CHAPTER TWO

Epidemiological Features and Effectiveness of Schistosomiasis Control Programme in Lake and Marshland Region in The People's Republic of China

S.-Q. Zhang[*,1], **C.-S. Sun**[*], **M. Wang**[*], **D.-D. Lin**[§], **X.-N. Zhou**[¶,||,#], **T.-P. Wang**[*,**]

[*]Anhui Provincial Institute of Schistosomiasis Control, Hefei, Anhui Province, The People's Republic of China
[§]Jiangxi Provincial Institute of Schistosomiasis Control, Nanchang, The People's Republic of China
[¶]National Institute of Parasitic Diseases, Chinese Center for Disease Control and Prevention, Shanghai, The People's Republic of China
[||]WHO Collaborating Center for Tropical Diseases, Shanghai, The People's Republic of China
[#]Key Laboratory of Parasite and Vector Biology of the Chinese Ministry of Health, Shanghai, The People's Republic of China
[**]Anhui Institute of Parasitic Disease, Hefei, The People's Republic of China
[1]Corresponding author: E-mail: zhangsq2820@163.com

Contents

1. Introduction 40
2. Background 41
3. Endemic Characteristics 43
  3.1 Natural environmental factors 43
  3.2 Infectious sources 44
  3.3 Distribution of snails 47
  3.4 Water contact 48
  3.5 Infection with schistosomes 49
4. Prevention and Control Measures 51
  4.1 Snail control 51
    4.1.1 Reclamation and cultivation for eliminating snail *52*
    4.1.2 Storing water to raise aquatic products for eliminating oncomelania snail *53*
    4.1.3 Forestry engineering for schistosomiasis control *54*
  4.2 Chemotherapy measure 55
  4.3 Synchronization chemotherapy for people and livestock plus other control measures 58
  4.4 Infectious sources control 61
5. Control Effectiveness 63
6. Challenges 64
  6.1 Influence of the Three Gorges Dam on schistosomiasis transmission 64

Advances in Parasitology, Volume 92
ISSN 0065-308X
http://dx.doi.org/10.1016/bs.apar.2016.02.018

6.2 Complexity of snails' habitats 66
6.3 Remaining infectious sources 66
7. Prospects 67
References 67

Abstract

Schistosomiasis is one of neglected tropical diseases in the world. The People's Republic of China has made great achievements in schistosomiasis control through integrated interventions. Although the morbidity and mortality have been reduced to the lowest level in all three endemic regions, namely lake and marshland regions, hilly and mountainous regions and plains with waterway networks regions, the endemic status in lake and marshland region is still that of implementing the interventions in the higher endemicity areas towards elimination of schistosomiasis transmission. This review explores and analyses the endemic characteristics, control measures and its effectiveness in the course of schistosomiasis control programme, in order to provide more theoretical information and experiences for development of appropriate strategies leading to schistosomiasis elimination in the next stage in the country.

1. INTRODUCTION

Schistosomiasis is one of neglected tropical diseases in the world, which has been targeted as one of diseases to be eliminated by World Health Organization (WHO). There are four major types of human schistosomiasis: schistosomiasis mansoni, schistosomiasis haemetobia, schistosomiasis japonica and schistosomiasis mekongi (Chitsulo et al., 2000; Collins et al., 2012). Schistosomiasis japonica is prevalent in the south of the Yangtze River basin and 12 provinces (municipalities and autonomous regions) in The People's Republic of China (Xu et al., 2016). According to the environmental characteristics of snail habitats, the endemic areas are divided into three types, namely lake and marshland regions, plain regions with waterway networks, and hilly and mountainous regions (Collins et al., 2012; Chen, 2014). Due to differences in the endemic factors and geographical characteristics, the control process was faster in the provinces dominated by waterway networks, while in the provinces with lake and marshland regions, the control process is relatively slow and tortuous. The five endemic areas dominated by waterway networks, namely Guangdong, Guangxi, Shanghai, Zhejiang and Fujian provinces achieved the standard of transmission interruption in 1985, 1988, 1985, 1995 and 1987, respectively (Shi et al., 2016). Hilly and mountainous areas such as Sichuan and Yunnan provinces, as well as mainly lake and marshland areas such as Hunan, Hubei, Jiangxi, Anhui and Jiangsu provinces have not yet reached the standard of transmission interruption (Liu et al., 2014, 2016). After more than 60 years of active and effective prevention and control measures, 124 counties achieved the standard of transmission control and 34 counties were not able to achieve the standard of transmission control in The People's Republic of China by the end of 2013; and all the 34 counties were distributed in lake and marshland regions (Lei et al., 2014). Therefore, lake and marshland region is the focus on schistosomiasis control, and it also is the key to realize the target of transmission interruption and elimination of schistosomiasis in The People's Republic of China. By analysing the epidemic characteristics in lake and marshland region, the achievements or experiences from the national schistosomiasis programme has been summarized for more than six decades, highlighting the problems and challenges of the current schistosomiasis control programme. This chapter aims to provide an important reference for the development of The People's Republic of China's 'Thirteen Five-Year' plans on schistosomiasis control and provide reference for schistosomiasis control in the world.

2. BACKGROUND

Lake and marshland regions are mainly distributed in Hunan, Hubei, Jiangxi, Anhui and Jiangsu provinces located in the middle and lower reaches of Yangtze River. At the beginning of the national schistosomiasis control programme, the infection rate of people and bovine was very high in those areas. The infection rate of people was as high as about 70% and a large number of acute schistosomiasis cases occurred every year. The infection rate of cattle and pig had reached up to 80–90% in some places (Chen, 2014). Snails are widely distributed in marshland regions, and the habitat of snails is so complex that the effect of mollusciciding is difficult to consolidate (Li et al., 2016). The process on schistosomiasis control is relatively slow and tortuous due to the special features of geographical environment and characteristic of prevalent situation in lake and marshland regions. At the beginning of prevention and control programme, the area of snail habitat accounted for 82.1% and the number of cases accounted for 43.9% of the total schistosomiasis patients in The People's Republic of China (Mao and Shao, 1982). In the 1960s and 1970s, the strategy on schistosomiasis control was emphasized on snails elimination. These measures including reclamation planting, changing paddy fields into dry land, environmental modification and mollusciciding were implemented in Hunan, Hubei, Jiangxi, Anhui and Jiangsu provinces, that is, 'five provinces in the lake regions'. Meanwhile, mass examination and treatment of people and bovine were carried out widely in the five provinces. Snail areas decreased substantially and the prevalent situation of schistosomiasis was controlled effectively. Snail areas were reduced 1.873 billion m^2 in Hubei by 1983, nearly 60% in Hunan, 920 million m^2 in Jiangxi combined with large-scale agricultural development in Poyang Lake, up to 78% in Anhui by the end of 1981, more than 97% of snail areas were eliminated in Jiangsu and reached the standard of transmission control by 1976 (Wang, 2006). Since the 1980s, with the advent of praziquantel that has safe and efficient therapeutic effect, the comprehensive measures with emphasis on chemotherapy on human and livestock were taken in The People's Republic of China. The infection rate of people and livestock decreased rapidly with the implementation of chemotherapy measures. However, acute schistosomiasis infection and reinfection were very serious due to the complexity of snail habitats, flood disasters and frequent contact with contaminated water for the production and living in lake and marshland regains. In the 1980s and 1990s, the prevalence of schistosomiasis presented up and down in The People's Republic of China, and even seriously rose in some areas. The snail areas increased from 2.75 billion m^2 in 1980 to 3.47 billion m^2 in 1988. The first national sample survey of schistosomiasis was conducted in 1989, which indicated that snail areas in lake and marshland regions accounted for 95.5% of the total snail areas in The People's Republic of China, the number of schistosomiasis patients accounted for 85.6% of the total patients, the average infection rate of people was 12.94% in the lake and marshland regions and a large number of acute schistosomiasis occurred every year along the Yangtze River (MOH, 1993). World Bank Loan Project on schistosomiasis control in The People's Republic of China was carried out in eight provinces from 1992 to 2001, in order to curb the upward trend of schistosomiasis. Chemotherapy for humans and livestock by praziquantel was adopted as the main measure. Mollusciciding, health education and limited environmental modification were taken as the supplemental measures. For chemotherapy on a large scale with high intensity, the prevalence of schistosomiasis was controlled effectively, the number of patients dropped by 50% and the number of infected cattle declined by 70% in the eight provinces. However, the change in snail situation was not significant, and the density of infected snails still remained at a certain level (MOH, PR China, 2002). To accelerate the process of schistosomiasis control further in The People's Republic of China, and protect the health of people to promote economic and social development in endemic regions, Ministry of Health, Development and Reform Commission, Ministry of Finance and six other central ministries jointly issued the 'Outline on national long-term plan for prevention and control of schistosomiasis (2004–15)', which aimed at achieving the target of transmission control by 2015 (Zhu et al., 2016). For this purpose, according to the prevalence situation of schistosomiasis in lake and marshland regions, comprehensive control measures that emphasized on infection source control (replacing cattle with machine for cultivation, forbidding depasturage of livestock on marshland and so on) were adopted in combination with the adjustment of farming and aquaculture in rural areas, water conservancy project, afforestation for schistosomiasis prevention, wetland protection projects to change the habitat of snail in the highlighted areas and reduce the endemic range. With the implementation of the Outline, the process of schistosomiasis control in The People's Republic of China received great impetus. The infection rate of people and livestock, the inventory of infected livestock, the number of acute schistosomiaisis and the area of infected snails dropped significantly. By the end of 2013, only nine acute cases occurred nationwide, the calculated number of patients dropped to 184,900, infected cattle were found to be 633, snail areas fell to 3.655 billion m^2 with infected snails scattered in the local environment, and the prevalence of schistosomiasis was reduced to the lowest level historically. However, 96.49% of snail areas were distributed in lake and marshland regions; 96.34% of the estimated patients were in Jiangxi, Hubei, Hunan and Anhui provinces which are mainly the lake and marshland endemic regions (Lei et al., 2014). Presently, the lake and marshland endemic regions are still the key districts for schistosomiasis control. To summarize, the experience of prevention and control, the epidemiological characteristics and the systematic achievements in lake and marshland endemic regions have implication for interrupting transmission or eliminating of schistosomiasis as soon as possible.

