CHAPTER FIFTEEN

China–Africa and China–Asia Collaboration on Schistosomiasis Control: A SWOT Analysis

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Abstract

Schistosomiasis, a disease caused by a trematode, parasitic worm, is a worldwide public health problem. In spite of great progress with regard to morbidity control, even elimination of this infection in recent decades, there are still challenges to overcome in sub-Saharan Africa and endemic areas in Southeast Asia. Regarded as one of the most successful countries with respect to schistosomiasis control, The People's Republic of China has accumulated considerable experience and learnt important lessons in various local settings that could benefit schistosomiasis control in other endemic countries. Based on an analysis of conceived strengths, weaknesses, opportunities and threats (SWOT) of potential collaborative activities with regard to schistosomiasis in Africa and Asia, this article addresses the importance of collaborative efforts and explores the priorities that would be expected to facilitate the transfer of Chinese experience to low- and middle-income countries in Africa and Asia.

1. INTRODUCTION

The trematode worm infection schistosomiasis has been known since antiquity and remains a major public health problem draining the economic development worldwide. According to the World Health Organization (WHO), the number of countries in tropical and subtropical areas that are endemic for this disease stands currently at 78, 50 of them in Africa and 17 in Asia (WHO, 2013). *Schistosoma mansoni* and *S. haematobium* are widespread in Africa that also harbours limited foci of *S. intercalatum* in the centre and western parts of the continent (Ross et al., 2013; WHO, 2013). In Asia, *S. japonicum* are reported in The People's Republic of China and the Philippines, while small pockets exist on the island of Sulawesi in Indonesia (Ross et al., 2013). Similarly, small pockets of *S. mekongi* exist along a short stretch of the Mekong River at the border between Cambodia and Laos

(Muth et al., 2010). In addition, *S. malayensis* which is closely related to *S. japonicum* has been reported in few sites of Malaysia (Greer et al., 1988).

S. mansoni, *S. haematobium* and *S. japonicum* are mainly responsible for the human disease burden. Recent estimates suggest that over 250 million people have schistosomiasis in the world, which translates into a global burden of 3.3 million disability-adjusted life years (DALYs) (Hotez et al., 2014), a figure even higher than the 200 million infected believed to have existed by the end of last century (Chitsulo et al., 2000). However, the true DALY figure may be almost 10 times higher as argued by King (2010). With the discovery and release for large-scale use of the safe and high-efficient anthelmintic drug praziquantel (PZQ) (Davis and Wegner, 1979) and its subsequent dramatic fall in price, chemotherapy became the backbone of schistosomiasis control programmes. Significant reduction of morbidity and prevalence of schistosomiasis was achieved, including local elimination in several countries (Barkia et al., 2011; Chen et al., 2005; Ebisawa, 1998; French et al., 2010). In recent decades, interests in schistosomiasis control and discussion of suitable strategies for elimination have been raised at international meetings (Fenwick and Savioli, 2011; Rollinson et al., 2013). Although morbidity control is still the main target, particularly in sub-Saharan Africa (SSA), the resolution passed by World Health Assembly (WHA 65.21) in 2012 calls for the increased investment in schistosomiasis control to initiate elimination programmes where appropriate (WHA, 2012).

More than 90% of populations in need of chemotherapy with PZQ live in Africa and the Middle East, where people often have scarce sanitation and lack safe water (WHO, 2013). Control and/or elimination of schistosomiasis are facing great challenges in these countries (Fenwick et al., 2006; Leonardo et al., 2002; Utzinger et al., 2009). Meanwhile, great achievements have been gained in The People's Republic of China for schistosomiasis control through more than six decades of uninterrupted national control activities (Chitsulo et al., 2000; Rollinson et al., 2013). This has led to the accumulation of a significant amount of experience of various endemic stages and surroundings and at varied degrees of economic development that should benefit schistosomiasis control in other endemic countries (Wang et al., 2008; Xu et al., 2015). As there are substantial differences between The People's Republic of China and African/Asian countries, both with respect to health system and economic situation as well control strategies and intervention approaches, the transfer of knowledge will not be straightforward. The experience gained in The People's Republic of China can be more easily duplicated in Asia than in Africa due to the difference between schistosome species and, in particular the snail intermediate hosts in the latter continent.

This article aims to review and explore the priorities of facilitating the cooperation with regard to schistosomiasis control between The People's Republic of China and African/Asian countries.

2. COOPERATION BETWEEN THE PEOPLE'S REPUBLIC OF CHINA AND ENDEMIC COUNTRIES IN AFRICA AND ASIA

Since the internal and external factors, which are either favourable or unfavourable with regard to collaboration on schistosomiasis control in geographical areas as different as The People's Republic of China and Africa (Xu et al., 2016), a thorough analysis should precede active collaboration. The differences with respect to other Asian endemic areas are less pronounced, but still need to be included in the analysis.

We chose a well-known, structured approach to identify and evaluate the strengths, weaknesses, opportunities and threats (SWOT) of the planned collaborative involvement, as it deals with internal and external factors impinging on our objective. The SWOT approach was first used for management and business analysis in the 1960s, but is nowadays widely used to find out the degree to which the internal environment of an activity matches with the external environment, ie, the 'strategic fit' (Fig. 1).

2.1 Strengths

2.1.1 Similar transmission patterns

The schistosome species in The People's Republic of China, Indonesia and the Philippines are transmitted by intermediate snail hosts different from those in Africa and in the two Southeast Asian countries Cambodia and Laos. *S. japonicum* and *S. mekongi* produce serious morbidity more often and more rapidly than other species due to higher output of eggs, which are also often released in aggregates (Chen and Mott, 1988). Although the different species have unique life cycles, people get infections through contact with water contaminated by cercaria (the infective stage of the parasite), either because of their professional (agriculture, fishing, washing) or pleasure activities such bathing (Clerinx and Van Gompel, 2011; Day et al., 1996). For this reason, school-aged children and fishermen are at a particularly high risk for infection (Alebie et al., 2014; Chipeta et al., 2013; Li et al., 2009). The distribution of schistosomiasis is strictly consistent with the snail breeding areas.

