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Approaches in scaling up schistosomiasis intervention towards transmission elimination in Africa: Leveraging from the Chinese experience and lessons

Eniola M. Abe[a,b], E. Tambo[c], Jingbo Xue[a,b], Jing Xu[a,b], Uwem F. Ekpo[d], David Rollinson[e], Kun Yang[f], Shi-Zhu Li[a,b], Xiao-Nong Zhou[a,b,*]

[a] National Institute of Parasitic Diseases, Chinese Center for Disease Control and Prevention, Shanghai 200025, China
[b] WHO Collaborating Centre for Malaria, Schistosomiasis and Filariasis, Key Laboratory of Parasite and Vector Biology, Ministry of Health, Shanghai 200025, China
[c] Département de Biochimie et Science Pharmaceutiques, Université des Montagnes, Bagangté, République du Cameroon
[d] Department of Pure and Applied Zoology, Federal University of Agriculture, Alabata Road, Abeokuta, 110001, Nigeria
[e] The Natural History Museum, Cromwell Road, London SW7 5BD, United Kingdom
[f] Jiangsu Institute of Parasitic Diseases, Wuxi, China

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ABSTRACT

Schistosoma japonicum, differs from the African species including *S. mansoni* and *S. haematobium,* is a zoonotic parasite as it infects both human and animals including domestic ruminant animals such as cattle and animals from the wild. Considering China's success story in the elimination of schistosomiasis, the China-Africa collaboration on schistosomaisis elimination in Africa is an important cooperative health development initiative. This review examines the importance of China-Africa collaboration on schistosomiasis elimination using effective surveillance-response intervention strategy as the platform to effectively drive the elimination of schistosomiasis in Africa. Three conclusions were made after reviewing the similarity and differences in schistososmiasis control programmes between China and African continent as follows: (i) Politically, China's lessons is that leveraging on the integrated control strategies and the recognition that schistosomiasis is a public health problem which prompted the interest of government in China. It is necessary for African leaders and governments to recognize schistosomiasis as a public health challenge that must be given serious attention in terms of funding and setting up frameworks to complement control efforts. (ii) Technically, efficient monitoring and surveillance system mechanism will facilitate contextual and effective management of schistosomiasis elimination across different environment, and African programme managers should embrace the use of appropriate diagnostic tools to guide treatment strategies at different thresholds of schistosomiasis control. (iii) Strategically, effective control of snail intermediate hosts and precision mapping of snail distribution should be prioritized for successful schistosomiasis elimination in Africa.

1. Introduction

The persistence of schistosomiasis endemicity in the tropical and subtropical regions is debilitating on children and adult population health, eroding national economic growth and development of the world (King 2015; 2010; Van der Werf et al., 2003). It is prevalent in approximately 78 countries and territories located in Africa, South America, Middle East and the southern Asia with an estimated 800 million people at risk and more than 250 million people infected with schistosome parasites globally (Colley et al., 2014; Rollinson et al., 2013; Mone et al., 2010; Hotez et al., 2007a; Engels et al., 2002). More than 95% of all infections of this water-associated disease caused by trematode parasites belonging to the genus *Schistosoma* are concentrated in Africa (Steinmann et al., 2006; Utzinger et al., 2009).

Schistosomiasis continued transmission is attributed to snail host distribution, which are required for asexual development of the trematode parasites in environment characterized with persistent neglect and poor access to and weak implementation of contextual WASH programmes (WHO, 2002; Gryseel et al., 2006; Hotez and Kamath, 2009; Stothard et al., 2009; Utzinger et al., 2011). Drug treatment through mass drug administration (MDA) is the major national schistosomiasis control effort aimed at reducing morbidity in

* Corresponding author.
E-mail addresses: abeeniola11@126.com (E.M. Abe), tambo0711@gmail.com (E. Tambo), xuejb@nipd.chinacdc.cn (J. Xue), xujing@nipd.chinacdc.cn (J. Xu), ekpouf@funaab.edu.ng (U.F. Ekpo), d.rollinson@nhm.ac.uk (D. Rollinson), jipdyk@163.com (K. Yang), lisz@chinacdc.cn (S.-Z. Li), ipdzhouxn@sh163.net (X.-N. Zhou).

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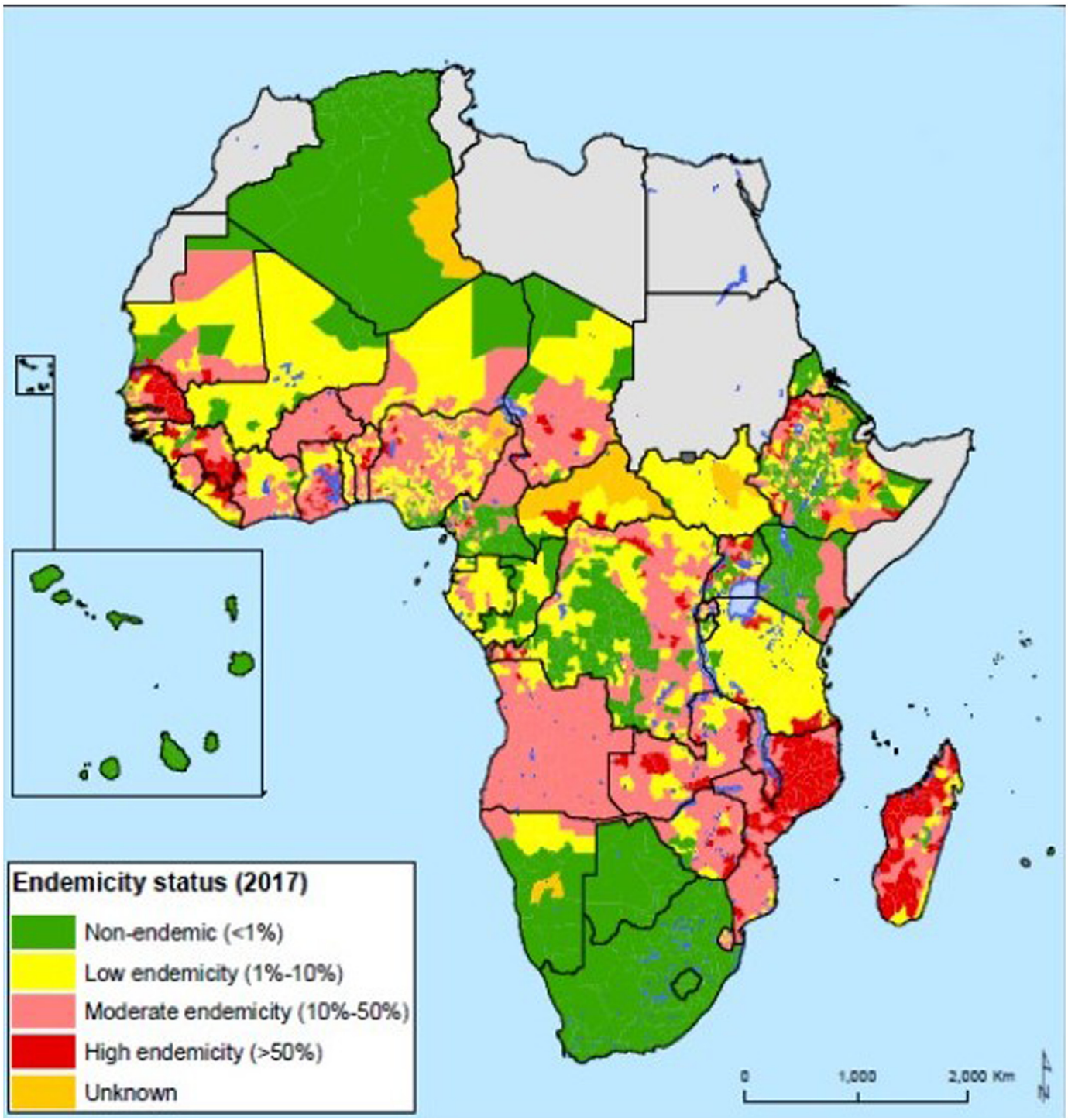

