

## Relationship between the transmission of *Schistosomiasis japonica* and the construction of the Three Gorge Reservoir

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### Abstract

**Objective:** To study the relationship between the changes of environment and the transmission of *Schistosomiasis japonica* after the construction of the Three Gorge Reservoir. **Methods:** On the basis of the predictive data on changes of water level and sediment in the middle and lower reaches of the Yangtze River after the dam construction provided by the Yangtze River Committee on Water Conservancy, corresponding data were collected and analyzed. In order to understand the effects of changes of water level and sediment on *Oncomelania hupensis*, the intermediate host of *Schistosoma japonicum*, field surveys and ecologically intimated experiments were done. The prevalence status and factors related to transmission were investigated by epidemiology, medical geography and public health. **Results:** Positive impact on control of schistosomiasis is that floods in the Yangtze River will occur less and will decrease the dispersal of snails and the chances of infection for humans and animals as well. Snail habitats' beach will be reduced in the flushed area along the Yangtze River. Exploitation of beach and elimination of snails will benefit from the beach's uplift in flushed area. The floods ahead of time in autumn will interfere with the development of snails. Negative impact is that the flushed beaches and migratory settlements at certain altitude may become snail habitats. So the reservoir area will be a potential transmission area of schistosomiasis due to dispersal of infectious resources and *Oncomelania* snails. The uprising of the water body level may cause the expending of the snail habitats in some places of Jiangnan plain during the transition of spring to summer. The destruction of the embankments of the Dongting Lake will be put off by its delayed flush, which causes the beach in a situation of growing reed-grass or

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grass for a long time that benefits the reproduction of the snails. The chances for schistosome infection to humans and animals will be on the increase, because the water regression occurs ahead of time in the Dongting Lake beach in autumn. The distribution of snails will not be affected by the changes of water level in the lower reaches of the Yangtze River after the dam is built, but the flushed section in Anhui in the recent 80 years are suitable for the snails' development. The environmental changes due to dam construction will not obviously affect the development of snails and the transmission of schistosomiasis in the Poyang Lake area. *Conclusion:* The construction of the huge dam and the formation of the Three Gorge Reservoir on the Yangtze River may have both positive and negative impact on schistosomiasis transmission and control. Great effort must be made to decrease the negative impact to avoid or, at least, to decrease *S. japonicum* transmission. © 2002 Elsevier Science B.V. All rights reserved.

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## 1. Introduction

The Three Gorge Project is an integrated, large scale project to exploit and improve the environment of the Yangtze River. It will have a profound effect on improving and accelerating China's social and economic development. But the transmission and prevalence of schistosomiasis was often aggravated by building new projects for water conservancy in the endemic area, of which there were many examples reported in the world. The upper and lower reaches of the Three Gorge Reservoir are heavily endemic areas for *Schistosomiasis japonica*. Temperature and rainfall are suitable for the survival and reproduction of *Oncomelania* snails and the transmission of schistosomiasis in the Three Gorges Reservoir. Up to now, the snails have not been found inside the Three Gorges Reservoir area. The main reason is that the velocity of water flow is too fast and is unsuitable for the survival of the snails. After the construction of the Three Gorge Reservoir, a series of changes of the environmental factors in the reservoir will occur. The study is aiming at elucidating the relationship between these environmental changes and the transmission of schistosomiasis.

## 2. Materials and methods

### 2.1. Environmental data

The data on changes of water level and sedi-

ment were provided by the Yangtze River Committee on Water Conservancy, China. Some of the data were obtained from a field survey.

### 2.2. Field study

The prevalence of schistosomiasis in humans and domestic animals, and the distribution and dispersal of *Oncomelania hupensis*, the intermediate snail host of *Schistosoma japonicum*, were surveyed by epidemiological methods.

### 2.3. Investigation of social factors

Factors that related to social-economics, behavior or migration of humans and domestic animals were investigated by means of questionnaire.

### 2.4. Analogical experiment

The environmental parameters, such as speed of marshland formulation, vegetation, physical/chemical characteristics of soil, were investigated in a reservoir with the similar environmental characteristics as the Three Gorge Reservoir.

### 2.5. Field trial

The development and reproduction of *O. hupensis* were observed in the field experiment in a mimic condition similar to what was presented after the dam construction.

### 3. Results

#### 3.1. Status of the Three Gorge Reservoir

The reservoir is about 600 km in length and 1.1 km in average width with an area of 1084 km<sup>2</sup>. About 1711 villages from 356 towns in 21 cities will be submerged under water after the Three Gorge Dam is built.

