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Impact of Mass Drug Distribution (MDD) of Praziquantel on Schistosomiasis through Sentinel Site Monitoring in Mali

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Abstract: **Background**—Mali was one of the first countries in sub-Saharan Africa to initiate a National Schistosomiasis Control Program (NSCP) in 1982. The WHO's 2021–30 roadmap sets out the criteria for eliminating and controlling schistosomiasis as a public health problem. Our study aimed to assess the impact of annual mass drug distribution (MDD) of praziquantel (PZQ) on the prevalence and intensity in school-aged children (SAC) at NSCP sentinel sites (SSs). **Methods**—This study took place at twelve SSs in the Kayes and Koulikoro regions. Two-round cross-sectional studies were carried out in December 2014–2015 and in April 2018 after four to five years of annual MDD. Our sample size was 2439 schoolchildren aged 7 to 14 years, i.e., 485 in the first round (2014), 246 in the second round (2015) and 1708 in the third round (2018). Urine filtration and the Kato–Katz method were used for determining *Schistosoma haematobium* and *S. mansoni* eggs, respectively. **Results**—A total of 1708 samples were successfully examined. Of the twelve SSs treated from 2014–2015, one met the criterion for elimination of *S. haematobium* as a public health problem (prevalence of heavy-intensity infections (PHI) < 1%) (i.e., ⩾50 *S. haematobium* eggs per 10 mL of urine or ⩾400 *S. mansoni* eggs per g of stool) and four met the morbidity control criterion (PHI < 5%), while two sites remained below the morbidity control criterion (PHI > 5%). Five SSs had no heavy-intensity infections. The prevalence of S. mansoni was less than 1%. **Conclusion**—The impact of MDD of praziquantel in the SSs of the NSCP highlights that it has significantly reduced the PHI of schistosomiasis. However, the high prevalence of schistosomiasis or its increase in some sites requires in-depth studies.

Keywords: Schistosomiasis; prevalence; intensity; MDD; control; elimination; sentinel sites; Mali

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1. Introduction

Schistosomiasis is one of the most important human helminthiasis in terms of morbidity and mortality [1]. The disease is endemic in many developing countries and mainly affects children, farmers and women who are frequently in contact with water inhabited by intermediate snail hosts. According to the WHO, in 2019, 236.6 million people needed preventive treatment in 78 countries [2,3], with the heaviest burden in sub-Saharan Africa (90%) [4].

According to the results of national surveys carried out by the National Schistosomiasis Control Program (SNCP) in 1984–1989, and again in 2004–2006, schistosomiasis due to *Schistosoma mansoni* and *S. haematobiu*m and soil-transmitted helminths (STHs) are still endemic throughout the country [5]. For instance, in 2004, the prevalence of *S. haematobium* and that of *S. mansoni* were 61.7% and 12.7%, respectively, in the Office du Niger irrigated area [6]. Along the Senegal river, the prevalence was higher than 70% in some villages [7].

Recommended by the WHO from 1970 to 1980 [8,9], large-scale chemotherapy to control morbidity with a coverage rate of 75% in school-age children was formally considered as an essential public health strategy to combat schistosomiasis at the Fifty-Fourth World Health Assembly (WHA 54.19) in 2001. As indicated in the WHO guidelines, a new initiative to resume the national control activities has been in place in Mali since 2004, targeting school-aged children (SAC) and adults at risk in order to achieve the WHA54.19 recommendation with technical and financial support from the Schistosomiasis Control Initiative (SCI), USAID/RTI/HKI, The Organization for the Development of the Senegal River (OMVS) and Sights avers in all endemic regions [10,11]. Following this initiative, i.e., MDA with PZQ, four regions first benefited from this strategy in 2005, targeting only school-age children (7–14 years old) attending school. By 2006, this strategy was expanding to other regions, targeting all school-age children (5–15 years old) [11]. In 2007, the Schistosomiasis and Soil-transmitted National Control Program (SNCP), devoted to combatting schistosomiasis, was integrated into the National NTD Control Program. Since that date, annual or bi-annual treatment campaigns have been carried out in all endemic areas (Ségou, Mopti, Koulikoro and Kayes regions) based on the current prevalence threshold as recommended by the WHO. The strategy for controlling schistosomiasis through the NSCP is the one recommended by the WHO (World Health Organization. Schistosomiasis: progress report 2001–2012: strategic plan 2012–2020). However, since 2005, the fight against schistosomiasis has been integrated into a global program of neglected tropical diseases (NTDs) in order to reduce the morbidity of certain diseases that are largely preventable through chemotherapy, such as guinea-worm disease, schistosomiasis, soil-transmitted helminthiasis, lymphatic filariasis, and trachoma. Accompanying measures such as health education, supplying drinking water by digging wells, sanitation, etc., have also been adopted. The current strategy consists of annual or biannual campaigns of integrated deworming with successive administration of azithromycin (against trachoma), albendazole + ivermectin (against lymphatic filariasis and STH), and praziquantel (against schistosomiasis) in areas where all these diseases are endemic. Week 1 treatment is devoted to the administration of azithromycin, followed by a two-week break; week 4 is