3. ENDEMIC CHARACTERISTICS

3.1 Natural environmental factors

Lake and marshland endemic regions are located on both sides of the Yangtze River and the adjacent areas of lakes interlinked with Yangtze River, for example Dongting Lake in Hunan Province, Poyang Lake in Jiangxi Province, lakes in Jianghan Plain in Hubei Province and lakes in the lower reaches of outlet of river in Jiangxi Province. The remarkable natural environmental feature of lake and marshland endemic area is the significant seasonal variation. The regions of 'water in summer and land in winter' are the potential snail habitats, which are covered with water when annual floods occur and snails are likely to breed on the water coverage regions. The marshland become exposed with large scale of lush vegetation after the flood subsides in the autumn. Thus, the annual floods play an important role in marshland deposition, formation of new marshlands and spread of snails in the lake and marshland endemic areas.

Snails immigrate and multiply quickly as the vegetation (weed and bulrush, etc.) grows with the accumulation of silty sand to a certain height, and the snail would be found in this region about 4 or 5 years later, resulting in the steady increase of snail area in lake and marshland regions. In the 150 km stretch between Jiangning and Jingjiang in Jiangsu Province, about 233.4 hm^2 of beach land was formed every year since 1985. The area of beach increased from 99.9 hm^2 in 1990 to 233.1 hm^2 in 1995 in Jiangan district of Wuhan city. The area of snail habitat increased 34.7 hm^2 every year in Dongting Lake due to the accumulation of silty sand. A total of 40.43 hm^2 of snail area was increased in 1988 in Hunan Province, and 929.2 hm^2 in Anhui Province (Zhang et al., 2002). The fluctuation of the flood provided appropriate environment for the growth and reproduction of snails, and the coverage of flood promoted the development and hatching of snail eggs. The surface of marshland would retain long-term moisture after being covered by water for 3–8 months, especially in the regions overgrown with weeds and bulrush, which was conducive to the growth and reproduction of snails. Lake and marshland endemic area was divided into four subtypes, namely fork-beach, marshland, inner embankment and embankment according to the variability of water level, the type of snail habitat, geographical position of the residential districts and endemic characteristics (Chen, 1980).

3.2 Infectious sources

It has been proved that livestock was the main source of schistosomiasis infection in lake and marshland endemic regions (Fig. 1). At the beginning of schistosomiasis control, more than 50% of cattle were detected positive for schistosomiasis (Shen, 1992). Epidemiologically, cattle played an important role in the transmission of schistosomiasis due to a large number of cattle pasturing frequently in the beach, which discharge a large quantity of excreta containing schistosome eggs. Because there is a wide range of lake and marshland endemic areas in The People's Republic of China, the type of infectious sources and their implication for schistosomiasis transmission varied in different regions. The marshland outer embankment of Dongting Lake is a natural ranch that is full of lush vegetation, where the mean infection rate was 20.63% for the cattle (Li et al., 2002). The cattle rowed faeces and

Figure 1 The main infectious sources in lake and marshland endemic regions (including more than 40 species of mammals).

contaminated the marshland. Cattle was the main infection source and accounted for 83.64% of annual actual contamination index (AACI); followed by swine (9.37%) (Wu et al., 1990). Xu et al. (1985) conducted five surveys on field stool in Muping Lake from 1979 to 1982; of the 5017 samples collected in the field, livestock's stools accounted for 99.58% and those of humans accounted for 0.42%. AACI is an objective indicator for determining the epidemic intensity of schistosomiasis, which can perceivably reflect the infectivity of the infectious sources.

Of the infectious sources in the south Dongting Lake, domestic pigs had the highest infection rate. The infection rate of domestic pigs was 45.94% in local areas. After the domestic pigs were checked and treated monthly for a year, the new infection rate of domestic pigs was 12.75% monthly, and the reinfection rate was 50% yearly. The highest positive rate (23.29%) and the highest density (22.46/10,000 m^2) of wild stool were found to be domestic pigs. Domestic pigs accounted for 89.83% of annual actual contamination index, which were 9 times higher than that of cattle and 200 times higher than that of humans (Hu et al., 1996). The activity of domestic pigs was in a relative narrow range and concentrated in place within 300 m distance of dike. The shorter to the dike, the higher the density of wild stool and the density of infected snails, and there was positive correlation between the density of wild stool and the density of infected snails (Chen et al., 1999). Therefore, domestic pigs might play much more important role in schistosomiasis transmission and bringing more serious harm to people in some places.

There were plenty of cattle and domestic pigs near the dike in Poyang Lake area, where the infection rate of schistosomiasis was 20–50% in domestic pigs, 20–30% in cattle and more than 30% in people (Xie, 1990). Some studies on contamination index of wild stool in marshland revealed that bovine faeces accounted for more than 90%, domestic pigs accounted for 6–8% and other livestock accounted for a smaller proportion. The infected cattle, domestic pigs and people (eg, fishing, mowing and swimming) in the marshland of Poyang Lake were all sources of schistosomiasis infection, while the infected cattle was the main infectious sources (Lin et al., 2003). More than 90% of endemic areas were located in Jianghan plain in Hubei Province; a survey conducted in Hanbei river revealed that the bovine faeces were severely infected by schistosomiasis, which accounted for 97.5% of wild stool and 89.5% of eggs per day (EPD) (Huang, 1998).

With the development of livestock husbandry, the amount of sheep is on the rise. Sheep is a susceptible host for schistosomiasis with higher infection rate and likely to defecate in the wild. Furthermore, sheep always dispersively defecate granulated faeces, which results in easy contact with snail. Therefore, the role of the faeces of infected sheep in contaminating environment and diffusion of pathogens should not be neglected. The infection rate of sheep was 7.5–17.5% in Jingzhou district and Honghu Lake; the positive rate of sheep faeces was significantly higher than that of cattle faeces, and sheep might become the new main infectious source (Yuan et al., 2003). Dog is also one of the definitive hosts, but it plays only a small role in the course of schistosomiasis transmission. However, the infection rate of dog was found to be 75.0% and EPD result was 80.4 in three pilot studies in the lower reaches of Dongjing lake; in some areas, the infection rate of dog was found to be more than 90% and relative contamination index was 46.6%. Dog might be one of the most important infectious sources due to its wide range of activities and freely spreading of eggs (Su et al., 1994).

There is large-scale marshland along Yangtze River in Anhui and Jiangsu provinces, where the cattle grazed freely on the beach. The infection rate of cattle generally was very high, reaching to as high a level as 77.3% in some places. The mean infection rate of cattle was 45.42% and the proportion of contamination index was 99.8% in beach areas in Anhui Province (He et al., 1995). Despite many years of active control, the infection rate of cattle was still very high due to the reinfection of schistosomes.

Sun et al. (1997) conducted a 5-year prospective study and reported a mean infection rate of 8.23% in cattle, and bovine faeces accounted for 85.15% of wild stool in river beach areas. The characteristics of water level in the lake and marshland endemic area, including water-rising stage and drought period, has direct effect on the activity of domestic animals and people on the beach. In general, livestock are the main infectious source in the drought period for it they are freely active in a large range, especially the cattle and pigs infected with schistosomiasis. While during the water-rising period, the fishermen may act as an important infectious source, who, living on the fishing boat, contaminate the water easily, and the infection rate of snail is generally higher in the moorings. In different seasons, there are some differences in the types and implication of the main infectious sources in the lake and marshland endemic area; the free-ranging cattle and pig are the main source of infection during drought period in Dongting Lake, while infected fishermen are the main infectious source during water-rising period (Wu, Xie, 1991).

3.3 Distribution of snails

The distribution of snails is associated with the annual flooding duration and vegetation in marshland. Snail often presents a planar distribution with wide range and large scale in the marshland. The 'water in summer and land in winter' appears in the snail habitats due to the uncontrollable water level, which results in the specific characteristics of the distribution of snails, namely 'two lines and three belts'. The 'two lines' represent the lowest and highest snail hypsometric curve, and the 'three belts' represent the upper rare snail areas, the middle dense snail areas and lower rare snail areas. Snails are generally distributed at a certain elevation in lake and marshland area, while dense snail areas are scattered in the beach covered by flood for 3—5 months. The height of attitude for 'two lines and three belts' varied in different beaches. Snails are widely distributed in Poyang Lake areas. While no snails were found in the marshland at an altitude of less than 13 m and over than 18 m above sea level, 5.4% of snail areas were found in the marshland at an altitude between 13 and 14 m and between 17 and 18 m, and 94.6% of snail areas were located in marshland at an altitude between 14 and 17 m above sea level. The dense snail areas were majorly distributed in the range from 27 to 29 m above sea in Dongting Lake, and from 24 to 27 m in Hubei Province. The snails were distributed along the new channel similar to the typical waterway networks regions in the dam-circled marsh region.