Fig. 1. Endemicity status of schistosomiasis in Africa (http://espen.afro.who.int/diseases/schistosomiasis, 2017. Accessed 1st Oct. 2018).

most African countries. However, this approach remains challenged by diverse local barriers and health systems bottlenecks including lack of early diagnosis, late care seeking behaviours (Mafe et al., 2005; WHO, 2006; Hotez et al., 2007b; Doenhoff et al., 2008) and re-infection after treatment. Efforts are continually made to provide useful data (Ekpo et al., 2012a; Opisa et al., 2011; Ekpo et al., 2010; Pullan et al., 2014) to initiate effective schistosomiasis control plan in Africa but reliable data on accurate epidemiological status and geographic distribution are lacking in most endemic settings. Fig. 1 shows the endemicity status of schistosomiasis in Africa. *Schistosoma japonicum* epidemiology differs from the African species including *S. mansoni* and *S. haematobium*. *S. japonicum* is zoonotic as it infects both human and animals including domestic ruminant animals such as cattle and animals from the wild. The epidemiology of both *S. mansoni* and *S. haematobium* is only limited to humans (definitive hosts) and the snail intermediate hosts (https://www.cdc.gov/globalhealth/ntd/diseases/schisto_burden.).

China's efforts to effectively control *S. japonicum* transmission is laudable (Zhang et al., 2016), they were once plagued with widespread *S. japonicum* transmission across the country with endemicity reported in 12 provinces, 11,600,000 people and 1200,000 cattle infected in the 1950s (Chen and Feng, 1999). Through government political-will and

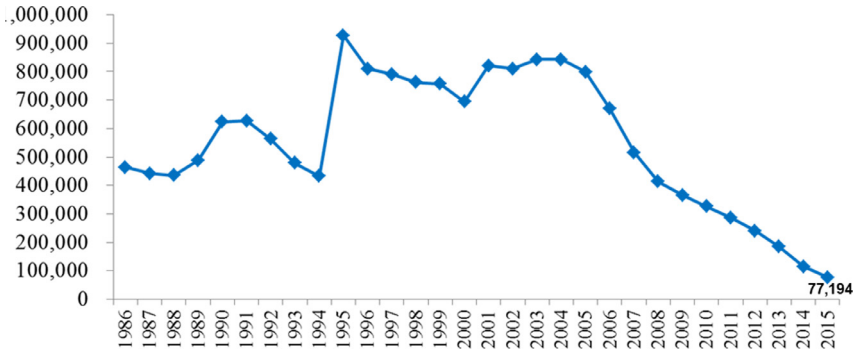

Fig. 2. Epidemiological change of schistosomiasis in last 30 years in China (Source: National annual report for schistosomiasis in China, 2016).

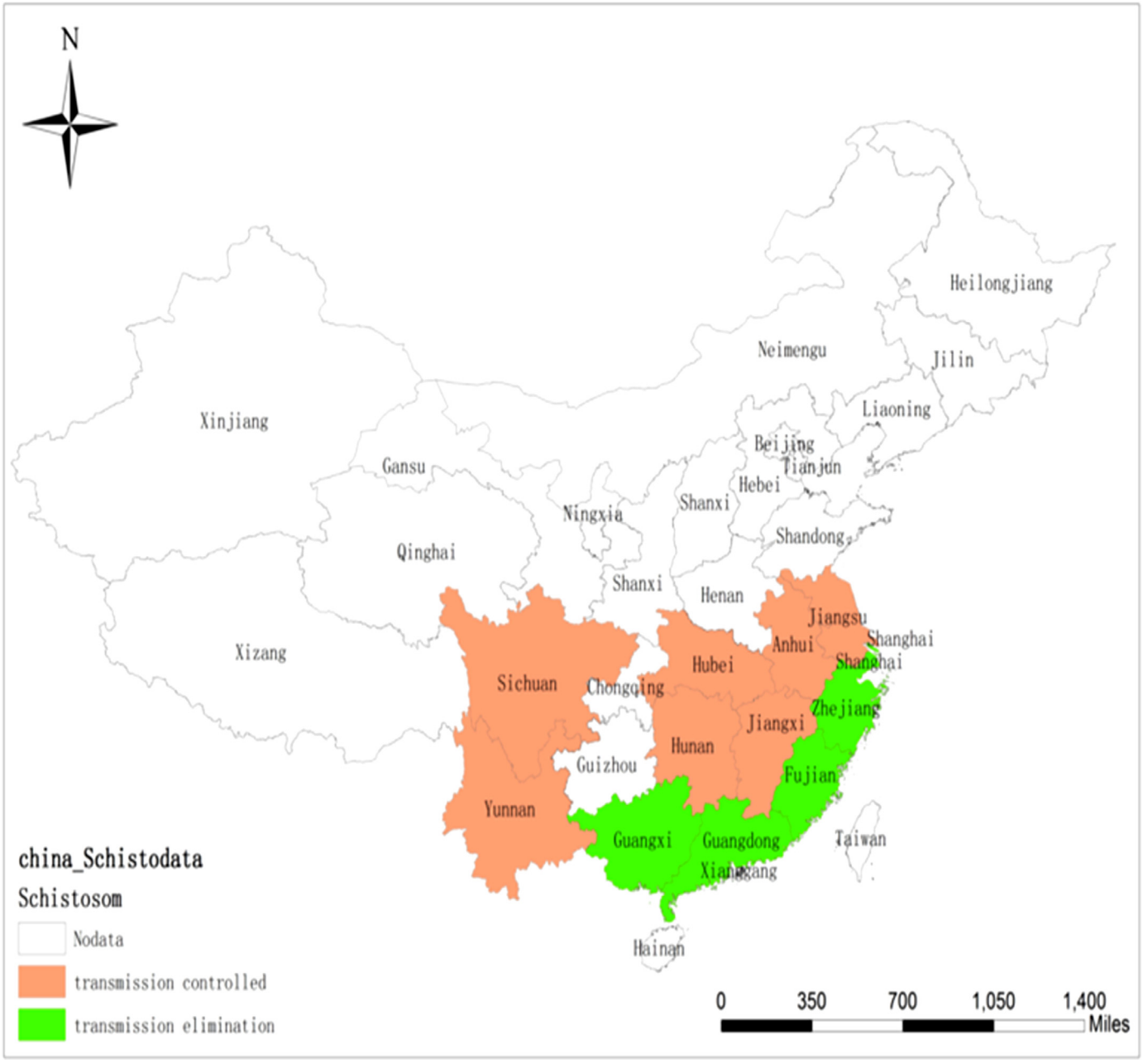

Fig. 3. Schistosomiasis control status in China for 2016 (Source: National annual report for schistosomiasis in China, 2016).

