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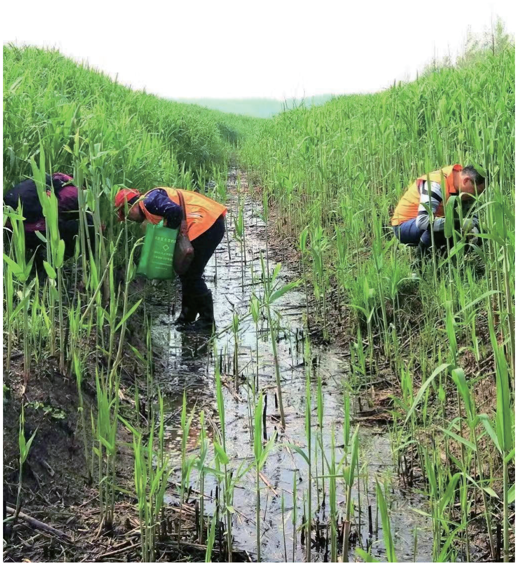

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Cover Photo: A local CDC schistosomiasis control team gathering *Oncomelania hupensis* in the reeds (Photographer: Shan Lyu from NIPD, China CDC).

Foreword

Letter of Congratulations from Prof. Duncan Selbie, Public Health England

On behalf of Public Health England, I warmly congratulate the Chinese Center for Disease Control and Prevention on its launch of *China CDC Weekly*.

The UK and China face many common challenges and our collaboration between us is very important to me personally. We already share our respective technical expertise and the opportunity is to further strengthen our partnership.

Public Health England (PHE) is England's equivalent of China CDC, responsible for protecting and improving the nation's health and for addressing health inequalities. We also host the UK focal point for compliance with the 2005 International Health Regulations. We have 5,500 staff, mostly clinicians and scientists and work in close partnership with local and national government, our National Health Service, internationally, and directly with the public.

In the first edition, the foreword by George Gao highlights the remarkable progress China has made in recent decades in truly transforming its mortality and morbidity outcomes, and the ambitious programme for future improvements set out in "Healthy China 2030". We are certain that *China CDC Weekly* will provide a significant contribution to both Chinese and global health and become a seminal worldwide resource for researchers, practitioners, and policymakers further cementing China CDC's position as one of the world's leading public health institutes.

Our role as public health institutes is to understand the causes and consequences of poor health; be clear about what works; and encourage the adoption of effective interventions at scale and pace. China's ability to draw on large data sets will significantly increase understanding of population health to know better where the greatest burden of disease is and therefore where to target resources.

Improving health is not always about spending more money, but about making sure we get the best impact for the money being spent – focusing on prevention and early intervention to reduce the high financial and societal cost of crises and failure. In the UK as in China, whilst life expectancy has improved over the past twenty years, the biggest determinant of years of life in good health remains income, with a near twenty-year difference between the affluent and the poor. This means that wider societal effort, not the health sector acting alone, is needed to create economic growth and increasing prosperity shared more widely. For our children, this means having the best start in life and being ready to start school. For our young people entering adulthood, this means the resilience to thrive. For adults this means having a secure job and home, and at all ages the importance of friendship and belonging in life. Essentially, economic growth creating jobs for local people in places that need them, with health and wealth being two sides of the same coin.

To make and win this argument with policy makers we must access high quality evidence from around the world and *China CDC Weekly* presents a new and rich resource on which to draw. The public health challenges faced globally are enormous, and the global health architecture is complex. The global public health family must share, cooperate, and learn from each other to inform and guide public health policies and strategies, and *China CDC Weekly* is a brilliant addition to the literature and evidence base.

Professor Duncan Selbie
Chief Executive, Public Health England

Preplanned Studies

Soil-Transmitted Helminthiasis — China, 2018

Huihui Zhu[1]; Jilei Huang[1]; Changhai Zhou[1]; Tingjun Zhu[1]; Menbao Qian[1]; Mizhen Zhang[1]; Yingdan Chen[1,#]; Shizhu Li[1,#]

Summary

What is already known about this topic?

Soil-transmitted helminthiasis (STH) is distributed widely in China and a large number of the population is afflicted. However, trends of STH infections are decreasing.

What is added by this report?

The most recent data indicates that the overall prevalence of STH was 1.29% in 2018 in China, which was based on the national sentinel surveillance and demonstrates a continuous decline pattern.

What are the implications for public health practice?

Considering the current prevalence in China and various endemic statuses in different regions, precision control measures should be implemented for the control and elimination of STH in China.

Soil-transmitted helminthiasis (STH) is caused by infections with parasitic worms such as hookworms (*Necator americanus* and *Ancylostoma duodenale*), *Ascaris lumbricoides*, and *Trichuris trichiura.* STH is highly endemic in underdeveloped areas and causes a burden of 3.38 million disability-adjusted life years globally (*1–2*). Based on the three national surveys implemented in 1988–1992, 2001–2004, and 2014–2015 in China, the infection rate of STH was 53.58%, 19.56%, and 4.49%, respectively. Correspondingly, the estimated number of population infected was 646 million, 129 million, and 29.12 million, respectively (*3–5*).

China's National Sentinel Surveillance (NSS) on STH started in 2006 when 22 sites from 22 provincial-level administrative divisions (PLADs) were launched for ten successive years. The range of the system has been greatly expanded since 2016, covering 30 of the 31 PLADs in Mainland China with more than 250 sentinel surveillance spots each year (*6*). The results of NSS on STH in 2018 are reported here.

In 2018, 29 PLADs were included in the NSS, and 10%–15% of counties from each PLAD were included. Five townships were selected in each sentinel surveillance site, which was county-based, with one from the east, west, north, south, and central regions of the site. One village was then sampled from each township, and finally about 200 people were investigated from each village by cluster sampling. Thus, a total of 1,000 people were investigated at each site. Stool samples (>30 grams) were collected from each participant and examined by the Kato-Katz method (double smears for each sample). An infection was defined as one or more eggs detected in either of the two smears. The data were analyzed using SAS software (Version 9.3, SAS Institute Inc.). The infection rate of STH was categorized by PLAD, sex, and age group, and chi-square tests were used to compare the differences between categories. Statistical significance was set as 0.05.

A total of 325 sentinel surveillance spots from 29 PLADs were included in 2018. The overall infection rate of STH was 1.29% (4,200/326,207). The infection rate in 2018 was significantly lower than that found in 2017 (χ^2=253.14, p<0.0001). The infection rate of hookworm was the highest (0.89%), followed by *A. lumbricoides* (0.27%), and *T. trichiura* (0.17%) (Table 1).