The infected snail plays an important role in the course of schistosomiasis transmission, which has remarkable aggregation in lake and marshland area

(Collins et al., 2012). The infection rate of snails was higher in the areas closer to village or the place with frequent activity of people and livestock. The infected snail can be easily found in the areas close to village or the places seriously contaminated by wild stool (Wang and Wang, 2000a). Generally, there was slight variation of the distribution of infected snails yearly, but infection rate of snails might increase with the rise of snail density. Because livestock was the main infectious source in the lake and marshland areas, the distribution of infected snail was closely related to the distribution of cattle in these areas. In Dongting Lake area, the width of distribution zones for the infected snails was closely related to the width of distribution zones of living snails, vegetation type, topography level, flow velocity and the type of infectious sources. In the high transmission areas with cattle faeces as the main contaminating source, the distribution range of infected snail could be as far as 1000 m to the dike due to a wider range of activity. While in the berth which can easily be contaminated by fisherman, the distribution zones of infected snail was narrow and concentrated in the range of 300 m away from bridge of dam and hill, and residential houses (Zhuo et al., 1991). To understand the distribution characters of infected snails it is necessary to focus on transmission as well as provide important information for mollusciciding. Generally, the areas with the density of infected snail more than 0.005/0.11 m^2 are deemed as highly susceptible or dangerous zone for the infection with schistosomes. It was proposed that the classification of high transmission zones be based on the density of infected snails as the criteria. The areas with the density of infected snails more than 0.005/0.1 m^2 with easily occurring acute schistosomiasis are classified as high focus areas of transmission, which account for about 25% in lake and marshland regions, the areas with the density of infected snails less than 0.005/0.1 m^2 are classified as the next focus areas of transmission zones, which also account for 25% of marshland, and infected snails were not found in more than half of the marshland (Zhang et al., 1996). Practically, carrying out mollusciciding in high-transmission areas and the strategy guided by the classification as above have led to remarkable achievements in lake and marshland regions (Zhou et al., 2013).

3.4 Water contact

Contacting cercariae-infested water is the essential step for the transmission of schistosomiasis. To understand the residents' habit of contacting affected water can provide the basis for making out specific control measures. There were significant variations in the mode and frequency of contacting affected water in the lake and marshland areas based on the differences of geographical environment, socioeconomic and cultural and living habits. The frequency (times/person-day) of contacting affected water in marshland areas was 10 times higher than that in fork-beach areas and embankment areas. The frequency in marshland was stable except for the month of February. While there was remarkable seasonal variation on the frequency of contacting affected water in fork-beach and embankment areas, April, May, October and November usually with the higher frequency of contact, presented a bimodal pattern. People who frequently contacted affected water were 15−29 year-olds in marshland, and 30−35 year-olds in fork-beach and embankment areas. The mode of contacting affected water included fishing, laundry and dabbling in marshland, and wading, grazing and fishing in fork-beach and embankment areas (He et al., 1997). The adult males contacted affected water mainly through working in paddy field in the inner embankment areas. Except for working in paddy field, the adult females might contact affected water through other manner, for example washing clothes and washing dishes. The main manner of contacting affected water among teenagers included washing clothes and dishes, fishing and playing in the water (Guan et al., 1999). The distance from their houses to dam impacted on contacting affected water; for example, the frequency of contacting infected water was significantly higher for people living within 200 m than the residents living more than 200 m away from the dike in Dongting Lake area. Generally, the seasons with highest frequency of contacting infected water were spring and summer, followed by autumn and winter in lake and marshland area. The manner of contacting affected water mainly included mowing grass in spring, washing clothes, swimming and catching fish/shrimp in summer and autumn. Contacting affected water is closely related to economic status. Poverty is a promoting factor in contacting affected water as the poor families tend to more frequently contact the affected water.

3.5 Infection with schistosomes

People living in lake and marshland areas can be infected by schistosome in a variety of manners. Infection can occur throughout the year except winter, and the outbreak of acute schistosomiasis might take place when a large number of people contact affected water due to floods, harvest and swimming. The infection was variable among different types of epidemic areas; the people living on island and inner embankment have the highest infection rate. At the beginning of schistosomiasis control, the infection rate was 57.9% in Nanji village, an island endemic area in Jiangxi Province, and 49.7% in Mingshan village in Hubei Province; the infection rate was more than 35% in inner embankment in Hubei Province. The mean infection rate was 20% in marshland and embankment endemic areas. In lake and marshland endemic areas, the infection rate was positively correlated with the distance from residential houses to the marshland. The infection rate of people in marshland regions was 15–30% when the distance was less than 500 m, 5% when the distance was from 500 to 1000 m and less than 3% when the distance was more than 1000 m (Lin and Zhang, 2002). The infection rate in embankment endemic areas was similar to that in marshland endemic areas. The infection rate of people in island endemic areas was significantly higher than that in other types of endemic areas and the infection rate could be as higher as 50–80% for the people living with the distance less than 500 m away from marshland, while the infection rate was about 30% when the distance was from 500 to 1000 m. The infection rate was similar between female and male in island-type and inner embankment endemic area. There were two age peaks for the infection of schistosome, namely teenager and adult, which present typical 'bimodal curve'. The infection rate of male was commonly higher than that of female in embankment and marshland endemic areas, and there was only one age peak in marshland endemic regions, namely 15–20 years of age, which presents typical 'unimodal type', with the infection rate in a higher level maintained constant for the older people. The fishermen were very easily infected by schistosome for their frequent and long duration contact with affected water.

Reinfection is very common in lake and marshland endemic areas. The prevalence situation rebounds once the intervention measures are reduced or stopped. Wu, Po, et al. (1995) conducted a survey along the Dongting Lake and revealed that the reinfection rate was 12.9% after treatment with PQT; the male reinfection rate was higher than that of female; and the people aged from 10 to 40 years had the highest reinfection rate. Wu et al. (1994) conducted a survey in island-type endemic area and revealed that the reinfection rate increased to 47.1% in September after a periodic flood, and increased to 54.5% in January in the second year, very nearly to the infection rate before chemotherapy (64.3%). The heavier the prevalence situation before chemotherapy was, the higher was the reinfection rate. The reinfection rate in the lower age group (<20 years) was significantly higher than that in the higher age group. Ceng et al. (1996) conducted a 3-year prospective study in an island-type endemic area and reported that the reinfection rate was 22.6% in 1990, 47.8% in 1991 and 40% in 1992. Qin et al. conducted a survey in a marshland epidemic area and reported reinfection rate of 13.49% after an epidemic season, which was similar to the infection rate before therapy (13.37%). The reinfection rate was 9.52% from June to September, and 3.97% from October to December. The reinfection rate in the lower age group (<20) was significantly higher than that in the older age group (≥20) (Qin et al., 2000). Carrying out effective intervention measures in heavy endemic areas could reduce reinfection. The reinfection rate has slight change if only single chemotherapy measure is taken in serious endemic areas, and the reinfection rate decreased year by year when environmental modification measures were taken. The reinfection rate was closely related with the intensity of transmission in endemic areas. The more serious the previous prevalence, the higher the reinfection rate of people and the shorter the period of rebound, and so is the contrary.

Acute infection was hard to avoid in lake and marsh epidemic areas due to the frequent exposure to contaminated water. Studiers have revealed that acute infection was positively correlated with water level, and the outbreak of acute schistosomiasis might take place in flood year. Acute schistosomiasis outbreak in Yangtze River valley in 1989 had the number of acute cases 2.97 times more than that in 1988, and 99.38% of the patients were in 'five provinces in lake regions'. As for Anhui Province, 96.5% of the acute patients in 1989 occurred in 18 counties mainly lake and marshland endemic areas, teenagers accounting for the majority of patients; the number of male patients was higher than that of female, and the main infection modes were fishing and paddling. Analysis on acute schistosomiasis occurred from 1987 to 1989 in Dongting Lake and Poyang Lake showed that the male cases accounted for 86.1% and the female cases for 13.9% in Dongting Lake areas, and 76.4% of cases in male and 23.6% of cases in female were found in Poyang Lake areas. The adolescent (<20 year-olds) accounted for 58.3% in Dongting Lake and 57.0% in Poyang Lake. The main infection modes were swimming (51.8%) and fishing (20.8%) in Dongting Lake, and fishing (44.9%), swimming (14.1%) and grazing (11.2%) in Poyang Lake regions.

4. PREVENTION AND CONTROL MEASURES

4.1 Snail control

Snail control is always one of the important measures in The People's Republic of China in the course of 60 years of schistosomiasis control. Shanghai, Zhejiang, Guangdong, Guangxi and Fujian provinces have achieved the goal of transmission interruption mainly by snail control measures. Due to wide distribution of sail areas and complex environment of snail habitats in lake and marshland regions, appropriate methods of snail control according to the local conditions can achieve better results. At present, 70% of snail habitats have been changed by means of reclamation and cultivation in low dyke or reclamation and cultivation without dam, aquaculture in low dyke, reclaiming farmland from lakes and other measures in lake and marshland regains in The People's Republic of China (Fig. 2), which are not only conducive to production, but also achieved significant snail control and elimination of snails. Environmental modification measures is an important experience for the elimination of snails in the long history of schistosomiasis control in lake and marshland regions in The People's Republic of China.

4.1.1 Reclamation and cultivation for eliminating snail

The best method for eliminating *Oncomelania* snail is to change the habitat and make it unsuitable for snails to survive. According to the environmental features of snail habitats in lake and marshland epidemic areas, we can control and eliminate *Oncomelania hupensis* by means of changing the environment of snail habitats, for example reclamation with low embankment, reclamation without embankment, reclamation with high embankment, filling lakes

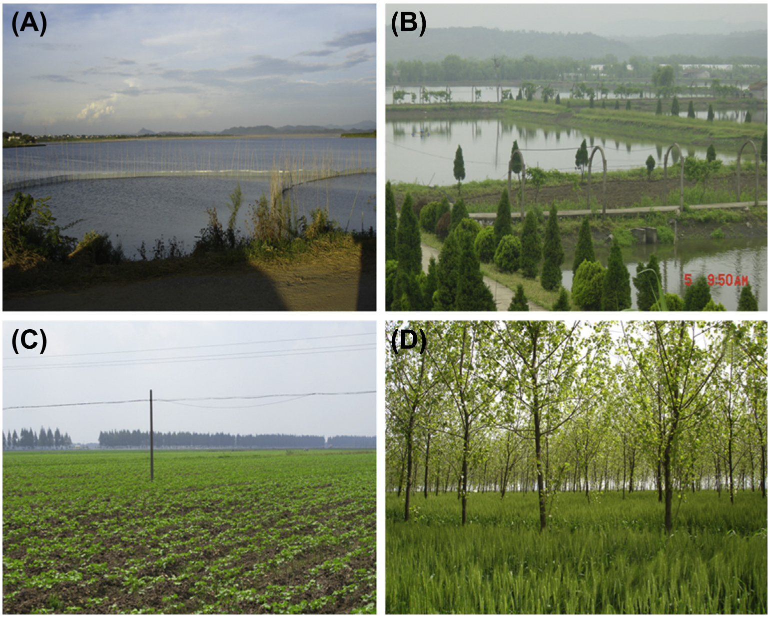

Figure 2 Environment modification measures for snail control in lake and marshland endemic regions. (A) Snail elimination by water immersion; (B) building fish ponds; (C) changing marshland into dry land and (D) planting trees to replace reeds.