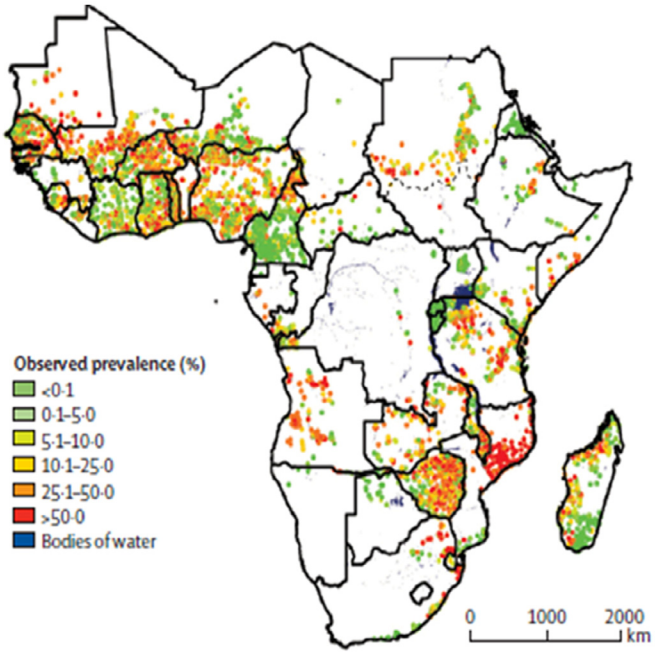

Fig. 4. Observed prevalence of *S. haematobium* in Africa (2000–2014) (Lai et al., 2015).

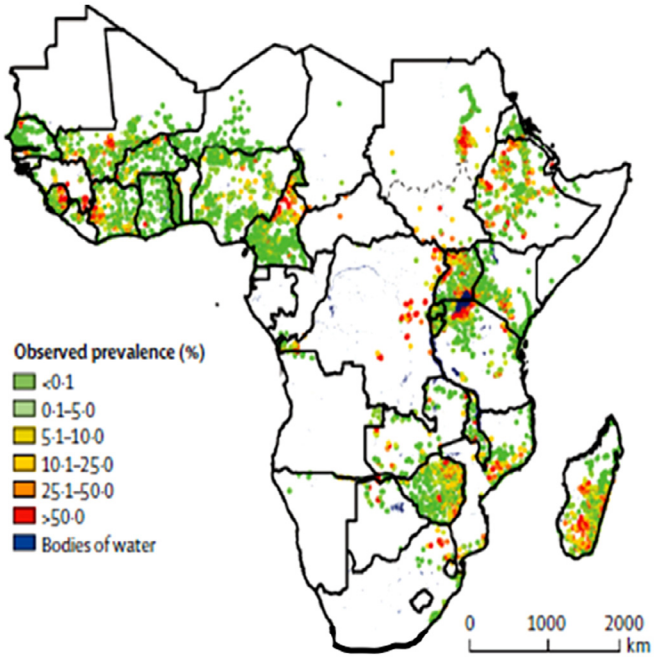

Fig. 5. Observed prevalence of *S. mansoni* in Africa (2000–2014) (Lai et al., 2015).

implementation of integrated control strategies, they eliminated schistosomiasis as a public health problem in the country (Zhang et al., 2016; Li et al., 2014; Collins et al., 2012). The strategies employed by China interrupted schistosomiasis transmission in five provinces, including Shanghai (1985), Guangdong (1985), Guangxi (1988), Fujian (1987) and Zhejiang (1995) (Utzinger et al., 2005; Wang et al., 2008) and finally attained elimination in 2016 (NRAS, 2016). The elimination status attained in 2016 in these provinces was a product of the ten years medium- and long- term target for the national schistosomiasis control programmes implemented since 2004. Transmission-controlled status was also achieved in seven other provinces including Sichuan (2008), Yunnan (2009), Jiangsu (2010), Hubei (2013), Jiangxi (2015), Anhui (2015) and Hunan (2015). All counties have achieved the criteria for schistosomiasis elimination as public health problem with village prevalence level < 1%, at the end of 2015 (Zhou, 2016).

Considering China's success story in schistosomiasis elimination and other parasitic diseases such as filariasis and malaria, the China-Africa collaboration on schistosomiasis elimination in Africa is an important cooperative health development initiative, that offers support to African countries from China in order to control schistosomiasis transmission in Africa. This review examines the importance of China-Africa collaboration on schistosomiasis elimination using effective surveillance-response intervention strategy as the platform to effectively drive schistosomiasis elimination in Africa.

2. Epidemiological trends and pattern in China and Africa

Schistosomiasis is termed neglected because it is associated with poverty and people that lives in communities that lack access to basic infrastructure such as good potable water sources, sanitary facilities, and also indulge in habits that promotes schistosomiasis transmission such as open defecation near waterbodies, swimming in water contaminated with infective schistosome cercariae (Ekpo et al., 2013). Being neglected and ignorance arising from poor knowledge of the disease epidemiology in many endemic communities expose inhabitants to waterbodies infested by schistosome cercariae, which facilitates the continued transmission of the water-associated disease (Ekpo et al., 2012b).

Schistosomiasis is of great economic importance in endemic areas especially in sub-Saharan Africa where an estimated 57 million disability-adjusted life years are lost annually due to infection with schistosomes, despite drug treatment with praziquantel, which is becoming increasingly expensive for donors to cope with its supply (Conteh et al., 2010). The debilitating disease is associated with long term morbidity that results into inflammatory reactions as a consequence of the eggs laid by adult worms. Proteolytic enzymes secreted by the eggs aid their migration to the intestine and bladder to shed (Gryseels et al., 2006). The type of adult schistosome worm determines the migration route of specific parasite worm within the host internal organs (Bennett et al., 2015). Most schistosomiasis infections are mildly symptomatic with malnutrition and anaemia especially in endemic areas (https://www.niaid.nih.gov). When untreated, the disease results in substantial morbidity and even mortality, however, the extent are disputed. Chronic infection in children compromise cognitive development, growth, physical fitness and naive immune system which can further increase susceptibility to other infections. In adult, chronic infection may discourage efficiency at workplace and also enhance low productivity (Gray et al., 2011).