Yunnan showed the highest infection rate (14.08%), followed by Sichuan (7.44%) and Hainan (7.16%). No infection was detected in Beijing, Heilongjiang, and Shanghai. As revealed by the NSS in 2018, STH was mainly prevalent in southern and southeastern parts of China (Table 1, Figure 1). In PLADs with infection rates over 0.5%, Yunnan, Hainan, and Sichuan were mainly prevalent with hookworm infection; Guizhou, Hunan, Qinghai, and Ningxia with ascariasis; and Shandong with trichuriasis.

The infection rate in males and females was 1.16% (1,849/159,925) and 1.41% (2,351/166,282), respectively. It was higher in females than in males (χ^2=42.59, p<0.0001). The overall infection rate was the highest in those aged 60 and above, followed by the age group of 45 to 59, 7 to 14, 15 to 44, and 0 to 6, which was also significant (χ^2=1,030.84, p<0.0001). However, the infection rate by *A. lumbricoides* and

TABLE 1. Infection rate of soil-transmitted helminth in China according to the 2018 National Sentinel Surveillance.

PLADs	No. of examination	Soil-transmitted helminth		Hookworm		*Ascaris lumbricoides*		*Trichuris trichiura*	
		No. of infections	Prevalence % (95% CI)	No. of infections	Prevalence % (95% CI)	No. of infections	Prevalence % (95% CI)	No. of infections	Prevalence % (95% CI)
Beijing	3,087	0	0.00 (0.00−0.00)	0	0.00 (0.00−0.00)	0	0.00 (0.00−0.00)	0	0.00 (0.00−0.00)
Tianjin*	3,023	4	0.13 (0.00−0.26)	0	0.00 (0.00−0.00)	4	0.13 (0.00−0.26)	0	0.00 (0.00−0.00)
Hebei	15,048	1	0.01 (0.00−0.02)	0	0.00 (0.00−0.00)	1	0.01 (0.00−0.02)	0	0.00 (0.00−0.00)
Inner Mongolia*	10,034	1	0.01 (0.00−0.03)	0	0.00 (0.00−0.00)	0	0.00 (0.00−0.00)	1	0.01 (0.00−0.03)
Liaoning*	12,042	31	0.26 (0.17−0.35)	0	0.00 (0.00−0.00)	29	0.24 (0.15−0.33)	2	0.02 (0.00−0.04)
Jilin*	21,812	61	0.28 (0.21−0.35)	0	0.00 (0.00−0.00)	60	0.28 (0.21−0.34)	1	0.00 (0.00−0.01)
Heilongjiang	19,065	0	0.00 (0.00−0.00)	0	0.00 (0.00−0.00)	0	0.00 (0.00−0.00)	0	0.00 (0.00−0.00)
Shanghai	2,003	0	0.00 (0.00−0.00)	0	0.00 (0.00−0.00)	0	0.00 (0.00−0.00)	0	0.00 (0.00−0.00)
Jiangsu	4,003	7	0.17 (0.05−0.30)	1	0.02 (0.00−0.07)	4	0.10 (0.00−0.20)	2	0.05 (0.00−0.12)
Zhejiang*	9,120	124	1.36 (1.12−1.60)	122	1.34 (1.10−1.57)	0	0.00 (0.00−0.00)	2	0.02 (0.00−0.05)
Anhui	14,689	166	1.13 (0.96−1.30)	157	1.07 (0.90−1.24)	1	0.01 (0.00−0.02)	8	0.05 (0.02−0.09)
Fujian	12,475	215	1.72 (1.50−1.95)	201	1.61 (1.39−1.83)	0	0.00 (0.00−0.00)	14	0.11 (0.05−0.17)
Jiangxi	13,082	109	0.83 (0.68−0.99)	82	0.63 (0.49−0.76)	14	0.11 (0.05−0.16)	13	0.10 (0.05−0.15)
Shandong	14,399	96	0.67 (0.53−0.80)	0	0.00 (0.00−0.00)	21	0.15 (0.08−0.21)	76	0.53 (0.41−0.65)
Henan	19,856	16	0.08 (0.04−0.12)	7	0.04 (0.01−0.06)	8	0.04 (0.01−0.07)	1	0.01 (0.00−0.01)
Hubei	10,099	2	0.02 (0.00−0.05)	1	0.01 (0.00−0.03)	0	0.00 (0.00−0.00)	1	0.01 (0.00−0.03)
Hunan	37,398	251	0.67 (0.59−0.75)	57	0.15 (0.11−0.19)	184	0.49 (0.42−0.56)	14	0.04 (0.02−0.06)
Guangdong	19,463	44	0.23 (0.16−0.29)	19	0.10 (0.05−0.14)	11	0.06 (0.02−0.09)	16	0.08 (0.04−0.12)
Guangxi	13,727	334	2.43 (2.18−2.69)	305	2.22 (1.98−2.47)	4	0.03 (0.00−0.06)	26	0.19 (0.12−0.26)
Hainan	2,959	212	7.16 (6.24−8.09)	201	6.79 (5.89−7.70)	0	0.00 (0.00−0.00)	11	0.37 (0.15−0.59)
Chongqing	6,372	367	5.76 (5.19−6.33)	356	5.59 (5.02−6.15)	12	0.19 (0.08−0.29)	2	0.03 (0.00−0.07)
Sichuan	14,292	1,064	7.44 (7.01−7.88)	867	6.07 (5.67−6.46)	185	1.29 (1.11−1.48)	47	0.33 (0.23−0.42)
Guizhou	4,617	213	4.61 (4.01−5.22)	9	0.19 (0.07−0.32)	126	2.73 (2.26−3.20)	92	1.99 (1.59−2.40)
Yunnan	5,567	784	14.08 (13.17−15.00)	526	9.45 (8.68−10.22)	113	2.03 (1.66−2.40)	214	3.84 (3.34−4.35)
Shaanxi*	8,993	15	0.17 (0.08−0.25)	0	0.00 (0.00−0.00)	15	0.17 (0.08−0.25)	0	0.00 (0.00−0.00)
Gansu	8,750	12	0.14 (0.06−0.21)	0	0.00 (0.00−0.00)	12	0.14 (0.06−0.21)	0	0.00 (0.00−0.00)
Qinghai	3,906	23	0.59 (0.35−0.83)	0	0.00 (0.00−0.00)	23	0.59 (0.35−0.83)	0	0.00 (0.00−0.00)
Ningxia*	2,948	40	1.36 (0.94−1.77)	0	0.00 (0.00−0.00)	40	1.36 (0.94−1.77)	0	0.00 (0.00−0.00)
Xinjiang*	13,378	8	0.06 (0.02−0.10)	0	0.00 (0.00−0.00)	8	0.06 (0.02−0.10)	0	0.00 (0.00−0.00)
Total	326,207	4,200	1.29 (1.25−1.33)	2,911	0.89 (0.86−0.92)	875	0.27 (0.25−0.29)	543	0.17 (0.15−0.18)

Abbreviations: PLADs=provincial-level administrative divisions.

