Geospatial Health 6(2), 2012, pp. 215-220

Successful outcome of an integrated strategy for the reduction of schistosomiasis transmission in an endemically complex area

Shi-Zhu Li[1*], Ying-Jun Qian[1*], Kun Yang[2], Qiang Wang[1], Hua-Ming Zhang[3], Jun Liu[3], Mu-Hua Chen[4], Xi-Bao Huang[5], Yin-Long Xu[6], Robert Bergquist[7], Xiao-Nong Zhou[1]

[1]*National Institute of Parasitic Diseases, Chinese Center for Disease Control and Prevention, Shanghai 200025, People's Republic of China;* [2]*Jiangsu Institute of Parasitic Diseases, Wuxi 214064, People's Republic of China;* [3]*Jiangling County Institute of Schistosomiasis Control, Jiangling 443100, People's Republic of China;* [4]*Jiangling County Bureau of Health, Jiangling 443100, People's Republic of China;* [5]*Institute of Schistosomiasis Control, Hubei Center for Disease Control and Prevention, Wuhan 430079, People's Republic of China;* [6]*Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agricultural Sciences, Beijing 100081, People's Republic of China;* [7]*Ingerod 407, Brastad, Sweden*

Abstract. Schistosomiasis is one of the major public health problems in the People's Republic of China (and elsewhere), seriously threatening health as well as social and economic development. An integrated control strategy, emphasising transmission control but also aimed at reducing greenhouse gases, was carried out in Jiangling county, Hubei province from 2007 to 2009. Three villages were chosen for a pilot study involving removal of cattle from neighbouring, snail-infested grasslands, improving sanitation and construction of units for household biogas production in addition to routine control measures. Both prevalence and intensity of infection in the snails in the neighbourhood were greatly reduced after two years of implementation, while the prevalence of schistosomiasis in humans in the three villages had been reduced by 29%, 34% and 24%, respectively. The removal of cattle and construction of biogas production units had an additional positive effect in that the annual, average emission of greenhouse gases such as methane (CH_4) and carbon dioxide (CO_2) were reduced by an estimated 7.8 and 80.2 tons, respectively.

Keywords: schistosomiasis, integrated control, greenhouse gases, adaptive strategies and technology, People's Republic of China.

Introduction

The national schistosomiasis control programme in People's Republic of China has been particularly successful in reducing both the distribution of schistosomiasis and the number of new infections (Lei et al., 2011), but various factors make remaining areas difficult to control: (i) strongly waterlogged areas favour overpopulation of the intermediate snail host; (ii) the zoonotic character of schistosomiasis japonica increases the risk for cross contamination between domestic animals and humans; and (iii) the potential impact of climate change includes alterations in distribution, transmission and intensity of infection. On the other hand, together with the acquired immune deficiency syndrome (AIDS), tuberculosis and hepatitis, schistosomiasis is currently a top priority for the Ministry of Health (Zhou et al., 2007).

The transmission of schistosomiasis is closely related to the ambient temperature, illumination, precipitation and humidity (Mao, 1990; Yang et al., 2010). While the two former environmental components particularly influence the reproduction and growth of the parasite stage (the miracidium) infective for the intermediate snail host, all four components affect the local distribution of schistosomiasis (Sun et al., 2003; Yang et al., 2010). So far, capping the emission of greenhouse gases has not been considered part of the schistosomiasis control programme. Still, only moderately higher temperatures would increase the rate of parasite maturation in the snail, lead to a prolonged transmission season and increase the risk for spreading the disease into areas, which are currently non-endemic (Hong et

*These authors contributed equally to the paper

Corresponding author:
Xiao-Nong Zhou
National Institute of Parasitic Diseases
Chinese Center for Disease Control and Prevention
Shanghai 200025, People's Republic of China
Tel. +86-21-64738058; Fax +86-21-64332670
E-mail: ipdzhouxn@sh163.net

al., 2002; Yang et al., 2010). Although only a large-scale, long-term caption scheme would have a measurable impact, it was felt worthwhile to investigate the direct effect of using a closed system for faecal matter.

When domestic animals and humans share the same geographical territory, and part of that territory is waterlogged, there is a strong risk for animals and humans engaging in zoonotic exchange of schistosome infection. The objective of this study was to reduce transmission not only by providing piper water and institute waste management, but also by reducing the risk for cross contamination through bringing down the number of cattle in the immediate neighbourhood of human activities.

