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A literature review of schistosomiasis in Ghana: a reference for bridging the research and control gap

Enoch Mensah Boateng [a,b], Jan Dvorak [a,c,d], Irene Ayi [e,*], and Marta Chanova [b]

[a]*Department of Zoology and Fisheries, Center of Infectious Animal Diseases, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences in Prague, Kamycka 129, 16500 Prague, Czech Republic;* [b]*Institute of Immunology and Microbiology, First Faculty of Medicine, Charles University and General University Hospital in Prague, Studnickova 7, 128 00 Prague, Czech Republic;* [c]*Institute of Organic Chemistry and Biochemistry of the Czech Academy of Sciences, Flemingovo namesti 2, 16000 Prague, Czech Republic;* [d]*Faculty of Environmental Sciences, Czech University of Life Sciences in Prague, Kamycka 129, 16500 Prague, Czech Republic;* [e]*Department of Parasitology, Noguchi Memorial Institute for Medical Research, University of Ghana, LG 1181, Legon, Accra, Ghana*

*Corresponding author: Tel: +233243670493; E-mail: IAyi@noguchi.ug.edu.gh

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Schistosomiasis is endemic in most sub-Saharan African countries, including Ghana, where the need for effective control involving preventive chemotherapy was indicated by the WHO. Mass drug administration commenced in 2008 and has continued since then in Ghana, but the country remains highly endemic. Here, we review the literature on schistosomiasis to identify research and knowledge gaps potentially affecting disease control. A total of 100 Ghana-related schistosomiasis literature sources were reviewed, showing that most studies were conducted on epidemiology, control of transmission and diagnosis. By contrast, many aspects of this disease remain neglected, including livestock schistosomiasis and its zoonotic potential, recent distribution of disease vectors or widely overlooked genital schistosomiasis. Stratified by region, the highest number of studies focus on Greater Accra, while studies are limited or absent for several other regions. Although this review shows apparent progress in terms of schistosomiasis research and control, a considerable amount of work remains to achieve at least a reduction in the prevalence of the disease, which affects a significant proportion of the population. National epidemiological data based on a nationwide survey, integrated control and improved monitoring and evaluation must be ensured.

Keywords: disease control strategies, Ghana, mass drug administration, neglected tropical disease, schistosoma, zoonosis

Introduction

Schistosomiasis is a waterborne helminthic disease caused by blood flukes of the genus *Schistosoma*.[1] The disease is prevalent in tropical and subtropical areas, mostly affecting poor rural communities without access to safe drinking water and adequate sanitation. Activities that expose people to infested natural freshwater bodies such as fishing, agriculture, washing clothes or swimming lead to infection.[2] An estimated 240 million people are infected, several million experience severe morbidity and 700 million live at risk of infection.[3] Approximately 85% of cases occur in Africa,[4] where almost all countries report schistosomiasis.

There are three major agents of human schistosomiasis (*Schistosoma haematobium*, *Schistosoma mansoni*, *Schistosoma japonicum*) and several other less common (e.g. *Schistosoma intercalatum*, *Schistosoma guineensis* and *Schistosoma mekongi*).[5] *Schistosoma haematobium* is predominantly present in Africa, *S. mansoni* in both Africa and Latin America and *S. japonicum* in Asia. Other species occur only focally in Asia (*S. mekongi*) and Africa (*S. intercalatum*, *S. guineensis*).[6] Concerning host specificity, *S. haematobium* and *S. mansoni* are considered primarily human parasites, while others are reported to be zoonotic with a broad spectrum of mammalian hosts (e.g. bovines, dogs, pigs and sheep).[7,8] Intermediate hosts include several snail species of the genera *Biomphalaria (S. mansoni), Oncomelania (S. japonicum), Bulinus (S. haematobium, S. intercalatum, S. guineensis) and the single species Neotricula aperta (S. mekongi)*.[4]

Humans become infected when infective larvae (cercariae) are released into water from snail intermediate hosts and penetrate the skin. They subsequently transform into migrating larvae (schistosomula) that move via the circulatory system where they feed on red blood cells, mature into adult worms and lay eggs in species-specific locations.[9] The eggs are transported either to the lumen of the urinary bladder (urogenital form of the disease caused by *S. haematobium*) or intestine (intestinal form