*These PLADs have no national surveillance spots before 2015 and started NSS since 2016.

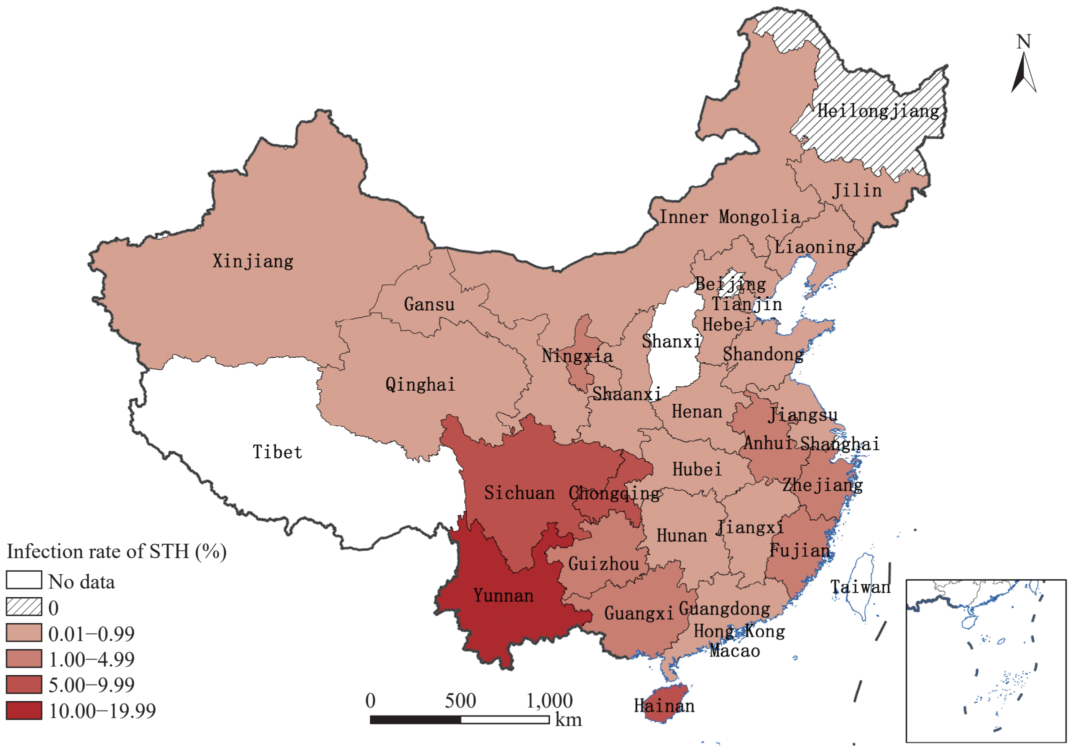

FIGURE 1. Infection rate of soil-transmitted helminth in each provincial-level administrative divisions of China according to the 2018 National Sentinel Surveillance.

T. trichiura was higher in children than that of other age groups, while the pattern of hookworm infection was similar to that of overall STH (Figure 2).

Discussion

STH declined in China based on the 22 NSS sites, and the rates in each year from 2006 to 2015 are as follows: 20.88%, 18.93%, 16.59%, 13.30%, 11.25%, 9.67%, 6.90%, 3.12%, 4.49%, and 4.95% (*7–8*). This is consistent with the results of the second and third national survey (*4–5*). Also, the expanded NSS from 2016 to 2018 revealed that STH infection rates were 2.46%, 1.78%, and 1.29%, respectively (*8*). These results indicated a continuous pattern of decline for prevalence for the 13 years following sentinel surveillance implementation. This can be attributed to improved economy and living standards of the

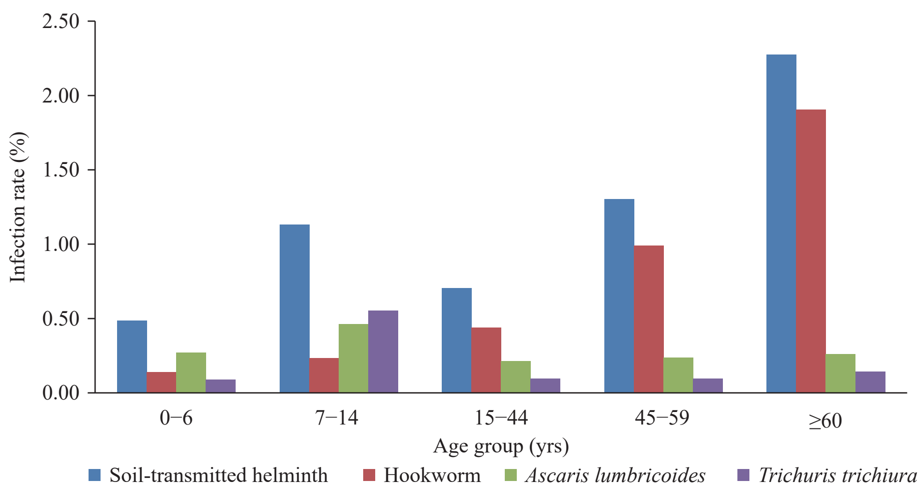

FIGURE 2. Infection rate of soil-transmitted helminth by different age groups in China according to the 2018 National Sentinel Surveillance.

population and effective implementation of control measures such as health education, chemotherapy, and improved sanitation and water safety in China (*9*).

The prevalence of ascariasis and hookworm infection was demonstrated to be similar between 2006 and 2010 and that trichuriasis was the lowest. However, the prevalence between types has changed since 2011 with hookworm infection becoming the highest one, followed by ascariasis and trichuriasis. Also, children rank highest with ascariasis and trichuriasis while the age group of 45-year-old and above ranks highest with hookworm infection as indicated by the NSS system (*8*). This is because elderly people usually have more exposure with hookworm, while *A. lumbricoides* and *T. trichiura* mostly infect children. Recognizing the predominant species of soil-transmitted helminth and different age group predisposed to risk of infection are crucially importance for implementing control strategies.

The NSS system provides basic information on STH's endemic status and trends, which are important for developing control strategies. Many PLADs have started or improved their own provincial sentinel surveillance following the efforts made by the NSS system regarding prevention and control of STH (*9*). In addition, this has greatly enhanced the capacity of staff members at the provincial, city, and county levels through training, communication, and other regular work during surveillance.

This study is subject to some limitations. Only 29 PLADs were included in the NSS in 2018 and Shanxi and Tibet were excluded, and the infection rates of STH in both PLADs were below average according to the third national survey (*5*). As a result, the infection rate of STH may therefore be slightly overestimated. Also, during the implementation of the surveillance system, participants may have become more aware and changed their behaviors, which would then contribute to further decreases of STH. Moreover, field investigations need to consider feasibility and scientific rigor because of increasing difficulties in field work, expanding surveillance ranges, and methods changing, such as the Kato-Katz method being changed from 3 slides to 2 slides since 2015 (*8*).