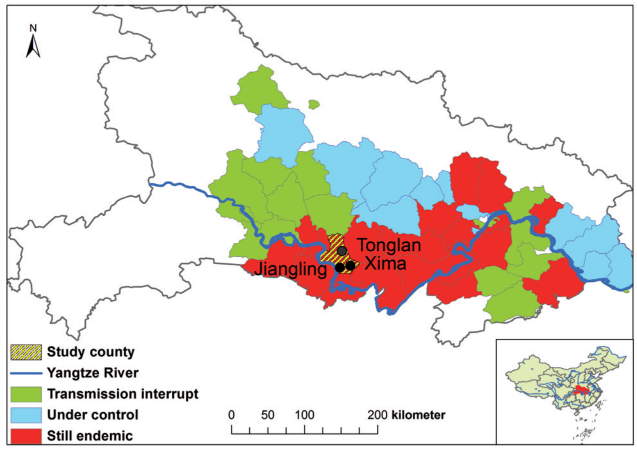

Fig. 1. Map of the region with the three study villages.

Materials and methods

Sites and populations

The study was performed in Jiangling county, a traditionally schistosomiasis-endemic area located in the central southern part of Hubei province, on the north shore of the Jingjiang River, which is part of the Yangtze River reach (Fig. 1). This county, situated in the humid, subtropical, monsoon-dominated region where four lakes and many streams form a water-bound area, stretches between longitude 112º14' and 112º44' E and latitude 29º55' and 30º20' N. Based on the endemic situation in 2007, the villages Tonglan and Jiangling, administratively under the Baimasi township, and Xima, belonging to the township of Hao Xue, were selected as the prevalence of human schistosomiasis in all three villages exceeded 3% (Fig. 1, Table 1).

Table 1. Populations and infection rates in the pilot villages before intervention.

Village	Population	Prevalence in humans	Prevalence in snails	Prevalence in cattle
Tonglan	1,504	3.35%	0.059%	8.54%
Jiangling	984	4.19%	0.254%	1.82%
Xima	1,472	3.86%	0.305%	6.98%

Climate data

Jiangling county has four distinctive seasons. Meteorological data during 1952 to 2008 in the pilot villages, downloaded from China Meteorological Data Sharing Service System (http://cdc.cma.gov.cn/index.jsp), show that the annual precipitation has been relatively constant, varying between 900 and 1,100 mm, while the average temperature shows strong swings up and down, particularly in January (Fig. 2). If, on the other hand, a longer perspective is applied, the annual temperature curve between 1952 and 2008 has a clearly visible minimum around 1970, while the January temperatures, although less impressive, show a continuous, upward direction during the whole period.

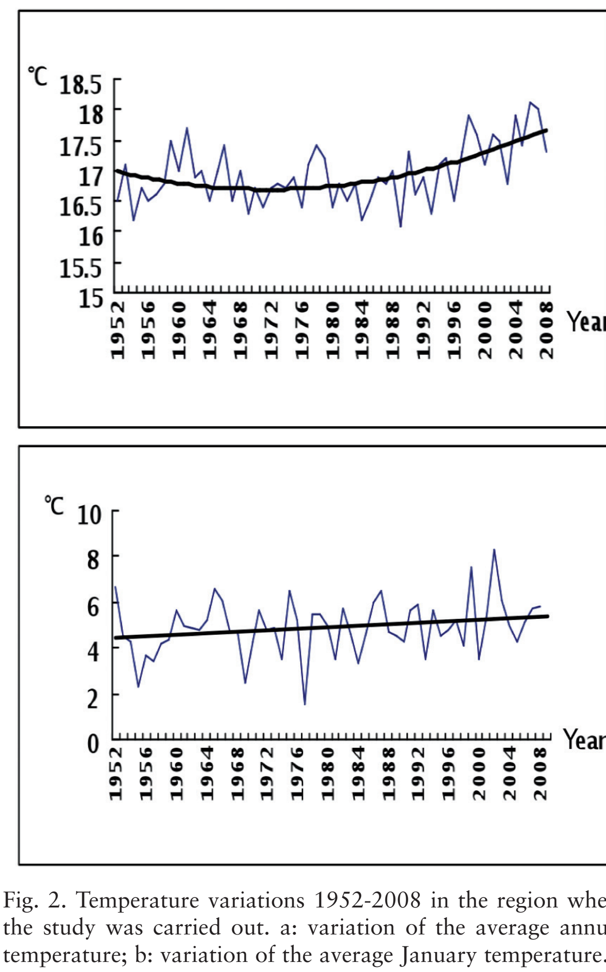

Fig. 2. Temperature variations 1952-2008 in the region where the study was carried out. a: variation of the average annual temperature; b: variation of the average January temperature.