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by *S. mansoni*), *S. japonicum*, *S. guineensis*, *S. intalactum* and *S. mekongi*) and are passed with excreta. However, a significant proportion of the eggs become entrapped in tissues both at the oviposition site and in distant organs such as the liver due to hematogenous spread. The eggs generally provoke tissue granuloma formation and fibrosis, resulting in associated symptoms.[10]

Apart from human schistosomiasis, livestock/animal schistosomiasis exists. The species causing animal schistosomiasis include *Schistosoma bovis*, *S. curassoni*, *S. hippopotami*, *S. indicum*, *S. intercalatum*, *S. mattheei*, *S. nasalis*, *S. rohhaini* and *S. spindale*. They infect a wide range of domestic and wild animals such as goats, sheep, pigs, cattle, horses, camels and buffaloes.[11] In addition, hybrids between *S. haematobium* and *S. bovis* and/or *S. curassoni* exist, demonstrating hybridization within the *Schistosoma* genus. These hybrids can infect both humans and animals, indicating a potential spillover either from animals to humans or vice versa.[12]

Human schistosomiasis is ranked among the most devastating tropical diseases and is a major cause of morbidity and mortality in endemic countries.[13] It is of public health concern due to years of productivity loss resulting from disease conditions. An estimated 3.31 million disability-adjusted life years and 11,700 deaths per year are attributed to schistosomiasis alone.[14,15] Moreover, livestock or animal schistosomiasis is a One Health concern due to animal morbidity and mortality, associated economic losses as well as the zoonotic threats that those infections pose, especially when there is no program targeting control of animal schistosomiasis.[16,17]

The devastating nature of schistosomiasis calls for the implementation of proper control and elimination strategies. According to the WHO, preventive chemotherapy through mass drug administration (MDA) of at-risk groups is needed in endemic countries with moderate to severe transmission. This covers about 242 million people living in 51 countries mostly in Africa, including an estimated 10.6 million in Ghana.[18] In 2019, only about 45% of these people had been treated by preventive chemotherapy.[2] Within the recently revised WHO 2021–2030 roadmap for Neglected Tropical Diseases (NTDs), a target to eliminate schistosomiasis as a public health problem in all endemic countries, and elimination in several of them, was established. Core strategic interventions have also been identified to achieve these targets, including improvements in MDA, water, sanitation and hygiene (WASH), vector control, veterinary public health, case management and others, such as behavioral changes.[19]

The objectives of this review are to sum up the basic geographic, demographic and socioeconomic characteristics of Ghana with a focus on those that are relevant for transmission of schistosomiasis, and to provide an up-to-date literature review. Research and knowledge gaps concerning schistosomiasis in Ghana are presented, followed by suggestions for future research and control bridging necessary to reach WHO targets over the next decade.

Methods

Guided by the objectives, a comprehensive data search was performed using PubMed, Scopus and Google Scholar search engines. The search was carried out using 'schistosomiasis' and 'Ghana' as the main keywords in combination with at least one of the following: animal, control, distribution, elimination, livestock, MDA, NTDs, prevalence, snail intermediate host and transmission. Further selection was performed according to the following criteria: studies conducted in Ghana from 1954 to 2021 and published as original research articles; research must be in English and must have an abstract. Reviews, case reports and short communications were excluded. Other relevant sources such as online documents by the Centre for Disease Control, the Global Atlas of Helminth Infections (GAHI), World Bank, Ghana Statistical Service, the WHO and Ministry of Environment, Science and Technology were also used. The sources have been comprehensively reviewed and research gaps have been identified, which formed the basis of the recommendations (see Knowledge gaps, future perspectives on schistosomiasis research and control).

Results and Discussion

Geography, demography and socioeconomics of Ghana

Ghana occupies a total area of 238 533 km^2 in West Africa, of which 95% is landmass, while the remaining 5% represents waterbodies. The territory comprises six agroecological zones, including Sudan, Guinea and coastal savannahs, forest/savannah transitional zone, deciduous forest zone and the rainforest zone.[20] The main river system draining 70% of the country is formed by the Volta basin, stretching from north to south, including Lake Volta with the significantly large Akosombo Dam, as well as other minor dams constructed for agricultural purposes.[21] Two other major basin systems, the south-western rivers and the coastal basin, drain 22% and 8% of the area, respectively (Supplementary Figure S1a).