The National Control Program for Echinococcosis and Other Important Parasitic Diseases (2016–2020) was issued and included STH. Establishment of national surveillance is vitally important in the control of STH as it provides platforms to achieve the control targets set by the national control program and to evaluate control effectiveness. The control of STH should be combined with poverty alleviation in China, which might increase effectiveness. Additionally, precise control of STH was needed by implementing different strategies in different endemic level areas. High endemic-disease areas should be addressed with health education, with provision of water, sanitation, and hygiene (WASH), and with chemotherapy, while low endemic-disease areas should be addressed with health education and with improvement of compliance for examination and chemotherapy of STH. Children and the elderly should be given special attention when controlling STH.

Overall, the infection rate of STH approaches 1.00%, with some areas achieving infection control and other areas still having endemic disease (*10*). The "Criteria for Transmission Control and Interruption of Soil-Transmitted Nematodiasis" has been issued in China. Therefore, China should pursue higher targets in national control of STH to eventually achieve interruption.

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Conflict of interests

The authors declare no competing interests.

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Vital Surveillances

Schistosomiasis Surveillance — China, 2015–2018

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Abstract

Background The prevalence of schistosomiasis in China is at the lowest level in history, and sentinel surveillance sites of schistosomiasis have fully covered all epidemic areas of China. This article has analyzed the surveillance data for the last four years and can help guide the next stage of surveillance work at the national level, including the scope of surveillance, surveillance content, and surveillance methods, etc.

Methods Data from the National Schistosomiasis Surveillance System were collected. The infection rate of schistosomiasis among the human population, livestock, snails, and the change of the breeding area of snails in sentinel surveillance sites for four consecutive years were analyzed, and the trends in schistosomiasis prevalence in surveillance sites were determined.

Results The prevalence of schistosomiasis in all sentinel surveillance sites of China showed downward trends from 2015 to 2018 with infection rates decreasing in this time period for local human population (0.05% to 0.00%), the floating population (0.020% to 0.003%), and cattle (0.037% to 0.000%). No infected snails were found during the period. From 2015 to 2018, the total area of newly found habitats of snails (*Oncomelania hupensis, O. hupensis*) were 34,730 m^2, 1,367,694 m^2, 18,944 m^2, and 50,420 m^2, and the total area of re-emergent habitats of snails (*O. hupensis*) were 822,194 m^2, 1,391,779 m^2, 1,516,292 m^2, and 1,750,558 m^2, respectively.

Conclusions and Implications for Public Health Practice The prevalence of schistosomiasis in human and livestock is going down and is sustained at a very low level, but new and re-emerging habitats of *O. hupensis* are new challenges regardless of the achievement of schistosomiasis control. Therefore, two actions are necessary to effectively further reduce the transmission risk of schistosomiasis: 1) taking effective measures to control the source of infection of schistosomiasis; and 2) reducing the breeding areas of *O. hupensis*.

Introduction

Schistosomiasis is one of the most serious parasitic diseases in China, which has a history of more than 2,100 years. In the mid-1950s, when China's population was about 600 million, an estimated 11.6 million people were infected with *Schistosoma japonicum* (*S. japonicum*). Control strategies were developed and adapted over time to align with epidemiological insights, technological advances, and the political environment, and this progress can be divided into three stages. The first was a mass campaign focused on snail control, which was based on understanding the epidemiology, the second was a morbidity control stage boosted by international cooperation, and the third stage was implementing strategies to block schistosomiasis transmission (*1–2*).

In 2000, the number of infected people was estimated to have been reduced to 694,778, *Oncomelania hupensis* (*O. hupensis*) breeding areas have been reduced by more than 75.0%, and 5 of the 12 previously prevalent provinces have eliminated the disease (*1*). Between the mid-1980s and 2003, the criteria of transmission interruption have been reached in 260 counties (60.0%) and transmission control has been achieved in 63 counties (14.5%), but the disease was still epidemic in the remaining 110 counties (25.4%) (*1*). Since 2005, China has implemented a comprehensive strategy of schistosomiasis control focusing on source control, which preliminary studies have indicated as effective in reducing the prevalence of schistosomiasis in both humans and bovines (*3*). Passive chemotherapy and health education still have had a significant impact on schistosomiasis control during the maintenance and consolidation phase (*4*).

By the end of 2014, the Chinese government has successfully interrupted the transmission of schistosomiasis in 313 of 457 epidemic counties and controlled the transmission of schistosomiasis in 135 counties; only 5 counties remain uncontrolled (*2*). According to *China's Medium-and Long-term Plan for*

Schistosomiasis Prevention and Control (2004–2015), China will accomplish the goal of schistosomiasis transmission control in 2015 with an infection rate of human and animal schistosomiasis of less than 1%, and schistosomiasis control's classification will be transitioned from epidemic control to transmission control accordingly (*5*). China CDC set up 457 national surveillance sites for schistosomiasis in 2014 to meet the needs of epidemic prevention, control, and surveillance, and have covered the whole schistosomiasis epidemic area (*6*).

The national surveillance system of schistosomiasis has become important to the prompt control and even elimination of the incidence and transmission of schistosomiasis in China (*7*). The epidemic situational analysis of schistosomiasis surveillance sites is essential to understanding the epidemic situational changes in surveillance sites and guiding the optimization and implementation of the surveillance program's next stage. These developments can make the monitoring system more comprehensive by providing an important basis for scientific surveillance of schistosomiasis and enhance a data-driven approach for the elimination of schistosomiasis of China in the future.

Methods

Schistosomiasis surveillance sites cover all epidemic counties including 142 transmission control counties, 311 transmission blocking counties (150 counties with snails, 161 counties without snails), and 4 Three Gorges Reservoir area counties (only with snail surveillance, including 2 non epidemic counties). The main work of the surveillance sites is to monitor the local and floating human populations, the livestock, and the snails by testing human blood, human feces, livestock feces, and *Oncomelania* infections in the epidemic area. The indirect hemagglutination assay (IHA) method is used to detect anti-*Schistosoma* antibody of blood samples from the local population and floating population. The nylon silk bag incubation method (one sample of fecal matter for three tests) and the Kato-Katz method (one sample of fecal matter for three tests) are used to detect the pathogens of feces of serum positive populations. For the surveillance of domestic animals, the plastic cup top tube incubation method (one sample of fecal matter for three tests) was used to detect infections of *Schistosoma* in domestic animals with. For the surveillance of *O. hupensis*, systematic sampling combined with environmental sampling were used to investigate the existing and suspected environments of *O. hupensis*, and the *O. hupensis* samples used will be registered as living or dead. Infections of living samples were detected by anatomical microscopy, and if infections were found, the nucleic acids of *Schistosoma* in the snails would be detected by loop-mediated isothermal amplification (LAMP).