Strategy

At the time of this investigation, the villages of Tonglan, Jiangling and Xima had a joint population of 3,560 (859 families). In 2007, by the end of the year, 42 (89%), 27 (84%) and 46 (64%) heads of cattle, respectively, were removed from the neighbouring land (Table 2). In addition, a total of 107 three-cell latrines were built: 20 in Tonglan, 20 in Jiangling and 67 in Xima and 58 biogas producing units were constructed: 14 in Jianling and 44 in Xima, covering 6%, 15% and 37% of the needs for the three villages, respectively.

Biogas, produced by digestion of human and livestock faeces and other organic waste, provides the basic energy for cooking, heating and light in the Chinese rural areas. While the reduction of methane (CH_4) is mainly due to removal of cattle, the capping of carbon dioxide (CO_2) release is an indirect effect resulting from biogas use replacing household burning of coal and wood as done traditionally. The amount of greenhouse gas emissions capped was estimated according to Dong et al. (1995), who calculated the annual, average emission of CH_4 from an adult scalper, buffalo and milk cow at 48.7 kg, 68.1 kg and 70.4 kg, respectively. The calculation of the amount of CO_2 capped was based on the energy equivalent saved by the households when burning gas from the biogas units instead of coal and wood. Since the former only emits about half the amount of CO_2 compared to the latter per unit of energy delivered, the amount of CO_2 capped was estimated as 1,382 kg per unit, i.e about the same as the average, annual emission of carbon dioxide per biogas pond constructed (Liu et al., 2006).

The expected outcome of waste management with respect to schistosomiasis was the resulting reduced contamination of neighbouring areas with schistosome eggs, which should contribute to breaking the parasite's lifecycle.

Table 2. Removal of cattle from the villages.

Village	Number of families	Cattle before	Cattle removed	Cattle left	Removal rate
Tonglan	331	47	42	5	89%
Jiangling	226	32	27	5	84%
Xima	302	72	46	26	64%

Evaluation

Each year, after the transmission season in October to December, testing for schistosomiasis antibody by indirect hemagglutination (IHA) (Yu et al., 2007) was performed in all residents between 6 and 65 years of age. Those with IHA titres above 1:10 were subjected to follow-up stool examination by the Kato-Katz technique with three smears from each positive sample (Lin et al., 2008). For livestock, hatching tests (Justesen, 1977) were carried out, while snail collection was done by systematic sampling around the three villages each spring using wooden collection frames measuring 0.1 m^2. All snails found were crushed and microscopically examined to account for prevalence and intensity of infection (Wang et al., 2009).

Treatment was provided for people living in the areas where infected snails were found, while routine snail control and health education as described by Wang et al. (2009) were carried out everywhere.

Results

Prevalence rates

By the end of 2009, two years after the implementation of the new, integrated control programme, the human prevalence had fallen by between 24.1% and 29.3% in the three villages (Table 3), a highly significant outcome (χ^2 = 12.62; P = 0.004). However, as can be seen in Table 3, the prevalence among the cattle had fallen even more strongly resulting in 60.2% to 100% reductions of prevalence between 2007 and 2008.

The average snail density had been reduced by 14.4% and 11.4% in Tonglan and Jiangling, respectively and none of the remaining snails found were infected (Table 4). In Xima, however, the average density of living as well as infected snails had increased by 13.0% and 6.6%, respectively (Table 4).

Mitigation of greenhouse gas emissions

A total of 115 heads of buffalo were removed in three villages. According to Dong et al. (1995) this

Table 3. Populations and infection rates in the pilot villages after intervention.