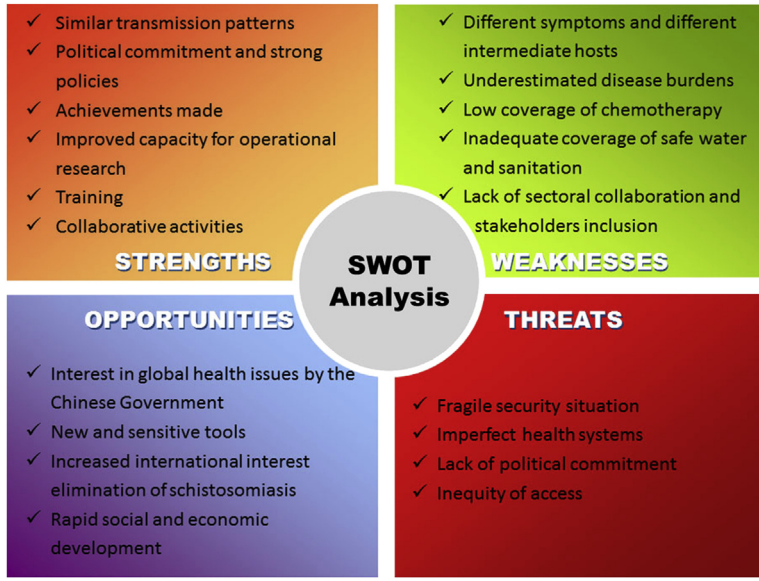

Figure 1 Strengths, weaknesses, opportunities and threats analysis on China–Africa and China–Asia collaboration on schistosomiasis control.

2.1.2 Political commitment and strong policies

Compared with other acute infectious diseases, schistosomiasis was neglected in African and most Asian countries in the past half century. Some countries, such as Brazil, Egypt, Morocco and The People's Republic of China have, however, made strong progress on its control. Recognizing the public health importance of schistosomiasis, Resolution WHA 54.19 was endorsed by Member States of the WHO in 2001 aiming to reach the target of 75% treatment coverage of school-aged children with PZQ by 2010. As the results of the decrease in prevalence and mortality led by deworming campaigns, some endemic countries have made it a goal to interrupt transmission or even elimination of the infection. For example, the Philippine government has stated that it aims to eliminate schistosomiasis as a public health problem by embarking on a vigorous, multisector approach in the endemic areas (Leonardo et al., 2008). The Zanzibar Elimination of Schistosomiasis Transmission, implemented in this part of Tanzania, shows a strong political will to eliminate schistosomiasis, which has already resulted in a significant decrease of the prevalence of this and other helminths (Knopp et al., 2012). The People's Republic of China is drafting a new national strategic plan aiming at the elimination of schistosomiasis as a public health threat from the whole country by the 2016–2025 period (Lei and Zhou, 2015).

2.1.3 Achievements made

Supported by Schistosomiasis Control Initiative (Fenwick et al., 2009) and the global network for the neglected tropical diseases (NTDs) (Liese et al., 2010), many African countries conduct chemotherapy, either for the control of schistosomiasis alone or in combined therapy schemes including also other NTDs (Mazigo et al., 2012; Savioli et al., 2009; Stothard et al., 2009). The number of people receiving treatment in WHO's African region has almost doubled, increasing from 12.37 million in 2006 to 35.56 million in 2012 (WHO, 2014). The prevalence of schistosomiasis in Cambodia, Laos, Indonesia and the Philippines has decreased to near or below 1% with the implementation of mass drug administration (MDA) (Garjito et al., 2008; Laymanivong et al., 2014; Leonardo et al., 2012; Sudomo and Pretty, 2007; Urbani et al., 2002). Many countries in Africa and Asia conduct or have already completed national surveys of human schistosomiasis prevalence as well as mapping of snail habitats (Brooker et al., 2009; Clements et al., 2008; Kabatereine et al., 2006; Leonardo et al., 2012). This information should be useful for the development of control strategies and allocation of the limited financial resources available.

2.1.4 Improved capacity for operational research

To accelerate research for schistosomiasis control and/or elimination in various parts of the world, international cooperation projects such as the Schistosomiasis Consortium for Operational Research and Evaluation (http://score.uga.edu/), CONTRAST, a multidisciplinary alliance in Africa (Bergquist, 2013), have optimized schistosomiasis control and transmission surveillance in SSA. The project on sustainable control of Asian schistosomiasis, a six-country collaboration within the Regional Network on Asian Schistosomiasis and other Helminth Zoonoses (RNAS+) supported by the Canadian International Development Agency through International Development Research Center (IDRC) was implemented to explore innovative control strategies (Zhou et al., 2015). This has led to research results being transferred or integrated into current control activities. For example, new diagnostic tools and modelling techniques were explored and implemented into national schistosomiasis control programmes (Hisakane et al., 2008; Ishikawa and Ohmae, 2009; Kato-Hayashi et al., 2013; Kirinoki et al., 2011; Obeng et al., 2008); A PZQ 'dose pole' that substitutes height for weight, validated in the Philippines and several African countries, facilitated the field administration of PZQ in situations when accurate weighing scales are unavailable (Erfe et al., 2013; Nordin et al., 2014; Palha De Sousa et al., 2014). Variations in the schistosome-intermediate host interplay have been analysed (Attwood

et al., 2008a,b; Bayne, 2009; Berriman et al., 2009; Liu et al., 2006). And cost-effectiveness of control programmes and strategies for schistosomiasis elimination have been analysed (Croce et al., 2010; Tallo et al., 2008).

