |              |
|            | DANGBO   | 20/250               | 8.00 [4.6–11.4]          | No PCT    |              |
|            | PORTO-NOVO | 5/250          | 2.00 [0.3–3.7]           | No PCT    |              |
|            | SEME-KPODJ | 34/250         | 13.60 [9.3–17.8]         | No PCT    |              |
| PLATEAU (5) | ADJA OUERE | 72/250       | 28.80 [23.2–34.4]        | X² = 4.171 p = 0.383 |
|            | IFANGNI  | 89/250               | 35.60 [29.7–41.5]        | 1 PCT/Year for SAC |
|            | POBE     | 81/250               | 32.40 [26.6–38.2]        | 1 PCT/Year for SAC |
|            | KETOUGÉ  | 71/250               | 28.40 [22.8–34.0]        | 1 PCT/Year for SAC |
|            | SAKÉTÉ  | 75/250               | 30.00 [24.3–35.7]        | 1 PCT/Year for SAC |
| ATLANTIQUE (8) | ABOUMEY-CALAVI | 28/250 | 11.20 [7.3–15.1]          | X² = 379.055 p < 0.00001 |
|            | ALLADA   | 73/250               | 29.20 [23.6–34.8]        | No PCT    |              |
|            | KPMASSE  | 14/250               | 5.60 [2.7–8.4]           | No PCT    |              |
|            | OUIDAH   | 25/250               | 10.00 [6.3–13.7]         | No PCT    |              |
|            | SÔ-AVA   | 20/250               | 8.00 [4.6–11.4]          | No PCT    |              |
|            | TOFFO    | 157/250              | 62.80 [56.8–68.8]        | 2 PCT/Year for SAC |
|            | TORI-BOSSITO | 82/250     | 32.80 [27.0–38.6]        | 1 PCT/Year for SAC |
|            | ZE       | 103/250              | 41.20 [35.1–47.3]        | 1 PCT/Year for SAC |
| LITTORAL (1) | COTONOU  | 8/250                | 3.20 [1.0–5.4]           | 8 (3.20)  | No PCT      |
| COUFFO (6)  | APLAHOUÉ | 122/250              | 48.80 [42.6–55.0]        | X² = 162.804 p < 0.00001 |
|            | DJAKOTOMEY | 150/250       | 60.00 [53.9–66.1]        | 2 PCT/Year for SAC |
|            | DOGBO    | 32/250               | 12.80 [8.6–16.9]         | No PCT    |              |
|            | KLOUKEKAME | 87/250        | 34.80 [28.9–40.7]        | 1 PCT/Year for SAC |
|            | LAO      | 78/250               | 31.20 [25.4–36.9]        | 1 PCT/Year for SAC |
|            | TOVIKLIN | 56/250               | 22.40 [17.2–27.6]        | 1 PCT/Year for SAC |
| MONO (6)   | ATHIEME  | 31/250               | 12.40 [8.3–16.5]         | X² = 54.397 p < 0.00001 |
|            | BOPA     | 25/250               | 10.00 [6.3–13.7]         | No PCT    |              |
|            | COME     | 50/250               | 20.00 [15.0–24.9]        | No PCT    |              |
|            | GRAND POPO | 23/250        | 9.20 [5.6–12.8]          | No PCT    |              |
|            | HOUYEHGBE | 48/250        | 19.20 [14.3–24.1]        | No PCT    |              |
|            | LOKOSSA  | 74/250               | 30.60 [24.9–36.3]        | 1 PCT/Year for SAC |
| SYNTHESIS  |          | 4378/19250           | 22.74 [22.15–23.33]      | X² = 660.386 p < 0.00001 |

https://doi.org/10.1371/journal.pntd.0006241.t004
Discussion

This study was part of national schistosomiasis and soil-transmitted helminthiasis mapping performed to collect baseline epidemiological data prior to launching STH MDA in Benin using WHO guidelines [18]. Results from this study provided evidence of nationwide distribution of STH parasites with variable prevalence and intensity of infection throughout the country.

Among the three STH species studied in the present work, *T. trichiura* had the lowest prevalence at the districts and national level. This overall low prevalence of trichuriasis confirmed data reported from previous studies in several districts of Benin [19,20]. The reported prevalence of trichuriasis in Benin, was also low as compared to other West Sub-Saharan African (WSSA) countries [7,21,22]. In contrast, ascariasis and hookworm infections are widely distributed with high prevalence in different regions of the countries.