devoted to the administration of ivermectin + albendazole, also followed by a two-week break; and week 7 is devoted to the administration of PZQ. As recommended by the WHO, the current strategy was based on treatment once a year in high-risk health districts, once every two years in moderate-risk health districts, and once every three years in low-risk health districts.

However, since the NSCP adopted the community-directed intervention (CDI) approach in 2005, the program has faced some difficulties, which led to a very low coverage (60%), particularly in some endemic areas such as the Diéma district in the Kayes region. In addition to these difficulties, its impact needs to be assessed regularly, particularly at sentinel sites. The current study was carried out with a view on the global fight against schistosomiasis in line with the WHO's 2021–2030 road map to achieve elimination of schistosomiasis as a public health problem and interrupt transmission in humans in selected countries, which was adopted in 2022. This study aimed to assess the impact of MDA with PZQ on the prevalence and intensity of schistosomiasis and STHs in sentinel sites identified by the National Schistosomiasis Control Program (SNCP).

2. Materials and Method

2.1. Study Site

Sentinel sites were defined according to the ecology of the country, which is subdivided into a Sahelian area (annual rainfall of 500 to 700 mm), a northern Sudanian area (annual rainfall of $\leqslant$ 1000 mm) and a "southern Sudanian" area (rainfall of > 1000 mm). In each of these areas, the village with the highest prevalence of one of the two schistosomes species (*Schistosoma haematobium* or *S. mansoni*) was selected as the sentinel site for either intestinal or urinary schistosomiasis. This study was carried out in twelve villages spread over six districts: Bafoulabé, Diéma and Kayes (in the Kayes region) and Kalabancoro, Kangaba and Nara (in the Koulikoro region) (Figure 1). The hydrographical network in this study is made up of Senegal River and its tributaries in the Kayes region and Niger River and its tributaries in the Koulikoro region. It is also composed of the lake system (Lac Magui) and pools (Doro and Goumbaye) in the Kayes region. The economic life in the study area is dominated by agro-pastoral activities, which are conducted more than 80% of the population. The health system is precarious, with high infant and maternal mortalities, a low life expectancy, chronic malnutrition among children and inadequate infrastructure and equipment [12]. The study site is recognized as a highly endemic area for schistosomiasis [8,13,14]. The Kayes region, particularly the Diéma district, is characterized by a low treatment coverage rate of less than 60% (oral communication from the PNLSH's coordinator). In terms of the health infrastructure, Mali's health system comprises three types of health structure: (i) regional hospitals in the regional capitals (Kayes and Koulikoro in the case of our study); (ii) district hospitals; and (iii) community health centers, which are also found in the regional capitals and in the districts (Koulikoro, Bafoulabé, Diéma and Kayes). The gross enrolment rate in the first cycle of basic education is estimated at 74.0% for the country. The district of Bamako (116%) is followed by the regions of Kayes (82.4%) and Koulikoro (65.6%). Generally, the school enrolment rate is strongly influenced in certain sentinel sites by the rural exodus (Diéma, Bafoulabé and Kayes districts) or rampant insecurity in the Koulikoro districts.