The country is divided into 16 (formerly 10) administrative regions, as shown in the map in Supplementary Figure S1b.[22] For the present study, the Upper East, Upper West and the Northern regions (the Northern region now separated into Savannah, North-East and the Northern regions) are reported as the northern sector of the country. As for the southern sector, Ashanti, Brong Ahafo (now the Ahafo, Bono and Bono East regions), Central, Eastern, Greater Accra, Volta (now the Oti and Volta regions) and the Western region (now the Western North and Western regions), are reported.

Ghana is a lower-middle income economy with a gross domestic product per capita of 2445.3 US$[23] and a poverty rate of 23.4%.[24] According to the 2021 population and housing census,[25] Ghana's total population is >30.8 million with a density of 129 persons per km^2. Its society is dominated by young people (aged 15–35 y), followed by children (aged 0–14 y), making up 38.2% and 35.3% of the total population, respectively. About 11.5 million people (58.1%) represent the labor force (i.e. the economically active population, aged $\geq$15 y), with a predominant 32.0% of the employed population engaged in agriculture, forestry and fishery. In addition, 182 000 (2.6%) children (aged 5–14 y) are engaged in agriculture-related economic activities. Of all people aged $\geq$6 y, 30.2% are illiterate. The rural population forms 43.3% of all inhabitants and only 7 out of 16 regions are urbanized. Concerning water, hygiene and

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sanitation, just 38.9% of households have access to a bathroom for exclusive use and 59.3% of households possess a private toilet. The most prevalent method of disposing of household wastewater is by throwing it onto the ground/street/outside (70.6%). More than 17.7% of households do not have access to any toilet facility and open defecation is practiced in 6.2%–68.5% of households in particular regions. Almost one-tenth of households (8.0%) do not have access to an improved source of drinking water. Of those, 79.9% (i.e. nearly 2 million people) rely on surface water (river/stream/dugout/pond/dam/canal). Most poverty-associated characteristics are more prominent in rural compared with urban areas, and in northern compared with southern sectors of the country.

Overall, geographical factors make Ghana suitable for schistosomiasis. Its transmission is further enhanced by widespread open defecation and disposal of wastewater to the environment that enables uncontrolled contamination of natural water sources. Predominant agricultural and fishing activities, as well as deprived access to safe water for some households, all resulting in regular contact with contaminated water, predispose a significant proportion of the population to schistosomiasis.

Moreover, increasing demands of the growing population have contributed to the rapid spread of schistosomiasis in general and *S. mansoni* in particular, thereby changing both prevalence and distribution throughout the country over the decades (Figure 1A,B). Generally, human migration contributes significantly to the introduction or spread of infectious diseases.[26] In addition, hydrological changes due to the development and management of water resources such as dams and irrigation constructions intensified the transmission of waterborne diseases, including schistosomiasis (e.g. by providing a more stable snail habitat or by changing human water-related activities).[27]

Schistosomiasis research in Ghana

Overall, a literature search using defined keywords returned 270 items, out of which 100 were included in this review (all the included papers are listed in Table S1). The epidemiology of human schistosomiasis in Ghana is a dominating topic (assessed in 33 articles). It is followed by studies on control of transmission (21 articles) and studies focused on diagnostic methods (18 articles). Other topics on human and livestock schistosomiasis were also covered. Out of all included articles, 15 represented purely laboratory-based studies. Concerning both laboratory and field studies, the Greater Accra region featured prominently (33 articles focused on the region alone). This was followed by the Eastern region (13 studies). Other regions are a subject of 0–10 studies.

Epidemiology of schistosomiasis

Prevalence Since the early 1950s, numerous data on local prevalence of human schistosomiasis have been reported, showing values of up to 95% (Table 1). However, the data have arisen from studies focused on various groups, usually with a limited number of subjects, and performed for different purposes, such as evaluation of novel therapeutic or diagnostic approaches. National prevalence data were comprehensively summarized into prevalence map in 1987 for the first time.[28] This document was later used for several prevalence estimations,[29,30] although limited comparability and representativity of original data make any further conclusions uncertain.