2.1.5 Training

To support and sustain the schistosomiasis control programmes, capacity building for governmental officials and technical staff has been strengthened to improve their technical and management skills in endemic countries. Training courses were conducted to teach the health staff how to detect and manage the schistosomiasis cases, conduct snail surveys, organize drug distribution, calculate drug requirements, and manage and analyse surveillance data (Fenwick et al., 2009; Garba et al., 2006). Through training courses and networks, government officials have been trained in communicating how to design control programs, manage chemotherapy campaign and mobilize social resources, etc. (Omedo et al., 2014; Zhou et al., 2015). To increase public knowledge how to prevent and control schistosomiasis, accurate and high-quality training materials including television sketches, radio, publicity leaflets, posters, comic strips, etc. have been designed to educate the population at large in endemic areas (Hu et al., 2005; Muth et al., 2010; Omedo et al., 2014).

2.1.6 Collaborative activities

The medical aid team sent to Algeria in 1963 was one of the first international health-related activities undertaken by the Chinese government (Liu et al., 2014). Since then, the China–Africa and China–Asia collaboration in the health field has increased through construction of hospitals, donation of medicine and equipment, sending medical teams, training health staff and malaria control. More than 23,000 Chinese medical workers have been sent to about 66 countries benefiting an estimated 270 million people. Among 49 countries supported by Chinese medical teams in 2013, 42 are in Africa and 4 in Asia (Zhu, 2013). One of the most visible cooperative research and control projects, the RNAS+ that was established in 2002 has assembled scientists and policymakers from 10 Asian countries (Leonardo and Bergquist, 2002). Activities include cooperative research projects, sharing experience and distribution of lessons for helminthiases control in Asian member countries. RNAS+ has also organized training courses and workshops related to disease control encouraging the establishment of reference laboratories and exploration of regional research priorities. To share experience on research and control of schistosomiasis and discuss the possibility of collaboration between African countries and The People's Republic of China, communication

has been established between RNAS+ and its African counterpart, the research network on schistosomiasis in Africa. During 2013 and 2014, cooperation of Chinese and African institutions were further strengthened by memoranda of understanding concerning Sino-Africa collaboration. These memoranda refer to strengthening of the cooperation on schistosomiasis control and research and were signed between the Public Health Laboratory in Pemba Island, which is part of Zanzibar, a semiautonomous part of Tanzania, and Jiangsu Institute of Parasitic Diseases, The People's Republic of China, the Blue Nile Institute in Sudan and the National Institute of Parasitic Diseases, The People's Republic of China CDC, respectively. More recently, an Institution-based Network on China-Africa Cooperation for Schistosomiasis Elimination (INCAS) was established after a China-Africa cooperation workshop on schistosomiasis held in Malawi in April 2015, and further strengthened by formal technical agreement signed in October 2015 between the National Institution of Parasitic Diseases in Chinese Center for Disease Control and Prevention and 5 institutions, including University of Yaoundé I, Cameroon; Institut National De Recherche En Santé Publique, Mali; Blue Nile National Institute for Communicable Diseases University Of Gezira-Wad Medani, Sudan; National Institute for Medical Research, Mwanza Centre, Tanzania; and University of Zimbabwe, Zimbabwe.

2.2 Weaknesses

2.2.1 Different symptoms and different intermediate hosts

Although all schistosome species causing human infections have similar transmission patterns, differences exist concerning the intermediate hosts, clinical manifestations and transmission seasons. *S. japonicum* and its amphibious, dioecious *Oncomelania hupensis* snail is the sole schistosome life cycle operating in The People's Republic of China. In contrast to the African schistosome species, *S. japonicum* is zoonotic and capable of infecting more than 40 mammalian animals (Chen and Feng, 1999). *S. mekongi* in Cambodia and Laos, transmitted by the aquatic snail *Neotricula aperta*, is also zoonotic with pigs, dogs and rodents serving as reservoir hosts (Attwood, 2001; Ohmae et al., 2004). *S. mansoni*, *S. haematobium* and *S. intercalatum* in Africa depend on various aquatic and hermaphrodite host snails; for *S. mansoni Biomphalaria* spp. and *Bulinus* spp. for the latter two schistosome species (Prter et al., 1993; Rozendaal, 1997). *S. haematobium* is decidedly different as it causes urinary schistosomiasis leading to damage in the bladder, ureters and kidneys with haematuria as the most common, early symptom. All other schistosomes cause intestinal schistosomiasis of various severity stating with abdominal pain and blood in the stools, sometimes diarrhoea and increased temperature,

while advanced, long-term, untreated cases have enlarged livers and spleens due to large numbers of parasite eggs, often accompanied by intestinal damage and portal hypertension. Due to the climate, there can be transmission all year around in some countries, mainly SSA, while in more temperate countries there is a marked seasonality (Adewunmi et al., 1991; Blas et al., 2004; Chandiwana et al., 1987; Sturrock et al., 2001). In addition, local temperature variations, rainfall, humidity and ecological features play an important role for presence of the intermediate hosts and thus for the transmission of schistosomiasis.