The Three Gorge Reservoir is located at 106–111°E longitude and at 28.50–32°N latitude which is inside the range of the areas suitable for endemic schistosomiasis. The upper and lower reaches of the Three Gorge Reservoir, Sichuan and Hubei provinces, belong to the heavily endemic areas of schistosomiasis where temperature and rainfall are suitable for the transmission of schistosomiasis (Table 1).

The area inside the Three Gorge Reservoir is a non-endemic area for schistosomiasis that was identified by the fact that no *Oncomelania* snails and infected animals were found in a number of field surveys. The velocity of water flow is too fast for the survival of the snails (Table 2).

#### 3.2. Changes of water level and sediment of the Three Gorge Reservoir after the construction of the dam

##### 3.2.1. Silt sediment and velocity of water flow

By prediction, the sediment of silt will increase and the velocity of water flow will slow down,

resulting in the formulation of three types of snail habitats after the dam is built. The first type of habitats is the beach, in a small scale, at the altitude between the highest water-level and flood level. The second is the sediment area at the entrance places to the reservoir of six main branches of the Yangtze River. The third is the beach formed by accumulated flush in the reservoir. Some islets are to be presented in the back-water area (the area with stir water-flow right behind the dam) in 10–14 years after the Three Gorge Reservoir is built, and more than 60 islets will be formed in 30 years. Twenty-seven large islets with a total area of 34 km<sup>2</sup> distributed in an altitude between 149 and 175 m will appear in 100 years.

##### 3.2.2. Water level

The lowest and highest water levels in the reservoir are 145 m in summer and 175 m in winter, respectively, after the dam is built. The period for the land out of water above 155 m altitude is about 300 days while that of above 145 m height is only 120 days. The period for the area below 175 m submerged wholly is about 2 months in winter, only the part of beaches at the altitude between the flood line and above 175 m is out of water (Fig. 1).

##### 3.2.3. Analogic experiment

The analogic investigation was conducted in Gongzui Reservoir, where functions are similar to the Three Gorge Reservoir. Five beaches formed

Table 1  
Temperature, rainfall and accumulated temperature in a year

Location	Annual average <i>T</i> (°C) <sup>a</sup>	Average <i>T</i> in January (°C)	Annual rainfall (mm)	Annual average accumulated <i>T</i> over 10 (°C)
Puling	18.1	7.1	1073.5	5903.8
Fengdu	18.2	7.1	1087.3	5892.7
Youyang	18.2	3.7	1389.4	4651.5
Wanxian	18.1	6.7	1185.4	5757.9
Yunyan	18.8	7.5	1145.1	5994.1
Wushan	18.4	7.1	1049.4	5694.0
Dangyang	16.4	3.9	996.8	≥ 5000
Zigui	18.0	6.8	1028.7	≥ 5000
Jiandong	17.2	5.9	1091.2	5985.3
Yichang	16.8	4.5	1031.0	≥ 5000

<sup>a</sup> Mean temperature in °C.

Table 2  
Results of snails survey in the Three Gorges Reservoir

Method	Number of sites investigated	Area investigated (km <sup>2</sup> )	<i>Oncomelania</i>	<i>Tricula</i>	<i>Assimineae</i>	<i>Planorbidae</i>	<i>Lymnaea</i>	<i>Bithynia</i>
Sampling in pilot spots	133	150.5	0	++	+	++	++	+
Tracing survey along waterways	75	105.0	0	+++	+	++	++	++
Remote sensing	54	83.0	0	+++	++	++	++	++
Total	262	338.5	0	+++	++	++	++	++