Generally, almost all widely referred national prevalence data have arisen from estimations using various methods. The first national prevalence estimation was reported within 15% to 20% in 1963, based on *S. haematobium* data only.[28] Later, national prevalence estimation of 72.4% based on mathematical calculation using various parameters was reported in 1986,[29] and 70.9% based on extrapolations from the Ministry of Health and United States Agency for International Development control programs in 2010.[30] In 2015, a national prevalence estimation of 23.3% based on geostatistical analysis of some selected local data was reported in a systematic review paper.[31]

The only known national epidemiological survey was conducted during 2007–2010, when 170 districts were surveyed and >6.5 million school children were considered at risk[32]; however, the survey did not include adults and out-of-school school-aged children who might be at risk, and the number of infected people was not reported. Common use of estimations and a lack of national epidemiologic surveys may result in overestimated or underestimated status of schistosomiasis in Ghana and significantly influence the control efforts.

Geographical distribution and transmission of schistosomiasis in Ghana The first schistosomiasis distribution map of Ghana was published by the WHO in 1987 (Figure 1A). The map depicts the co-dominance of *S. mansoni* and *S. haematobium* in the northern sector of the country, while the southern sector was mostly dominated by *S. haematobium*.[28] Later, a distribution map (Figure 1B) produced by the GAHI in 2015 depicted the widespread presence of both *S. haematobium* and *S. mansoni* throughout all regions of Ghana.[33] Maps generated by the WHO during 2016–2019 (Figure 1C) confirm that schistosomiasis is endemic in all regions of Ghana. Significant parts of southern Ghana show moderate to high endemicity, while for Brong Ahafo, Northern, Upper East and Upper West regions, low prevalence is reported. The status of endemicity changed mildly from 2016 to 2019 as some communities (Figure 1C, highlighted in the rectangle) in the Brong Ahafo and Northern regions shifted from low to high endemicity status, which is a cause for concern.

Disease diagnosis

Generally, studies on diagnosis evaluated various diagnostic tools suitable for different settings in comparison with the egg detection method by microscope, which is the 'gold standard' for schistosomiasis and still seems to represent the ideal method for disease diagnosis, surveillance and monitoring of schistosomiasis in highly endemic countries like Ghana. More complex laboratory-based diagnostic tools such as antibody/antigen detection, real-time PCR and other modified molecular methods have been evaluated as the most sensitive and specific for diagnosing schistosomiasis under various conditions[34,35]; however, their application in the field is very limited (Supplementary Table S1). Several papers evaluated field applicable methods, for example, self-reporting metrics through questionnaires and urine reagent strips/dipsticks as low-cost, rapid and easy diagnostic approaches on-site in

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Table 1. Overview of regional/local prevalence studies of human schistosomiasis in Ghana published from 2000 to 2021 (14 studies)

SECTOR	Region	Community	Target group	Study participants	% Prevalence		Year of study	Reference
					S. mansoni	*S. haematobium*		
Northern	Northern	Kuli	Mixed	208	-	6.8	2008	36
	Upper East	Kassena-Nankana District	SAC*	1001	-	30	Not stated	37
	Upper East	Kassena-Nankana District	SAC*	1764	14.2	38	Not stated	38
Southern	Ashanti	Bunuso	Children	100	-	95	2009	39
	Central	Okyereko	Infants	97	-	33.0	2004	40
	Eastern	Adasawase	SAC*	255	-	43.6	2008	41
	Eastern and Greater Accra	Akuapem and Ga South districts	Children	354	-	83.9	Not stated	42
	Eastern and Greater Accra	Akuapem and Ga South districts	Mixed	2562	-	57.4	1992/1993	43
	Greater Accra	Accra	Mixed	91/163	49.5	12.9	Not stated	44
	Greater Accra	Accra	SAC*	730	-	7.8	Not stated	45
	Greater Accra	Doblo, Chento, Ntoaso	Adults	220	-	15.5	Not stated	45
	Greater Accra	Kasseh-sub- district	SAC*	417	-	20.9	Not stated	46
	Greater Accra	Manheam	Mixed	696	30.0	3.3	2016	47
	Greater Accra	Tomefa	Mixed	635	78.3	14.3	2016	47
	Greater Accra	Torgahkope-Adakope	Mixed	598	31	19	2016	47
	Greater Accra	Zenu	SAC*	274	-	30.7	Not stated	48
	Greater Accra	Zenu and Weija	SAC*	420	-	18.3	2016/2017	34

Only the studies that adopted the standardized microscopy diagnostic method with the stated sample size are included.