2.2.2 Underestimated disease burdens

Regardless if the true DALY figure for schistosomiasis in the world is 3.3 million (Hotez et al., 2014) or 24–29 million (King, 2010), it has been estimated that there may be about 200 million cases of schistosomiasis in Africa, 192 million of which in SSA (accounting for 25% of SSA's population) (Steinmann et al., 2006; Utzinger et al., 2009). In Asia, recent reports show the average prevalence of schistosomiasis has decreased with near 1% in Laos, Cambodia, Indonesia and the Philippines (Garjito et al., 2008; Leonardo et al., 2012; Laymanivong et al., 2014). However, we know that currently used diagnostic tools lack the sensitivity required for areas characterized by low-level infections (Bergquist, 2013) and the data may underestimate the prevalence for other reasons as well, eg, unreasonable statistic methods or low coverage of enrolment (Leonardo et al., 2012; Rollinson et al., 2013; Tallo et al., 2008). New endemic foci and resurgence of schistosomiasis in urban or rural areas have been reported recently (Blanton et al., 2015; Leonardo et al., 2015; Mwakitalu et al., 2014). On the other hand, although the mortality rate of schistosomiasis is relatively low, severe, debilitating chronic illness is caused in millions of people. It has been estimated that SSA accounts for 93% of global disease burden caused by schistosomiasis (King et al., 2005). Although recent research have adjusted the disease burden caused by schistosomiasis upwards (Hotez et al., 2014; Murray et al., 2012), the disease burden may still be considerably underestimated due to lack of a precise measuring basis for what has been called 'asymptomatic disease' (King, 2010, 2015).

2.2.3 Low coverage of chemotherapy

Preventive chemotherapy is the major intervention and coverage is the key issue of efficacy of control in most endemic countries. Among the 67 endemic countries in Africa and Asia, 50 need to MDA. Out of these countries, 44 are located in Africa as of 2012 (Fig. 2) (WHO, 2013). In 2012, only

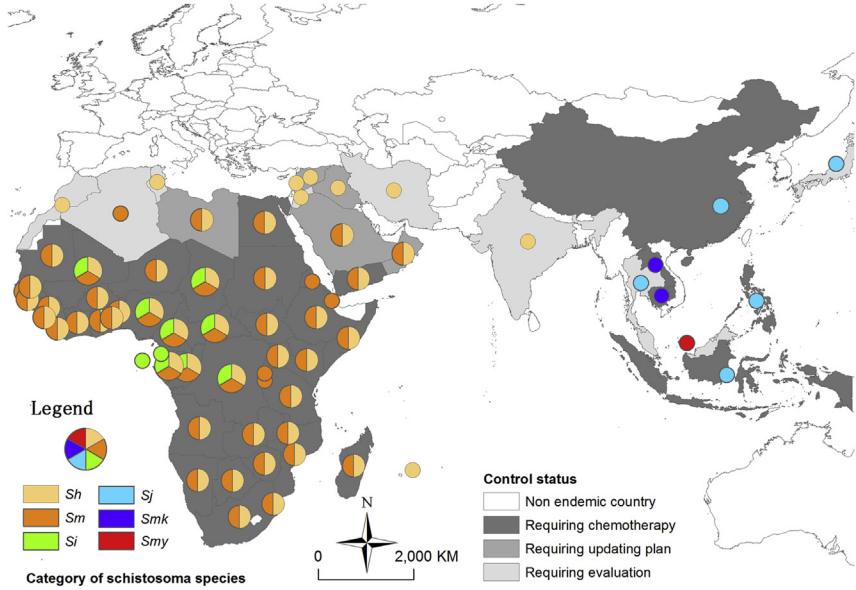

Figure 2 Geographical distribution of schistosomiasis and control status in Asia and Africa.

13.6%, 13.3% and 36.0% of people in need of preventive chemotherapy in the WHO regions of Africa, Eastern Mediterranean and Western Pacific, respectively, actually received treatment. Thus, a substantial number of patients were left at high risk (WHO, 2014). School-based MDA, the major approach in Africa, is regarded as a highly cost-effective approach, since at least 50% of those suffering from schistosomiasis there are school-aged children (Guyatt et al., 1994; Stothard et al., 2013b; Toure et al., 2008). However, as the proportion of school enrolment of children is low in most poor areas, and the high-risk population including fishermen, irrigation workers and preschool children account for a large part of all infected cases, there is a need to supplement with another drug delivery approach to increase coverage (Stothard et al., 2011, 2013a). Community-based approach is a good alternative that has been widely used in Asia (Chigusa et al., 2006; Inobaya et al., 2015). However, a recent report from the Philippines shows that the average coverage is only 48.3% in spite of various community-related control activities were introduced (Tallo et al., 2008). Ethnicity, incentives, ratio of population to available drugs, mode of distribution, infection status, etc. may have influenced the coverage (Dabo et al., 2013; Leslie et al., 2011; Massa et al., 2009; Mwinzi et al., 2012).

2.2.4 Inadequate coverage of safe water and sanitation

Chemotherapy cures infection, prevents morbidity and lowers prevalence but is unable to prevent reinfection. However, access to safe water and improved sanitation have interrupted transmission in many parts of previously endemic areas in The People's Republic of China through reducing the frequency of water contact with potentially contaminated water outside the home. This has reduced the contamination of schistosome eggs in the environment, which also improves control of other helminthiases transmitted by the faecal, urinary or oral route (Asaolu and Ofoezie, 2003; Huang and Manderson, 2005; Utzinger et al., 2003). The WHA 65.21 resolution underlines the importance of safe tap water, improved sanitation and public health education as means to control schistosomiasis. However, these approaches depend to a great extent on economic development (WHO, 2012b). By 2012, 89% of global population had gained access to improved drinking water, but more than 700 million people still lack access to drinking water of acceptable quality, 43% of them in SSA. Indeed, Southern Asia and SSA still have the lowest coverage of improved sanitation, the coverage in the latter being only 30% (WHO/UNICEF, 2014). Lack of investment, inadequate political will, inequity of access and difficulty in maintaining water supply are the main reasons. To improve these figures, sanitation services need to be upgraded in a large number of countries.