Village	2007		2009		Reduction	
	Prevalence in humans	Prevalence in the cattle	Prevalence in humans	Prevalence in the cattle	in humans	in the cattle
Tonglan	3.35%	8.54%	2.37%	2.13%	29.3%	75.1%
Jiangling	4.19%	1.82%	2.75%	0.00%	34.4%	100.0%
Xima	3.86%	6.98%	2.93%	2.78%	24.1%	60.2%

Table 4. Level of snail infection after intervention.

Village	2007			2009			Change		
	Snail density*	Infected snails*	Infection rate	Snail density*	Infected snails*	Infection rate	Snail density*	Infected snails*	Infection rate
Tonglan	2.78	0.0020	0.059%	2.38	0	0%	-14.46%	-100%	-100%
Jiangling	3.40	0.0087	0.256%	3.01	0	0%	-11.38%	-100%	-100%
Xima	6.45	0.0197	0.305%	7.29	0.0210	0.288%	+13.06%	+6.58%	+5.42%

*Number of snails per 0.1 m^2

Table 5. Implementation of the integrated strategy.

Village	Families	Threecell latrines	Biogas units	Family coverage*	Estimated CO_2 reduction**	Cattle removed	Estimated CH_4 reduction***
Tonglan	331	20	0	6.0%	-	42	2,860
Jiangling	226	20	14	15.0%	19,348	27	1,838
Xima	302	67	44	36.8%	60,808	46	3,132

*based on latrine + biogas facility per family; **annual average in kg; ***annual average in kg.

should result in a total, annual reduction of 7.83 tons of CH_4. The 58 household biogas units that had been constructed (Tables 2 and 5) were estimated to have contributed to a reduction of 80.16 tons of CO_2 emission.

Discussion

The study area, situated in one of the seriously endemic areas of schistosomiasis in the People's Republic of China, was subjected to control of the infection source, a strategy previously proved effective (Wang et al., 2009). Cattle constitute the main infection source (for humans as well as with regard to livestock) as their faecal excretion contributes 80-90% of the overall transmission (He et al., 1991; Guo et al., 2005, 2006). Indeed, as shown in Tables 3 and 4, the reduction of the number of cattle did not only contribute to reducing the prevalence in humans and cattle, but also moderated the infection rates in the intermediate host snail populations. The results support the idea that waste management (of animal and human faeces) is a crucial part of control activities (Wang et al., 2005). The Jiangling village had the highest level of human infection and, together with Xima, also the highest snail infection before the intervention. However, after the intervention, Jangling had the lowest human infection rate and no snail infection at all, while Xima was struggling on both counts. The explanation must be tied to the fact that the removal rate of cattle from this village was much lower than in Jiangling and Tonglan. In fact, the original idea was to remove all cattle providing tractors instead. However, this was not possible in any of the villages since possession of cattle is important for cultural as well as economic reasons.

Routine control no doubt played a part for the overall lower snail counts, while the installations of piped water, latrines and biogas units no doubt was the reason for the disappearance of snail infection in Jiangling and Tonglan. The fact that the rates of both snail density and snail infection increased in Xima must be due to failure of routine control activities as well as the modernization instituted, underlining the need for strengthening control efforts there.

The perturbation of the balance of temperature and precipitation may enhance the transmission and range of infectious diseases by producing increasingly suitable for certain vectors/intermediate hosts and pathogens (Chen et al., 2008). For example, the freezing January temperatures in northern China effectively limit extensions of the snail intermediate host in the areas not far north of the Yangtze River. However, the average January temperatures have steadily moved northwords over the latest 60 years (Fig. 2b) providing possibilities for a probable future expansion into these currently non-endemic areas (Zhou et al., 2002, 2004). In addition, the increased average temperatures during the last 40 years (Fig. 2b) have facilitated transmission by bolstering snail propagation (Sun et al., 2003a,b) and increasing the speed of parasite development in the snail (Sun et al., 2003c). Clearly, the benefits of reducing greenhouse gases can only be measurable in the very long term and only if all countries worked in unison towards this goal. However, waste management would also have the immediate effect of reducing the environmental pollution with schistosome eggs (Sun et al., 2008).