The epidemiological changes of schistosomiasis in last 30 years in China, and schistosomiasis control status in China for 2015 are shown in Figs. 2 and 3, respectively, while the observed prevalence of *S. haematobium* and *S. mansoni* in Africa (2000–2014) are shown in Figs. 4 and 5, respectively.

2.1. Priorities for effective blocking of schistosomiasis transmission in Africa

The World Health Assembly, set the roadmap targets of schistosomiasis elimination as “public health problem” in African countries and elimination in few selected countries or parts of countries by 2020. In addition, global schistosomiasis elimination as a public health problem by 2025 (WHO, 2012) bearing in mind that mass drug administration (MDA) coverage treatment is limited to treating only school-aged children in many countries endemic for schistosomiasis in Africa. For schistosomiasis elimination to be achieved in Africa by 2025, the following two-folds activities should be urgently prioritized and considered.

Firstly, studies have shown that the burden of schistosomiasis in

Table 1
Factors responsible for schistosomiasis transmission and elimination in Africa and China.

Disease	Indicators	Africa		References	China		References
		Present	Future		Present	Future	
S. haematobium/ S. mansoni	Transmission	1 Poor access to potable water sources. 1 Poor access or lack of basic amenities such as sanitary facilities. 1 Continued distribution of snail intermediate hosts. 1 Poor knowledge on the epidemiology and economic importance of schistosomiasis. 1 Poor hygiene culture and health education in most endemic areas. 1 Political instability, lack of government political-will to recognize schistosomiasis as a serious public health problem and also complement control programmes to block schistosomiasis transmission in Africa	1 Imported schistosomiasis cases. 1 Water contact activities of fishermen and other people who earn their daily livelihood through similar avenue.	Akinwale et al., 2015; Salawu and Odaibo, 2014; Hotez and Kamath, 2009; Stothard et al., 2009; Gryseels et al., 2006; Mathers et al., 2007; World Health Organization (1985), (1993), (2002); Mafiana et al., (2003); Bosompem et al., al.(2004); Ekpo et al. (2010); Garba et al. (2010); WHO (2002); Utzinger et al. (2011); Lengeler et al. (2002); Brooker et al. (2009); Soniran et al. (2015); Bonfoh et al., 2011	Presence of *Biomphalaria a* but no reported case of transmission yet.	*Biomphalaria* snails are invasive species in mainland China and their continued spread poses danger for *S. mansoni* transmission.	Qu et al. (2016) Huang et al. (2014)
	Elimination	1 Mapping population of school-aged children affected with schistosome parasites. 1 Snail intermediate hosts study at local scales in few localities.	1 Mapping of all age groups infected with schistosome parasites 1 Identification of waterbodies where schistosomiasis transmission is on-going and mapping snail intermediate hosts distribution for effective elimination 1 Identification of infection sources 1 Snail detection 1 Molluscicidal application 1 Health education, efficient WASH implementation and environmental modification. 1 Active surveillance monitoring through integrated control strategies. 1 Commitment from governments in African countries to be actively involved by providing funds to complement efforts from donor agencies and nations.	Zhou et al., (2005); Smits (2009); WHO (2011) Abe et al. (2012); Abe et al. (2016); Ekpo et al. (2013); King et al. (2006); WHO (2010); Sturrock, 1995; Lardans and Dissous, 1998; Fenwick et al., 2006; Asaolu & Ofoezie (2003); Utzinger et al. (2003); Ziegelbauer et al. (2012); Singer & Castro (2007); Knopp et al. (2013); Holveck et al., 2007; Wang et al. (2009)			
S. japonicum	Transmission	1 Imported schistosomiasis cases. 1 Environmental factors such as water fluctuation that influences snail distribution in lakes and marshlands. 1 Creation of freshwater sites through dam construction.	1 Imported schistosomiasis cases. 1 Faecal contamination from wild faeces	Wang et al. (2005); Southgate (1997); Jobin (1999); Steimann et al. (2006); Rollinson (2009); Zhou et al. (2007); Lei et al. (2015)			

(*continued on next page*)

Table 1 (*continued*)

Disease	Indicators	Africa Present	Future	References	China Present	Future	References
	Elimination	1 Mapping of infection sources. 1 Surveillance monitoring of mobile populations. 1 Snail and bovine surveillance in high risk regions.	1 Improved surveillance strategy to sustain schistosomiasis elimination. 1 Snail detection 1 Molluscicidal application 1 Monitoring imported infection sources 1 Improved diagnostics for effective detection of infection in areas with low schistosomiasis prevalence areas. 1 Control of other potential risk factors	Xu et al. (2014); Yang et al. (2014); Yang et al. (2006); Wen et al. (2011); Wu et al. (2005); Zhu et al. (2009); Tong et al. (2015); Tambo et al. (2014); X.N. Zhou et al. (2011); Lei et al.,)2014(; Wang et al.,)2015a(; Zheng et al., 2012a, Zheng et al., 2012b, 2013(, Zhu & Xu (2014), Cao et al. (2014), Zheng et al., (2014)			

Africa is high, particularly in the pre-school aged children, that have been exempted from receiving treatment over the years because the control programme of preventive chemotherapy is implemented based on cost-effectiveness (Ekpo et al., 2012b; Ekpo et al., 2011; Dabo et al., 2011; Mutapi et al., 2011; Garba et al., 2010). It is therefore, important to investigate the predisposing factors that makes the population across all age groups susceptible to schistosomiasis infection in order to access information that would aid efficient schistosomiasis control plan in most endemic settings.

Secondly, with all the challenges and bottlenecks that surrounds schistosomiasis elimination in Africa, it is difficult to implement preventive chemotherapy as the only control strategy to achieve the target of schistosomiasis elimination by 2025. There is urgent need to assess the population of people infected with schistosomiasis across all the age groups and map their distribution, to establish a comprehensive database with holistic and precision mapping of infected population that would help guide intervention plan, so that we can identify the risk factors associated with schistosomiasis transmission in the environment at different settings to achieve the global targets by 2025.

Increased efforts are required for the development of serodiagnostic tools and vaccines against schistosomiasis (de Assis et al., 2016; Driguez et al., 2016). With the emerging resistance to praziquantel, the application of micro-array immunomic platform for novel drug development must be improved. Therapeutic vaccines have been explored and are effective for the treatment of parasitic diseases, cancer and some infectious diseases (Guo et al., 2013; Prabowo et al., 2013). Application of vaccines to complement praziquantel could be effective in reducing schistosomiasis burden when considered. Although both *S. mansoni* and *S. haematobium* are not zoonotic, but, it is important to randomly screen farms and work animals for infection, especially areas that are identified as schistosomiasis hotspots. The current global environmental changes due to human activities have further promoted infectious diseases transmission, which is responsible for the modification of species geographical distribution and hybridization (Nichols et al., 2014; Lafferty, 2009).

2.2. Measures required to reduce persistent schistosomiasis burden in Africa

Schistosomiasis transmission is focal, however, it is difficult to identify and manage the sources of infection as well as discourage reinfection in treated persons without identifying the indicators responsible for transmission. Understanding these indicators would provide the needed guidance for the development of control strategies that will be supported by efficient surveillance and monitoring system (Zhang et al., 2016). Surveillance component of the control strategy provides a framework of sensitive network to guide intervention and activities of control programmes (Yang et al., 2014; Xu et al., 2014).