Data from schistosomiasis surveillance sites from 2015 to 2018 were obtained from the National Schistosomiasis Surveillance System, which includes basic information from schistosomiasis surveillance sites and surveillance data of the local and floating populations, livestock, snails, and wild feces and other floating materials in the Three Gorges Reservoir Area. Factors surrounding *S. japonicum* infection were analyzed for the local and floating human population, livestock, and *O. hupensis*, and habitat changes of *O. hupensis* were also monitored. Trends of the epidemic were then observed and used to predict future changes of the schistosomiasis epidemic based on four-year continuous monitoring data.

Results

The overall prevalence of schistosomiasis in 457 surveillance sites across China showed a downward trend from 2015 to 2018. The sero-prevalence in the local population decreased 40.9% by declining from 3.35% in 2015 to 1.98% in 2018, which match sero-prevalence trends in the local populations of lake and marsh regions, water-network regions, and mountainous regions. The sero-positive rate of the floating population decreased by 24.35% from 1.15% in 2015 to 0.87% in 2018 (Figure 1). The prevalence of schistosomiasis in the local population decreased from 0.05% in 2015 to 0.00% in 2018, all of which belong to the lake and marshland epidemic areas. Only 96 parasitologically-diagnosed cases were found from 524,093 individuals in the four years, leading to an overall prevalence of 0.018%. The prevalence of schistosomiasis in the floating population decreased from 0.020% in 2015 to 0.003% in 2018. A total of 34 infected cases were found from 377,088 floating individuals from 2015 to 2018.

The prevalence of schistosomiasis in livestock decreased from 0.037% (5/13,406) in 2015 to 0.000% (0/8,669) in 2018 (Table 1). No snails were found to be infected with *S. japonicum* for four consecutive years. For each year from 2015 to 2018, the total area of newly found habitats of snails was 34,730 m^2, 1,367,694 m^2, 18,944 m^2, and 50,420 m^2, respectively,

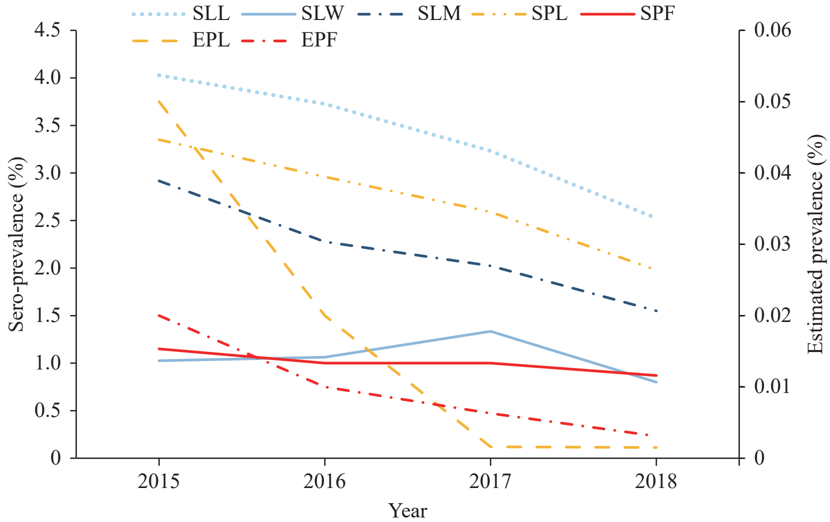

FIGURE 1. Sero-prevalence and estimated prevalence* of the local population and floating population in national schistosomiasis surveillance sites in China from 2015 to 2018.

*Data include results of serological and fecal tests of local and floating populations in all surveillance sites throughout the country from 2015 to 2018 and all tests are standardized according to the requirements of the surveillance scheme.

SLL: sero-prevalence of the local population in lake and marsh regions; SLW: sero-prevalence of the local population in water-network regions; SLM: sero-prevalence of the local population in mountainous regions; SPL: sero-prevalence of the local population; SPF: sero-prevalence of the floating population; EPL: estimated prevalence of the local population; EPF: estimated prevalence of the floating population.The estimated prevalence is equal to the fecal positive rate, which is the infection rate of Schistosoma in the population.

TABLE 1. *Schistosoma* infection rate in cattle in national schistosomiasis surveillance sites in China from 2015 to 2018.

PLADs	2015			2016			2017			2018		
	No. of examined cattle	No. of infected cattle	Infection rate (%)	No. of examined cattle	No. of infected cattle	Infection rate (%)	No. of examined cattle	No. of infected cattle	Infection rate (%)	No. of examined cattle	No. of infected cattle	Infection rate (%)
Shanghai	854	0	0.000	0	0	0.000	369	0	0.000	0	0	0.000
Jiangsu	162	0	0.000	448	0	0.000	138	0	0.000	63	0	0.000
Zhejiang	152	0	0.000	242	0	0.000	243	0	0.000	120	0	0.000
Anhui	2,072	0	0.000	1,753	0	0.000	1,620	0	0.000	1,161	0	0.000
Fujian	712	0	0.000	761	0	0.000	552	0	0.000	958	0	0.000
Jiangxi	1,013	0	0.000	1,862	0	0.000	669	0	0.000	584	0	0.000
Hubei	1,857	0	0.000	1,492	0	0.000	1,778	0	0.000	969	0	0.000
Hunan	2,389	5	0.209	2,367	1	0.042	3,051	0	0.000	1,158	0	0.000
Guangdong	187	0	0.000	0	0	0.000	195	0	0.000	0	0	0.000
Guangxi	739	0	0.000	936	0	0.000	1,158	0	0.000	580	0	0.000
Sichuan	1,434	0	0.000	1,635	0	0.000	4,026	0	0.000	1,081	0	0.000
Yunnan	1,835	0	0.000	1,693	0	0.000	1,778	0	0.000	1,988	0	0.000
Chongqing	0	0	0.000	0	0	0.000	22	0	0.000	7	0	0.000
Total	13,406	5	0.037	13,189	1	0.008	15,599	0	0.000	8,669	0	0.000

Abbreviations: PLADs=provincial-level administrative divisions.

and the total area of re-emergent habitats of snails was 822,194 m^2, 1,391,779 m^2, 1,516,292 m^2, and 1,750,558 m^2, respectively. The newly found habitats of *O. hupensis* have been minimally changing every year outside of the explosive growth in habitats found in lake and marsh regions in 2016 (Table 2). But the re-emergent of *O. hupensis* habitats have been increasing year by year from 2015 to 2018, mainly in lake and marsh regions or water-network regions (Figure 2).