and reclaiming land from lakes, and so on. In the 20 years, two-thirds of lake had been reclaimed in Hubei Province, including two-fifths in Dongting Lake, one-thirds in Poyang Lake and large area in the middle and lower section along Yangtze River in Anhui and Jiangsu provinces. Reclaiming and planting in marshland has a good effect on eliminating oncomelania snail, which reduced two-thirds of the total snail areas in lake and marshland regions in The People's Republic of China (Wang and Wang 2000a,b). The snails were in patchy distribution in Poyang Lake and Dongting Lake. Reclaiming and planting by using large machinery directly to change the environment of snail habitats could get better effect on snail control and elimination of snails in the places with relatively higher elevation. A survey conducted in 21 places on land reclaimed and planted by machinery revealed that the occurrence rate of frames with living snails and the density of living snails decreased over 80% in 15 places, between 30% and 80% in 2 places and less than 10% in 4 places (Tu et al., 1992). For the environment with higher density of living snails, mollusciciding should be carried out prior to reclaiming by machinery or reclaiming combined with planting crops to further enhance the effect of snail control. More than 3 years of continuous ploughing and planting can ensure the quality and effect of eliminating snails. If reclaiming by machinery is not implemented successively, the density of living snails would rise again. The effect of snail control by different methods in Dongting Lake regions showed that the mean density of living snails reduced by 86.6% and the occurrence rate of farms with living snails decreased by 92.95% after reclaiming for 3 years; the mean density of living snails reduced by 93% and the occurrence rate of frames with living snails decreased by 83.4% after building lower embankment and mollusciciding by immersion for 3 years. However, the effect was not remarkable by single mollusciciding only; the density of living snails only decreased by 17.78% and the occurrence rate of farms with living snails was similar to that 3 years ago. In recent years, with the development of the city along Yangtze River, the environment of snail habitat changed greatly since the areas were filled with sand, especially some low-lying areas that were not suitable for ploughing and inter-planting (Huang et al., 2013).

4.1.2 Storing water to raise aquatic products for eliminating oncomelania snail

As protection against floods, storing water to raise aquatic products by constructing low embankment in low-lying marsh areas and then mollusciciding in the inner and outer of the embankment, not only brought economic benefits, but also played the role of elimination of snails. Hu et al. (2003) conducted a prospective study in 41 projects of building dike and revealed that 50% of projects reached the standard of elimination of snails in 7 years, all projects reached the standard of elimination of snails in 15 to 17 years, the number of schistosome patients and snails declined simultaneously and no rebound was reported showing that ultimately we can achieve the aim of controlling or eliminating of schistosomiasis. Hubei Province is one of the larger lake and marsh epidemic areas in The People's Republic of China, it had significant changes on the environment by hydrographic engineering projects since 1956, including reclamation of 81 lakes, that provides favourable conditions for snail control. Xinmin beach which is located between Gaoyou lake and Shaobo lake in Jiangsu Province, the infection rate of residents was more than 80%; 4019 peoples were infected with acute schistosomiasis of which 1335 peoples died and 45 households had been extinct due to acute schistosomiasis in 1950. Building low embankment and molluscicidng with sodium pentachlorophenate since 1971, the density of living snails decreased to 0 in 1979 and the infection rate of people reduced from 36.59% in 1971 to 0.17% in 1980.

4.1.3 Forestry engineering for schistosomiasis control

Peng (2001) put forward the concept of construction of forestry ecological engineering after extensive investigation and evaluation in the 1980s. The mechanism is to construct forestry-based complex ecological systems comprising forestry, agriculture, animal husbandry, fishery and so on according to eco-environment speciality, improve the natural environment and enhance biodiversity so as to achieve ecological improvement and economic benefits. By strengthening management of the forestry project, it could prevent livestock and nonprofessional people from entering forestry, reduce faeces containing schistosome eggs that contaminate environment with snails and decrease probability for the infection of people and livestock to realize the objective of snail control and schistosomiasis prevention. The forestry engineering for schistosomiasis control provides a new way for snail control in lake and marshland regions. It was considered in 1044 spots with snails in lake and marshland areas in Anhui Province and 43.8% of the spots implemented forestry ecological project for snail control and schistosomiasis prevention. The main afforestation model was pure forestry and accounted for 57.8% of the total spots. The occurrence rate of frames with living snails in the environment with afforestation (14.9%) was lower than that in the environment without afforestation (19.7%) ($\chi^2 = 2219.42$, $P < 0.01$). Of the different engineering modes, agroforestry pattern had the lowest occurrence rate of frames with living snails. The mean density of living snails was 0.552/0.1 m^2 in marshland with afforestation and 0.989/0.1 m^2 without afforestation (Huang et al., 2010) in the survey. At present, forestry ecological projects for snail control and schistosomiasis prevention have been promoted widely in Hunan, Hubei, Jiangxi, Anhui and Jiangsu provinces. For it to be a systematic engineering, the project should be designed specifically, implemented strictly and managed carefully to play a better role in schistosomiasis control.

4.2 Chemotherapy measure

Praziquantel is one of anti-schistosoma drugs with low toxicity, high efficiency and low price (Tambo et al., 2015). Since the late 1980s, chemotherapy measure for schistosomiasis control had been taken extensively in The People's Republic of China and it was very important for schistosomiasis control especially in the early phase. The measure of mass chemotherapy with praziquantel was carried out once a year for three consecutive years in marshland area of Guifan, Anhui Province, and the infection rate of people decreased from 19.2% to 8.9%, 6.8% and 7.2% yearly after 3 years of chemotherapy, but it rose to 13.6% after 2 years' interruption (Jiang et al., 1991). Wu, Yuan, et al. (1991) carried out the selective population chemotherapy trials with praziquantel once a year for two consecutive years in island area of Jishan, Jiangxi Province, and the infection rate of people changed a little, from 39.3% to 32.6%. It was thus clear that the annual mass chemotherapy was difficult to reduce the reinfection in severely affected marshland areas. Extending mass chemotherapy in the severe endemic areas of Dongting Lake, the infection rate of local residents reduced from 17.2% to 6.5% in 3 years and decreased by 62.2% after which it was stable under 5%, but the positive rate of wild faeces, the density of infected snails and the infection rate of sentinel mice remained at a high level and it was difficult to achieve the effect of blocking transmission of schistosomiasis (Wu et al., 1995). Due to the high missing rate of faecal examination, single strategy of individual chemotherapy could not control the infectious sources fully. In the middle of 1980s, expanding chemotherapy strategy was carried out to treat people with positive of serum immunological screening, obvious symptoms or signs and clear history of contacting infected water by praziquantel, except for positive of stool examination. This extended chemotherapy for three consecutive years was carried out in serious endemic villages where the infection rate of residents was 57.5% and the infection rate of residents and children decreased by 74.9% and 87.7%, respectively. This chemotherapy strategy had low inputs and could control the disease soon (Wang et al., 1989). A strategy that including treating patients and infected cattle in combination of killing of snails for 3 years was implemented. The prevalence of infection in residents did not decrease but slightly increased from 33.1% to 34.7%; however, it reduced by 80.2% after extending chemotherapy strategy for one more year (Tian et al., 1996). Therefore, the coverage of chemotherapy and selecting appropriate chemotherapy targets were very important in serious endemic areas. Since 1992, World Bank Loan Project for schistosomiasis control was implemented in eight provinces of The People's Republic of China. The mass chemotherapy strategy for three consecutive years was carried out widely in the endemic villages where the infection rate of residents was above 15%. Until 1998, the number of serious endemic villages in The People's Republic of China where the infection rate of residents was above 15% reduced by 47.40% compared to that in 1992. But the consecutive mass chemotherapy measure not only wasted drugs but also involved in ethical issues; moreover, the compliance of chemotherapy drive reduced year by year. Therefore, the intermittent mass chemotherapy strategy research was launched in Hubei, Sichuan, Jiangxi and Anhui provinces from 1996 to 2000. The effect on schistosomiasis control was also better and the positive testing rate of faecal examination for residents decreased by 39.3% with 1 year interval mass chemotherapy and 54.7% with every year mass chemotherapy, respectively, in serious endemic areas in Hubei Province. This strategy considered to alleviate the complicated process of pathogenic and serological test was implemented in the endemic villages where the infection rate of residents was below 20% to control schistosomiasis gradually, but the coverage of chemotherapy should not be less than 70% each time in order to get better effect (Wang et al., 1998).

Mass chemotherapy for cattle was very important to maintain the prevalence at a low level in marshland endemic areas, but the single measure for livestock was insufficient to block the reinfection of schistosomiasis (Chen et al., 1996). The infection rate of cattle still remained at around 10% after six consecutive years of mass chemotherapy by longitudinal observation at Dongliu township, Dongzhi County, Anhui Province. The infection rate of cattle still remained as high as 42% after four consecutive years of treatment by longitudinal observation at Wucheng township, Yongxiu County, Jiangxi Province. The pigs that grazed in south Dongting Lake areas were tested and treated 12 times a year, but the infection rate was still above 10% (Wang and Wang, 2000b). Since 1987, in order to investigate the effect of chemotherapy on decreasing the infection rate of livestock and the role in transmitting schistosoma, 30 villages in Dongting Lake area were selected for trial pilots and the potential contamination indexes of all kinds of infectious sources were calculated by longitudinal observation for 8 years. The results showed that the actual contamination indexes of all kinds of infectious sources reduced but the proportion remained unchanged. The infection rate of cattle and pig declined definitely in the early phase of chemotherapy, but could only be controlled at a certain level after consecutive chemotherapy and it was hard to continue decreasing the infection rate of livestock. The effect of cleansing the marshland of snails was difficult to achieve by livestock chemotherapy alone (Guo and Zheng, 2000). Chemotherapy effect on controlling cattle infected by schistosoma was positively correlated with the coverage of chemotherapy. Expanding the coverage of chemotherapy on cattle from 35% to 50% resulted in reduction of the positive rate of cattle by 77.52% with the coverage of 50%, and 48.25% with the coverage of 35% (Xu et al., 1999). The effect of chemotherapy was associated with the environmental characteristics of marshland regions. The closed type of endemic areas was the best, semi-open type was the second and open type endemic area was the worst.