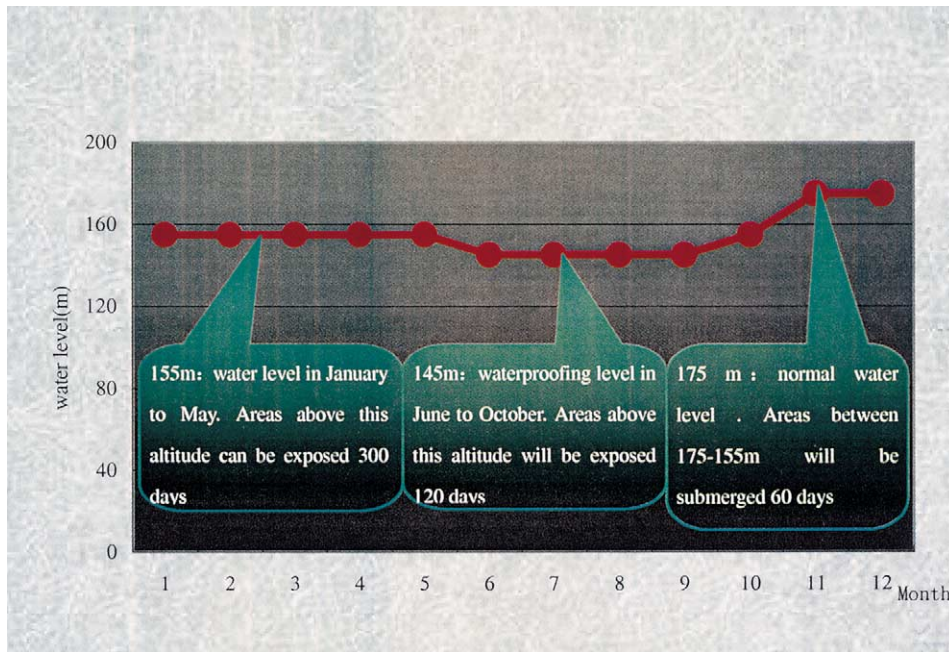


Fig. 1. The water level of the Three Gorge Reservoir and period for beaches submerged under water.

8 or 10 years after dam construction were selected for the experiment since the environment was suitable for the development of *Oncomelania* snail in terms of vegetation, sediment and water containing (Table 3).

### 3.3. Possibility of becoming snail habitats in migratory settlements

More than 1 million acre farmlands will be submerged under water and 1.2 million people migrate to higher places after the Three Gorge Dam is built. The environment in migratory settlements will be improved by changing slope into terrace under the government's support. A total area of 24 million acres will be farmland till 2010 according to the plan. Those lands will be suitable for snail development in the irrigation systems where the ditches are mainly earth trenches with seepage and the underground water level in these places will remain higher than 0.4 m under the surface of the earth.

### 3.4. Experimental observations on snail development in the Three Gorge Reservoir

The conditions of the Three Gorge Reservoir at different altitudes were imitated in terms of earth type and humidity to observe the development of *Oncomelania* snails. The results of snail development and reproduction are shown in Tables 4 and 5.

### 3.5. The introduction probability of *Oncomelania* snail and source of infection

The survey showed that there were 255.4 thousand of people from reservoir areas moved out for working in endemic areas every year, 10.20% of them were possibly infected with *S. japonicum* as assessed by seroimmunological tests. While 258.4 thousand of migrant labors to the areas were under effective control, about 0.1% of them were positive by serological test. About 295.4 thousand persons who migrated to non-endemic areas showed negative serological tests.

Table 3  
The environment of beaches formed after the Gongzui Reservoir construction

	Name of Beach	Distance from Ebian city	Length × width (km)	Sediment values (m)	Vegetation	Period of forming beach
Changeable Flooded area	Maocao beach	3 km	0.8 × 0.4	3	2/3 weeds, 1/3 grass	10
	Nuyian beach	6 km	0.4 × 0.2	2.5	Lake weeds	10
	Dajiang beach	10 km	1.8 × 0.6	2.2	Lake weeds/mat grass	10
Annual flooded area	Beach corner	To dam	0.04 × 1 × 5	1.00	Lake weeds/bush	8

Table 4  
Survival of adult snails and development of young snails at pilots of Gaoyang and Jianshe, in Xingshan County from May to June

Group	Snail	Number observed	Gaoyang (at 175 m altitude)				Jianshe (at 150 m altitude)			
			Number of survival	Survival rate (%)	Number of survival for young snails	Number of dead young snails	Number of survival	Survival rate (%)	Number of survival for young snails	Number of dead young snails
Water	Ribbed	150	34	22.7	32	30	23	15.3	8	4
–variety										
Moisture	Smooth	150	26	17.3	16	27	19	12.7	8	7
	Ribbed	150	18	12.0	20	2	27	18.0	16	10
	Smooth	150	13	8.7	3	6	23	15.3	5	4
Control	Ribbed	150	14	9.3	6	11	0	0	0	0
	Smooth	150	6	4.0	10	22	0	0	0	0

The field survey implicated that snails can shield on reeds, a kind of plant used for paper-making material. In addition, snails can migrate with the trees introduced from endemic areas to reservoir areas.

### 3.6. Changes of underground water body level in Jiangnan Plain after construction of the dam

The water level of Hubei section of the Yangtze River will increase by 1.2–1.5 m from January to May and decrease by 1.8–2.4 m from November to December in a year. As a result, the underground water body level of the Jiangnan Plain will be raised, which benefits the development of the snails and the transmission of schistosomiasis. (Fig. 2).