2.2.5 Lack of sectoral collaboration and stakeholders inclusion

Since schistosomiasis transmission involves natural, social and biological factors, sectoral cooperation is essential for progress in schistosomiasis control (King, 2009; Zhou et al., 2005). Although chemotherapy plays a crucial role by reducing prevalence and morbidity of schistosomiasis, while health education, supply of clean water and improved sanitation could interrupt the chain of infection (Rollinson et al., 2013). Poor knowledge with respect to behavioural change, treatment-seeking habits and sanitation have been observed (Musuva et al., 2014; Odhiambo et al., 2014; Worku et al., 2014). In addition, the construction of water conservancy projects without considering their impact on schistosomiasis has contributed to the spread of schistosomiasis in many parts of the world (Steinmann et al., 2006). Intersector cooperation and collaboration are essential to implement each intervention in an equitable and harmonized way, but most African and Asian countries lack mechanisms to deal with this situation, in particular if financial support is lacking coupled with insufficient enforcement of policies and absence of political will.

2.3 Opportunities

2.3.1 Interest in global health issues by the Chinese government

After its entry into World Trade Organization in 2001, The People's Republic of China has joined a large majority of other UN specialized agencies and multilateral health foundations. The number of Chinese experts participating in WHO's global normative work has increased significantly in the latest decade. Chinese funding for health-related aid has been augmented with an average of $4.8 billion per year during the period 2010–2012, 51.8% of which was received by African countries and 30.5% by Asian countries (Liu et al., 2014). Since 2000, The People's Republic of China has hosted a series of triennial meetings (forums) on China–Africa Cooperation (FOCACs), with each forum announcing and focussing on different topics related to health aid, eg, hospital construction, malaria control, high-education scholarships, health worker training, artemisinin drug donation and the Brightness Action campaign (FOCAC, 2012; King, 2006). Since 2005, in the field of parasitic diseases, The People's Republic of China had set up 30 antimalaria centres in African countries including a joint border malaria control project with Myanmar, Laos and Vietnam (Liu et al., 2014; Xu and Liu, 2012). At the fifth China–Africa Cooperation Forum in July 2012, The People's Republic of China made a promise to increase its investment continuously, extend cooperation to fields such as health care and disease control as well as carry out joint pilot schistosomiasis control and prevention projects through international cooperation with African countries (FOCAC, 2012).

2.3.2 New and sensitive tools

Regular monitoring and evaluation are necessary to ensure that programmes are efficiently implemented and receive maximal benefit. Surveillance is important when the goal move from morbidity control to elimination. This is particularly challenging given the diversity of tools and indicators. With the deep understanding of the schistosome genome and its host compatibility (Berriman et al., 2009; Hu et al., 2003; Zhou et al., 2009), sensitive and quality-assured diagnostic tools based on the monoclonal antibody technique and molecular methods, new drug candidates have been identified, some of them already widely used in control programmes (Cnops et al., 2013; Colley et al., 2013; Pontes et al., 2002; Tong et al., 2015). Some vaccine candidates have also been explored and shown high efficacy against schistosomiasis (Curti et al., 2013; Da'dara et al., 2008, Riveau et al., 2012). With the development of geographic information systems

(GIS), global positioning systems and remote sensing (RS) systems, mathematical and statistical modelling based on spatial, temporal, spatial–temporal analysis have been developed and used for predicating schistosomiasis risk (Chipeta et al., 2013; French et al., 2010; Hurlimann et al., 2011; Simoonga et al., 2009; Wu et al., 2008).

2.3.3 Increased international interest elimination of schistosomiasis

Although schistosomiasis remains a public health problem, morbidity and prevalence of schistosomiasis have decreased in many countries due to long-term interventions and some countries moving towards schistosomiasis elimination, which should be possible in countries where the prevalence is low and adequate resources coupled with strong political commitment are available (Hotez et al., 2012; Melo et al., 2014; Rollinson et al., 2013; Xu et al., 2015). With the significant reduced price of PZQ, increased advocacy and resources for NTD control, the Bill & Melinda Gates Foundation, the US and UK governments and Merck Serono donated a large amount of PZQ tablets to African countries in the recent decade (Fenwick and Savioli, 2011). Large-scale preventive chemotherapy was implemented across several countries and millions of children were given single standard PZQ doses. The agreement on the WHO's roadmap (2012) raised optimism that many NTDs can indeed be eliminated (WHO, 2012a) and led to the signing the London Declaration (http://unitingtocombatntds.org/resource/london-declaration), which represents an unprecedented commitment to control or eliminate 10 diseases by the end of this decade by global health leaders, including the chief executive officers of major pharmaceutical companies, Bill Gates of the Bill & Melinda Gates Foundation, WHO and senior government officials from both endemic and donor countries (NTDs, 2012; Webster et al., 2014).

2.3.4 Rapid social and economic development

One of the Millennium Declaration Goals (http://www.un.org/millenniumgoals/) is to eliminate absolute poverty, hunger and diseases by 2015 (General Assembly, 2000). These goals need to be supported by economic growth. Indeed, the economic situation of African and Asian countries has increased substantially in the past decade. African exports rose in real terms at an annual rate of 5.2%, higher than that of global average rate of 4.8% in 2011 (UNCTAD, 2013), and in Asia, the growth rate in many countries remains above 6% (Asian Development Bank, 2014). Correspondingly, the living conditions in Africa and Asia have improved during the past

decade. The coverage of safe water increased to 64% in 2012 in SSA and over 89% in Asia. The total sanitation coverage increased in SSA at a slower pace, from 25% in 1990 to 30% in 2012, but covered 71% and 89% of population in Southeast Asia and Western Asia, respectively (WHO/UNICEF, 2014). Meanwhile, health systems were strengthened or reformed in several countries including promulgation of laws related to health, establishment of primary health-care infrastructures and health information systems for health services monitoring, improving medical services and capacity of disease diagnosis, resulting in easier access to health services (Benatar, 2004; Frenk and Horton, 2006; Green, 2013; Lieberman et al., 2005; Liljestrand and Sambath, 2012; Sekwat, 2003).