More importantly, the success of schistosomiasis control programmes in Africa is dependent on identifying the critical epidemiological factors in endemic areas, monitor activities in areas with high potential risk of transmission and provide technical guidance for effective surveillance and response until schistosomiasis elimination goal is achieved (Xu et al., 2013). Indicators required for tracking schistosomiasis control and elimination can be detected through the following indices, e.g. case finding (in humans), case detection, case reporting, case management and surveillance for detection of schistosomiasis in humans within localities and imported cases, determine snail hosts distribution, assess schistosome parasites in snails, mobilize for snail control and set-up surveillance for snail control. The key factors for schistosomiasis transmission and elimination in Africa and China are shown Table 1.

2.2.1. Case finding and detection

This involves schistosomiasis diagnoses and early reporting of cases which could be acute or chronic with information of the infected individual bio-data such as age, gender, date of diagnosis, residential

Table 2
Current endemic situation of schistosomiasis in China, 2016.

Province (Municipality, autonomous region)	No. of counties (cities, districts)	No. of Townships	Elimination		Transmission interruption		Transmission control	
			No. of counties (cities, districts)	No. of townships	No. of counties (cities, districts)	No. of townships	No. of counties (cities, districts)	No. of townships
Shanghai	8	81	8	81	0	0	0	0
Jiangsu	64	473	16	145	45	312	3	16
Zhejiang	55	469	55	469	0	0	0	0
Anhui	51	366	7	18	16	167	28	181
Fujian	16	75	16	75	0	0	0	0
Jiangxi	39	317	4	11	20	175	15	131
Hubei	63	522	7	27	34	290	22	205
Hunan	41	343	0	0	15	122	26	221
Guangdong	13	33	13	33	0	0	0	0
Guangxi	20	69	20	69	0	0	0	0
Sichuan	63	662	13	99	50	563	0	0
Yunnan	18	74	0	0	11	49	7	25
Total	**451**	**3484**	**159**	**1027**	**191**	**1678**	**101**	**779**

address, type of diagnosis and locality taken and reported immediately within 24 h to the national control programmes database for follow-up and action (Li et al., 2014). Cases are considered acute schistosomiasis when information reveals that (i) the person has contact with water-bodies between one and three months (ii) when the individual has symptoms of fever, hepatosplenomegaly and peripheral eosinophilia (iii) when *Schistosoma* eggs are found in faeces (Li et al., 2012).

The details of case finding, case detection, case reporting and case management are monitored through effective surveillance system (Zhou et al., 2007). Hence, the surveillance indicators required for tracking and planning effective schistosomiasis elimination include schistosomiasis cases, snail intermediate hosts and other related epidemic factors such as environmental factors which include rainfall, temperature and water level (Xu et al., 2014).

2.2.2. Schistosomiasis cases

Case finding of infection in human population across age groups will help identify and quantify the actual number of infected persons in the population. It will also help classify the level of schistosomiasis cases amongst the infected population. Level of schistosomiasis infection in humans can be classified as acute, chronic and advance schistosomiasis depending on the degree of severity in the individual. Surveillance activities majorly make use of information on acute cases in areas where schistosomiasis transmission is not controlled (Zhang et al., 2016; Lin et al., 2007).

2.2.3. Snail intermediate hosts

Snail intermediate hosts play active role in schistosomiasis transmission. Therefore, it is pertinent to identify the different types of snail hosts in endemic communities and areas with potential risk of transmission as well as assess information about their spatial distribution (Abe et al., 2016, 2012). This is important in Africa especially countries where more than one snail intermediate host transmits schistosome parasites. Snail host monitoring is crucial for effective schistosomiasis surveillance (Abe et al., 2018; Sokolow et al., 2016; Zhang et al., 2016; Li et al., 2014).

2.2.4. Related epidemic factors

Surveillance tracking of environmental factors such as rainfall, temperature, humidity, human behavioural and socio-cultural patterns especially the people in endemic areas should be monitored for successful implementation of integrated control strategy for schistosomiasis elimination (Wang et al., 2015; Zhou et al., 2008).

2.3. Surveillance strategy as intervention in scaling up schistosomiasis response in Africa

Surveillance involves the continuous, systematic collection, analysis and interpretation of health-related data for effective planning, implementation and evaluation of public health practices (WHO, 2016). It is important in assessing the impact or tracking of an intervention and monitoring the progress of intervention, to allow priorities to be set and inform decisions on control strategies (WHO, 2016). It is, also, a fundamental element that facilitates the implementation of control strategies and will provide programme managers and stakeholders in the control programme, information on the dynamics of schistosomiasis distribution, transmission pattern and environmental factors which play crucial role in the development of schistosome parasites and distribution of snail intermediate hosts (Yang et al., 2006).

All information through surveillance provides the platform for strategy development, decision making, implementation of control strategies and evaluation in the Chinese national schistosomiasis control and elimination programme (Tables 2–5, Fig. 7). Principally, surveillance can be classified into active and passive surveillance (Fig. 6). In passive surveillance, routine surveillance data are obtained and recorded mainly through various clinics, while active surveillance investigates disease occurrences and transmission patterns for appropriate intervention to be taken. Active surveillance is further divided into three categories (Zhang et al., 2016), such as:

i Risk surveillance: this is a follow-up surveillance action in areas where schistosomiasis transmission has been interrupted to discourage prevalence from getting back to baseline level. There are four types of risk surveillance, including (i) sentinel surveillance, (ii) routine surveillance, (iii) emergency endemic surveillance, and (iv) cross-sectional sampling survey.
ii Surveillance on sentinel sites: this is a type of longitudinal active surveillance in the fixed sites which represent the transmission patterns of schistosomiasis in a region.
iii Repetitive cross-sectional sampling survey: this involves carrying out schistosomiasis epidemiological surveys on national scale to determine the prevalence level, quantify the infected population, and evaluate intervention within a certain period.

The function of the different types of risk surveillance is summarized as indicated in Fig. 6. First, sentinel surveillance involves assessing the prevalence of schistosomiasis amongst humans and carrying out snail surveys at intervals. Results from this exercise are processed and control action will be taken. Sentinel surveillance is important for evaluating and planning control strategies. The process of sentinel surveillance includes schistosomiasis investigation, provide information

Table 3
Examination and chemotherapy for human schistosomiasis in endemic regions of China, 2016.

