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Initiating NTD programs targeting schistosomiasis and soil-transmitted helminthiasis in two provinces of the Democratic Republic of the Congo: Establishment of baseline prevalence for mass drug administration

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ABSTRACT

Background: Schistosomiasis (SCH) and soil-transmitted helminthiasis (STH) are widely distributed in the Democratic Republic of the Congo (DRC) and constitute a serious public health problem. As recommended by the World Health Organization (WHO), before launching mass chemotherapy to control these diseases, parasitological surveys were conducted in sentinel sites in six health zones (HZs) in Bandundu and Maniema provinces. Baseline prevalence and intensity of infection for SCH and STH were determined to establish the appropriate treatment plan using Praziquantel (PZQ) and Albendazole (ALB).
Methods: Parasitological surveys were conducted from April to May 2015 in twenty-six selected sampling units (schools) for baseline mapping in six HZs: Fifty school children (25 females and 25 males) aged 9–15 years were randomly selected per sampling unit. A total of 1300 samples (urine and stool) were examined using haematuria dipsticks, parasite-egg filtration and the point-of-care Circulating Cathodic Antigen (POC-CCA) assay for urine samples and the Kato-Katz technique for stool specimens.
Results: Three species of schistosomes (*S. mansoni*, *S. haematobium* and *S. intercalatum*) and three groups of STH (hookworm, *Ascaris* and *Trichuris*) were detected at variable prevalence and intensity among the schools, the HZs and the provinces. In Bandundu, no SCH was detected by either Kato-Katz or the POC-CCA technique, despite a high prevalence of STH with 68% and 80% at Kiri and Pendjua HZs, respectively. In Maniema, intestinal schistosomiasis was detected by both Kato-Katz and POC-CCA with an average prevalence by Kato-Katz of 32.8% and by POC-CCA of 42.1%.

List of Abbreviations: ALB, albendazole; CDC, centers for diseases control; DRC, Democratic Republic of the Congo; HRA, high risk adults; HZ, health zone; MDA, mass drug administration; NTD, neglected tropical diseases; POC-CCA, point of care circulating cathodic antigen; PZQ, praziquantel; RDT, rapid diagnostic test; RSA, Republic of South Africa; SAC, school age children; SCH, schistosomiasis; STH, soil transmitted helminths; USAID, United States Agency for International Development; WHO, World Health Organization.

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Comparative studies confirmed the greater sensitivity (and operational feasibility) of the POC-CCA test on urine compared to Kato-Katz examination of stool for diagnosing intestinal schistosomiasis even in areas of comparatively light infections. STH was widely distributed and present in all HZs with a mean prevalence (95% CI) of 59.62% (46.00–65.00%). The prevalence of hookworm, roundworm and whipworm were 51.62% (32.40%–71.50%), 15.77% (0.50%–39.60%) and 13.46 (0.50%–33.20%), respectively.

Conclusion: This study provided the evidence base for implementing programs targeting SCH and STH in these Health Zones. Observations also reinforce the operational value and feasibility of the POC-CCA test to detect *S. mansoni* and, for the first time, *S. intercalatum* infections in a routine NTD program setting.

1. Background

Neglected tropical diseases (NTDs) are a subset of infectious diseases that pose public health problems worldwide. Of the seventeen NTDs currently listed by the World Health Organization (WHO) as occurring in the poorest and most underserved populations globally (Liese et al., 2014), seven (lymphatic filariasis, onchocerciasis, schistosomiasis, trachoma and soil transmitted helminthiasis [STH, caused by ascaris, trichuris and hookworm]) are targeted for control or elimination through 'preventive chemotherapy' regimens of mass drug administration (MDA) once or twice yearly. Schistosomiasis and STH are responsible for a large proportion of the NTD burden in the tropical and subtropical regions of the world, with WHO estimating that 249 million people now require preventive chemotherapy for Schistosomiasis and up to 1 billion for STH infections (WHO, 2015).