Synchronization chemotherapy for people and livestock was adopted in the closed type of marshland areas for six consecutive years and the prevalence of infection among residents reduced from 15.6% in 1980 to 0.9% in 1985, a decrease by 94.2%. But once the measures paused, the infected snails reappeared and the infection rate of people also began to rebound 4 years later. Synchronization chemotherapy measures for people and livestock were carried out in Dongting Lake regions and in the second year the infection rate of residents, fishermen, cattle and pigs decreased by 65.17%, 30.18%, 62.62% and 26.85%, respectively. However, the infection rate of people and livestock remained at a certain level in the subsequent years. The infection rate of snails and the density of infected snails in susceptible zones declined significantly 1 year after chemotherapy and fluctuated in the subsequent years (Liu et al., 2003). The coverage of chemotherapy was related to the positive rate of stool examination directly. The positive rate of stool examination reduced significantly while the coverage was above 80%. Continuous mass chemotherapy could reduce the incidence of patients, delay onset time, reduce the number of advanced schistosomiasis cases and protect the labour force.

4.3 Synchronization chemotherapy for people and livestock plus other control measures

Chemotherapy was an effective method for schistosomiasis control in marshland areas. This measure could decrease the infection rate and the degree of infection for residents and control the prevalence situation at a certain level, but it was still difficult to block the transmission of schistosomiasis (Chen et al., 2000). To improve the effect of chemotherapy, National Research Committee of Schistosomiasis selected 22 pilots in marshland areas to launch the study on comprehensive control strategy based on chemotherapy for 5 years since 1980. These pilots were divided into three types and the corresponding control measures were implemented respectively. The measures for eliminating infectious sources and killing snails in susceptible zones were carried out in the first type regions, eliminating infectious sources and killing snails in large areas in the second type regions and eliminating infectious sources thoroughly (that is, expanding to chemotherapy) in the third type regions. The results showed all the measures had remarkable effects after 5 years of observation. In marshland areas, the measures implemented in first type of pilots were good and feasible for schistosomiasis control and had the most remarkable effect. The second type of measures controlled the disease well with relatively stable effect, but there was low feasibility and high cost for killing snails in large areas. Moreover, the third type of measure was easy to carry out but susceptible to external factors; the prevalence situation rebounded fast and the control effect was influenced by the coverage of chemotherapy and mobility of infectious sources. On this basis, the study on optimization control strategy was carried out in serious marshland areas, including chemotherapy for people and livestock, health education and killing snails in susceptible zones combined with environment improvement. The comparative field study was launched to eliminate infectious sources and block transmission of schistosomiasis by different control measures from 1989 to 1990 in Bailang Lake areas, Anhui Province. Simply extending chemotherapy could reduce the prevalence at a certain degree but it was hard to block the transmission. General control measures could only retain the prevalence at a certain level. The effect of extending chemotherapy supplemented with killing the snails one time in the susceptible zones was remarkable and the prevalence of infection among residents decreased from 15.39% to 0.30%, reduced by 98.05% after 4 years (Xu et al., 1990). The control measures were carried out in marshland areas including expanding chemotherapy for people and livestock, health education and environment improvement. The infection rate of people and livestock decreased by 93.1% and 72.6%, while the density of infected snails and infection rate of snails reduced by 66.7% and 77.3% respectively. The comparative study on three categories of measures was implemented in serious endemic areas of Dongting Lake, including selective mass chemotherapy, selective mass chemotherapy combined with killing snails in susceptible zones and simple treatment for positive cases of stool examination. After 3-year investigation, the actual contamination indexes reduced by 74.7%, 84.6% and 36.2% respectively, but the density of infected snails and infection rate of sentinel mice all remained at higher levels and the threshold of blocking transmission was not reached (Wu et al., 1993). Comparative experiments of three strategies were once launched in Guichi, Anhui Province. The first type strategy was simple mass chemotherapy, the second was killing snails in susceptible zones combined with mass chemotherapy and the third was comprehensive measures including those based on killing of snails. In Guifan pilot with the first strategy, the infection rate of residents reduced from 19.2% in 1981 to 7.2% in 1984, decreased by 62.5% in 3 years. There were acute schistosomiasis cases occurring every year and the infectious sources could not be controlled effectively by this measure. The density of infected snails was 0.0465/0.11 m^2 in 1981 and 0.0989/0.11 m^2 in 1984. The infection rate of sentinel mice was 100% in 1984 and the transmission of schistosomiasis still existed. The infection rate of residents rebounded to 13.6% in 1987 after the termination of intervention measures. In Sanlian pilot with the second strategy, the population prevalence reduced from 21.0% to 1.7%, decreased by 91.9% in 3 years. The density of snails decreased from 1.51/0.11 m^2 to 0.22/0.11 m^2, the density of infected snails reduced under 0.002/0.11 m^2 in the 3-year period of experiment and no case of acute schistosomiasis occurred. After 2 years' pause of intervention measures, the density of snails rebounded from 0.22/0.11 m^2 in 1984 to 4.01/0.11 m^2 in 1986. It was obvious that snails could not be eliminated only by chemicals and snails would reproduce fast once the intervention ceased. The prevalence of infection among people would rebound 1∼2 years later than snails, the infection rate of residents was 10.2% and cases of acute schistosomiasis occurred in 1988. Integrated control strategy could maintain the prevalence at a trough for 2∼3 years. In Jijiaba pilot with the third strategy, the mollusciciding effect was consolidated by constructing low embankment and storing water for fish-farming in marshland areas with snails. The infection rate of residents in 1981, 1984 and 1988 were 17.4%, 1.36% and 0.4%, respectively. No acute case occurred after intervention measures and the disease was controlled effectively in this region (Jiang et al., 1991). The study on control strategies and effect was carried out in five serious endemic villages of lake regions from 1995 to 1999. In the villages implemented with chemotherapy and killing snails, the infection rates of people and livestock reduced by 68.62% and 84.01% in 5 years, and the area of snails, the average density of live snails and infected snails decreased remarkably. In the villages implemented with health education and expanding chemotherapy, the prevalence decreased by 66.31% which was significantly higher than the villages implemented with single expanding chemotherapy, but the indexes of snails reduced unremarkably. In the villages implemented with single expanding chemotherapy, the indexes of the disease and snails both decreased unremarkably. Comprehensive control effect indexes showed that the effect on villages implemented with chemotherapy and killing snails was evident and stable, long-term effect of health education and chemotherapy was better than single chemotherapy and the comprehensive control effect of villages implemented with single chemotherapy was the worst. The results showed that chemotherapy was the major measure for schistosomiasis control in marshland areas, but in order to achieve the best control effect, chemotherapy must combine with snails control and health education. Therefore, the strategy of chemotherapy combined with killing of snails should be the preferred measure for schistosomiasis control (Huang et al., 2002).

Conventional chemotherapy measure was difficult to control schistosomiasis in marshland areas and simple chemotherapy could only control the disease to a certain extent. The effect of chemotherapy combined with killing of snails was maintained only for 2∼3 years once the measures were terminated and this strategy was also hard to block the transmission. The control effect of improving the ecological environment on snails was permanent and the prevalence situation did not rebound after the termination of intervention measures. Through the comprehensive comparison of the effects of different measures for schistosomiasis control and cost-effectiveness analysis, chemotherapy for people and livestock combined with health education should be chosen when schistosomiasis control is the major target at hand, and meanwhile the measure of environment improvement could be added in the regions with appropriate economic conditions. In the areas with prevalence situation almost under control, the achievement of schistosomiasis control should be consolidated by the measures as follow: repeated examination and chemotherapy for people and livestock combined with eliminating infected snails, chemotherapy for susceptible people and cattle, health education, killing the snails in susceptible zones and individual protection (Xu et al., 1996).

4.4 Infectious sources control

To control the faeces of infected people and livestock is the key for schistosomiasis control in The People's Republic of China (Wang et al., 2009). It was difficult to eliminate snails in marshland areas and protect cattle from being infected and reinfected with schistosoma by praziquantel. Contamination to environment with snails, from livestock especially cattle, as one of infectious sources of schistosoma, persistently existed and it was difficult to block the transmission of schistosomiasis. So, an integrated control strategy for schistosomiasis with emphasis on infectious sources control was proposed in 2004 in The People's Republic of China. Under this strategy, the measures including replacing cattle with machine for cultivation and forbidding livestock pasturing on marshland were implemented for eliminating contamination of marshland from faeces of cattle and other livestock effectively and to cut off the transmission chain. Moreover, to achieve the purpose of blocking transmission, these measures were supplemented by conventional measures, for example, chemotherapy, killing of snails, health education and so on (Fig. 3).