Province (Municipality, autonomous region)	No. examined							No. of people treated			
	Total population examined	No. of people receiving serological tests	No. of serological positive	No. of people receiving Stool examinations	No. of people receiving Stool examinations amongst serological positives	No. stool positives	No. stool positives amongst serological positives	Acute cases	Chronic cases	Advanced cases	No. of people covered by preventive chemotherapy
Shanghai	11,530	11,530	57	50	47	2	2	0	2	0	0
Jiangsu	437,164	392,945	3277	87,043	3272	1	1	0	1	679	5761
Zhejiang	108,020	108,020	652	690	651	9	9	0	9	1095	608
Anhui	1,876,336	1,835,859	23,245	243,517	23,200	0	0	0	23,244	4573	290,043
Fujian	4021	4021	1	0	0	0	0	0	0	0	0
Jiangxi	769,968	768 365	21 411	44 672	20 868	6	5	0	21 301	5 210	70 883
Hubei	1 728 326	1 728 300	41 154	42 290	40 557	0	0	0	36 689	4 580	631 741
Hunan	862 009	861 079	39 774	39 244	35 346	582	581	0	46 058	3 347	484 621
Guangdong	1 911	1 911	6	6	5	0	0	0	0	0	0
Guangxi	9 220	8 397	29	843	26	0	0	0	0	0	0
Sichuan	2 393 543	2 212 128	42 713	282 821	42 312	0	0	0	0	680	575 382
Yunnan	298 662	255 925	9 925	42 737	8 981	0	0	0	0	174	244 516
Total	**8 500 710**	**8 188 480**	**182 244**	**783 913**	**175 265**	**600**	**598**	**0**	**127 304**	**20 338**	**2 303 555**

on outbreak or schistosomiasis status in a particular location, diagnosis of infection with serological examination and patent and prepatent detection of infection in snails.

Second, routine surveillance mainly involves reporting schistosomiasis cases, case surveys and warning on acute schistosomiasis cases. (i) Reporting schistosomiasis cases involve reporting cases to national schistosomiasis control centre immediately after diagnosis in any of the health centres or hospitals. It is advised that the means of communicating schistosomiasis reports to the national control centre should be through a web-based information system to enhance efficiency. The bio-data of the schistosomiasis patient will also be included in the information that will be documented and forwarded to the national control centre with the status of schistosomiasis infection which could be either acute or chronic schistosomiasis. (ii) case survey is used to assess information about the reported schistosomiasis cases which could be chronic, acute or advanced schistosomiasis, it differs with stages of control efforts in terms of implementation. More information is collected in case survey including name, gender, age, address, contact information, occupation, history of schistosomiasis, history of schistosomiasis treatment, time of diagnosis, diagnostic results, clinical symptoms, results from sera test and stool examination and characteristics of infection sites.

Third, emergency epidemic surveillance involves setting parameters for case detection at different schistosomiasis controlled/intervention settings or environment. Using the China schistosomiasis control programme model as an example, epidemic emergency is raised in communities where schistosomiasis transmission is interrupted. When schistosomiasis infection is detected in the inhabitant or snail intermediate host within the schistosomiasis-controlled area. Emergency epidemic is raised when ten or more acute schistosomiasis cases are reported within one week. The call for emergency epidemics requires thorough investigation of all acute cases in the community or area and the scope of the possible waterbody where transmission has occurred will be determined using information obtained from case survey and the people that might have visited the waterbody during this period will be monitored. In addition, intensive snail survey will be carried out, environmental and socio-economic factors that might influence schistosomiasis transmission will also be investigated.

Fourth, cross-sectional sampling survey is important for effective schistosomiasis control programmes because when conducted it provides reliable data and scientific basis for the development of workable guideline and control strategies, as well as evaluation of previous strategy. It is advised that this survey be carried out five years interval for three times in Africa especially the sub-Saharan region followed by evaluation to determine the impact of control strategies.

2.4. Targeting integrated control strategies for effective schistosomiasis transmission interruption in Africa

The main goal of snail intermediate hosts control is to interrupt schistosomiasis transmission (Lo et al., 2018). China targeted schistosomiasis elimination by controlling snail host with molluscicide and environmental modification of snail habitats to discourage recolonization of snail population (Wang et al., 2008; Utzinger et al., 2005). Similar approaches can be employed in Africa, more importantly, targeting snail control using a combination of molluscicide and ecological control with the modification of environment in areas identified as schistosomiasis hotspots in endemic settings.

2.4.1. Mollusciciding

Application of molluscicides such as 50% niclosamide ethanolamine (which has proved effective in China) in endemic areas of Africa would help disrupt schistosomiasis epidemiology significantly. The molluscicide is formulated in different form such as powder, suspension concentrates and granules (Yang et al., 2012) to ease application targeting snail hosts elimination with mild impact on the environment. Although

Table 4
Oncomelania hupensis snail survey in China, 2016.

Province (Municipality, autonomous region)	No. of endemic townships	No. of endemic townships with snail survey	No. of townships with snails detected	No. of endemic villages	No. of villages surveyed	No. of villages with snails detected	Surveyed areas (hm2)	Area with detected snails (hm2)
Shanghai	81	50	6	1 127	345	17	708.01	1.16
Jiangsu	473	475	60	4 181	4 105	143	84 874.56	2 058.83
Zhejiang	469	419	91	5 185	2 773	266	5 731.37	44.41
Anhui	366	342	210	2 392	2 117	1007	14 1617.76	25 042.43
Fujian	75	65	7	328	266	9	1 632.37	3.05
Jiangxi	317	248	123	2 182	1 062	429	108 356.99	31 668.6
Hubei	522	485	335	5 447	4 566	2553	19 7418.62	50 884.47
Hunan	343	311	185	3 475	2 255	813	182 384.29	119 290.84
Guangdong	33	30	0	120	63	0	66.71	0
Guangxi	69	58	5	265	196	6	2 420.07	4.19
Sichuan	662	617	353	4 522	3 982	1603	43 847.87	5 029.80
Yunnan	74	73	55	468	410	260	44 905.29	1 068.26
Total	**3 484**	**3 173**	**1 430**	**29 692**	**2 2140**	**7106**	**813 963.91**	**235 096.04**

the economic situation in most African countries is not strong compared to China, to embark on drastic environmental modification projects but efforts can be made to properly manage the removal of weeds and aquatic plants from canals and ensure that waterways are free from plants and debris that influences snails' survival. Adequate provision and upgrade of basic infrastructure that will improve access to potable water sources and sanitary facilities in homes and communities to reduce frequent contact with unsafe waterbodies should be prioritized by the authorities concerned.

2.4.2. Sanitary facilities

China ensured that all houses especially in endemic areas were equipped with toilets as well as built public toilets in strategic areas for mobile migrants to access. Legislations should be in place to ensure that house owners in remote and peri-urban areas of Africa provide sanitary facilities in their homes when constructed to discourage open defecation. There is urgent need to include parasitic diseases control and prevention in health education syllabuses of both primary and secondary schools to educate pupils which are the target group for drug treatment at early stages of their lives on schistosomiasis epidemiology and other infectious diseases to reduce exposure to risk of infection.