Even if the looming greenhouse effect on schistosomiasis will not be felt immediately it will eventually become important making it necessary to discuss this issue already now. Methane (CH_4) is over 20 times more effective in trapping heat in the atmosphere than CO_2. Since ruminants are an important source of greenhouse gas emission, especially cattle, livestock waste management (or move towards mechanized agriculture) offers the most viable, near-term opportunities for CH_4 recovery and utilization (http://www.globalmethane.org/agriculture/index.aspx). Capping the emission of greenhouse gases by means of biogas production should counteract global warming in the long term if carried out on a sufficiently large scale. If cattle were removed and biogas production units were built everywhere in the endemic areas, emissions would decrease considerably compared to the current situation. Based on the current total number of heads of cattle in endemic areas in the People's Republic of China (1,476,606), from 71,900 to 104,000 tons of CH_4 could theoretically be subtracted, depending on the relative numbers of scalpers, buffalos or milk cows (Lei et al., 2011). Likewise, biogas units should half the emission of CO_2.

Conclusions

An integrated schistosomiasis control strategy focusing on the mitigation of the risk of zoonotic transmission would not only have an immediate beneficial effect in humans and livestock, but also contribute to energy conversation and a decrease of the emission of greenhouse gases.

Acknowledgements

This study was funded by the Eleventh Five-Year Plan on Science and Technology (2007BAC03A02), National Key Program on Infectious Diseases (no. 2008-ZX10004-011), National Natural Science Foundation of China (no. 81101280 and no. 81101275)

References

Chen KX, Tang J, Shen DJ, Xiong Y, Wang B. 2008. Climate change threats human health. Imp Sci Soc 1, 19-23.

Dong HM, Lin ED, Yang QC. 1995. Estimation of methane emission from ruminants in China and mitigation techniques. J Ecol Rur Environ 11, 4-7.

Guo JG, 2006. Status and role of strategy for control of sources of infection of schistosomiasis in China. Chin J Schisto Control 18, 231-233.

Guo JG, Ning A, Hu GH, Chen HG, Dang H, Zhu R, Gail W, Li YZ, Feng Z, Don McManus. 2005. The field trial on the control of schistosomiasis by treatment of buffaloes with chemotherapy in the Poyang lake region of Jiangxi province. Chin J Zoon 21, 860-862.

He YK, Zhuo SJ, Wu SW, Liu QL, Xie MS, Yang RQ, Yu XL. 1991. Role of cattle and swine in schistosomiasis transmission in Dongting lake region. Chin J Schisto Control 3, 44-46.

Hong QB, Zhou XN, Sun LP, Yang GJ, Huang YX, Yang K. 2002. Impact of global warming on the transmission of schistosomiasis in China I. The hibernation and lethal temperature of *Oncomelania hupensis* in laboratory. Chin J Schisto Control 14, 192-195.

IPCC, 1992. Climate change: the supplementary report to the IPCC sceientific assessment[M]. Cambridge University Press, UK, pp. 25-67.

Justesen DW, van Sloterdijck DW, 1977. A quantitative and qualitative hatching test for schistosomiasis. Acta Leiden 45, 61-66

Lei ZL, Zheng H, Zhang LJ, Zhu R, Guo JG, Li SZ, Wang LY, Chen Z, Zhou XN. 2011. National schistosomiasis epidemic updating. Chin J Schisto Control 23, 599-604.

Liao CM, Yan ZQ, 2002. Effect of global environmental change on human health and its research significance. J Guangxi Norm Univ (Nat Sci) 19, 23-26.

Lin DD, Liu JX, Liu YM, Hu F, Zhang YY, Xu JM, Li JY, Ji MJ, Bergquist R, Wu GL, Wu HW. 2008. Routine Kato-Katz technique underestimates the prevalence of *Schistosoma japonicum*: a case study in an endemic area of the People's Republic of China. Parasitol Int 57, 281-286.

Liu SY, Luo ZG, Zhao DQ. 2006. Greenhouse gas reduction and cdm analysis on countryside biogas engineering. Acta Energi 27, 652-655.

Mao SB, 1990. *Schistosoma* biology and control of schistosomiasis. Beijing: People's Medical Publishing House, pp. 95-100.

Shen LF, Wang Q, Xuan Z, Ma QL, Zhao QY, Zhang QG, 2009. Effects of household biogas pond construction on energy-saving, emission-reducing and increase in farmers' income. Trans Chin Soc Agr Eng 25, 220-225.