According to the SNCP, from 2005 to 2023, the number of rounds of MDA provided in each site (district) was twelve (12) for Kayes, fourteen (14) for Diema and Bafoulabé and eleven (11) for Nara and Kangaba and Kalabancoro. Table 1 shows the number of people treated and the last coverage rates (2023) per risk group and per district (the data for sentinel sites only are not available).

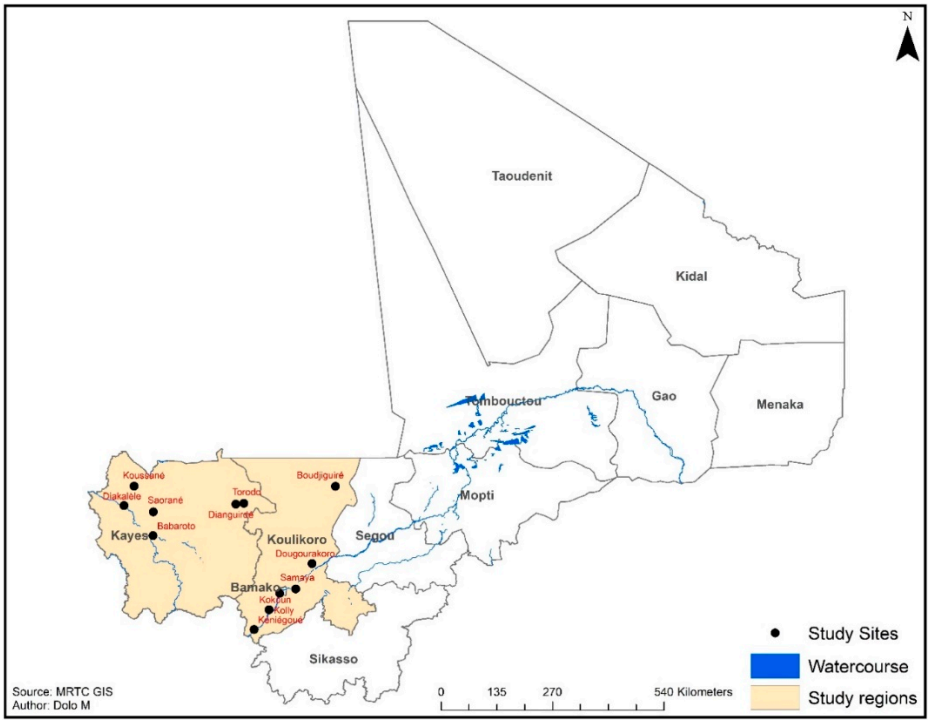

Figure 1: The map of Mali showing the localization of study sites.

Table 1: Repartition of the number of people treated (coverage rate between parenthesis) and the coverage rate per risk group in the study districts in 2023 (PNLSH, unpublished data).

Districts	Total Population Treated (%)	5–14 Years Coverage (%)	Adult Coverage (%)
Kayes	86,063 (25.04)	87,85	0.0
Bafoulabé	40,965 (101.36)	100.72	101.72
Diéma	3939 (35.69)	100.20	0.0
Kalabancoro	56,886 (27.3)	97.46	0.0
Kangaba	66,641 (23.65)	110.11	0.0
Nara	24,312 (34.28)	122.43	0.0

2.2. Population and Study

All the children enrolled in this study were pupils regularly attending schools in these localities. We carried out a two-round observational cross-sectional study: the first baseline round was conducted in December 2014–2015 and the second in April 2018. According to SNCP officials, from December 2014–2015 to April 2018, children were regularly submitted to MDA with PZQ. During each pass, stool and urine samples were examined. The time lag between the different treatment rounds is due to the treatment agenda of the SNCP in relation to each district's planned treatment frequency. Children suffering from serious pathologies who did not provide urine or stools were systematically excluded. All menstruating girls were also excluded.

2.3. Sampling Design and Sample Size Calculation

For the 2018 study, students were randomly selected from schools from the list of students present in each class on the day of the survey. A random draw without exclusions was adopted for the selection of participants. The sample size was calculated on the basis of the prevalence of *S. haematobium* (the most frequent schistosome species) described in 2009. The assumed precision around the prevalence rates to be measured was 6% with an alpha risk of 5%. We added 10% to this sample size to compensate for the loss of sight. The Schwartz formula was used to calculate the minimum sample size. The results of this study were compared to those of the 2014–2015 study carried out by the NSCP. According to the officials of the program, the sample size examined in 2014–2015 (n = 631) was calculated according to the WHO's sample size estimation [15]. Finally, the minimum sample size calculated was 485 at the first round in 2014; 246 in the second round in 2015; and 1708 in the third round in 2018.