The Democratic Republic of the Congo (DRC) has a vast network of water bodies and a tropical climate that favors many parasitic and infectious diseases. In 2009 the Ministry of Health established a National NTD Program and started 'mapping' the seven preventive-chemotherapy diseases including Schistosomiasis and STH. The Schistosomiasis and STH mapping was completed in 2015 for 512 out of 516 health zones (HZs) in the country. This mapping strategy used the traditional Kato-Katz preparations of stool specimens to test for *S. mansoni* and STH, and hemastix or urine filtration to detect *S. haematobium* in the urine. The mapping showed moderate to low SCH endemicity in all the studied HZs, with high prevalence of SCH (prevalence ≥50%) in 17 HZs scattered in the eastern, northern and western provinces. In total, 22,123,725 individual are at risk for SCH\STH is endemic in all the provinces, with 291 health zones having moderate to high prevalence (prevalence ≥20%) and 37,623,567 people being at risk (MPSMRM, 2014).

For control of Schistosomiasis, the current WHO guidelines depend on the level of infection assessed in school age children (SAC), with the recommendations that preventive-chemotherapy MDA be administered as: 1) annual treatment for SAC and high-risk adults (HRA) in highly endemic communities (prevalence above 50% in SAC); 2) every-other-year treatment for SAC and selected high-risk adults in moderate to high prevalence areas (10–49% in SAC); 3) treatment for SAC just twice during their primary school years in areas with lower prevalence (<10% in SAC) (WHO, 2006). In addition, before beginning the actual MDA phase of the NTD programs targeting Schistosomiasis and STH, WHO recommendations and Ministry of Health requirements call for baseline sentinel site assessments to be made in each implementation unit (the Health Zone in DRC). These sentinel sites are also intended to serve as reference for subsequent program monitoring of the Schistosomiasis and STH programs.

Accordingly, the DRC national NTD program has recently undertaken sentinel site surveys for Schistosomiasis and STH in the first six targeted HZ in order to determine the prevalence of infection for each. In addition to using the traditional Kato-Katz stool assessment technique, the program took advantage of this programmatic field opportunity to conduct a careful comparison of the Kato-Katz test with the new point-of-care, circulating cathodic antigen (POC-CCA) rapid diagnostic test (on urine specimens) that can detect both intestinal and urinary tract schistosomiasis. The present manuscript records the epidemiological, parasitological and comparative diagnostic data on schistosomiasis and STH infections following use of these tools in the six sentinel sites studied in two provinces (Bandundu and Maniema) to determine the appropriate, WHO recommended control strategy for those health zones.

2. Methods

2.1. Study area

The present sentinel site survey (Table 1) was conducted in four HZs (Kasongo, Lubutu, Obokote and Punia with a total population of 558,000) in Maniema province and two HZs (Kiri and Pendjua with a total population of 195,000) in Bandundu province (MPSMRM, 2014).

Maniema is the least populated (15 inhabitants per km square) and the most isolated province in the country. The province is crossed by the *Congo River* from the north spanning across Lubutu, Punia and Obokote to the South where Kasongo is situated. Bandundu is also sparsely populated with 27 inhabitants per km square. It is bisected by the *Kasai River*, which flows into the *Congo River* on the western boundary. Pendjua and Kiri are both part of the upper north HZs of the province. Pendjua is located in the middle of the Equatorial forest whereas Kiri is situated near lake *Mai-Ndombe*, the largest lake in the province (Fig. 1).

2.2. Study design and sample collection

The populations targeted by the survey were primary school children of ages 9 to 15 years. The administrative distribution and total populations of the Health Zones studied are given in Table 1. The study was done in the areas that had been mapped for SCH/STH 6 years earlier in 2009. Schools were selected based on existing mapping data or according to their proximity to water bodies. A total of 26 sampling units (schools) were surveyed in the six HZs assessed. Five schools were selected in each of the two HZs surveyed in Bandundu province, and four schools were targeted in each of four HZs in Maniema province. The targeted sample size per health zone was 250 school children. But only 4 schools were available per health zone in Maniema making a total sample size of 1300 participants. The study was conducted from April to May 2015. In each school, urine and stool samples were collected from 50 children. Equal numbers of participants (25 boys and 25 girls) were selected randomly via a random number generator at each site. School children of the 3rd grade were preferentially enrolled and then those in higher grades whenever the number of children in the 3rd grade was less than 50.

Urine samples were collected in 250 mL plastic bottles, and 10–20 g stool samples were collected in 50 mL plastic screw-cap

Table 1
Study populations and samples sizes.