2.4 Threats

2.4.1 Fragile security situation

The political situation is a key determinant of consecutive social and economic development. Although the Middle East remains in unrest and conflict, warfare in SSA and most of Asian countries is declining both in frequency and intensity since the late 2000s (Straus, 2012). While schistosomiasis control is continuously conducted in regions with recovering economies and strong political commitment, the chaos caused by war and political change present in other countries has a great impact on the sustainability of these activities (Kahler, 2013; Straus, 2012). The local health system in countries sinking into turmoil is difficult uphold as warfare and conflict influence external funding and other investments. Careful considerations of local sociocultural, economic and political situations are needed to determine the application and/or acceptance of control measures.

2.4.2 Imperfect health systems

WHO and many other international agencies have encouraged countries to take concrete steps to move towards universal health coverage, which is an ideal target. However, various factors apart from warfare, such as ethics, politics and economy, influence society including the health system (Rodrigo and Smith, 2012; Savedoff et al., 2012). Although the funds donated by western developed countries has increased nearly three times from $1.5 billion in 1990 to 4.24 billion in 2011, the health system in Africa is still fragile and the health conditions have not improved significantly. African key problems include lack of primary health staff, health insurance and a functioning health information system (OECD, 2013). Indeed, many endemic countries do not have the public health infrastructure or

necessary resources to implement proper schistosomiasis control. Loss of skilled health workers migrating from Africa exacerbates the problems of an effectively functioning health-care system (Connell et al., 2007). In Asia, most staff working on schistosomiasis control are on part-time basis, which is not sufficient to fulfil the national control requirements. With nearly 2.5 times the number of schistosomiasis cases in The People's Republic of China, the Philippines has only 200 part-time staff to do what is needed, which amounts to only 1% of the number of full-time staff in The People's Republic of China (Ross et al., 2013).

2.4.3 Lack of political commitment

Schistosomiasis as well as other NTDs is commonly endemic in rural and poor regions in low-income countries (Hotez and Kamath, 2009). In most African and Asian countries, the schistosomiasis control programmes mainly depend on external funds. The experience from Mali and the Philippines shows that the diminishing or termination of funding often result in staff reductions in control agencies as well as rebound of the disease (Clements et al., 2009; Inobaya et al., 2015). Even if chemotherapy does not prevent reinfection, sustainable and integrated interventions could be cost-effective, resulting in morbidity control or even elimination of schistosomiasis (Rollinson et al., 2013; Ross et al., 2013). For this to function, however, strong policy commitment and continuous donor funding is necessary. The global economic recession that started with the setback of 2008 may increase the instability of financial support. Furthermore, limited engagement and involvement of senior policymakers in endemic countries may result in less political commitment for schistosomiasis control leading to less available internal funds and lack of collaboration with other stakeholders.

2.4.4 Inequity of access

Due to current insufficient availability of PZQ, full coverage of effective drug delivery cannot be achieved. School-aged children are normally targeted for chemotherapy as prevalence and intensity of disease in this age group are normally higher than in adults. Children less than 5 years of age are often neglected by national control programmes as formal legislation and suitable paediatric PZQ dosages so not exist (Stothard et al., 2011). 'New' foci where schistosomiasis may have been endemic for a long time can become known as enlarged surveys and/or use of more sensitive diagnostic tools are implemented. Whether a village or a region is included in schistosomiasis control can be a matter of political and religious intracommunity priorities, which

obviously leads to inequity. People living in rural areas are more often ignored with respect to treatment than urban dwellers (Aagaard-Hansen et al., 2009). Inequity can also be due to geographically uneven economic development, availability of donated funds, ethnicity or religion, rich or poor background. Inequalities also exist within countries or regions with regard to access to drinking water and sanitation services.

3. PRIORITIES IN CHINA – AFRICA/ASIA COLLABORATION

The Chinese national schistosomiasis control programme has been sustained without interruption for six decades. It has not only terminated the development of morbidity due to schistosomiasis, but has also produced a significant reduction of prevalence and is now geared at elimination of this infection (Li et al., 2013). Various approaches, products, techniques applied by experienced professionals ensured the success of the strategies that shifted according to the social situation and scientific development, with interventions adjusted and recombined accordingly. To translate the successful experience with schistosomiasis control/elimination to Africa and other parts of Asia, The People's Republic of China would promote an approach consisting of a set of priority fields as follows:

1. Transmission mapping;
2. Population dynamics;
3. Modelling based on available data sets;
4. Sensitive and specific diagnostics;
5. Response packages tailored to different transmission settings and levels; and
6. Validation.

3.1 Coordination

Lack of coordination among different sectors hinders the development of schistosomiasis control in Africa and other parts of Asia. Achievements gained in The People's Republic of China on coordinated schistosomiasis control are based on the close collaboration among different departments, including National Health and Family Planning Commission, State Forestry Administration, Ministry of Agriculture, Ministry of Water Resources, Ministry of Finance, Ministry of Land Resources, and the National Development and Reform Commission (Xu et al., 2015; Zhou et al., 2005). The State Council on schistosomiasis control is responsible for the coordination between

different departments. The The People's Republic of China CDC, health bureaus and hospitals at all levels collaborate to manage and implement disease control activities. Regional collaboration has been strengthened via platforms such as RNAS+ and research programmes supported by the Canada's International Development Research Center (Zhou et al., 2015). The People's Republic of China could disseminate its experience on collaboration mechanisms and strengthen capacity building of management systems through training courses. International advocacy workshops and stakeholder meetings at the national or regional level are needed.