2.4. Data Collection Techniques and Procedures

All urine samples were collected between 10.00 a.m. and 2.00 p.m. in the field by trained laboratory technicians to determine the prevalence and intensity of *S. haematobium* infection. Urine was collected from each subject in a properly labeled specimen container. A filtration technique [16] was used to analyze the urine samples. A total of 10 mL of urine was taken from each specimen bottle after mixing it. The mixed sample was filtered through a Whatman filter (CAT N° 1001-025, 25 mm) which was stained with 3% ninhydrin solution before being sent to Bamako to be examined under a microscope using $\times$10 magnification to study *S. haematobium* egg characteristics. One single molded stool sample from each child was collected and examined immediately in the field with the standard Kato–Katz method for *S. mansoni* and STH eggs. The intensity of *S. haematobium* infection was expressed as the number of eggs per 10 mL of urine and was classified into three categories: (i) no eggs; (ii) slight infection (1–49 eggs per 10 mL of urine); and (iii) heavy infection ($\geqslant$50 eggs per 10 mL of urine). The intensity of *S. mansoni* was expressed as eggs per gram of stool (pg) and classified into four classes: (*i*) no eggs; (*ii*) slight infection, 1–99 EPG (eggs per gram of stool); (*iii*) moderate infection, 100–399 EPG; and (*iv*) heavy infection, $\geqslant$400 EPG [11]. To ensure quality control, 10% of the filters and slides were randomly selected and recounted by another senior biologist. At the end of the study, all the positive children were treated with PZQ (40 mg/kg body eight) according to the Schistosomiasis and STH National Control Program in Mali (PNLSH).

2.5. Mass Drug Administration

The preventive chemotherapy strategies recommended by the WHO have been adopted by Mali's Schistosomiasis Control Program since 2005 in four endemic areas [8,12]. To carry out this strategy, an MDA campaign is designed each year in schools and health authorities, and regional, district and community school staff are mobilized. Drugs are distributed through school-based delivery in schools targeting school-going children. This drug delivery strategy is carried out by trained school teachers. PZQ tablets (600 mg) were delivered using the WHO dose pole method to determine the dosage for each child [17]. Target populations with a prevalence of heavy-intensity infections (PHI) of <5% are classified as having a controlled schistosomiasis morbidity, and when a target population has <1% PHI, that population has eliminated schistosomiasis as a public health problem.

2.6. Ethical Approval

Before carrying out the survey in each sentinel school, informed verbal consent was first obtained from the school teachers before the children were recruited. This was recorded by the survey team leader. During recruitment, informed verbal consent was obtained from parents or guardians and an

informed verbal assent from each child was recorded with the presence of the school teachers. Any children who did not wish to participate were free to leave without prejudice to their support for the treatment. Study participants who tested positive for S. haematobium or S. mansoni were treated with praziquantel at the standard dose of 40 mg/kg body weight as recommended by the SNCP. The drug was administered orally after the child had eaten. The proposal was reviewed and approved by the Institutional Review Board (IRB) of the Faculty of Medicine, Pharmacy and Dentistry of the University of Bamako (N°2017/135/CE/FMPOS).

2.7. Statistical Analysis

Data were entered in duplicate using Access and Prevalence, and the intensity of infection with 95% confidence intervals was calculated using SPSS (IBM, Armonk, NY, USA, version 19). Differences in proportions were tested using the chi-square test or Fisher's exact test depending on the data. Percentage prevalences were calculated by dividing the number of infected children by the number of children examined. The intensity of *S. haematobium* infection was expressed as the number of eggs per 10 mL of urine and classified into three categories according to the WHO's classification: (i) no eggs; (ii) mild (1–49 eggs per 10 mL of urine); and (iii) heavy ($\geqslant$50 eggs per 10 mL of urine). *S. mansoni* intensity was expressed in eggs per gram of stool (epg), then classified into four WHO categories: (i) no eggs; (ii) 1–99 epg; (iii) 100–399 epg and (iv) $\geqslant$400 epg [18]. p values less than 0.05 were considered to be significant.