Hookworm infections were widely distributed throughout the country and have been detected in 100% of the surveyed districts. This study clearly highlighted the predominance of hookworm infections nationwide with several hotspots where the prevalence reached 50% and more. Ascariasis was detected in 62/77 districts with the highest prevalence observed in Toffo. In this district, elevated prevalence of hookworm and Ascaris infections was detected, suggesting that populations living in that area are more vulnerable to these infections. Although, moderate to heavy hookworm and *Ascaris* infections have been observed in several districts of the country, most of the detected infections had a light parasite load. These findings confirmed that *Ascaris* and hookworm infections are endemic in all the departments of Benin and that the prevalence of STH in Benin varied steadily over localities and the current results are similar to those from our previous studies [13,19,20] and reports from other SSA countries [2,4,7,21]. Ascariasis appeared to be the predominant STH infection in the border districts between Benin and Burkina Faso (Materi and Boukoumbe), Benin and Togo (Copargo, Bante and Aplahoue), and Benin and Nigeria (Pobe, Ouinhi, Adjouere and Segbana), whereas hookworm infections appeared to be predominant in peripheral districts in the northern and in the central districts in the southern part of the country. This distribution of STH infection could be explained by recently published data from Ivory Coast [22], which found a significantly positive association between STH infection rates and activities involving close contact to water and access to latrines. On the other hand, a negative association between STH infection and deworming, higher socioeconomic status, living in urban settings has been reported [22]. Our study showed that prevalence estimates in some districts are higher than those reported in previous studies from Benin [19,20], suggesting an increased exposure to STH in those districts.

We believe that Benin follows the trends reported from other countries in SSA where the prevalence of the neglected tropical diseases appeared higher [7,22] than previously thought. However, this general trend of high prevalence of STH in WSSA is exceptional. In Burkina Faso for example, a recent study conducted on 3514 schoolchildren aged from 7 to 11 years randomly selected from 22 schools in 11 regions revealed low prevalence of hookworm, *A. lumbricoides* and *T. trichiura* infections [21].

In the current study the predominance of STH infections in boys compared to girls (hookworms: 21.31% of boys vs. 14.03% of girls, Z = 11.53, p<0.0001; Ascaris: 5.79% of boys vs. 4.91% of girls, Z = 2.68, p<0.01) might be explained by a difference in terms of behavior and activities [19,21].

Our study has a few limitations. First, the prevalence of STH in adult populations and particularly in pregnant women has not been investigated. Although having data on prevalence/intensity in other population groups such as pre-school-age children (PSAC) and women of child-bearing age (WCBA) is certainly useful, WHO does not strictly recommend collecting
such information. However, since age prevalence curves have been well established for all three infections, information collected among school-age children can guide decision-making on treatment of this age-group, as well as of PSAC and WCBA. Data shown in this report are therefore sufficient to justify treatment in these two additional population groups as well [1].

Second, only one sample was analyzed for each participant due to the nationwide scale of this study and the limited financial and human resources. Day-to-day variation in STH detection that may influence the prevalence estimates reported in this study could not be considered [23]. Third, the impact of STH infections on the health of the Beninese population has not been addressed in the current study. Many studies conducted in Benin [8,11] and in other West Africa countries [10,24] showed that people living in the endemic areas are at risk of helminth infections, with the most vulnerable populations being pregnant women and children. Helminth and hookworm infections have been associated with poor cognitive and gross motor outcomes in infants, as well as maternal anemia in pregnant women [8,10,11,24]. The high prevalence of hookworm and its predominance in all the districts has an implication in terms of maternal child health policy, which should be strengthened. PCT for STH should be tailored to prevent sequelae and disabling consequences in these populations at risk. Those infections may cause not only maternal anemia but also affect infants’ hemoglobin levels, their growth, their susceptibility to helminth infections, their cognitive development, their selective attention, their socioeconomic status, their physical fitness and their immunological responses to vaccination [25–30].

Supporting information

S1 Table. Geographical positions of the surveyed schools during the mapping in 77 districts in Benin. UTM: Universal Transverse Mercator.

S2 Table. Prevalence of three STH infections by sex.

Acknowledgments

The authors thank the schoolchildren who participated in this study, the teachers, the PTA and local authorities for facilitation and laboratory technicians for collaboration during the field and laboratory work. Manuscript publishing has been supported by DeWorm3 project which authors thank the staff and especially Dr Judd Walson, DeWorm3 central Principal Investigator.

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