2.4.3. Health promotion

The media and volunteer groups should be targeted to educate the public, more importantly, the vulnerable group such as fishermen, people living in riverine areas and rice farmers in swampy environment about the importance of snail hosts in schistosomiasis epidemiology and the need to imbibe good sanitation and hygiene culture. China targeted educating the fishermen and boatmen in communities (Liu et al., 2009) along the Yangtze river using health education volunteers trained by the local Centre for Diseases Control professionals. They discouraged the fishermen and boatmen from allowing their faeces to have contact with the waterbodies, also, they were equipped with mobile toilets in their boats as well as provided them with sanitary facilities at the shore of the river (Sun et al., 2017). This facilitated successful control implementation in the region. Health promotion authorities should target encouraging water, sanitation and hygiene strategy in schools and communities with improved access to water sources to reduce disease burden.

2.4.4. Multi-sectoral collaboration

One major step taken by the Chinese government to successfully interrupt schistosomiasis as a public health problem was ensuring that government at all levels and the organized private sectors were involved and committed to the schistosomiasis control programme. This collaborative approach is lacking in Africa, it is difficult because the government are yet to recognize schistosomiasis as a public health problem that requires serious attention from all stakeholders.

With the increasing economic struggles of most African countries, reliable collaborations with the organized private sectors could help get their support and commitment to funding control programmes in Africa. However, government must come up with potent national policies and work plans to guide schistosomiasis control programmes. This is necessary to complement efforts from international stakeholders, donor agencies and nations.

Meanwhile, it is important to tailor and adapt control strategies to the different endemic settings across Africa. The institution-based network on China-Africa cooperation for schistosomiasis elimination is a platform setup to enhance transferring Chinese schistosomiasis experiences through building capacities of experts, scholars and stakeholders from Africa on malacology, schistosomiasis and snail hosts surveillance.

2.5. Institution-based network on China-Africa cooperation for schistosomiasis elimination (INCAS)

The Chinese government has prioritized schistosomiasis elimination in Africa and willing to offer support in achieving the elimination goal as indicated in the First and Second Ministerial Forum on China-Africa Health Cooperation held in 2013 and 2015, respectively.

The government commitment prompted the National Institute of Parasitic Diseases and Control (NIPD), Chinese center for Diseases Control and Prevention (China CDC), to embark on establishing the Institution-based Network on China-Africa Cooperation for Schistosomiasis Elimination (INCAS) in 2015. INCAS is a platform designed to effectively drive schistosomiasis elimination in Africa through the development and application of multipronged schistosomiasis integrated control strategies. INCAS activities are targeted towards building capacities and providing technical support to stakeholders, scholars, experts from member institutions in order to strengthen schistosomiasis control programmes in Africa. The platform provides training support to African scholars on schistosomiasis and malacology research in the last three years. These efforts target building capacities and knowledge transfer between experts from China and Africa as well as integrate ideas for better understanding.

2.6. Understanding African schistosomiasis, adapting and tailoring control strategies to local setting through pilot study to block schistosomiasis transmission in Zanzibar

For better understanding of schistosomiasis situation in Africa, INCAS through the Chinese government initiated a three-year pilot survey at Pemba Island, Zanzibar in 2016. The project is co-implemented by Jiangsu Institute of Parasitic Diseases from China and the Ministry of Health, Zanzibar. The project offers the Chinese experts the

Table 5
Actual snail infested area and snail control in China, 2016.

Province (Municipality, autonomous region)	No. of townships with snails	No. of villages with snails	Total snail areas (hm^2)	Marshland and lake regions		Plain region with waterway network (hm^2)	Hilly and mountainous regions (hm^2)	Area with snail control		
				Inner embankment	Outside embankment			Accumulatedarea with mollusciciding	Actual area with mollusciciding	Area covered by environmental modification
Shanghai	6	20	2.13	0.00	0.00	2.13	0.00	175.54	0.64	0.04
Jiangsu	60	150	2 335.69	0.00	2 195.14	132.82	7.73	12 312.02	1 884.02	33.49
Zhejiang	96	328	74.18	0.00	0.00	0.67	73.51	1 925.97	96.17	4.30
Anhui	213	1 016	26 531.28	0.00	23 147.38	0.00	3 383.90	11 415.08	7 198.68	17.88
Fujian	7	9	2.26	0.00	0.00	0.00	2.26	28.33	1.74	1.00
Jiangxi	151	645	78 486.76	0.00	76 056.54	00.00	2 430.22	12 115.73	8 314.86	216.70
Hubei	343	2 617	68 391.50	20 588.29	45 470.14	0.00	2 333.07	43 315.72	29 699.53	2 637.55
Hunan	195	839	172 646.75	702.43	171 014.64	0.00	929.68	21 974.56	19 870.40	118.02
Guangdong	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guangxi	5	6	4.24	0.00	0.00	0.00	4.24	26.29	4.24	0.00
Sichuan	436	2 173	7 044.55	0.00	0.00	0.00	7 044.55	25 095.22	5 560.31	72.54
Yunnan	49	253	1 315.25	0.00	0.00	0.00	1 315.25	11 099.38	1 311.16	0.00
Total	**1 561**	**8 056**	**356 834.59**	**21 290.72**	**317 883.84**	**135.62**	**17 524.41**	**13 9483.84**	**73 941.75**	**3 101.52**

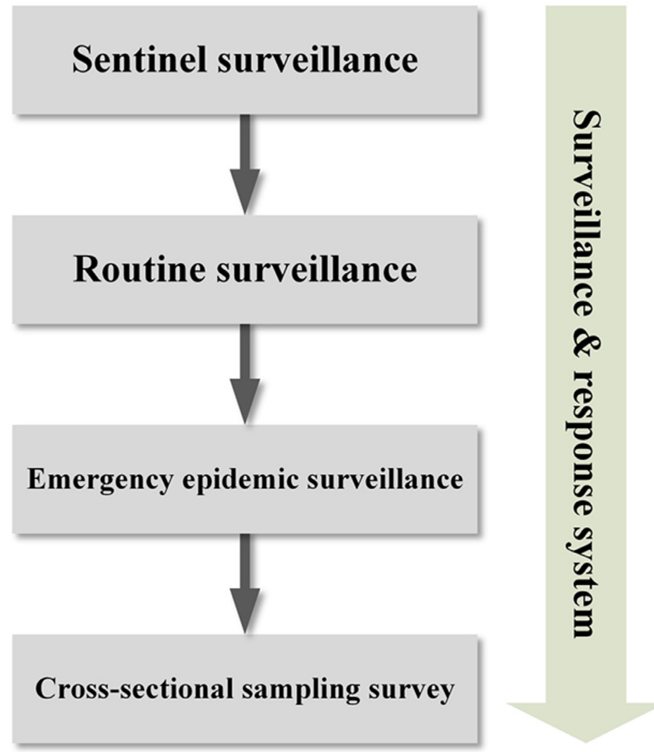

Fig. 6. Surveillance-based strategy for effective schistosomiasis control.

opportunity to study the transmission dynamics of schistosomiasis and also give them insight about adapting and tailoring their control strategies into epidemiological settings in Africa. The project will facilitate knowledge sharing and transfer between both Chinese and Tanzanian schistosomiasis control teams, as it involves the implementation of integrated control strategy as well as establishment of surveillance and response system for schistosomiasis control in the country.