Province	Health Zones	Total Population*	Number of sampling units (schools)	Sample size		
				Males	Females	Total
Bandundu	Kiri	116,931	5	125	125	250
	Pendjua	78,095	5	125	125	250
Maniema	Kasongo	234,793	4	100	100	200
	Lubutu	121,892	4	100	100	200
	Obokote	125,261	4	100	100	200
	Punia	76,027	4	100	100	200
Total		752,999	26	650	650	1300

* Data from national NTD program report DRC 2010.

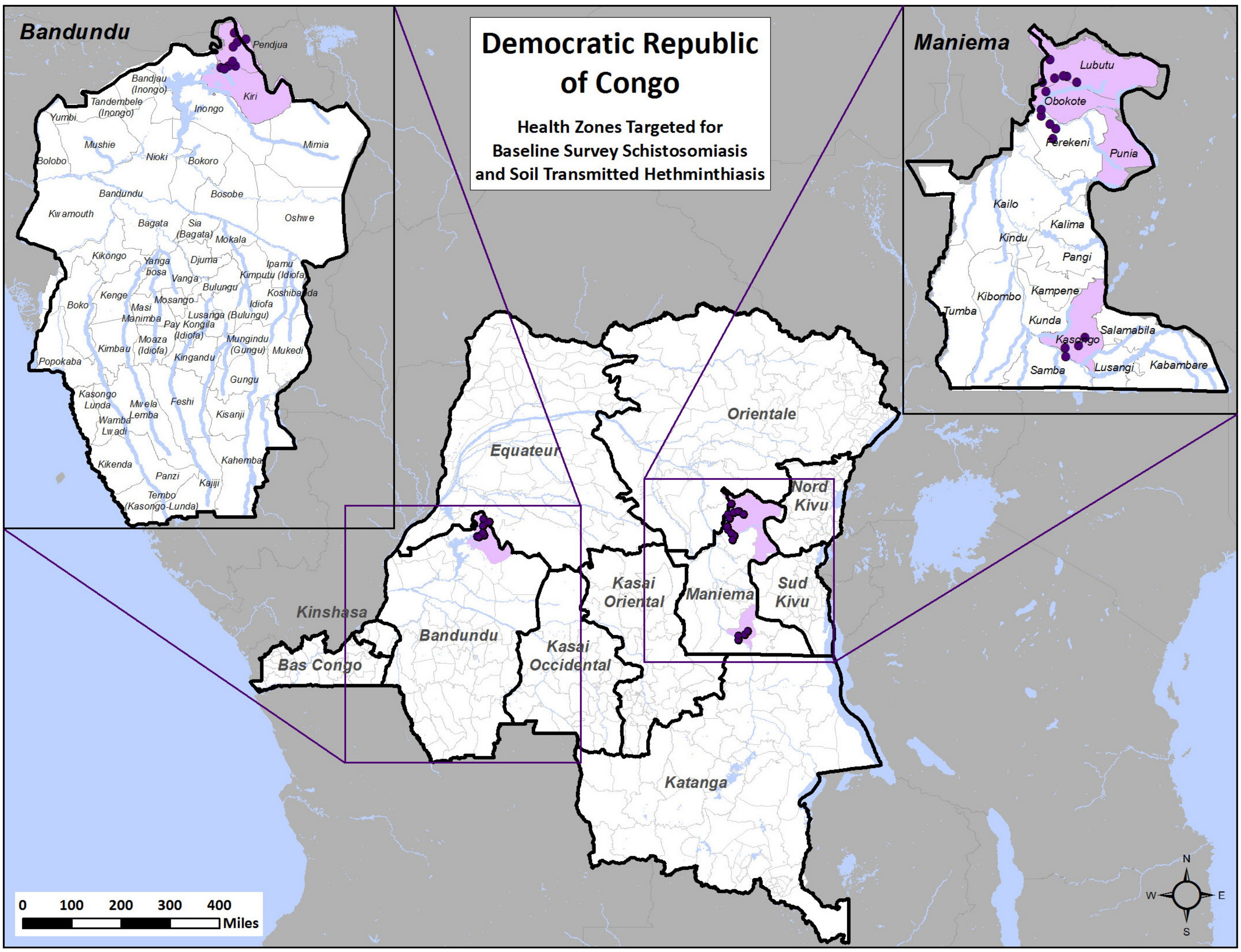

Fig. 1. Democratic Republic of Congo, Health zones targeted for baseline survey Schistosomiasis and Soil Transmitted Helminthiasis.

vials, between 9:00 am and 1:00 pm. The samples (urine and stool) were stored cool in dark plastic bags and transported to the central laboratory of the HZ for processing the same day. A total of 1300 school children (650 boys and 650 girls) were screened with urine and stool samples being collected from 500 children in the HZs of Bandundu and 800 children in Maniema province.