3.2 Risk mapping

Disease mapping has been given a high priority in The People's Republic of China as it can supply the needed, basic information for drafting control programmes and start-up activities (Guo et al., 2005; Yang et al., 2005). The addition of GIS and satellite-generated, remotely sensed environmental data and geostatistics to the arsenal in the last two decades has facilitated the understanding of the location of endemic and potentially endemic areas in a global warming scenario (Zhou et al., 2008). These new geospatial tools have been of critical importance for our understanding and prediction of the true distribution of schistosomiasis (Wu et al., 2008; Yang et al., 2006, 2013; Zhang et al., 2008). Such systematic, progressing input combined with data from surveys available in the *Atlas of Schistosomiasis Transmission in The People's Republic of China* that was recently updated (NIPD, 2013) present information on schistosomiasis in the form of thematic maps, diagrams and charts that are easy to understand. Annual risk mapping at the national, regional and county levels are regularly conducted to guide policy decisions. The People's Republic of China has now a cadre of skilled technicians with accumulated experience on disease mapping, communication, who can provide advanced training courses on disease mapping and be counted on to finalize the mapping in those countries which do not currently possess these tools.

3.3 Chemotherapy coverage

PZQ is the drug of choice for the treatment of all forms of schistosomiasis (Dömling and Khoury, 2010). It is an inexpensive, highly effective drug with low toxicity against all schistosome species and many other parasitic helminths. However, the quantity of existing donated PZQ is far short of the demand (Stothard et al., 2011). In addition, many cases could not receive treatment due to the absence of efficient drug delivery systems. Nanjing Pharmaceutical Factory (producing 50 tons of raw material annually

corresponding to 100 million PZQ tablets at the strength of 200 mg/tablet) has improved the product by a film-coated form to increase the compliance rate of medication (Xu et al., 2009). This production can rapidly be upgraded to cover the needed amounts of drug. Community-based approach is the main delivery system in The People's Republic of China with the collaboration of the local hospital or rural doctors with the CDC or schistosomiasis stations. This way of distribution works well together with a reporting system, which is in operation nationwide to reflect the timing of chemotherapy guarantees the high coverage and efficacy (Zhou et al., 2012). The amounts of PZQ tablets needed, even at the international scale, can thus be supplied and thus increase the current coverage of chemotherapy in Africa and elsewhere. The Chinese government and nongovernmental organizations (NGOs) could use this new source of available PZQ to fill the gaps through drug donations. The People's Republic of China could also disseminate its experience through training programmes at the district level designed for persons administering pharmaceuticals and health-care personnel for improving the skills of drug delivery and supervision of local staff. Reporting systems for drug delivery could also be supported by Chinese experience.

3.4 Snail control

Control or eliminate snails will benefit to control or eliminate schistosomiasis. Different from the scarce snail control activities in Africa and other part of Asia, varieties of environmental modification were developed and implemented in The People's Republic of China, integrated with projects of other sectors such as land resources, agriculture, water conservancy, forestry through activities of reclaiming wetlands, environmental management (digging new ditches and filling up the old ones that would kill the amphibious snails), changing rice paddies into dry crops, etc. (Chen, 1999; Yuan et al., 2005). In addition, there are many various forms of molluscicides, the most common and effective being 50% niclosamide ethanolamine formulated as powder, granules, suspension concentrate, retarder, etc. were developed adopting to the local situation of the snail-infested areas (Xin and Dai, 2010; Yang et al., 2012a). Since the efficiency does not reach 100%, repeated application could be considered to increase the effect (Yang et al., 2012a, 2010). Before the advent of PZQ, molluscicding was a cornerstones of schistosomiasis control in Africa, and some of its former role may have to be resurrected there as PZQ alone cannot stop transmission. The People's Republic of China has a strong industrial capacity in molluscicide production, and the main Chinese companies manufacturing niclosamide

could produce 1000 tons per year. To effectively control snails in African and Asian countries, training courses and exchange of senior scientists could be conducted to share the experience and technology. If the molluscicides made in The People's Republic of China pass WHO prequalification certification, The People's Republic of China would be willing to supply quality-assured molluscicides to other endemic countries.

3.5 Diagnostic tools

Accurate diagnosis is essential to obtain data regarding the distribution, prevalence and infection intensity of schistosomiasis in endemic area, and diagnostic approaches should differ at different stages of schistosomiasis control (Bergquist et al., 2009; Zhou et al., 2011). Based on laboratory and field assessment, quality-assured immunodiagnostics approved by the State Food and Drug administration have been integrated into the national control programme, while basic principles using appropriate diagnostics to monitor disease trends and assess the effectiveness and impact of interventions have been established for guiding treatment strategies at different thresholds of schistosomiasis transmission and for certifying elimination (Xu et al., 2011; Zhou et al., 2011). Other sensitive and specific techniques based on the monoclonal antibody technique to detect circulating antigen, as well as molecular methods, eg, the polymerase chain reaction and the loop-mediated isothermal amplification (LAMP) were also developed, supplying tools populations studies, surveillance of snails and diagnosis of individual cases (Guo et al., 2012; Hung and Remais, 2008; Tong et al., 2015; van Dam et al., 2015). A network for schistosomiasis diagnosis was constructed with the establishment of provincial reference laboratories and sentinel monitoring laboratories at the county level (Qin et al., 2013). These laboratories are responsible for diagnosis, verification and providing scientific evidences for schistosomiasis surveillance and response in the elimination stage (Zhu et al., 2013). As some kits produced in The People's Republic of China have shown high sensitivity and specificity for diagnosis of other schistosomiasis (Zhu et al., 2005, 2006), these kits could be supplied at a competitive cost or freely delivered to African and Asia countries. Experience on developing diagnostic assays, decision-making of using appropriate diagnostic tools as well as management of diagnostic quality control could be transferred through training programmes or academic activities.