### 3.7. Impact on the Dongting Lake

Water level will go up 0.06–1.5 m from January to May and descend 1.6–2.0 m from November to December. But not much effect on the distribution of snails either in the year with abundant water, regular water or drought. The chances of water contact by humans and animals will increase, because water will recede 3–7 days earlier than that in regular water year and 17–25 days earlier than that in drought year after dam construction.

Sediment of silts in lake will decrease in 30 years after the construction of the Three Gorge Reservoir. Consequently, the formulation of marshland will be delayed which is suitable for the development of snails and the transmission of schistosomiasis.

### 3.8. Impact the Poyang Lake

The water level will rise by 0.11–0.90 m from January to March and go down by 0.07–0.13 m in December after dam construction. It will be less than 13 m above sea either in the year with abundant water, normal water or drought, which will have no effect on the development of the snails since these areas are free of snails. Water level will rise at different levels from April to June with little impact on snail development.

The changes of sediment for flushing will not be apparent in 30 years after dam construction.

### 3.9. Impact in Anhui and Jiangsu sections of the Yangtze River

The water level of the Yangtze River will rise by 0.14–0.76 m in Anhui section from January to April but will not change from July to September, while it will go down about 0.06–1.26 m from October to December. In the Jiangsu section, practically no change will appear in water level from August to September and a little change in January, May, June, July and December. But it will rise by 0.15–0.40 m from February to April and go down 0.32–0.75 m from October to November. All of these changes will have no effect on the distribution of the snails.

The experimental results showed that the survival rate (5.60%) of snails living in the places where flood came ahead of time and lasted for 20 days was lower than that of control group (92%) ( $P < 0.01$ ).

Table 5  
Number of mating pairs of *Oncomelania* snails

Group	Snail	Gaoyang (at 175 m altitude)					Jianshe (at 150 m altitude)				
		April	May	June	July	August	April	May	June	July	August
Water-variety	Ribbed	7	14	21	3	5	6	6	1	0	0
	Smooth	9	16	30	2	0	4	7	0	0	0
Moisture	Ribbed	9	23	15	4	1	3	6	3	0	0
	Smooth	11	10	21	0	0	1	4	0	0	0
Control	Ribbed	0	9	4	0	0	0	0	0	0	0
	Smooth	0	11	4	0	0	0	0	0	0	0

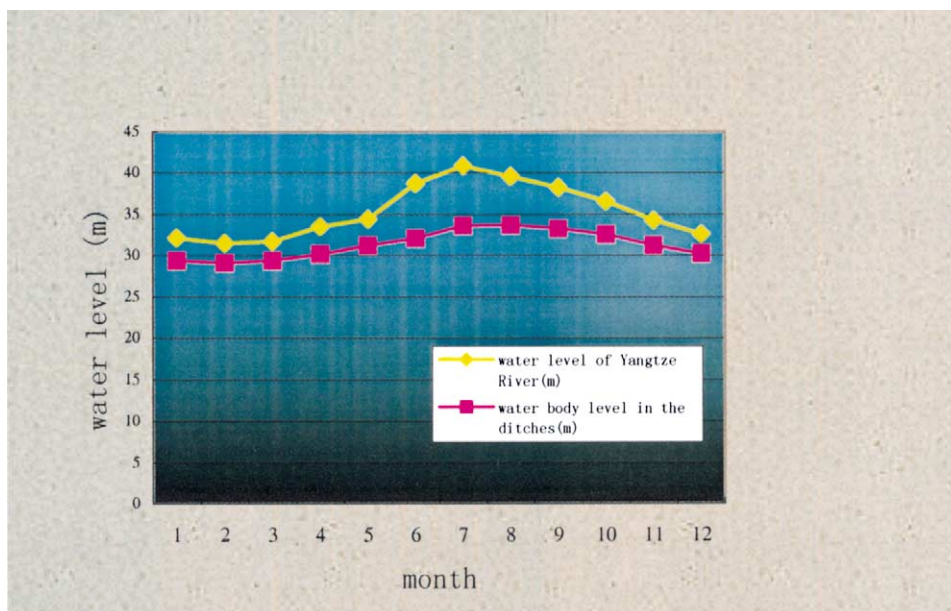


Fig. 2. The relationship between water level of the Yangtze River and that under the surface of the earth in the Jianhan plain.

### 3.10. Impact on dispersal of snails and infection of humans and domestic animals

Big floods will occur once every 100 years in the middle and lower reaches of the Yangtze River after the construction of the huge dam of the Three Gorge Reservoir, while the big floods have occurred once per 10–20 years period, before the construction. Therefore, the dispersal of the snails and the infection of humans and animals will decrease.