TABLE 2. Monitoring results of *O. hupensis* in national schistosomiasis surveillance sites in China from 2015 to 2018.

Items	2015	2016	2017	2018
Surveillance area (m^2)	222,951,328	219,179,774	246,797,869	236,951,253
Area infested by snail (m^2)	74,266,296	69,977,767	69,406,026	65,456,951
Number of sampling frames (0.11 m^2)	1,691,779	1,155,680	1,447,609	1,366,937
Number of samples infested	68,721	70,061	93,479	66,102
Number of live snails	211,545	222,921	272,273	151,968
Number of infected snails	0	0	0	0
Density of live snail (per 0.11 m^2)	0.13	0.19	0.19	0.11
Area of new habitats (m^2)	34,730	1,367,694	18,944	50,420
Area of re-emergent habitats (m^2)	822,194	1,391,779	1,516,292	1,750,558

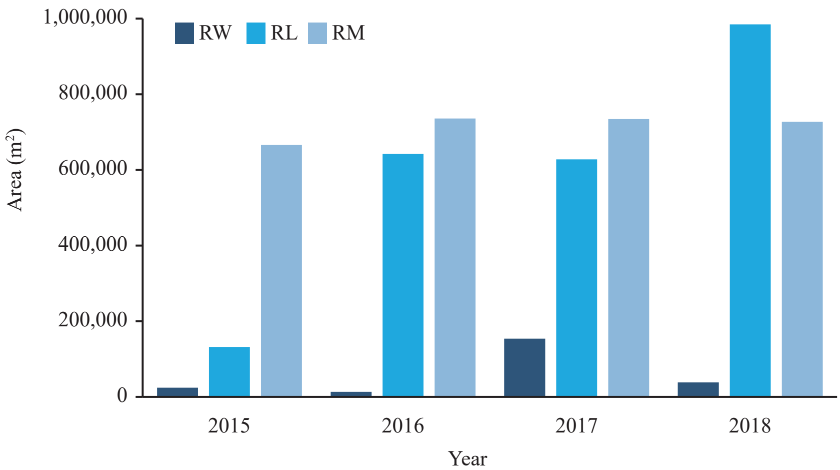

FIGURE 2. Re-emergent habitats change of *O. hupensis* by different epidemic types in national schistosomiasis surveillance sites in China from 2015 to 2018.

Abreviation: RL: Re-emergent habitats of *O. hupensis* in lake and marsh regions; RW: Re-emergent habitats of *O. hupensis* in water-network regions; RM: Re-emergent habitats of *O. hupensis* in mountainous regions.

Discussion

The infection rate of local and floating populations in surveillance sites is decreasing year by year, which is mostly consistent with the downward trend of the schistosomiasis epidemic in China and closely related to the formulation of policies for schistosomiasis control and the implementation of relevant measures (*8*). For another source of infection, the cattle infection rate has shown decreases every year like that of the population and has eventually dropped to zero in both 2017 and 2018. Previous reports have shown that comprehensive control measures, mainly replacing cattle with machines, can effectively control the transmission of *S. japonicum* and significantly reduce the infection rates of humans and other cattle (*9*). Although the infection rates of population and cattle have been decreasing year by year, a lack of effective methods makes the supervision of the floating population of humans inconvenient and brings more severe challenges to infectious sources control (*10*). At the same time, a large base of cattle in the epidemic area with no long-term mechanism for forbidding depasturing of livestock on marshland and for replacing cattle with the machine have made controlling cattle populations difficult (*11*). The above conditions indicated that the infection source control is still facing tremendous challenges.

As shown in Table 2, the infection rate of *O. hupensis* at surveillance sites has been zero for four consecutive years, but the total area of the breeding area of *O. hupensis* has not shown much change even though *O. hupensis* control is carried out every year. This demonstrates that existing strategies have limitations on the control of the breeding area of *O. hupensis*, possibly due to environmental factors such as precipitation and change of temperature (*12*). The newly found habitats of *O. hupensis* showed explosive growth in area in 2016, which may be related to the flood disasters caused by too much rainfall in the previous year which allowed *O. hupensis* to spread widely.

The epidemic situational analysis reports of national surveillance sites in 2015 and 2016, without continuity analysis of epidemic situation, are limited to analysis of data for that year (*13–14*). This is the first continuity analysis of the epidemic situation since all surveillance sites in epidemic counties have been fully covered. The 457 surveillance sites cover every epidemic county, and almost all aspects of schistosomiasis transmission are involved in the surveillance contents. The results of each surveillance site may only reflect the local epidemic situation or, to some extent, the epidemic situation of the whole county where the surveillance site is located.

The results indicated that the habitats of *O. hupensis* reemerged and were increasing every year. In addition, people and livestock that are frequently mobile may become sources of infection for schistosomiasis, and the areas with epidemic *O. hupensis* may become areas with high risk of transmission of imported schistosomiasis. Therefore, monitoring of infectious sources of schistosomiasis needs to be strengthened, especially in human populations, and effective control and reduction of snail breeding areas may be an effective method for reducing the risk of schistosomiasis transmission.

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Recollections

The Role of the WHO Collaborating Centre for Tropical Diseases in China

Yayi Guan[1]; Ning Xiao[1]; Xiao-nong Zhou[1,#]

In the Memorandum of Understanding on Health Technology Cooperation issued in Beijing in 1978, the Ministry of Health (MOH) of China and the World Health Organization (WHO) agreed to create a series of WHO Collaborating Centres (WHOCC). The Institute of Parasitic Diseases at the Chinese Academy of Medical Sciences (the predecessor of the National Institute of Parasitic Diseases [NIPD] at China CDC) was officially designated as a "WHO Collaborating Centre for Malaria, Schistosomiasis, and Filariasis" in 1980 based in Shanghai (*1*). Since then, the WHOCC for Malaria, Schistosomiasis, and Filariasis has played an important role in promoting the development of medical science in China.

From 1980 to 2015, the WHOCC for Malaria, Schistosomiasis, and Filariasis has conducted fruitful cooperative activities facilitating the building of a first-rate organization for research and control of malaria, schistosomiasis, and filariasis (*2*). It has hosted international conferences and training courses, introduced advanced technologies, and validated tools for control approaches. New diagnostics, drugs, and vaccine candidates have been developed and evaluated, which has effectively promoted the control of parasitic diseases in China. Briefings and disease-specific reports have been produced to guide the process of controlling and eliminating the three diseases within its sphere of responsibility. To achieve this, the WHOCC for Malaria, Schistosomiasis, and Filariasis established and coordinated international networks and projects, such as the development of strategies for schistosomiasis elimination and liver fluke control. It has also provided leadership for a Southeast Asian multi-country network called the Regional Network on Asian Schistosomiasis and Other Helminthic Zoonoses (RNAS+) (*3*).