*SAC, school-age children.

Mixed: both adults and children.

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● *S. haematobium*

● *S. mansoni*

Figure 1A. *Schistosoma* species distribution map of Ghana, 1987.[1] The map was adopted from the WHO with some modifications. It depicts the widespread of *S. haematobium* countrywide, while *S. mansoni* is limited to the upper part of the northern sector of the country. Most of the cases occurred along Lake Volta. https://www.who.int/schistosomiasis/epidemiology/en/ghana.pdf (accessed on 26 October 2021)

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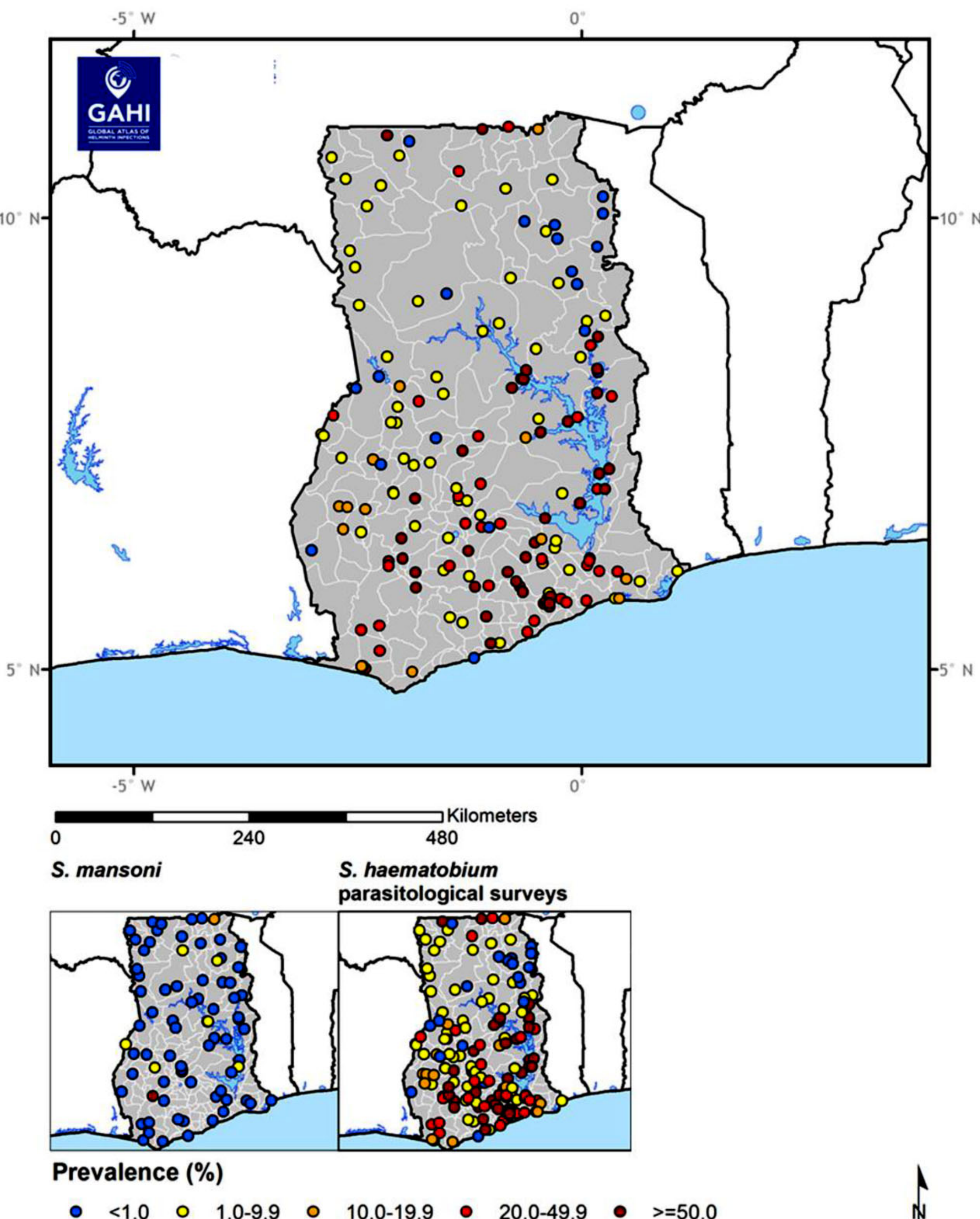