2.3. Urine analysis

Urines were examined using biochemical (hematuria dipstick [Hemastix; Bayer A.G,]), immunological (POC-CCA point-of-care Circulating Cathodic Antigen cassettes; Rapid Medical Diagnostics, Pretoria, RSA), and parasitological (urine filtration and microscopy) tests. The sensitivity of the POC-CCA using a single urine specimen, POC-CCA to detect *S. mansoni* infection is estimated at >90% (Colley et al., 2013; Danso-Appiah et al., 2016). Hematuria was determined in each urine sample using urine reagent strips (YD Diagnostics Corporation) and the results were recorded after one minute. For the urine filtration, after each urine sample was mixed to ensure adequate dispersal of eggs, 10 mL of urine were immediately filtered through a Nuclepore ® filter 13 mm size pore, and the filters were examined by microscopy after adding Lugol (5%) to detect the presence of schistosome eggs. Intensity of infection was calculated and expressed as eggs per 10 mL of urine (eggs/10 mL). The intensity of schistosome infection was graded, according to WHO guidelines, as negative (0 egg/10 mL), light (1–49 eggs/10 mL) and heavy (≥50 eggs/10 mL).

An aliquot (50 μL) of each urine sample was also assessed using POC-CCA cassettes according to the manufacturer's instructions. Results were recorded twenty minutes after adding one drop of buffer to the cassette. Any results read outside twenty-five minutes or where the control line did not develop correctly were considered invalid and were repeated. Any line in the test area was considered positive.

2.4. Stool analysis

Stool samples were examined with a single thick smear technique using a 41.7 mg Kato-Katz template (Katz et al., 1972) which allowed for the identification of STH and discrimination of intestinal schistosomes eggs as *S. mansoni*, *S. guineensis* or *S. intercalatum*. Each Kato-Katz slide was read twice using microscopy: first from 20 to 60 min after slide preparation to detect hookworm eggs, and second, on the following day, 24 h after preparation, for other helminth eggs (*S. mansoni*, *S. intercalatum, Ascaris lumbricoides*, *Trichuris trichiura*). The presence of infection was recorded; the number of eggs for each parasite was tallied and the intensity of infection calculated and expressed as eggs per gram of feces (epg). Egg counts were used to classify infection intensities into light, moderate, or heavy infections respectively as follows: 1) for *S. mansoni*, and *S. intercalatum* 1–99 epg, 100–399 epg, and ≥400 epg; 2) for *Ankylostoma duodenale/Necator americanus* (not distinguished) 1–1999 epg, 2000–3999 epg and ≥4000 epg 3) for *Ascaris lumbricoides*, 1–4,999 epg, 5000–49,999 epg and ≥50,000 epg; 4) for *T. trichiura*, 1–999 epg, 1000–9999 epg and ≥10,000 epg (WHO, 2006). In each site, microscopy was conducted by three experienced technicians and supervised by a senior technician for quality control. The cumulative prevalence of STH infections reflect the number of individuals with *any* of the three STH parasites (*Ascaris*, *Trichuris*, hookworm). Cases of co-infection were counted once.

2.5. Statistical 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. A Z-test was used to compare prevalence values.

3. Results

3.1. Prevalence and intensity of schistosomiasis

Prevalence of *S. mansoni* was assessed both by Kato-Katz and by POC-CCA tests (Table 2). In all 10 schools surveyed in the Bandundu province, no urine or stool was found positive using either test. In contrast, samples from all 16 schools in Maniema province were positive for *Schistosoma* infections, with a significant difference in sensitivity of the Kato-Katz and POC-CCA tests (Z-test = 3.447; p = 0.0003). All Kato-Katz positive individuals were also POC-CCA positive, and there were more POC-CCA positives than Kato-Katz positives at all endemic sites. 262 of the 800 stools screened from Maniema tested positive by Kato-Katz test with a mean prevalence among the 16 schools of 33% (95% CI: 16%–66%),while POC-CCA test resulted in 337 positive urines with a mean prevalence of 42% (95% CI: 23%–77%).

