Rural electrification in Brazil and implications for schistosomiasis transmission: a preliminary study in a rural community in Minas Gerais State, Brazil

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Abstract

OBJECTIVES To evaluate the potential transmission of *Schistosoma mansoni* through well water pumped into households in a rural Brazilian community within the context of Brazil's rural electrification program *Luz Para Todos* (Light for All).

METHODS All households were interviewed about their water facilities and domestic water use, all household members were examined for *S. mansoni* infections and positives treated, and malacological and water contact studies were performed between 2001 and 2009.

RESULTS Thirty-one of the 142 households in the Virgem das Graças study area owned wells with electric pumps in 2009, vs. no wells in 2001, and the number of water storage tanks increased from 85 to 131. The potential for schistosomiasis transmission through piped well water was indicated by the recovery of *Biomphalaria gabrata*, including *S. mansoni*-infected snails, from wells, the presence of *Biomphalaria* in tanks and the ability of *S. mansoni* cercariae to remain infective for considerable distances in flowing water. However, access to well water was not associated with higher *S. mansoni* infection rates.

CONCLUSIONS Our results indicate that further studies are needed to determine the infectivity of well water and its impact on schistosomiasis transmission.

keywords schistosomiasis, risk-taking, water supply, rural

Introduction

Rural electrification programs have been initiated in many countries in developing countries during the last two decades. Their major objectives are poverty reduction, increasing overall socioeconomic development at the national level, creating small industries in rural areas that can reduce rural-urban migration, reducing reliance on biomass sources for fuel and corresponding reductions in CO_2 emission, and enhancing activities in agriculture, health, education and tourism (World Bank 2008; Nietz 2010). Various UN conferences and initiatives, including the Millennium Development Project and the 2005 World Summit at the United Nations, proposed and implemented various development goals that are environmentally sustainable and facilitate rural electrification programs (UN 2008). The magnitude of the need for electricity is indicated by the fact that an estimated 1.5 billion people in developing countries lack access to electricity (ARE 2010). In Brazil, 24.3% of all rural households lacked access to electricity at the end of 2002, one year before the implementation of the national rural electrification program (Goldemberg *et al.* 2004) summarized below.

The rapid increase in energy consumption as a result of rural electrification showed that electricity is being used mainly for lighting, television and refrigeration, and benefiting school learning and nutrition, school attendance, and the quality of health services, and reducing indoor air pollution from burning biomass (World Bank 2008). The International Energy Agency (2011) publishes annually an extensive database on electrification rates for each country and region in relation to the needs and status of rural development. Little is known about unintended negative health effects of rural electrification. For example, the increased transmission of malaria during evening hours was associated in some endemic regions with staying up an additional one to two hours with the introduction of electricity (Roper *et al.* 2000; World Bank 2008). The installation of electric wells in schistosomiasis-endemic areas may also carry health hazards. In rural communities in Brazil, many shallow wells harbor *Biomphalaria* snails (Kloos *et al.* 2004) and in Nigerian communities, *Schistosoma mansoni* infections have been associated with well water use (Goselle *et al.* 2010).

The Brazilian government implemented in 2003 the *Luz Para Todos* (Light For All) rural electrification program, the largest electrification program ever installed in Brazil and the first program with an universal access mandate that aimed to provide affordable electricity to 15 million people by the end of 2010. By 2009, the national electrification rate had reached 99.5% in urban areas and 88.0% in rural areas (up from 73% in 2005). Many rural communities remain without electricity due to the high cost of extending the electric network to isolated populations (Gomez & Silveira 2010; Nietz 2010).

The objective of this study was to examine the potential risk of *S. mansoni* transmission through well water pumped in Virgem das Graças in northern Minas Gerais State, Brazil, a rural community of around 600 people lacking a centralized water supply system like many other small Brazilian rural communities.

Methods

Virgem das Graças is a typical endemic rural village located in the Jequitinhonha Valley in northern Minas Gerais State. This valley is known as one of the poorest areas in Brazil. All 142 households in Virgem das Graças in 2001 and the 146 households in 2009 were interviewed about their domestic water supply, water use and socioeconomic status using a questionnaire as part of a larger and ongoing epidemiological study (Gazzinelli *et al.* 2006; Pereira *et al.* 2010). Socioeconomic status was evaluated, in this study on the basis of support households received from the *Bolsa Familia Program*, a social welfare program of the Brazilian government that provides direct cash transfer for poorest families nation-wide (Brasil, 2009b). This *program* started in 2002, attempts to both reduce short-term poverty through direct cash transfers and fight long-term poverty by increasing human capital through conditional cash transfers.

Residents were examined for *S. mansoni* infections in 2001, 2002, 2005 and 2009 using the Kato–Katz method (Katz *et al.* 1972) and treated with praziquantel at 60 and 50 mg/kg according the Ministry of Health guidelines (Brasil 2009a). All potential snail habitats in the study area, including all wells, were surveyed for intermediate hosts and infections three times during the dry and wet seasons in 2001/2002 (Kloos *et al.* 2004) and water contact behaviour studied at the streams and all other surface waters in 2001 and 2009 (Pereira *et al.* 2010). Of the 38 electrified wells installed by households, six contained *Biomphalaria glabrata* in 2001, two of them with *S. mansoni*-infected snails. These six wells were thus considered to be potential transmission sites and revisited and examined for snails in 2010.