In line with the development of China's economy and social development, the NIPD has taken on a supporting role for the Belt and Road Initiative as it extends into the field of global health. To reflect these wider responsibilities, the WHOCC for Malaria, Schistosomiasis, and Filariasis was re-designated as the "WHO Collaborating Centre for Tropical Diseases" in May 2015. The aim of this article is to review its achievements since 1980, to summarize the role played by the centre during its development, and to outline its role in global health governance.

Development

International exchange and cooperation have been important components of the NIPD's promotion of developmental achievements in improved tropical diseases research and control. Meanwhile, the NIPD has expanded its activities related to global health through the WHOCC. With the open-door policy instituted in the country in the late 1970s, international exchange developed rapidly, and the WHOCC took the lead in moving through four stages from the WHOCC for Malaria, Schistosomiasis, and Filariasis to the WHOCC for Tropical Diseases based on funding resources.

The Initial Stage (1976–1979) The WHOCC for Malaria, Schistosomiasis, and Filariasis, inaugurated at the Institute of Parasitic Diseases in February 1980, came about after the Director, Dr. Mao Shou-Pai, visited the WHO headquarters in Geneva, Switzerland and had discussions with Dr. Halfdan Mahler, Director-General of WHO in 1976. In the two years following meeting, the NIPD was reviewed and evaluated by many visits by WHO representatives including Dr. T. A. Lambo, Deputy Director-General of WHO, and Dr. A. O. Lucas, Director of the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR). These visits were followed up by training exchanges and courses, the first of which was a workshop on application of the enzyme-linked immunosorbent assay (ELISA) for the diagnosis of tropical diseases.

The WHO-Funding Stage (1980–1997) The WHOCC for Malaria, Schistosomiasis, and Filariasis was one of the earliest established such centres in China. From 1980 to 1997, 25 research projects were funded by WHO at a total of USD 344,099. In addition, USD 140,000 was awarded by the TDR's

Institution Strengthening Fund to improve research capacity. Other TDR funding included support for returning scientists after training (re-entry grants) and specific research projects from the Director's Initiative Fund. This provided evidence of research capacity and laid the foundation for future multilateral financial support (*4*). With the initiated funds from WHO, more international funding resources came into the WHOCC for Malaria, Schistosomiasis, and Filariasis at NIPD as well (Figure 1).

The Co-Funding Stage (1998–2010) At this stage, the research capacity was further strengthened through co-funding involving the WHO and the Chinese MOH. Research on diagnosis, drug, and vaccine development received support from the WHO, while control strategies for parasitic diseases, such as "study on the distribution of *Anopheles anthropophagus*" and "schistosomiasis control strategies in the mountainous region", were supported by the MOH, with the number of projects and funds from the Chinese government showing an increasing pattern over time. Funds from international organizations, such as the USA's National Institute of Health (NIH) and the World Bank, were also obtained showing the start of growth in international cooperation. This led to more comprehensive research being carried out by both local and international institutions.

The Self-Funding Stage (2011–2018) With the rapid development of China's economy, more research and training activities were being carried out in both the WHOCC for Malaria, Schistosomiasis, and Filariasis and the WHOCC for Tropical Diseases using domestic funds after 2011. In this stage, the amount of funding that projects received from local governments grew more than those involving WHO support, which declined after reaching their intended goal of promoting the new collaborating centre (Figure 1). However, with lymphatic filariasis, malaria, and schistosomiasis almost eliminated in China, the WHO augmented its sponsoring of training activities at the NIPD, which provided opportunities for international scientists from low- and middle-income countries (LMIC) to learn from the national control programs in China. This led to more scientists from the NIPD to start implementing research projects in other countries, such as Cambodia, Laos, Thailand, Papua New Guinea, Tanzania, etc.

Achievements

Academic Exchange From 1980 to 2018, many research professionals were sent to international institutions abroad for training, attending meetings, and collaborative projects. In the last four decades, there were a total of 3,277 visits by international experts, trainees, and consultants to the NIPD, with growing numbers of NIPD staff travelling abroad.

Scientific Collaboration The NIPD coordinated the implementation of international projects on parasitic disease control, such as the World Bank Loan Program

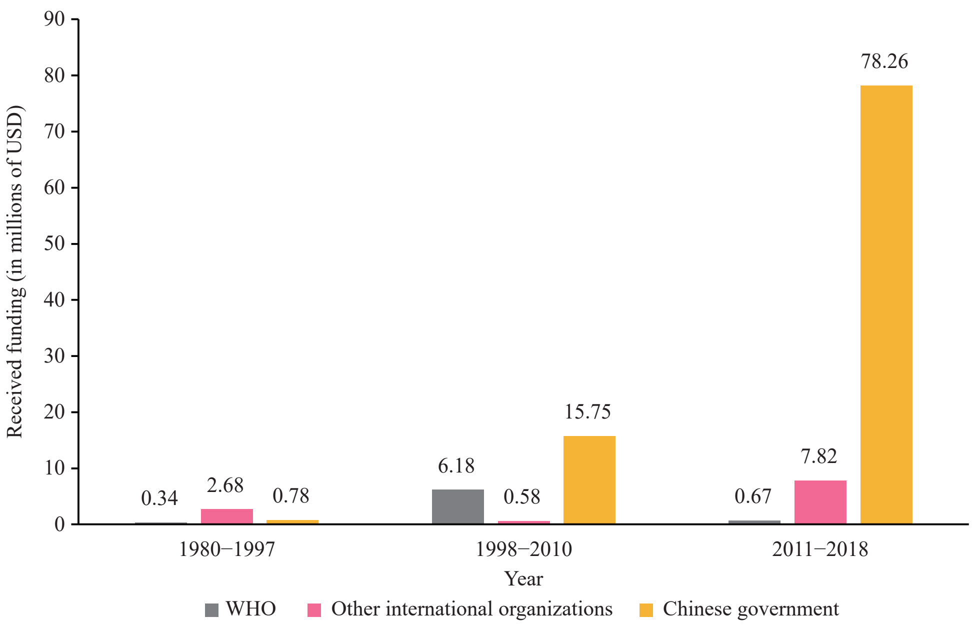

FIGURE 1. Amount of research funds (USD) in the WHOCC for Malaria, Schistosomiasis, and Filariasis and the WHOCC for Tropical Diseases with sources information from 1980 to 2018.

for Schistosomiasis Control in China, the Global Fund to Fight AIDS, Tuberculosis and Malaria Program on Malaria Control in High Transmission Regions in China, and the China-Korea Collaborative Project of Control Strategies for Helminthiasis. In 1996, the Tropical Medicine Research Center, funded by the USA's NIH, was established in the NIPD and in 2002 renewed for another 5 years. From 2008 to 2018, two rounds of funding from the International Development Research Centre (IDRC) of Canada supported "Strategies for schistosomiasis elimination and liver fluke control in South-Eastern Asian countries". From 2014 to 2018, three projects of the Global Health Supported Programmes (GHSPs) funded by the Department of International Development (DFID) of UK, were successfully implemented. Among them, the "China-UK-Tanzania Pilot Project on Malaria Control" covering 200,000 people in 4 communities in Rufiji region of Tanzania significantly reduced the incidence of malaria from 2015 to 2018 (*5*). Funded by the Australian Government, the "Australia-China-Papua New Guinea Pilot Trilateral Development Cooperation Project on Malaria Control" was implemented from January 2016 to December 2019 in Papua New Guinea.