Figure 1B. *Schistosoma* species distribution and prevalence map of Ghana, 2015.[2] Adopted from Global Atlas of Helminths Infection (GAHI) with modification. The map depicts widespread of both *S. haematobium* and *S. mansoni* throughout Ghana; however, the prevalence of *S. mansoni* was very low compared with *S. haematobium*. https://www.thiswormyworld.org/maps/distribution-of-schistosomiasis-survey-data-in-ghana (accessed on 5 June 2021).

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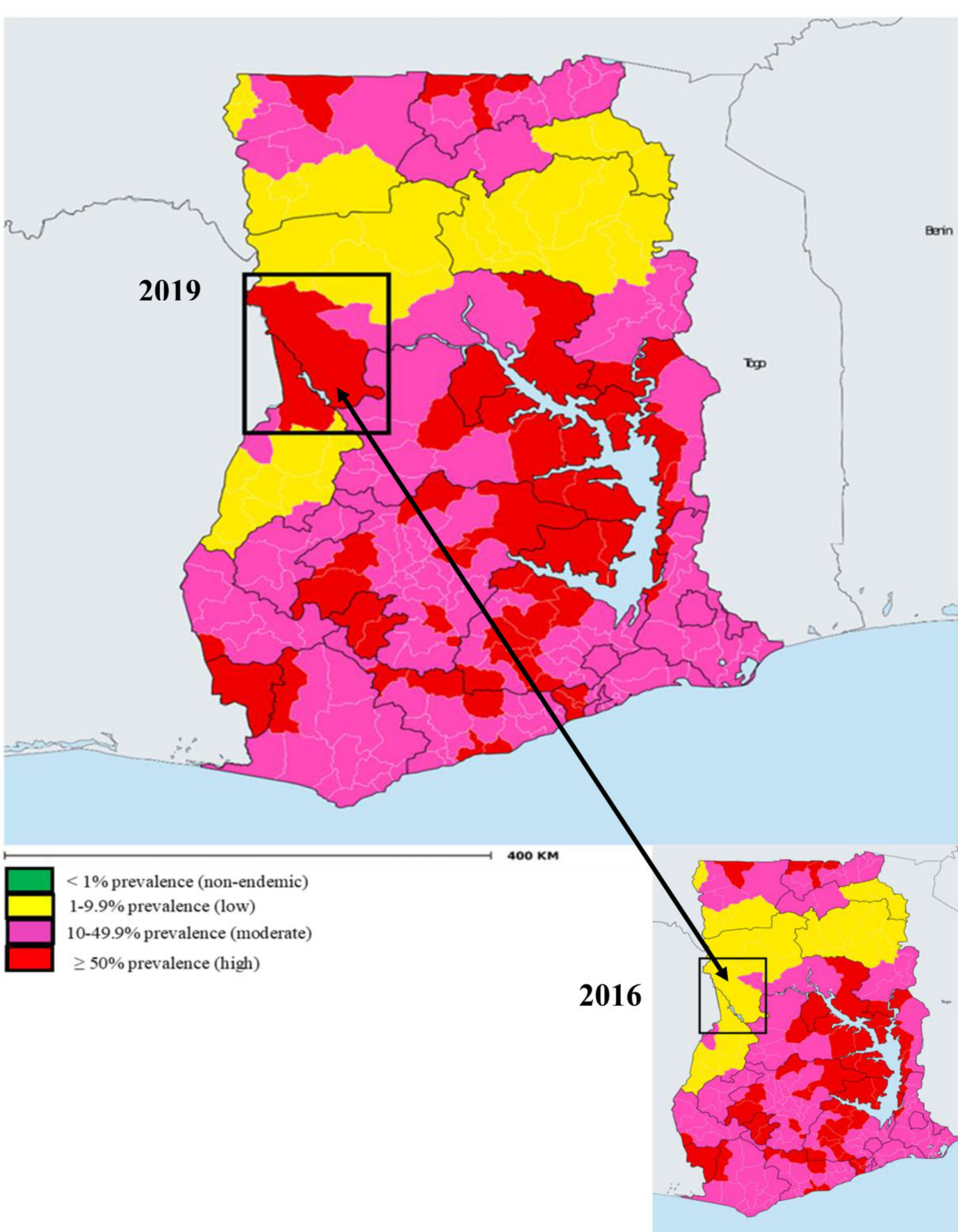