S. haematobium was found in only 2 children, both at the same school, among the 26 schools included in this study. In a school from Lamba in Kasongo HZ (province of Maniema) three urine samples

Table 2
S. mansoni prevalence by POC-CCA tests and intensity of infection by Kato-Katz tests.

Study Population		Total examined	Females	Males	Kato-Katz Results					POC-CCA Results		Comparison KK+/CCA+ Z-Test
					0 egpg	Light (%)	Moderate (%)	Heavy (%)	KK Positive (%)	Negative	Positive (%)	
						1–99 egpg	100–399 egpg	> or = 400 egpg				
Bandundu	Kiri	250	125	125	250	0	0	0	0	250	0	–
	Pendjua	250	125	125	250	0	0	0	0	250	0	–
Maniema	Kasongo	200	100	100	134	62	4	0	66 (33%)	109	91 (46%)	Z = 2.457; p = 0.004
	Lubutu	200	100	100	69	127	4	0	131 (66%)	46	154 (77%)	Z = 2.43; p = 0.008
	Obokote	200	100	100	166	32	1	1	34 (17%)	153	47 (24%)	Z = 1.493; p > 0.05
	Punia	200	100	100	169	31	0	0	31 (16%)	155	45 (23%)	Z = 1.657; p = 0.039
Total		1300	650	650	1038	252	9	1	262	963	337	Z = 3.447; p = 0.0003

from 2 boys and 1 girl tested positive for haematuria by dipstick. While the urine filtration of the girl's sample was negative for *S. hematobium* eggs, the POC-CCA test was positive. The other two individuals were confirmed positive for light *S. haematobium* infection (1 and 48 eggs/10 mL urine), and both were also co-infected with *S. mansoni* as detected by both POC-CCA and Kato-Katz assays (density 1–99 egpg).

S. intercalatum eggs were found in a single school at Nyakisende in Lubutu HZ in the province of Maniema (1/16 schools tested in the province). In this location 24 samples out of the 50 tested (48.00% prevalence) were positive byboth POC-CCA test (urines) and Kato-Katz technique (stools). 50% of those positive specimens (12/24) showed light, 20.8% (5/24) moderate and 29.2% (7/24) heavy intensities of infection. Of the *S. intercalatum*-infected individuals, 4 were co-infected with *S. mansoni*.

No significant difference between males and females was observed in the prevalence or intensity of any of the schistosome infections.

3.2. Prevalence and intensity of STH infection

STH infection was common at all study sites and included all three STH infections assessed: hookworms (*Ankylostoma duodenale/Necator americanus* – not distinguished), *A. lumbricoides* and *T. trichiura* (Tables 3–6). Except in Kasongo (Maniema) the cumulative prevalence for STH was above 50% in each HZ, though for each of the three STH infections, the prevalence and parasite intensity varied among provinces, HZs (sentinel sites) and sampling units (schools).

The average prevalence of hookworm infection across all studied schools (Table 3) was 51.6% (range, 32.4% to 71.5%). The majority of positive samples showed light intensity of infection (89.3%), with 5.4% and 5.3%of cases being moderate and heavy intensity, respectively. Overall, there was no significant influence of gender observed in the prevalence or the intensity of infection, except in the HZ of Kiri where hookworm infection was twice as high in boys (54%) as in girls (21.6%).

The two HZs surveyed in the province of Bandundu were the most affected by *A. lumbricoides*. The prevalence was 34.8% and 39.6% in Kiri and Pendjua, respectively, where as in the four HZs surveyed in Maniema province the average prevalence was 2.3% (range 0.5–4.5) (Table 4).

Whipworm was present in all six HZs surveyed but two of them (Kiri and Pendjua) in Bandundu province were the most affected with prevalence of 33.2% and 30.8%, respectively (Table 5). In each of the other four HZs of Maniema, the prevalence of infection was less than 4%. There was no statistical difference between males and females, and most of the surveyed individuals (86%) had light intensity of infection.

The cumulative STH prevalence that determines which of the WHO recommended treatment strategies to be followed was greater than 50% in 5 of the 6 HZs. Only in Kasongo was it 46%. Co-infection was frequent in the Bandundu HZ and less so in Maniema (Table 6).