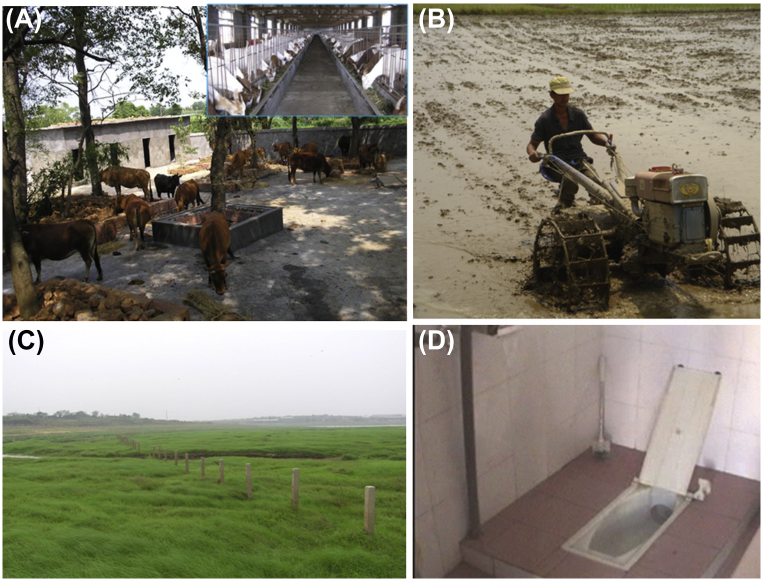

Figure 3 Infectious sources control measures in lake and marshland regions. (A) Raising animals in fen; (B) replacing bovine with machine; (C) building barrier to hind herding and (D) safe treatment of night-soil.

Forbidding livestock pasturing on marshland by setting up fences in the marshland with snails, deterring cattle and other livestock from grazing there, cutting off pathogen and cleansing the marshland aimed at achieving the goal of schistosomiasis control without killing snails. In the 1990s, X.Y. Wang, X.H. Wang and K.D. Zhang carried out the studies on the measure of forbidding livestock pasturing on marshland in Poyang Lake. Their results showed, respectively, that after 2 years the infection rate of residents reduced by 75.67%, 79.25% and 56.72%, the infection rate of cattle decreased by 88.53%, 97.14% and 87.7%, and the density of infected snails declined by 100%, 99.26% and 75.0%. The results of the three pilots proved it was an immediate and effective measure (Wang et al., 1999, 2003; Zhang et al., 2003). With the measures of constructing fences and forbidding livestock pasturing implemented on marshland, the number of livestock reduced by 73.6%, activities of residents in marshland decreased by 83.21%, the wild faeces reduced obviously and the infection rate of people, livestock and snails decreased remarkably, and the transmission of schistosomiasis was controlled effectively (Liu et al., 2010).

With the development of social economy and changes in production methods in rural areas, cattle were no longer the major way for cultivation and replacing cattle with machine became a trend gradually. The measure of replacing cattle with machine was promoted in marshland areas and the number of cattle decreased greatly, the role of cattle as major infectious source in the transmission of schistosomiasis was eliminated gradually. Meanwhile, the labour productivity was improved and the process of mechanization of agriculture was accelerated. The field experiments in marshland areas of Hunan, Hubei, Jiangxi, Anhui and Jiangsu provinces showed that schistosomiasis could be controlled effectively by comprehensive strategies with emphasis on eliminating cattle and replacing cattle with machine. The measure of replacing cattle with machine was implemented in six villages of Hubei Province and forbidding livestock pasturing on marshland was enforced in seven villages of Hunan Province. The results showed that the infection rate of people in the two groups decreased by 83.08% and 81.62%, respectively, there being no significant difference between them. But the infected cattle were still detected in the pilot with the measure of forbidding livestock pasturing on marshland and the prevalence of infection in cattle was 0.65%. The density and positive rate of wild faeces in seven villages with the measure of forbidding livestock pasturing on marshland were all higher than the six villages with the measure of replacing cattle with machine. The density of wild faeces in two groups of villages was

25.73/hm^2 and 0.1/hm^2 and the positive rates were 1.15% and 0, respectively (Cao et al., 2014). To maximize the effectiveness of replacing cattle with machine and forbidding livestock pasturing on marshland on blocking the transmission of schistosomiasis, the measures of infectious sources control should be promoted in whole village, town and county, otherwise the effectiveness of infectious sources control would be influenced by the existence of cattle in adjacent domains and their activities in environment with snails. Moreover, the later management of infectious sources control should be strengthened for preventing the return of livestock. The fences should be protected by specially assigned persons for preventing the facilities from being destroyed. Control and elimination of infectious sources is one of the important measures for schistosomiasis control. It is hard to eliminate snails in lake regions of The People's Republic of China at present and the integrated strategy with emphasis on forbidding livestock pasturing on marshland should be adopted based on epidemiology of schistosomiasis, biology of schistosoma, ecology of *Oncomelania* snails, hydrology and the activities characteristics of people and livestock. This measure not only protects the people and livestock from being infected by schistosoma, but also cuts off pathogen and cleanses the marshland.

5. CONTROL EFFECTIVENESS

The People's Republic of China has seen remarkable achievements in schistosomiasis control after 60 years of active and effective control. The snail area in marshland regions reduced from 11.3 billion m^2 in the early stage to 3.627 billion m^2 in 2013, a decrease by 67.9%, while, the snail area of Poyang Lake regions reduced from 1.4 to 0.63 billion m^2 by the measures of reclamation, storing water for fish-farming and killing snails in susceptible zones (Lin and Zhang, 2002). The snail area of Dongting Lake regions reduced from 3.333 to 1.77 billion m^2 by the snails control measures of large-scale construction of conservancy and farmland, reclamation and killing snails by drugs, a decrease by 46.89% (Li et al., 2014a). In early stage, the prevalence of infection among residents along the Yangtze River and lakes was very high, generally above 20%, and in some villages as high as 70%. There were large number of acute schistosomiasis and more cases of new and reinfection occurred every year. For example, the positive rate of stool examination of villagers near Poyang Lake was mostly more than 30%, even up to 80%; the infection rate of residents was more than 10%

in 79.3% of the villages and 5~10% in 14.5% of the villages in Dongting Lake areas. The prevalence of infection among livestock including cattle and pigs was also very high. Schistosomiasis was one of the important public health problems in endemic areas and restricted the development of rural economy seriously. Schistosomiasis was controlled effectively as the snail distribution area decreased greatly in marshland areas. The results of epidemiological sampling survey on national schistosomiasis in 1989, 1995 and 2004 showed that the prevalence of the infection among people in 1989 in marshland areas was still as high as 12.94%, the infection rate of livestock including cattle, buffalo and sheep was overall higher than people and the prevalence in sheep was as high as 43.59%. But in the present century, the prevalence of infection among people in 2004 decreased below 5%, reduced by 70.32%, compared to that in 1989. Moreover, the infection rate of cattle, buffaloes, pigs and sheep decreased by 72.14%, 61.53%, 93.72% and 93.85%, respectively (Table 1). Jiangsu and Hubei provinces reached the standard of schistosomiasis transmission control in 2011 and 2013 respectively; Anhui and Jiangxi provinces passed the assessment and achieved the goal of transmission control during the end of 2014 and April of 2015; Hunan Province was expected to achieve the target of transmission control for schistosomiasis by the end of 2015.

6. CHALLENGES

6.1 Influence of the Three Gorges Dam on schistosomiasis transmission

After the construction of the Three Gorges Dam, the temporal and spatial distribution of water and sand and the ecological environment of related areas in the middle and lower reaches of the Yangtze River underwent changes which influenced the distribution of snails and the prevalence of schistosomiasis in marshland areas. The highest and lowest water lever of flooding outer embankment with snails in Dongting Lake regions changed and the flooding time of altitude above 27 m reduced. In drought period, the phenomenon of shortage of water continuously occurred in upper and middle reaches of the Xiangjiang River, but the reproduction ability of snails in Dongting Lake regions was not influenced by the Three Gorge Project. The highest and lowest altitude of snails' distribution fell down. The altitude of high-density snails' zone and the density of living snails decreased, and the snail area increased when the water level rose (Guo et al., 2012).

Table 1 Results of stool examination for residents and domestic animals in different subtypes of lake and marshland endemic regions (nationwide sampling survey on schistosomiasis in 1989, 1995 and 2004 in The People's Republic of China)

Year	Subtype	Infection rate of residents (%)	Infection rate of cattle (%)	Infection rate of buffaloes (%)	Infection rate of pigs (%)	Infection rate of sheep (%)
1989	Fork-beach	10.33	19.51	10.28	5.25	—
	Islet without embankment	10.41	20.0	15.8	1.79	53.33
	Islet with embankment	13.29	17.89	15.85	6.38	88.24
	Inner embankment	15.44	3.57	20.05	3.66	9.68
	Total	12.94	17.03	16.56	3.98	43.59
1995	Fork-beach	7.72	1.08	8.82	1.92	—
	Islet without embankment	5.95	15.73	19.07	5.0	5.91
	Islet with embankment	7.13	7.18	6.66	0.88	—
	Inner embankment	6.67	21.28	8.65	1.89	4.48
	Total	6.63	7.74	11.84	2.73	5.73
2004	Fork-beach	3.36	8.57	8.65	0.56	1.95
	Islet without embankment	2.71	10.26	2.87	0	0
	Islet with embankment	4.28	0.36	13.07	0	6.87
	Inner embankment	4.25	3.83	5.54	0	0
	Total	3.84	4.55	6.37	0.25	2.68

After the Three Gorges Project became operational, the spatial distribution pattern of vegetation in marshland of Poyang Lake regions changed, the dominant population and distribution of vegetation occurred succession, and the natural meadow vegetation and snails presented a trend of slowly migrating to the lower altitude areas of the marshland (Li et al., 2014b). Earlier, the flood submerged partial marshland of Jiangsu and Anhui provinces along the middle and lower reaches of the Yangtze River in spring and receded in autumn, leading to the downtrend of the density of snails and the prevalence of schistosomiasis (Li et al., 2013). But the changes of water level led to the reduction of flooding time in partial marshland which was appropriate for snails reproduction and had became the potential, expanding areas of snails. Some embankments became the regions with snails distribution and the snail area appeared on an increasing trend as the measures of returning farmland to lake and detruding embankments for flood discharge were implemented.