3. Results

In April 2018, 1836 school children were screened, from which 1708 were successfully examined, including 733 girls. They were aged between 7 and 14 years with an average age of 9 $\pm$ 1.970 years.

As shown in Table 2, the *S. haematobium* prevalence in 2014 varied from zero in Boudjiguiré to 96.8% in Babaroto. In 2018, the prevalence increased to 11% in Boudjiguiré, while it decreased significantly to 33.95% in Babaroto ($p < 0.001$). Overall, from 2014 to 2018, the prevalence decreased significantly in Babaroto, Saorane, Torodo and Koussané ($p < 0.001$) and Dianguirdé ($p = 0.004$) and increased significantly in Diakalel ($p < 0.001$) and not significantly in Kolly and Boudjiguiré ($p > 0.05$). From 2015 to 2018, the prevalence increased significantly in Samaya ($p = 0.006$) and Kokoun ($p = 0.02$) (Table 2).

Table 2: Variation in the prevalence (% in parenthesis) of *S. haematobium* in the sentinel schools/villages in the Kayes and Koulikoro regions from 2014–2015 to 2018.

		Periods			
		First Survey	Follow-Up		
Districts	**Sentinel Sites**	**2014**	**2018**	**Diff. (%)**	***p***
Bafoulabé	Babaroto	96.8 (62)	62.8 (78)	33.95	<0.001 **
	Saorane	70.0 (60)	31.5 (108)	38.51	<0.001 **
Diéma	Dianguirdé	76.7.0 (60)	54.3 (184)	22.32	0.004 **
	Torodo	80.0 (60)	39.6 (169)	40.36	<0.001 **
Kayes	Diakalel	31.7 (63)	84.1 (226)	−50.56	<0.001 **
	Koussane	65.0(60)	32.1(1.8)	32.89	0.02
Nara	Kolly	8.3 (60)	15.5 (103)	−7.2	0.28
	Boudjiguire	0 (60)	11.9 (109)	−11.9	0.011

		2015			
Kaalabancoro	Dougourakoro	5.0 (60)	7.7 (65)	−0.03	0.80
	Kokoun	16.7 (60)	34.4 (160)	−17.71	*0.02*
Kangaba	Keniegue	1.6 (63)	7.4(214)	−5.89	−0.16
	Samaya	1.6 (63)	15.9 (183)	−14.26	0.006
Total		731	1708		

** Statistically significant *p*-value ($p < 0.05$).

Between 2014 and 2018, there was a significant reduction in the prevalence of heavy-intensity infections with *S. haematobium* in the districts of Bafoulabé (Babaroto and Saorané) and Diéma (Dianguirdé and Torodo) ($p \leqslant 0.001$) (Table 3). In Diakalel, the prevalence of heavy infections rose to 19.21% from 2014 to 2018 ($p < 0.001$). In Kolly and Bougoudjiré, the prevalence remained at zero.

From 2014 to 2018, the prevalence of heavy infections decreased slightly in Kokoun.

In terms of the results obtained after treatment campaigns regarding the intensity of the disease, one SS (Saorané) met the criterion of eliminating schistosomiasis as a major public health problem (prevalence of heavy-intensity infections—PHI < 1%); four sites (Dianguirdé, Torodo, Koussané and Kokoun) met the criterion for controlling morbidity (prevalence of high excretors—PHI < 5%); and two sites (Babaroto and Diakalel) remained below the control criterion (PHI > 5%). The status of five SSs which did not have any heavy-intensity infections in 2004 did not change in 2018 for Boudjiguire, Keniegue and Samaya, but two Kolly and Dougourakoro showed a slight increase.

Table 3: Variation in the prevalence of high-intensity (% in parenthesis) *S. haematobium* infections in sentinel sites of Kayes and Koulikoro regions between 2014–2015 and 2018.