Sun HS, Yu CF, Li ZJ, He QL, Xu YZ, Xiong YQ, Zhang LP, Wang WL, Zhu XY, 2008. Effectiveness of methane pool combined with mass chemotherapy for schistosomiasis control. J Public Health Prev Med 19, 15-17.

Sun LP, Zhou XN, Hong QB, Yang GJ, Huang YX, Xi WP, Jiang YJ, 2003a. Impact of global warming on transmission of schistosomiasis in China III. Relationship between snail infections rate and environmental temperature. Chin J Schisto Control 15, 161-163.

Sun LP, Zhou XN, Hong QB, Huang YX, Yang GJ, Wu F, Xi WP, Jiang YJ, Yang K, 2003b. Impact of global warming on transmission of schistosomiasis in China VI. Accumulated temperature of infected *Oncomelania* snails during survival stage in natural environment. Chin J Schisto Control 15, 415-417.

Sun LP, Zhou XN, Hong QB, Yang GJ, Huang YX, Xi WP, Jiang YJ, 2003c. Impact of global warming on transmission of schistosomiasis in China V. Effectively growing degree days of *Schistosoma japonicum* developing in different snail populations. Chin J Schisto Control 15, 342-345.

Yang GJ, Utzinger J, Lu S, Qian YJ, Li SZ, Wang Q, Bergquist R, Vounatsou P, Li W, Yang K, Zhou XN, 2010. The Regional Network for Asian Schistosomiasis and other helminth zoonoses (RNAS+): target diseases in face of climate change. Adv Parasitol 73, 101-135.

Wang LD, 2005. Management of human and animal feces is a key element for effective control of epidemic of endemic schistosomiasis in China. Chin J Epidemiol 26, 929-930.

Wang LD, Chen HG, Guo JG, Zeng XJ, Hong XL, Xiong JJ, Wu XH, Wang XH, Wang LY, Xia G, Hao Y, Daniel P. Chin, Zhou XN, 2009. A strategy to control transmission of *Schistosoma japonicum* in China. N Engl J Med 360, 121-128.

Wang TP, Chen GX, Cao ZG, He ZG, Zhang SQ, Han SM, Cui DY, 2009. Effect evaluation on the integrated schistosomiasis control strategy with an emphasis on infection source control in Gui Chi district of Chi Zhou in An Hui province. Chin J Schisto Control 21, 250-258.

Yang K, Pan J, Yang GJ, Li SZ, Xu XL, Zhou XN, 2010. Projection of the transmission scale and intensity of schistosomiasis in China under A2 and B2 climate change scenarios. Adv Clim Change Res 6, 248-253.

Yang K, Wang XH, Lv S Zhang L, Jia TW, Li LH, Deng Y, Zhou XN, 2006. Impact of global warming on transmission of vector-borne diseases in China. Int J Med Parasit Dis 33, 132-138.

Yu JM, de Vlas SJ, Jiang QW, Gryseels B, 2007. Comparison of the Kato-Katz technique, hatching test and indirect hemagglutination assay (IHA) for the diagnosis of *Schistosoma japonicum* infection in China. Parasitol Int 56, 45-49.

Zhou XN, Guo JG, Wu XH, Jiang QW, Zheng J, Dang H, Wang XH, Xu J, Zhu HQ, Wu GL, Li YS, Xu XJ, Chen HG, Wang TP, Zhu YC, Qiu DC, Dong XQ, Zhao GM, Zhang SJ, Zhao NQ, Xia G, Wang LY, Zhang SQ, Lin DD, Chen MG, Hao Y, 2007. Epidemiology of schistosomiasis in the People's Republic of China., 2004. Emerg Infect Dis 13, 1470-1476.

Zhou XN, Yang GJ, Yang K, Wang XH, Hong QB, Sun LP, Malone JB, Kristensen TK, Bergquist R, Utzinger J, 2008. Potential impact of climate change on schistosomiasis transmission in China. Am J Trop Med Hyg 78, 188-194.

Zhou XN, Yang K, Hong QB, Sun LP, Yang GJ, Liang YS, Huang YX, 2004. Prediction of the impact of climate warming on transmission of schistosomiasis in China. Chin J Parasitol Parasit Dis 22, 262-266.