Figure 1C. Schistosomiasis distribution and prevalence map of Ghana, 2016 and 2019.[3] The maps were adopted from the WHO and modified accordingly. The maps depict that the whole country is endemic to schistosomiasis, with the vast part of Ghana having moderate to high prevalence. There is evidence of change in the endemicity status of some localities from low endemic status in 2016 to high endemic status in 2019 marked by the squares. https://espen.afro.who.int/countries/ghana (accessed on 6 June 2022).

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both light and heavy infection settings.[41] Also, the potential of portable mobile phone-based devices for quality diagnostics on-site, where standard laboratory facilities are unavailable, has been documented.[49] However, none of these field-applicable methods, which would be of extremely high importance for monitoring schistosomiasis in very remote communities without access to electricity, have been implemented into routine use.

Control of schistosomiasis transmission in Ghana

Articles on transmission control are focused on snail intermediate host control, water and sanitation quality control, evaluation of human water contact activities, knowledge, awareness of schistosomiasis and finally on evaluation of MDA campaigns (Supplementary Table S1). Among efficient environmental interventions, snail control due to the removal of weeds and the application of molluscicides in water contact sites is reported.[50] On the contrary, increased levels of schistosomiasis transmission have been attributed to dam constructions, irrigation channels and proliferation of aquatic weeds.[27,51] Metrics such as water contact activities, disease symptoms awareness, knowledge of disease transmission, health-seeking behavior, knowledge of disease treatment and prevention/control were assessed. The overall knowledge of schistosomiasis in terms of symptoms among studied groups, including females and health workers, was very poor.[52] Respondents tended to have more knowledge about urogenital compared with intestinal schistosomiasis; however, for example, symptom-aware children were highly infected with *S. haematobium*.[42] The health-seeking behavior on schistosomiasis, compared with other diseases (e.g. malaria/fever), was very low and practices such as the fetching of surface water, swimming and wading were predominant among school-aged children[53] (Supplementary Table S1).

Preventive chemotherapy as a measure to control the disease was almost nonexistent in the early years[54] until 2008, a year after a nationwide survey had commenced, and the target group of this nationwide MDA was school-aged children. The most updated data on schistosomiasis MDA in Ghana and endemicity status were published in 2019 on the WHO website.[18]

Pathogenesis of human schistosomiasis

Articles on the pathogenesis of human schistosomiasis cover studies focused on female genital schistosomiasis (FGS), oncogenic alterations and immune response (Supplementary Table S1). Greater than 10% prevalence of FGS has been reported in a schistosomiasis endemic community. Also, poor knowledge has been reported elsewhere: interviewees thought that schistosomiasis was a 'boys' disease'.[52,55] However, these studies are too sparse to paint a clear picture of FGS specifically and genital schistosomiasis in general in Ghana.

Snail intermediate host

Snail surveys conducted in Ghana during 1954–1980 indicated the widespread presence of *Bulinus* spp. and *Biomphalaria pfeifferi* as vectors for *S. haematobium* and *S. mansoni*, respectively. These studies showed the presence of snail intermediate hosts in an environment dominated by water dams, drainage and irrigation channels for agricultural activities.[51,56] In addition, other studies have explored the susceptibility of snails to different strains of schistosomes in different localities, while others examined snail intermediate host control using chemical compounds together with ecological modifications (Supplementary Table S1). Data on snail distribution and prevalence for the past 3 decades are absent, although the importance of snail intermediate hosts in the transmission of schistosomiasis is clear.

Animal schistosomiasis

Two studies conducted on intestinal parasites of livestock in southern Ghana are the only available records of prevalence, reporting distant values of 0.2% and 21.7%, particularly for cattle schistosomiasis (Supplementary Table S1).[57] In a related study, the prevalence of schistosomiasis in pigs was 0.4% in northern Ghana.[58] Such a negligible focus on animal schistosomiasis in Ghana neither reflects close relationships of animal and human schistosomiasis nor the economic impact of livestock schistosomiasis.