4. Discussion

Parasitological data collected from the 6 health zones in DRC showed the presence of three species of schistosomes (*S. mansoni, S. haematobium* and *S. intercalatum*) and three types of STH (hookworm, *Ascaris lumbricoides, Trichuris trichiura*). Polyparasitism has been frequently reported in the DRC and such helminth co-infections, as confirmed in the present study, emphasize the importance of initiating both preventive chemotherapy and ancil-

Table 3
Prevalence and intensity of hookworm infection by Health Zone and sex.

Province	Health Zone	Total Examined (N)	Number of Female examined	Number of Male examined	Total Infected n (%)*	Prevalence by sex		Parasite intensity		
						Female n (%)**	Male n (%)**	Light (%)***	Moderate (%)***	Heavy (%)***
								1–1999 epg	2000–3999 epg	≥4000 epg
Bandundu	Kiri	250	125	125	81 (32.4)	27 (21.6)	54 (54.0)	73 (90.1)	4 (4.9)	4 (4.9)
	Pendjua	250	125	125	114 (45.6)	62 (49.6)	52 (52.0)	104 (91.2)	7 (6.1)	3 (2.6)
Maniema	Kasongo	200	100	100	89 (44.5)	45 (45.0)	44 (44.0)	89 (100.0)	0	0
	Lubutu	200	100	100	143 (71.5)	69 (69.0)	74 (74.0)	113 (79.0)	16 (11.2)	14 (9.8)
	Obokote	200	100	100	126 (63.0)	62 (62.0)	64 (64.0)	110 (88.1)	4 (3.2)	12 (9.5)
	Punia	200	100	100	118 (59.0)	54 (54.0)	64 (64.0)	109 (92.4)	6 (5.1)	3 (2.5)
TOTAL		1300	650	650	671 (51.6)	319 (49.1)	352 (54.1)	598 (89.3)	37 (5.5)	36 (5.3)

* Percentage of study population (denominator N = Total number examined in the zone).
** Percentage of female or male examined (denominator n = total number of males or females examined).
*** Percentage of infected population (denominator n = Infected population).

Table 4
Prevalence and infection intensity of *Ascaris lumbricoides* by Health Zone and sex.

Province	Health Zone	Total Examined (N)	Number of Female examined	Number of Male examined	Total Infected n (%)*	Prevalence by sex		Parasite intensity		
						Female (%)**	Male (%)**	Light N (%)***	Moderate N (%)***	Heavy N (%)***
								1–4999 epg	5000–49999 epg	≥50000 epg
Bandundu	Kiri	250	125	125	87 (34.8)	47 (37.6)	40 (32.0)	50 (57.5)	37 (42.5)	0
	Pendjua	250	125	125	99 (39.6)	47 (37.6)	52 (41.6)	63 (63.6)	35 (35.3)	1 (1.0)
Maniema	Kasongo	200	100	100	9 (4.5)	4 (4.0)	5 (5.0)	8 (88.9)	1 (11.1)	0
	Lubutu	200	100	100	1 (0.5)	0	1 (1.0)	1 (100.0)	0	0
	Obokote	200	100	100	3 (1.5)	0	3 (3.0)	3 (100.0)	0	0
	Punia	200	100	100	6 (3.0)	2 (2.0)	4 (4.0)	6 (100.0)	0	0
TOTAL		1300	650	650	205(15.8)	100 (18.4)	105 (16.1)	131 (63.9)	73 (35.6)	1 (0.5)

* Percentage of study population (denominator N = Total number examined in the zone).
** Percentage of female or male examined (denominator n = total number of males or females examined).
*** Percentage of infected population (denominator n = Infected population).

Table 5
Prevalence and intensity infection of *Trichuris trichiura* by Health Zone and sex.

Province	Health Zone	Total Examined (N)	Number of Female examined	Number of Male examined	Infected (%)*	Prevalence by sex		Parasite intensity		
						Female (%)**	Male (%)**	Light n (%)***	Moderate N (%)***	Heavy N (%)***
								1–999 epg	1000–9999 epg	≥10000 epg
Bandundu	Kiri	250	125	125	83 (33.20)	41 (32.8)	42 (33.6)	62 (74.70)	21 (25.3)	0
	Pendjua	250	125	125	77 (30.8)	37 (29.6)	40 (32.0)	74 (96.10)	3 (3.9)	0
Maniema	Kasongo	200	100	100	1 (0.5)	0	1 (1.0)	1 (100.00)	0	0
	Lubutu	200	100	100	7 (3.5)	3 (3.0)	4 (4.0)	6 (85.71)	1 (14.3)	0
	Obokote	200	100	100	3 (1.5)	3 (3.0)	0	3 (100.00)	0	0
	Punia	200	100	100	4 (2.0)	2 (2.0)	2 (2.0)	4 (100.00)	0	0
TOTAL		1300	650	650	175 (13.4)	86 (13.2)	89 (13.7)	150 (85.7)	25 (14.3)	0

* Percentage of study population (denominator N = Total number examined in the zone).
** Percentage of female or male examined (denominator n = total number of males or females examined).
*** Percentage of infected population (denominator n = Infected population).