2.6.1. Training on the application of molluscicide

To foster capacity building on snail control in Africa, the INCAS-NIPD platform through WHO was involved in the training of Chinese and African professionals on mollusciciding in the pilot field in 2016 and 2017 in Tanzania. All these efforts are targeted towards equipping both Chinese and African experts for robust continental schistosomiasis elimination programme in Africa.

2.7. Major constraints hindering effective schistosomiasis control strategies in Africa

2.7.1. Lack of political-will by the government

The inability of government in most countries endemic for schistosomiasis in Africa to identify schistosomiasis as a public health problem contribute largely to the increasing burden of the disease. Control efforts are majorly initiated by global health stakeholders, donor nations and agencies without adequate support from the government. The situation is different in China, the central government took the lead role in combating schistosomiasis plague in the country, formulating policies and making funds available for control programmes.

2.7.2. Lack of funds for control programmes

Funding of control programmes in most African countries is limited to funds from donors and this hampers implementation of control strategies. Provision of adequate funds for the execution and sustenance of schistosomiasis control programmes is important to effectively reduce disease burden. Poor coverage with drug treatment for school-aged children is often experienced in some countries, government

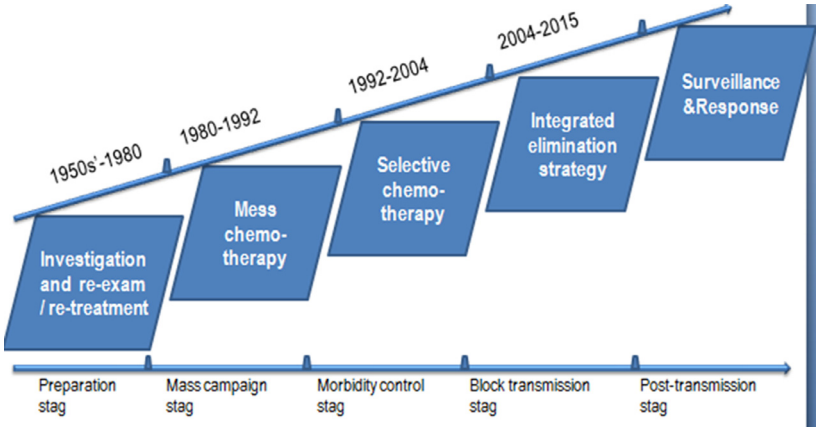

Fig. 7. Phases of control strategies implemented for effective schistosomiasis control in China (Zhou, 2016).

support is needed to ensure good treatment coverage.

2.7.3. Poor health system

The health systems in most countries endemic for schistosomiasis is weak and cannot support the large number of people seeking medical attention. Hospitals lack facilities for diagnosis and treatment of most infections including schistosomiasis (Xu et al., 2016).

2.7.4. Poor awareness of schistosomiasis epidemiology in most endemic settings

Infected populations and those at risk of schistosomiasis infection in most endemic settings are not informed about the disease epidemiology. They have no knowledge about the danger posed by the snail hosts that they often see around waterbodies, where they do their daily chores and other activities. There is need for awareness on the economic importance of schistosomiasis through health education from the media and community-wide participation (Abe et al., 2018).

2.7.5. Challenges in executing effective schistosomiasis surveillance and response in China

The effective application of schistosomiasis surveillance and response in China has gone through three different stages, namely disease mapping, epidemiological surveillance and monitoring of public health surveillance (Wen et al., 2011). Surveillance and response mechanism to monitor programme implementation involves cross-sectional and longitudinal surveillance, active and passive surveillance and other types of surveillance (Fig. 7) (Zhang et al., 2016). However, there exist gaps in the schistosomiasis surveillance system currently used in China (Wen et al., 2011; Zhou et al., 2013a). The gaps include (i) outdated monitoring tools (ii) unstable monitoring team (iii) inadequate feedback mechanism (iv) inadequate monitoring indicators. Other gaps include poor tracking of mobile population, diagnosis not based on criteria (sero test), low surveillance capacity in transmission-interrupted counties (lack of basic technology and knowledge) and lack of surveillance on the invasive *Biomphalaria spp*. to check possible outbreak of *S. mansoni* in China.

It is essential to strengthen schistosomiasis surveillance system in China at this period of transition from control to elimination in the national programme. Hence, the need to strengthen the development, innovation and continuous improvement of schistosomiasis surveillance and response system in the country. Surveillance components that requires strengthening could be summarized as follows: (i) Research on sensitive efficient monitoring indicators, establishment of scientific and reasonable index system; (ii) Carry out multi-channel monitoring and explore a comprehensive monitoring management mode (iii) The development and utilization of advanced monitoring techniques and tools, improve the sensitivity of the monitoring system. (iv) Establish high quality monitoring team, enhance the monitoring capacity and the ability to respond to schistosomiasis outbreak.

It is also important to encourage an integrated surveillance management approach at this period of schistosomiasis control transition from schistosomiasis interrupted phase to elimination phase in China, to strengthen the quality control of surveillance system (Zhou et al., 2013a), periodic evaluation of surveillance efficiency and effectiveness should be prioritized and also encourage the flexibility and adaptation of surveillance to the different environmental settings and stages or status of schistosomiasis endemicity.

3. Conclusion

Evidence-based schistosomiasis control programme should be guided by the outcome of schistosomiasis mapping in providing a robust understanding of schistosomiasis distribution and transmission dynamics and also inform stakeholders especially programme managers on the tools needed. There is need for the implementation of efficient monitoring and surveillance system mechanism to facilitate contextual and effective management of schistosomiasis elimination across different environment (Dang et al., 2014; Zhao et al., 2005). It is, also, imperative that different stakeholders of schistosomiasis control programme in Africa and programme managers should embrace the use of appropriate diagnostic tools to guide treatment strategies at different thresholds of schistosomiasis control (Zhou et al., 2011a; Bergquist et al., 2009).

The elimination of schistosomiasis transmission as a public health problem will take a long time in most African countries but it is more achievable following the progress made in China in this respect. Leveraging on the integrated control strategies and the recognition that schistosomiasis is a public health problem which prompted the interest of every level of government in China to get involved in the schistosomiasis control programme. It is, therefore, necessary for African leaders and government to recognize schistosomiasis as a public health challenge that must be given serious attention in terms of funding and setting up frameworks to complement control efforts rather than leaving schistosomiasis control programmes and infected populations at the mercy of donor agencies to supply praziquantel for preventive chemotherapy which focus mainly on school-aged children.

Effective control of snail intermediate hosts should be prioritized for successful schistosomiasis elimination in Africa (Loker, 2005). Therefore, their geographic distribution should be monitored and analysed consistently using both geographic information system and remote sensing tools to map and predict their distribution (Abe et al., 2016; Gao et al., 2014, 2012). Hence, routine snail survey and monitoring should be seriously considered especially in endemic and high-risk areas to assess infection rate and also get improved molluscicides with low toxicity to other aquatic lives but effective in destroying snail intermediate hosts (Yang et al., 2010; Zhou et al., 2013b).

Declaration of Competing Interest

None.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.actatropica.2020.105379.

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