## 4. Discussion

Quite a few reports have been published on the impact of dam construction for large reservoirs to the introduction or increase of the prevalence of schistosomiasis (Cooper Weil, 1990; Hunter et al., 1982), which raise more attention to the impact on the transmission of schistosomiasis by construction of the Three Gorge Reservoir (Allen, et al., 2001). During the past 20 years, a series of studies undertaken by experts have proved that schistosomiasis has not been endemic in areas of the Three Gorge Reservoir. However, it is neces-

sary to reinforce monitoring on schistosomiasis in these areas, because snails can develop and reproduce in the imitated surroundings after dam construction although their survival rate was low (Cai et al., 1987; Gu et al., 1987). Some experts consider that the performing way of the Three Gorge Reservoir diverse with the snail habitats which are drought in winter and submerged into water in summer, so it is not suitable for snail development (Xiao et al., 1988). Based on the predictive studies on the changes of water level and sediment of silts, this study is aiming to understand the possible impacts on the transmission of schistosomiasis by changes of ecology and environments after the dam construction. This study showed that the natural conditions of the Three Gorge Reservoir are suitable for snail development and prevalence of schistosomiasis. It will form many beaches after the dam construction due to the decrease of velocity of water flow and the sedimentation of silts. The necessary conditions for snail development are available in the areas above the altitude of 145 m above the sea level, in beaches located in the areas higher than 175 m but lower than the flooded water level. In addition, snails may breed in the ditches surrounding migratory settlements



(Scientific Leading Team of Chinese Academy of Science, 1987).

Analogic experiment showed that the vegetation, soil and physical and chemical characteristics of beaches in the reservoir areas are similar to those in current schistosomiasis endemic areas. It is also suggested that not only ribbed snails of Hubei Province but also smooth snails from Sichuan Province could survive, develop and reproduce under the imitated conditions. An epidemiological investigation showed that it is possible to introduce snails and infectious sources into the reservoir areas. The monitoring of snail dispersal should be reinforced and corresponding control strategies should be formulated to prevent the transmission of schistosomiasis in reservoir areas.

Jiangnan plain, a serious endemic area for schistosomiasis now, is located at the head of the Three Gorge Reservoir. The rising of underground water level in some areas of the Jiangnan plain caused by ascending water level of the Yangtze River during the turn of spring and summer will change the snail distribution as well as the agricultural structure. To control the dispersal of snails and decrease the chances of infection for humans and domestic animals, the way of production should be altered. For example, the paddy fields may be transformed into dry farmlands and practice of cultural alternation between these two types of farming may be used widely (Zheng et al., 1996).

It is obvious that the decrease of sediment of silts in the Dongting Lake will slow down the development of grass beaches and reed-grass beaches that are beneficial to snail breeding and development. Water recession ahead of time in autumn may raise the chances of water exposure to humans and animal reservoirs.

The impact of the dam construction on the transmission of schistosomiasis in the Poyang Lake and other areas on the lower reach of the Lake is not significant. A study in Jiangsu section showed that flood earlier than before in spring was harmful to the survival and development of snails.

The way of flush and sediment in the Yangtze River will be changed after the dam construction.

Snail habitats will be reduced in these sediment-aggravated areas which cause harm to the development of snails. Some areas in sediment probably enlarge snail distribution.

The floods have occurred infrequently in the middle and lower reaches of the Yangtze River during the past 100 years (Scientific Leading Team of Chinese Academy of Science, 1987; Xu, 1991). Each time after flooding, a lot of acute infection with *S. japonicum* happened, and the transmission in humans and animals, as well as the dispersal of the snails, have been on the increase (Zhang et al., 1999; Zhou et al., 1999; Chen et al., 1999; Xiao et al., 2000). But floods will be controlled effectively after the dam construction and that will improve the schistosomiasis control program to protect people from loss of life or estates, and decrease the dispersal of the snail intermediate host and infection of humans and animals as well.

The Three Gorge Project is a large project. The changes of ecology and environments after dam construction will be a gradual process. The relationship between the dam construction and schistosomiasis only can be analyzed according to the predictive data at present. The results of future impact of the dam construction need to be further investigated and tested.

In conclusion, there are two sides to the impact on the transmission of schistosomiasis by construction of the huge dam for the Three Gorge Reservoir. What is important is to work out effective and practical strategies for monitoring and controlling the transmission of schistosomiasis in order to decrease its negative impact.

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