6.2 Complexity of snails' habitats

Since the mid-1990s, the snail area in The People's Republic of China was maintained at around 3.5 billion m^2, of which 95% was distributed in marshland regions. Because of the large area of marshland, wide distribution and complicated habitats of snails and influence factors from water conservancy, environment and ecological aspects, the past experience of large-scale reclamation was no longer suitable for eliminating snails in order to maintain the ecological balance and water level (Zheng et al., 2013). The water level in marshland areas of the middle and lower reaches along the Yangtze River was difficult to control and mollusciciding effect was not ideal. Furthermore, snails drifted with streams and attachment for long distance, resulting in the expanding trend of snails and increasing the difficulty and complexity of snail control (Li et al., 2016).

6.3 Remaining infectious sources

In recent years, through the integrated control strategy including forbidding livestock pasturing on marshland, replacing cattle with machine and eliminating cattle, the number of cattle and the prevalence of livestock in marshland areas decreased year by year. There were abundant grass resources in marshland areas that were the ideal place for grazing. In spite of replacing cattle with machine for cultivation, the number of cattle for beef and sheep were present for utilizing the grass resources fully and promoting economy in epidemic areas. However, the effect of the measure of forbidding livestock pasturing on the marshland was not ideal because the later management of fences was not enough, resulting in damage. Besides human, there are more than 40 kinds of mammal as the reservoir hosts of *Schistosoma japonicum* and the wild animals living in marshland areas are often infected with schistosoma (Tambo et al., 2014). In addition, a large number of fishermen can play an important role in the transmission of schistosomiasis during the flood season. The persistent existence of many infectious sources and contamination of the environment by their faeces and by snails are important potential risks for further consolidating the achievement of schistosomiasis control.

7. PROSPECTS

The Chinese government has always attached great importance to the control and elimination of infectious diseases, including schistosomiasis (Collins et al., 2012; Tambo et al., 2015). In order to further consolidate the success of schistosomiasis control, the Chinese government held the National Conference of Schistosomiasis Control in November 2014, proposed the goals of blocking transmission of schistosomiasis by 2020 and eliminating schistosomiasis by 2025 in whole country, and confirmed the targets of the national schistosomiasis elimination programme in the next 10 years (Zhu et al., 2016). Based on the comprehensive analysis of epidemic characteristics in marshland areas and distilling experiences on schistosomiasis control, in the next decade of the national schistosomiasis elimination programme will be developed around the goal of eliminating schistosomiasis. The integrated control strategy with emphasis on infectious sources control will be continuously implemented along with the strengthening of the epidemic situation surveillance, constantly improving the ability of scientific control in order to block the route of transmission effectively through a decade-long battle against schistosomiasis, and finally achieve the goal of eliminating schistosomiasis.

REFERENCES

Cao, C.L., Bao, Z.P., Yang, P.C., et al., 2014. Schistosomiasis control effect of measures of replacing cattle with machine for cultivation and forbidding depasturage of livestock on marshlands in marshland and lake regions. Chin. J. Schistosomiasis Control 26 (6), 602–607 (in Chinese).

Ceng, X.J., Wu, F.D., Zhang, S.J., et al., 1996. Observation on reinfection of *Schistosoma japonicum* by selective chemotherapy on inhabitants in heavy islet endemic region. Chin. J. Schistosomiasis Control 8, 83–86 (in Chinese).

Chen, W., Fu, Y., Liu, L.M., et al., 1996. Observation on the role of control the transmission of schistosomiasis by mass chemotherapy on cattle. Hubei J. Prev. Med. 7 (3), 23–25 (in Chinese).
Chen, K.X., 1980. Sub-type of habitats of *Oncomelania hupensis* in marshland endemic regions. Acta Hunan Med. Coll. 5, 129–130 (in Chinese).
Chen, M.G., 2014. Assessment of morbidity due to *Schistosoma japonicum* infection in China. Infect. Dis. Poverty 3, 6.
Chen, X.Y., Jiang, Q.W., Guo, J.P., et al., 2000. Analysis of effectiveness of chemotherapy on schistosomiasis control in marshland regions. Chin. J. Schistosomiasis Control 12 (1), 8–11 (in Chinese).
Chen, Y., Xie, M.S., Yang, R.Q., et al., 1999. Study on the relationship between the field stool and density of infected snails in endemic foci of schistosomiasis outside Dongting Lake. Prac. Prev. Med. 6, 11–13 (in Chinese).
Chitsulo, L., Engels, D., Montresor, A., Savioli, L., 2000. The global status of schistosomiasis and its control. Acta Trop. 77, 41–51.
Collins, C., Xu, J., Tang, S., 2012. Schistosomiasis control and the health system in P.R. China. Infect. Dis. Poverty 1, 8.
Guan, W.H., Yuan, H.C., Zhao, G.M., et al., 1999. A quantitative study on human water contact in dam circled marsh region of *Schistosoma japonicum*. Chin. J. Schistosomiasis Control 11, 211–214 (in Chinese).
Guo, F.Y., Zhao, Z.Y., Ren, M.Y., et al., 2012. Impact of marshland changes on snail distribution in Dongting Lake after the construction of the Three Gorge Dam. Trop. Dis. Parasitol. 14 (3), 125–127 (in Chinese).
Guo, J.G., Zheng, J., 2000. Prevalence and prevention of schistosomiasis in China. J. Dis. Control 4 (4), 289–293 (in Chinese).
He, J.C., Wang, E.M., Wang, T.P., et al., 1995. The prevalence situation of schistosomiasis of cattle and transmission role in river beach region in Anhui Province. Chin. J. Schistosomiasis Control 7, 288–289 (in Chinese).
He, N., Yuan, H.C., Zhang, S.J., et al., 1997. Quantitative research on human water contact after reclamation in an islet region of *Schistosoma japonicum*. Chin. J. Parasitol. Parasit. Dis. 5, 410–414.
Hu, F., Lin, D.D., Zhang, B.L., et al., 2003. Study on the influence of the project of building dike for storing water to schistosomiasis trasmission in Duchang County. Chin. J. Schistosomiasis Control 15, 177–181 (in Chinese).
Hu, S.G., Qin, S.T., Shi, Z.G., et al., 1996. Investigation on prevalence situation and harmless of schistosomiasis of pig in Dongting Lake. Hunan J. Anim. Sci. Vet. Med. 4, 25–26 (in Chinese).
Huang, X.B., Fang, T.Q., Li, S.H., et al., 2002. Evaluation on control strategies and effectiveness in schistosomiasis hyper endemic marshland areas. Chin. J. Parasit. Control 15 (3), 166–168 (in Chinese).
Huang, Y., Zhang, S.Q., He, J.C., et al., 2010. Investigation on the status of afforestation for schistosomiasis prevention in marshland regions in Anhui Province. Trop. Med. Parasitol. 8, 198–200 (in Chinese).
Huang, Y.J., 1998. Characteristic of wild feces contamination in the river beach. Parasitol. Parasit. Dis. 6, 86 (in Chinese).
Huang, Y.J., Tang, H.P., Hang, D.R., et al., 2013. Effect of sand buried on elimination of *Oncomelania hupensis* snails in marshland along the Yangtze River in Jiangdu District, Jiangsu Province. Chin. J. Schistosomiasis Control 25, 672–673 (in Chinese).
Jiang, Q.W., Yuan, H.C., Zhong, D.M., et al., 1991. A longitudinal evaluation of efficacy on control of schistosomiasis by comparative study of different control measures. Chin. J. Schistosomiasis Control 3 (5), 260–263.

Lei, Z.L., Zheng, H., Zhang, L.J., et al., 2014. Endemic status of schistosomiasis in People's Republic of China in 2013. Chin. J. Schistosomiasis Control 26, 591–594 (in Chinese).
Li, S.M., Ren, G.H., Huo, H.B., et al., 2014a. The impact of development in the ecological economic zone of Dongting Lake on transmission of schistosomiasis. Trop. Dis. Parasitol. 12 (1), 10–14 (in Chinese).
Li, W., Hang, D.R., You, B.R., et al., 2013. Effect of environmental change in marshland after implementation of Three Gorges Reservoir Project on schistosomiasis in Jiangsu Province. Chin. J. Schistosomiasis Control 25 (6), 576–580 (in Chinese).
Li, Y.Y., Liu, Z.C., Huo, H.B., et al., 2002. Study on the characteristics of grazing and chemotherapy strategies on bovine in endemic area of Dongting Lake. Chin. J. Schistosomiasis Control 14, 270–272 (in Chinese).
Li, Z.J., Chen, H.G., Ceng, X.J., et al., 2014b. Studies on changes of vegetation and *Oncomelania hupensis* snails in Poyang Lake after impoundment of Three Gorges Project. Chin. J. Schistosomiasis Control 26 (2), 115–120 (in Chinese).
Li, Z.J., Ge, J., Dai, J.R., Wen, L.Y., Lin, D.D., Madsen, H., et al., 2016. Biology and control of snail intermediate host of *Schistosoma japonicum* in the People's Republic of China. Adv. Parasitol. 92.
Lin, D.D., Liu, Y.M., Hu, F., et al., 2003. Animal host of *Schistosoma japonicum* and transmission of schistosomiasis in Poyang Lake regions. J. Trop. Med. 3, 383–387 (in Chinese).
Lin, D.D., Zhang, S.J., 2002. Geographical environment and schistosomiasis transmission in Poyang Lake regions. Chin. J. Epidemiol. 23, 90–93 (in Chinese).
Liu, L., Yang, G.J., Zhu, H.R., Yang, K., Ai, L., 2014. Knowledge of attitudes towards, and practice relating to schistosomiasis in two subtypes of a mountainous region of the People's Republic of China. Infect. Dis. Poverty 3, 16.
Liu, Q.L., Zhao, Z.Y., Yang, G.F., et al., 2003. Schistosomiasis control effect by chemotherapy in Dongting Lake area. Parasit. Infect. Dis. 1 (3), 119–120 (in Chinese).
Liu, Y., Zhou, Y.B., Li, R.Z., Wan, J.J., Yang, Y., Qiu, D.C., et al., 2016. Epidemiological features and control effectiveness of schistosomiasis in mountainous and hilly region of the People's Republic of China. Adv. Parasitol. 92.
Liu, Z.C., Huo, H.B., Wang, Z.X., et al., 2010. Effect of marshland isolation and grazing prohibition on schistosomiasis control in Dongting Lake region. Chin. J. Schistosomiasis Control 22 (5), 459–463 (in Chinese).
Mao, S.B., Shao, B.R., 1982. Schistosomiasis control in People's Republic of China. Am. J. Trop. Med. Hyg. 31, 92–99.
MOH, PR China, 1993. Epidemiological Situation of Schistosomiasis in China-Results from a National-Wide Sampling Survey in 1989. Chengdu University of Science and Technology Publishing House, Chengdu, pp. 16–30 (in Chinese).
MOH, PR China, 2002. World Bank Loan Project Completion Report on Infectious and Endemic Disease Control Project Schistosomiasis Control Component (1992–2001), pp. 1–15 (in Chinese).
Peng, Z.H., 2001. Study on the beaches snails outwipping forest ecological engineering. Eng. Sci. 3 (7), 12–16 (in Chinese).
Qin, X.Y., Xiao, X., Wang, T.P., et al., 2000. A prospective cohort study on human infection and reinfection with *Schistosoma japonicum* in river beach area. J. Pract. Parasit. Dis. 8, 1–5 (in Chinese).
Shen, W., 1992. Review and suggestion on animal schistosomiasis control. Chin. J. Schistosomiasis Control 4, 82–85 (in Chinese).
Shi, L., Li, W., Wu, F., Zhang, J.F., Yang, K., Zhou, X.N., 2016. Epidemiological features and control progress of schistosomiasis in waterway-network region in P.R. China. Adv. Parasitol. 92.