		Periods			
Survey and Follow-Up		**First Survey**	**Follow-Up**		
Districts	**Sentinel Sites**	**2014**	**2018**	**Diff. (%) ***	***P***
Bafoulabé	Babaroto	29.0 (62)	9.0 (78)	20.0	0.004 **
	Saorane	13.3 (60)	0 (108)	13.3	0.0004 **
Diéma	Dianguirdé	26.7 (60)	3.3 (184)	23.4	<0.001 **
	Torodo	25.0 (60)	4.7 (169)	20.3	<0.001 **
Kayes	Diakalel	1.6 (63)	20.8 (226)	−19.2	0.0007 **
	Koussane	8.3 (60)	1.8 (109)	6.5	0.10
Nara	Kolly	0 (60)	1.8 (103)	−1.8	>0.05
	Boudjiguire	0 (60)	0 (109)	0	
		2015			
Kaalabancoro	Dougourakoro	0 (60)	1.1 (65)	−1.1	1
	Kokoun	3.3 (60)	1.9 (160)	1.4	0.89
Kangaba	Keniegue	0 (63)	0 (214)	0	>0.05
	Samaya	0 (63)	0.5 (183)	0	1
Total		731	1708		

** Statistically significant *p*-value ($p < 0.05$), * Statistically non-significant *p*-value ($p > 0.05$).

Schistosoma mansoni was found in six SSs spread over four districts (Table 4). The highest prevalences were observed in Dougourakoro (66.70%) and Kokoun (35.0%). Parasite loads were low to moderate everywhere. While prevalences were significantly reduced in Babaroto, Dougourakoro and Kokoun, they increased in Keniegue, Samaya and Kolly.

Table 4: Variation in the prevalence of *S. mansoni* infections in some sentinel sites of Kayes and Koulikoro regions from 2015 to 2018.

		Periods			
		First Survey	Follow-Up		
Districts	**Sentinel Sites**	**2015**	**2018**	**Diff. (%)**	***p***
Bafoulabé	Babaroto	1.60(60)	0	100	<0.001 **
Kalabancoro	Dougourakoro Kokoun	66.70 (60) 35.0 (60)	1.1 (65) 1.9 (60)	65.6 33.3	<0.001 **
Kangaba	Keniegue Samaya	0 (63) 0 (63)	0.39 (255) 0.89 (224)	−0.39 −0.89	0.11
Nara	Kolly	0 (60)	3.73 (134)	−3.73	0.75

** Statistically significant *p*-value ($p < 0.05$), No soil-transmitted helminths were found.

4. Discussion

This study aimed to assess the impact of repeated MDA with praziquantel in twelve sentinel sites among two *S. haematobium* endemic areas (Kayes and Koulikoro) covered by the National Schistosomiasis Control Program (NSCP). Children aged between 6 and -14 were identified as the targeted population in regard to the peak prevalence and intensity of schistosomiasis and STHs observed in this age group [12]. The priority given to this age group is based on the fact that the level of infection observed in this population reflects the impact of several rounds of MDD with PZQ after the implementation of a control program. In line with the WHO's current roadmap guidelines (2021–2020), only one and four out of the twelve SSs reached the elimination and morbidity criteria for the control of schistosomiasis as a public health problem (PHI < 1% and PHI < 5%, respectively) in 2018 after four to five MDD rounds. Reducing the prevalence of heavy infection is important as it is well known that the severity of morbidity caused by schistosomiasis is closely related to the intensity of infection. In many National Control Programs, cases of severe morbidity were avoided or reversed with MDA. This is in line with what was achieved in other national MDA programs, particularly in East and West Africa through preventive chemotherapy [19–23]. However, besides the heavier infections, there still exists a significant proportion of children with infections of a relatively low intensity (1–49 eggs per 10 mL of urine), not counting those that were not detected due to the low sensitivity of the urine filtration technique. This is the case at five sites (Dougourakoro, Keniegue, Samaya, Kolly and Boudjiguiré), where no heavy-intensity infections were observed in 2014–2015. Such low intensities of infection have long been overlooked in terms of the morbidity consequences, while recent findings suggest that light infections can cause considerable morbidity due to anemia, chronic pain, diarrhea, exercise intolerance and undernutrition [24]. Similar studies were carried out, but with calculated cure rates for *S. haematobium* in Cameroon of 50.4% three weeks after treatment [25], and in two villages in Mali, values of 46% (Koulikoro) and 56.8% (Selingue) were recorded after administration of two doses of PZQ (40 mg/kg) two weeks apart [22]. In Niger, the CR of children infected with *S. haematobium* 6 weeks after treatment with 40 mg/Kg of PZQ was 53.1% [26]. Likewise, in the case of *S. mansoni*, cure rates of 76.1% were reported in the Senegal River valley after the administration of two doses of 40 mg/kg of PZQ over four weeks [27]. In Niger, the authors noted a CR of 59.6% and an ORR of 56.1% 6 weeks after treatment with 40 mg/kg PZQ [26]. In Senegal, Webster et al. (2013) recorded CRs ranging from 81 to 95.5%, with high ERRs of 98.4 to 98.9%, as in our study, but at 6 weeks after PZQ treatment [28]. Nevertheless, the objective of MDD is to prevent morbidity due to schistosomiasis by regular treatment in line with WHO recommendations [12,29] via administration at the sentinel sites. On other hand, in contrast to the low success rate of eliminating schistosomiasis as a public health issue (one and four SSs with a PHI of < 1% and 5% for schistosomiasis elimination and control, respectively), the prevalence of infection was significantly reduced at 66.7% (8/12) of sites. In view