Knowledge gaps, future perspectives on schistosomiasis research and control

According to the documents reviewed, several issues regarding schistosomiasis arise:

1. To ensure effective control, sound national epidemiological data are required for proper planning and implementation of control programs, especially for MDA campaigns. Real data, rather than estimations and inferences on at-risk group, infected people, their age groups, respective communities and parasite species, will ensure the right amount of medication is procured and the right people in need of treatment are reached. Besides, epidemiological data will also enhance the monitoring and evaluation of control programs effectively. In the past, some countries that achieved effective control and elimination (e.g. Morocco) have employed effective screening and treatment of infected persons.[59] A significant lack of reliable data in Ghana, especially on prevalence, but also, for example, on general morbidity from a large part of the country, might negatively influence any control-related efforts at local level. Thus, the focus of schistosomiasis research in neglected regions needs to be improved drastically.
2. It is also necessary to fully implement international strategies and protocols aimed at controlling and eliminating NTDs in general and schistosomiasis in particular (e.g. adhering strictly to the current WHO 2021–2030 roadmap on NTDs would help to improve schistosomiasis control). MDA campaigns need to be expanded, regularized and consistent. Provision of recreational water centers in at-risk communities, along with control of snail intermediate hosts, are needed to achieve low endemic status in the long term. Proper monitoring and impact evaluation of control programs are required to identify cases of resurgence and reinfection borne out of reduced efficacy of praziquantel (PZQ). This will help to

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improve control of schistosomiasis in Ghana significantly. We recommend that improving control of schistosomiasis in Ghana requires: (a) integration of political will for the formulation of effective and efficient health-supportive policies; (b) cooperation of control program managers and implementers with local communities; and (c) active involvement of researchers in planning and implementing schistosomiasis control programs, without which little or no success would be achieved towards the goal of disease elimination.

3. To improve disease diagnosis, training of clinical laboratory technicians must be ensured by the National NTD program and partners. Also, practices, including routine checks for the presence of schistosome eggs during every routine stool and urine examination, should be introduced.
4. Genital schistosomiasis is an emerging topic and evidence points to incidence of FGS in some communities in Ghana; however, no study on male genital schistosomiasis (MGS) has been conducted, although records of MGS do exist.[60] Hence, critical attention must be paid to genital schistosomiasis, starting from awareness creation and sensitization of health workers in endemic communities with updates on the complex symptoms of schistosomiasis.
5. A few limited malacological studies have been conducted in Ghana, but these are archaic. New nationwide studies on snail distribution, susceptibility to schistosomes and prevalence are necessary to indirectly monitor the transmission trend of schistosomiasis.
6. There is an urgent need to establish research focused on livestock schistosomiasis, population structure and genetics, the interrelatedness of animal and human schistosomiasis, zoonotic potentials, their transmission routes, susceptibility to PZQ and, subsequently, to implement this knowledge in control programs. This will equally enhance molecular research on schistosomiasis that is currently lacking in Ghana.

Conclusion

This pivotal comprehensive literature review of schistosomiasis in Ghana covers almost 7 decades of published research. Most of the studies included in the present review are focused on the epidemiology, diagnosis and control of schistosomiasis. As per the estimated prevalence values, Ghana has achieved significant progress in disease control over recent years by reducing prevalence from >70% in 2010 to <25% in 2015. However, the estimation is already 7 y old and more recent data are needed. Moreover, the control effort that yielded such results was heavily dependent on morbidity control in humans through PZQ MDA, with very little on snail intermediate hosts control and other relevant strategies. Hence, there remains the need for animal schistosomiasis studies and improvement in other control strategies such as monitoring and evaluation of MDAs, control of snail intermediate hosts, WASH and community sensitization.

Supplementary data

Supplementary data are available at *Transactions* online.

Authors' contributions: All authors contributed immensely to this review article. EMB conceived the idea, reviewed the literature and drafted the review. IA expanded the scope of coverage and restructured the conclusion; JD performed the structuring and organization of topics and subtopics and introduced technicalities to the review. He was also instrumental in the internal review of the article. MC supervised and carried out the internal revision of the revised version and participated in the literature search. All the authors read and approved the final version of the manuscript.

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Disclaimer: The authors originally compiled this review article and apart from the materials duly cited and referenced, no part of the review has been presented anywhere prior to this submission.

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