3.6 Surveillance and response

To achieve control and/or elimination of communicable diseases, surveillance and response to detect pockets of transmission and reemergence of

disease are needed as the final, long-term activity in the control chain. Resource-constrained countries, which generally carry heavy NTD burdens, schistosomiasis not the least, face a challenge in strengthening their health system. Effective tools tailored to local settings are needed for surveillance and response that should take place by collating the components according to the priorities mentioned previously under 'Priorities'. Thus an effective and rapid response, including an early warning mechanism, is the prerequisite for the efficient management of infectious diseases (Zhou et al., 2013). The People's Republic of China relies on a variety of monitoring systems with different aims in longitudinal or cross-sectional format. The contents of surveillance have been developed from simple mapping of endemicity to factors, such as environmental monitoring, water conservancy, dam construction, irrigation projects, climate change, etc. (Dang et al., 2014; Zhao et al., 2005; Zhu et al., 2011). As the prevalence of schistosomiasis decrease significantly, transmission interruption becomes the next hurdle to overcome. Regular surveillance is now conducted in The People's Republic of China, and early warning systems (EWS) have been set up based on research and experience (Sun et al., 2011; Wu et al., 2005; Xu et al., 2014). This and the involvement of acute schistosomiasis monitoring in a real-time reporting system have provided a solid foundation for decision-making. Built in 2010, the schistosomiasis information management system provides valuable source data at the village level to support management. At the same time, new technologies such as RS systems, GIS and predictive modelling including sentinel mice (Yang et al., 2012) are applied for schistosomiasis monitoring and surveillance (Yang et al., 2006, 2012b; Zhang et al., 2005). To improve the capacity of African and Asian countries of monitoring and surveillance of schistosomiasis, basic and higher-level training could be provided through Chinese scientist visitors or by computer-based remote education. With the help from Chinese scientists, an EWS could be set up for tracking information about the density and infection status of intermediate snail host species.

4. CURRENT STATUS

The Ebola outbreak as well as the threat of and other infectious diseases have exposed the fragility of the public health system in some areas of the world. Chinese engagement in global health has been increased and more experts are involving in global health governance. As one of the main components of The People's Republic of China's health activities,

medical teams composed of clinical doctors or nurses have been sent to Africa and Asia, while lower-level public health staff are usually not included. Hospitals and clinics targeting individual patients will benefit from this service (Liu et al., 2014). The public health system needs reform, training of health providers and general strengthening. According to the Beijing Declaration produced during the Ministerial Forum of China–Africa Health Development in 2013 (NHFPC, 2013), The People's Republic of China aims to extend its cooperation to health care and disease control. Schistosomiasis, malaria, and HIV were given priority for pilot studies in Africa and Asia through multilateral cooperation.

To promote the control and elimination of schistosomiasis, WHO and some European countries have expressed willingness to facilitate bridging perceived gaps in the endemic countries and it has been pronounced that The People's Republic of China could play a crucial role for the scientific exchange of experience and lessons on schistosomiasis control. Supported by the Department for International Development (DFID) in United Kingdom, two China–UK Global Health Support programmes have been initiated in the last 2 years. The first programme aims to distil Chinese experience and lessons on schistosomiasis and malaria, exploring the possibility to conduct control based on Chinese experiences in low- and middle-income endemic countries. The other programme aims to establish a centre of excellence in The People's Republic of China to provide health aid emphasized on NTDs through capacity building and information dissemination. A memorandum of understanding to conduct joint activities among WHO, The People's Republic of China and Tanzania governments for schistosomiasis control in Tanzania was signed in May, 2014. To explore the priority for schistosomiasis control and research as well as establishing cooperation mechanism between The People's Republic of China and Africa, a China–Africa institutional cooperation of schistosomiasis elimination meeting was held in Malawi, supported by WHO in April 2015. Based on the experience of RNAS+, regarded as an excellent model for schistosomiasis cooperation between The People's Republic of China and other Asian countries, the institution-based network on China–Africa cooperation of schistosomiasis (INCAS) is coordinated by the National Institute of Parasitic Diseases (NIPD) and WHO.

Global health is an important component of The People's Republic of China's foreign policy, and the selection of counterparts for schistosomiasis control will be based on requests from other countries for schistosomiasis control and decisions by The People's Republic of China's Health and Family Planning Commission, Ministry of Foreign Affairs, and Ministry of

Finance. To ensure a successful collaboration, countries would be selected according to the following principles:

1. Existing trade, economic, cultural and medical cooperation with the Chinese government via economic and technical agreements;
2. Rural public health is a high-priority item on the counterpart country's government agenda;
3. Impact of the opportunities in collaboration with Chinese institutions is identified;
4. The counterpart country's government has identified schistosomiasis control/elimination as a target with ongoing activities; and
5. Preventive chemotherapy is implemented nationwide.

Recently, pilot study for malaria control has been conducted in Tanzania in 2015 supported by DFID, which will accumulate experience for China–Africa, China–Asia collaboration in public health field in future. In addition, strengthening the capacity of Chinese scientists involved in international health collaboration on schistosomiasis control and coordination with WHO regional offices and other experienced organizations in developed countries would facilitate the coordination and implementation of cooperation activities.

5. CONCLUSIONS

Programmes tacking schistosomiasis are increased worldwide but great challenges exist to meet the set goals of WHO roadmap. As schistosomiasis mainly affects and infects the poorest and marginalized people in subtropical and tropical regions, collaborating with other health and development activities to reduce poverty and break the life cycle of schistosomes will contribute schistosomiasis control and elimination. To help control and eliminate schistosomiasis, The People's Republic of China will need to establish partnerships with Ministries of Health in African and other Asian countries, WHO regional offices, and existing NGOs at the international or national level, and collaborate closely to expand support for schistosomiasis programmes. Financial and technical support for training, designing national programme strategies and plans, intervention implementation, operational research, disease surveillance-response and production of health education materials should be provided. Coordination of INCAS, RNAS+ activities by NIPD and WHO would be helpful for strengthening the cooperation among institutions for basic and operational research and accelerate the process of schistosomiasis control in Africa and Asia. Governments, national or internationals foundations, as well as nonprofit organization

are expected to take part in funding and supervising such kind of cooperation to maintain the sustainability of the cross-border monitoring of schistosomiasis risk.

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