of such results, some authors suggested a reevaluation of the criteria for schistosomiasis control because of the inability of current PHI categorizations to differentiate the prevalence of standard morbidity markers. To this end, they proposed to shift the definition of schistosomiasis elimination as public health (EPHP) targets to a function of the prevalence of any *Schistosoma* infection rather than its intensity [30].

The persistence or increase in infections in some SSs (Table 1) emphasizes, in line with the World Health Organization (WHO) guidelines, the need for more effort to implement comprehensive control measures, including reinforcement of preventive chemotherapy, intensified case management, snail intermediate host control, health education and improvement of sanitation and access to improved water sources, sanitation and hygiene [31,32]. Another hypothesis in addition to the low impact of treatment could be hybrid strains of *S. haematobium*/*S. bovis* or *S. haematobium/S. curassoni* identified in the study site [33], which have been found to influence parasite establishment, growth, maturation and reproductive success and/or drug efficacy [34]. Our study was limited by the amount of urine (10 mL) or feces (25 mg) examined from the filtration of a single urine sample (10 mL) or the examination of a single feces sample (25 mg of feces) using the Kato–Katz technique. The two surveys (2014–2015 and 2018), although conducted by two different teams, did not call into question the validity of the results obtained. It is important to remember here that a comparison with other groups could be more or less complex, because monitoring adults is complex except in cohort studies. In contrast, we believe that subsequent studies could make an easy comparison with the new PZQ formula in syrup form. In Senegal, among 351 people treated with 40mg/kg of PZQ, there was no significant difference in the CR according to age and sex ($p > 0.05$). The CR was high in both SAC (91.9%), adults (98.2%), females (97.9%) and males (89.2). Heavy infections were eliminated after treatment as well as in adults and in female SAC. However, a reduction in the prevalence and proportion of heavy infections after treatment was strongly correlated with the age and sex of the infected individuals ($p< 0.05$), with a large decrease in adults and females [35].

The impact of MDD with PZQ resulted in a significant reduction in the prevalence and intensity of infection in the NSCP SSs after four to five treatment rounds. The persistence of the disease or its increase in some other sites calls for further investigations, including of the regularity and the therapeutic coverage for each treatment round, the existence of hybrid schistosome strains and their susceptibility to PZQ.

5. Conclusion

This study assessed the impact of MDD with PZQ over a period of four to five years in twelve sentinel sites of the NSCP. One SS met the criterion for schistosomiasis elimination as a public health problem, while four met the criterion for morbidity control in line with the WHO's 2021–2030 roadmap. However, two sites remain below the control criterion. These results call for a major improvement in therapeutic coverage in addition to intensified case management, sanitation and hygiene to interrupt the schistosome transmission cycle. We finally underline the importance of continuing pilot studies at sentinel sites for the national scale-up of elimination strategies.

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