Su, Z.W., Hu, C.Q., Fu, Y., 1994. Role of several hosts in transmission of schistosomiasis japonica in lake region. Chin. J. Parasitol. Parasit. Dis. 12, 248–251 (in Chinese).
Sun, L.P., Zhang, Y.P., Cao, Q., et al., 1997. Schistosomiasis transmission role of farm cattle in marshland region in Jiangsu Province. Prac. J. Parasit. Dis. 5, 66–68 (in Chinese).
Tambo, E., Ai, L., Zhou, X., Chen, J.H., Hu, W., Bergquist, R., et al., 2014. Surveillance-response systems: the key to elimination of tropical diseases. Infect. Dis. Poverty 3, 17.
Tambo, E., Khater, E.I., Chen, J.H., Bergquist, R., Zhou, X.N., 2015. Nobel prize for the artemisinin and ivermectin discoveries: a great boost towards elimination of the global infectious diseases of poverty. Infect. Dis. Poverty 4, 58.
Tian, Z.Y., Xiao, J.W., Liu, D.S., et al., 1996. The effect of three different strategies on schistosomiasis control at Wuyi village. Chin. J. Schistosomiasis Control 8, 96–98 (in Chinese).
Tu, Z.X., Liu, Z.D., Sun, Y.S., et al., 1992. Observation on the Effect of Reclaiming and Planting by Machinery for Snail Control on a Large Scale in Lake Region. Data Compilation on Schistosomiasis Research (1986–1990). Shanghai Science and Technology Publishing House, p. 262 (in Chinese).
Wang, L.D., 2006. The Progress and Prospect of Schistosomiasis Control in People's Republic of China. The People's Medical Publishing House, Beijing, pp. 133–176 (in Chinese).
Wang, L.D., Chen, H.G., Guo, J.G., et al., 2009. A strategy to control transmission of *Schistosoma japonicum* in China. New Eng. J. Med. 360 (2), 121–128.
Wang, X.H., Liu, W., Zhou, H., et al., 2003. Study on schistosomiasis control with "marshland isolation and farming prohibition" but no snail control in Lake marshland. Chin. J. Schistosomiasis Control 15 (4), 259–261 (in Chinese).
Wang, X.Y., Wang, X.H., 2000a. Consideration and suggestion on the control strategies of schistosomiasis in marshland endemic regions in China. Jiangxi Sci. 18, 45–50 (in Chinese).
Wang, X.Y., Wang, X.H., 2000b. Strategies on schistosomiasis control in Lake regions in China. Chin. J. Vet. Parasit. Dis. 8 (4), 40–45 (in Chinese).
Wang, X.Y., Wang, X.H., Wu, G.C., 1999. Studies on the purification of meadow and control of schistosomiasis in Lake area by means of isolating the meadow and prohibiting pasture farming. Jiangxi Sci. 17 (3), 163–167 (in Chinese).
Wang, Z.H., Yi, Z.H., Zhang, Y.H., et al., 1998. Studies on the effectiveness of varied chemotherapy strategies with praziquantel for schistosomiasis control. Chin. J. Schistosomiasis Control 10 (4), 203–206 (in Chinese).
Wang, Z.H., Zhang, J.W., Yi, Z.H., et al., 1989. Studies on expanding chemotherapy measures with praziquantel for schistosomiasis control. Chin. J. Schistosomiasis Control 1 (2), 19–22, 37 (in Chinese).
Wu, G.L., Yuan, J.H., He, Q., et al., 1991. Clinical epidemiological investigation on liver and spleen swelling of schistosomiasis japonica. Chin. J. Parasitol. Parasit. Dis. 9, 274–277 (in Chinese).
Wu, Z.W., Peng, X.S., Li, W.C., et al., 1995. A longitudinal pilot study of chemotherapy effect for schistosomiasis control in Dongting Lake region. Pract. Prev. Med. 2 (1), 5–7 (in Chinese).
Wu, Z.W., Po, K.M., Liu, Q.L., et al., 1993. The effect of chemotherapy with praziquantel on morbidity and transmission of schistosomiasis japonica in Dongting lake region. Chin. J. Schistosomiasis Control 5 (6), 325–328 (in Chinese).
Wu, Z.W., Po, K.M., Yuan, L.P., et al., 1995. Analysis on reinfection factors of *Schistosoma japonicum* in lake region. Pract. Prev. Med. 2 (2), 87–88 (in Chinese).
Wu, Z.W., Xie, M.S., Zhuo, S.J., et al., 1991. The relevance of human behavior to the endemicity and control of schistosomiasis japonica in Dongting Lake region. Chin. J. Schistosomiasis Control 3, 7–11 (in Chinese).

Wu, Z.D., Zhang, S.J., Hu, L.S., et al., 1994. Observation on reinfection of schistosomiasis after chemotherapy at Gaojia village. Chin. J. Schistosomiasis Control 6, 252–253 (in Chinese).
Wu, Z.W., Zhuo, S.J., Po, K.M., et al., 1990. Application and calculation on the index of actual contamination for the infectious resources in Dongting Lake. Chin. J. Schistosomiasis Control 2, 31–34 (in Chinese).
Xie, Z.M., 1990. Discussion on schistosomiasis control measures in Poyang Lake. Chin. J. Schistosomiasis Control 2, 69–71 (in Chinese).
Xu, F.N., Wang, T.P., Qin, X.Y., et al., 1990. Study on the interruption of transmission of schistosomiasis by the elimination of infection source. Chin. J. Schistosomiasis Control 2 (3), 11–16 (in Chinese).
Xu, F.N., Wu, Z.X., Wu, W.D., et al., 1996. Study on epidemiological factors and control strategies of schistosomiasis in beach regions Yangtze River. Chin. J. Schistosomiasis Control 8 (6), 325–330 (in Chinese).
Xu, J., Steinman, P., Maybe, D., Zhou, X.N., Lv, S., Li, S.Z., et al., 2016. Evolution of the national schistosomiasis control programmes in the People's Republic of China. Adv. Parasitol. 92.
Xu, S.T., Dai, Y.H., Wu, W.M., et al., 1985. Study on Epidemiology of Animal Schistosomiasis and Control Strategies in Area of Pingmuhu. Single Copy, Hunan Province (in Chinese).
Xu, X.J., Yang, X.X., Chen, L.Y., et al., 1999. Evaluation on the effect of expanded chemotherapy on farm cattle in middle endemic region of *Schistosoma japonicum*. Chin. J. Zoonoses 5 (3), 106–107 (in Chinese).
Yuan, Y.S., He, H.S., Chen, W.X., et al., 2003. The survey of epidemilogy of sheep's schistosomiasis in Jingzhou city along the Changjiang River-line. Chin. J. Vet. Parasit. 11, 48–50 (in Chinese).
Zhang, K.D., Wang, S.Z., Li, F., et al., 2003. Observation on the effect of control and prevention for schistosomiasis by marshland isolation and farming prohibition in lake region. Chin. Vet. Parasit. Dis. 11 (3), 38–39 (in Chinese).
Zhang, S.J., Wu, Z.D., Lin, D.D., 1996. Progress on epidemiology and control strategy of schistosomiasis in Poyang Lake region. Acta Nanchang Univ. (Nat. Sci.) 20 (Suppl.), 98–102 (in Chinese).
Zhang, S.Q., Jiang, Q.W., Ge, J.H., 2002. Influence of flood on schistosomiasis transmission. Chin. J. Schistosomiasis Control 14, 315–317 (in Chinese).
Zheng, Q., Vanderslott, S., Jiang, B., Xu, L.L., Liu, C.S., Huo, L.L., et al., 2013. Research gaps for three main tropical diseases in the People's Republic of China. Infect. Dis. Poverty 2, 15.
Zhou, X.N., Bergquist, R., Tanner, M., 2013. Elimination of tropical disease through surveillance and response. Infect. Dis. Poverty 2, 1.
Zhu, H., Yap, P., Utzinger, J., Jia, T.W., Li, S.Z., Huang, X.B., et al., 2016. Policy support and resources mobilization for the national schistosomiasis control programme in the People's Republic of China. Adv. Parasitol. 92.
Zhuo, S.J., Wu, Z.W., He, Y.K., 1991. Study on factors affecting the prevalence and epidemiological patterns of schistosomiasis in Dongting Lake region. Chin. J. Schistosomiasis Control 3, 133–137 (in Chinese).