Table 6
Cumulative prevalence of Soil Transmitted Helminths by health zone.

Province	Health Zone	Examined	Infected with at least one STH	Cumulative Prevalence	Co-infections (N)	Cumulative STH Prevalence (WHO Treatment Categories)
Bandundu	Kiri	250	171	68%	80	>50%
	Pendjua	250	199	80%	91	>50%
Maniema	Kasongo	200	92	46%	7	Between 20 and 50%
	Lubutu	200	143	72%	8	>50%
	Obokote	200	128	64%	4	>50%
	Punia	200	120	60%	8	>50%
TOTAL		1300	853	60%	198	>50%

lary interventions to improve sanitation, hygiene and potable water in the endemic health zones.

The study was done during April–May in the relatively short dry season. The peak of SCH transmission is known to be the hot and dry season when eggs are discharged out to the fresh water, and later the released cercariae penetrate the human body. That's the period when children are more likely to be infected. However since the main determining factor of infection in these children is the absence of treatment (pre-control period with no drug pressure), there is minimal impact of any seasonality on the prevalence. Of either SCH or STH in the study.

4.1. Comparing the POC-CCA assay and kato-Katz technique to assess the presence of schistosomiasis

The Kato-Katz technique has been used extensively to diagnose both schistosomiasis and STH in stool specimens (WHO, 2006), and it has become established in the WHO guidelines for morbidity control programs targeting both schistosome and STH infections. However, the test is acknowledged to be relatively insensitive at detecting low levels of schistosome infection, and this study confirms the greater sensitivity of the POC-CCA test (Colley et al., 2013; Danso-Appiah et al., 2016) for field surveys where intestinal schistosome infections are relatively light with the potential of detecting other species like *S. intercalatum* (Kremsner et al., 1993). The POC-CCA, adapted from the earlier laboratory assay, is clearly an effective new tool that is easy, rapid, and convenient for field schistosomiasis surveys – both large-scale mapping efforts (Sousa-Figueiredo et al., 2015) and smaller-scale data collection for program monitoring, as in the baseline surveys reported here.

Operationally, the POC-CCA test was also significantly faster to perform than the Kato-Katz test, requiring little more than 1 min for preparation, 20 min to allow lateral flow on the cassette and 10 s for the result reading. The completion of 50 samples for a sentinel site using POC-CCA tests required only about 70 min. The Kato-Katz technique, on the other hand, required significantly more time at least 3 min for preparation, up to hours for clarification, and at least 3 min on average for slide reading. Thus, assessment by the Kato-Katz test required an appreciably longer time than that required by POC-CCA. Also, of course, obtaining and working with urine specimens are simpler and more convenient than working with stool specimens.

In addition to its operational ease the POC-CCA was also seen to have significantly greater sensitivity for detecting *S. mansoni* infection ($Z = 3.447$; $p = 0.0003$; Table 2), and, indeed, the POC-CCA proved to be extremely useful in the HZ of Kiri and Pendjua in Bandundu where it *confirmed* the zero prevalence for intestinal schistosomiasis found on Kato-Katz testing. Interestingly, even with its greater diagnostic sensitivity (and even in such low-intensity settings), the WHO treatment categories determined by POC-CCA turned out to be the same as those determined by Kato-Katz for all Health Zones (<10% for 2 HZ; 10–50% for 3 HZs; >50% for 1 HZ), However, because of its greater operational simplicity compared to the Kato-Katz technique (Lamberton et al., 2014), it is likely that the POC-CCA will soon lead to a reconsideration of WHO's currently recommended diagnostic approaches for schistosomiasis and its guidelines for program monitoring and decision-making in managing these infections in the future (Adriko et al., 2012; Colley et al., 2013), especially since other comparative studies in *post-treatment* areas have sometimes shown a lack of concordance between the two approaches to SCH assessment.