Cooperative researches have provided the opportunity to develop useful tools for the diagnosis and treatment of parasitic diseases, including support from the TDR for research on using artemether for the prevention of schistosomiasis haematobia and schistosomiasis mansoni. This research was done in cooperation with the Swiss Tropical and Public Health Institute (Swiss TPH) and Cocody University of Côte d'Ivoire.

The experience gained from Chinese domestic control programs has also been transferred to LMICs in cooperation with the WHO. There are three examples: 1) the threshold (at microfilaria rate <1%) at which to stop filariasis control interventions developed by NIPD scientists; 2) control standards for schistosomiasis elimination developed by NIPD scientists; and 3) Chinese experiences for malaria control implemented in Tanzania and Papua New Guinea with several international agencies.

Training and Technology Sharing WHO-sponsored fellows from more than 20 LMICs, including Vietnam, Malaysia, Indonesia, Cambodia, Egypt, the Democratic People's Republic of Korea, and the Philippines, were trained at the NIPD. Since 1999, the NIPD was entrusted by the MOH to host several international symposia on schistosomiasis, malaria, and echinococcosis.

International cooperation has promoted the development of parasitology, disease control, and research in China and encouraged the development of human resources at the NIPD. During the latest 4 decades, a total of 55 international symposia or conferences were held with 3,055 people attending. In addition, 1,571 persons were trained at different workshops. New AI-based technology and new methods for rapid diagnosis, GIS technology, and prompt forecasting tools for parasitic epidemics have been introduced and have improved the performance of routine work of disease control and prevention.

Network Coordination So far, six networks have been established including RNAS+; the Regional Network on Malaria Surveillance in Greater Mekong Sub-Region Countries (RNMS); the Institutional-Based Network of China-Africa Cooperation on Schistosomiasis Elimination (INCAS); the Asia-Pacific Network on Drug and Diagnostics Innovation (AP-NDI); the B&R Network for the Elimination and Control of Echinococcosis and Cysticercosis (BR-NEC); and the Institutional-based Network of China-Africa Cooperation on Malaria Elimination (INCAM).

The locations of the networks (Figure 2) not only provide opportunities to update knowledge and information and to share experience, but also lead to better research capacity building, collaborative projects, and strengthening of ongoing control and elimination of diseases at the international, national, and regional levels.

Future

Cooperative Networks More member counties are expected to be involved in the mentioned networks and more training activities on pragmatic and research capacity building will be performed using the network platforms.

Control Programs With more challenges in the final steps of tropical disease elimination programmes in LMICs, the WHOCC needs to work together with local colleagues on integrated control or elimination programmes by localizing Chinese approaches in its cooperation across sectors, countries, and institutions to improve efforts using new mechanisms and techniques based on the surveillance-response system initiated at the NIPD.

Research Projects In order to further improve the efficiency of diagnosis, treatment, monitoring, and evaluation, more joint research projects will be

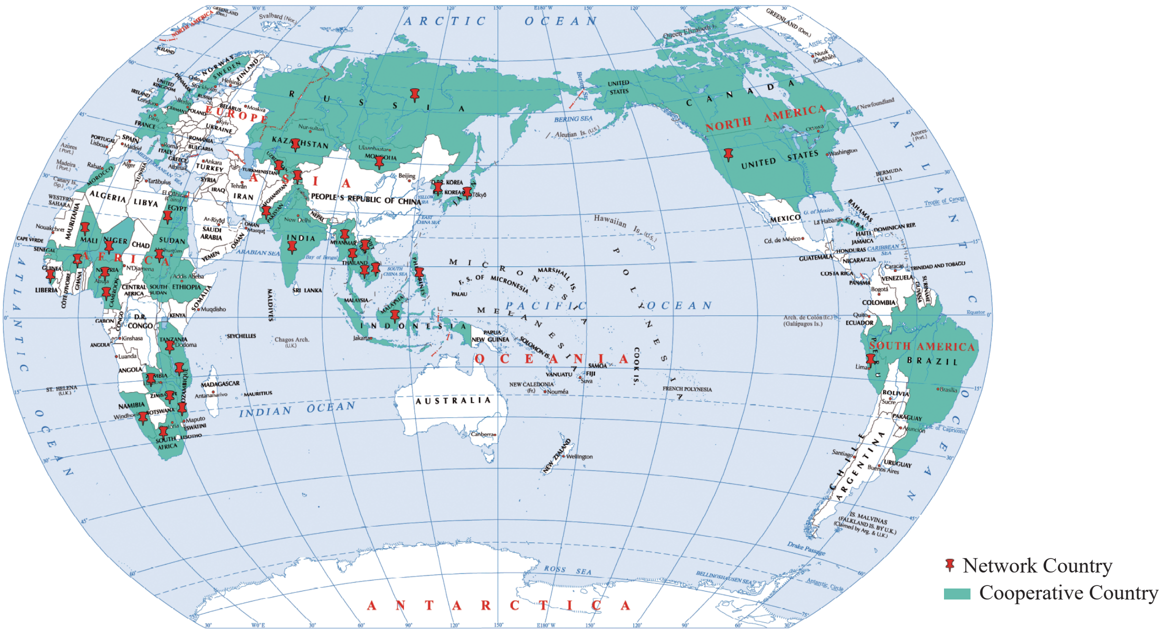

FIGURE 2. Countries with mutually participating networks led by the WHOCC for Malaria, Schistosomiasis, and Filariasis and the WHOCC for Tropical Diseases.

performed in the LMICs. In doing so, the WHOCC will need to perform joint research projects through various funding agencies and scientific resources in cooperation with scientists from both the developed and the developing world.

The WHOCC should reach out as described but also focus on its own capacity building. This has been achieved by not only promoting the development of the institute and its talented team, but also by accumulating adequate experience in international cooperation and exchange through effective bilateral and multilateral cooperation. Through the new opportunities made possible by the Belt and Road Initiative, the WHOCC will promote and develop additional cooperation by playing a greater role in global health activities according to targets of the Healthy China 2030 and Sustainable Development Goals.

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