S. intercalatum has been documented by several studies (Jourdane et al., 2001; Tchuenté et al., 1997, 2012) in the forest areas of Cameroon and in the suburbs of urban areas including Kinshasa (Ripert, 2003; Chu et al., 2012). While laboratory assessment of POC-CCA has previously been shown to be capable of detecting *S. intercalatum* (8), our study is the first to show the usefulness of the rapid diagnostic test (RDT) POC-CCA for detecting *S. intercalatum*. This finding demonstrates the value of the POC-CCA test in detecting this parasite and emphasizes a 'cross-reactivity' with other schistosomes to be aware of, in interpreting the result from a positive POC-CCA. The definitive differentiation and identification of the two intestinal parasites (*S. mansoni* and *S. intercalatum*) in the present study was made using the Kato-Katz method, highlighting a valuable complementary role of the Kato-Katz diagnostic technique. Our study also confirms that *S. intercalatum* is not restricted to urban setting and areas surrounding cities where pollution of the environment, rivers and other water bodies have been postulated earlier to contribute to its geographic localization (Tchuenté et al., 1997; Chu et al., 2012).

4.2. *Prevalence of* STH *in bandundu and maniema provinces*

The surveyed areas in both provinces showed high levels of STH infection. Notably, all the three STH infections assessed (hookworm, roundworm and whipworm) are endemic in all the HZs, with high prevalence hookworm infections recorded particularly in Lubutu (71.50%), Obokote (63%) and Punia (59%) (Table 3). There was no significant difference for STH infections between females and males in the two Provinces, but the cumulative STH prevalence found in these HZs (Table 3) indicate the need of STH MDA twice a year according to WHO's guidelines. Such positive findings should trigger preventive chemotherapy to control hookworm infection in these populations as the infection clearly predisposes to severe anemia and other potential complications, not only for children but especially for women of child bearing age. Similar high endemicity of STH has been reported in several previous studies in the DRC (Jusot et al., 1996; Linsuke et al., 2014), and in these tropical, humid environments, inadequate levels of hygiene and poor sanitation along with insufficient potable water contribute significantly to the spread of the STH in school age children (Matangila et al., 2014; Hotez and Kamath, 2009).

5. Conclusion

This study has provided the groundwork for appropriately initiating MDA targeting SCH and STH in six HZs in DRC. It also demonstrated the operational value and feasibility of the POC-CCA test to detect *S. mansoni* – and, for the first time, *S. intercalatum* – infections in a routine NTD program setting. Although the urine POC-CCA test is more sensitive than the Kato-Katz stool test for intestinal schistosomiasis, the differences seen in these *pre-treatment* settings were not great enough to affect the WHO recommendations for treatment of intestinal schistosomiasis based on the Kato-Katz diagnostic. Moreover, the Kato-Katz method still remains essential for assessing STH infection until an improved STH diagnostic tools are developed.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

MI, AK, EAO and JJT study design, AK, MI, JJT and EAO data collection, analysis and manuscript preparation, MN, SS, FM, NA and SM critically reviewed the manuscript and the interpretation of the results. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Ethical approval for the survey was obtained from the Ministry of Public Health, Democratic Republic of the Congo. The study was part of the programmatic baseline surveys routinely implemented under the national policy for SCH and STH control which stipulates that sentinel sites must be implemented prior to starting mass drug administration. The current study was rolled out in line with the national guide – *Plan directeur MTN de la RDC May 2012*. The protocol was registered as a project within the Ministry of Public Health, reviewed by the national NTD program and implemented according to their recommendations and did not require specific ethical clearance from the national ethical board.

School children were also given information on the purpose of the study prior to data collection, and all communities included in the sentinel sites were informed. Participation in the study was voluntary and the procedures were fully explained by the national NTD program officers and to those who chose to participate. School directors received information detailing the objectives and the methodology of the study. Community informed consent was obtained following discussion with the administrative authorities, district medical officers, school Inspectors, teachers and Community-Teachers Associations. Parents and legal representatives of school children were fully informed and provided oral consent. Written informed consent and assent to participate in the study was secured through a signed letter from the head of the school and from the pupils.

Consent for publication

Not applicable

Availability of data and materials

Data in spreadsheet excel format are included in the "Supplementary materials" with the submission of the manuscript.

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