The relationship between *S. mansoni* infection and individual access to pumped well water, stored water and *Bolsa Familia* recipience was calculated using a chi-square test. The Wilcoxon test was used for paired comparisons of continuous variables between 2001 and 2009. The McNemar test was used for paired comparisons of the categorical variables at different time points, 2001 and 2009. A P-value of <0.05 was considered statistically significant.

Results

The national *Luz Para Todos* (Light for All) Program supplied 143 households in Virgem das Graças with electricity in 2009, up from 65 in 2001 ($P < 0.001$) and the number of households pumping water from shallow wells via PVC pipes for domestic use increased from 0 to 31 ($P = 0.021$). The number of households owning tanks also increased during that 8-year period, from 85 to 131 ($P < 0.001$) and the number of persons reporting the use of stream and other unsafe water decreased from 421 to 303, although this decline was not statistically significant. Schistosomiasis prevalence decreased in the study area from 58.3% to 26.6% ($P < 0.001$) between 2001 and 2009 and geometric mean egg counts from 58.9 to 13.3 epg ($P < 0.001$) (Table 1).

Table 1 Changes in the number of households (hhs) receiving electricity, types of water supply, water contact and *S. mansoni* infection in Virgem das Graças between 2001 and 2009

	2001	2009	P-value
No. of hhs	142	146	–
No. of hhs with electricity	65	143	<0.001
No. of hhs with shallow well	32	38	<0.05
No. of hhs having wells with electric pumps	0	31	<0.05
No. of hhs having storage tanks	85	131	<0.001
No. of people who had contact with unsafe water sources*	421	303	–
Schistosomiasis prevalence (%)**	58.3	26.6	<0.05
S. mansoni geometric mean egg counts***	58.9	13.3	<0.05

*Contact with well water was not included.
**$P < 0.05$ in McNemar test.
***$P < 0.005$ in Wilcoxon test.

In 2009, 23.2% of the study population had access to pumped well water and 89.2% of the 146 households had tanks storing well water or spring water. Individuals in households owning electrified wells had significantly lower infection rates (18.4%) than those without a well (28.7%) ($P = 0.021$) but the differences in gender-specific infection rates were not significant. Rates were also lower among children aged 8 years and younger in households with pumps, members of households owning a water storage tank and people receiving *Bolsa Familia* government assistance (Table 2).

Six of the 15 wells existing in 2001/2002 contained *B. glabrata* during that year, two of them with *S. mansoni*-infected snails (Kloos *et al.* 2004). Of the 31 wells with electric pumps that were revisited and examined for snails in 2010, six contained large populations of *B. glabrata* snails. One of them was lacking a cover and poorly maintained, with abundant macro-vegetation (Figure 1). The other well is located next to a stream and seasonally flooded by stream water during the rains (Figure 2). Twenty-nine of the 31 electrified wells in the study area were either located too close to streams, improperly constructed, or inadequately maintained. Sixteen of the 31 households with electrified wells shared water with neighbours, 12 of them shared water with a single neighbouring household, 1 household shared with another 2 households and 3 households had reciprocal arrangements with other households. Households diverted water from the wells to neighbouring households via pipes, a common practice in Brazil.

Table 2 Individual access to pumped well water, stored water, *Bolsa Familia* and schistosomiasis prevalence in Virgem das Graças in 2009

	No. of persons	No. of infected (%)	P*
Have electrified well			
Yes	125	23 (18.4)	0.021
No	428	123 (28.7)	
Children ≤8 years in households			
With electric pump	11	0 (0)	0.132
Without electric pump	51	9 (17.6)	
Adult males and females having electrified well			
Males	60	10 (16.7)	0.631
Females	65	13 (20.0)	
Have water tank at home			
Yes	495	131 (26.5)	0.922
No	58	15 (25.9)	
Receive Bolsa Familia assistance			
Yes	316	87 (27.5)	0.486
No	237	59 (24.9)	

*Chi square test.

Figure 1 Well with electric pump containing abundant macro-vegetation and *B. glabrata*.

Figure 2 Well located next to a stream contained *S. mansoni*-infected *B. glabrata*.

Discussion

Electrified wells may decrease schistosomiasis transmission, possibly due to both the reduction in human water contact at the well sites and the use of the streams as a result of improvements of household water supplies. This is also indicated by lower *S. mansoni* prevalence among children 8 years and younger in households with electrified wells than in households without them, although this may in part be due to higher infection rates in poorer households receiving *Bolsa Familia* assistance. Nevertheless, there is a possibility that individuals are becoming infected from well water due to lack of protection, the location of most wells near infective river water that may seasonally inundate wells, and the presence of *B. glabrata* in some wells. The possibility of infective *S. mansoni* cercariae surviving the movement through pumps and water pipes in Virgem das Graças is indicated by earlier field experiments. Live *S. mansoni* cercariae remained viable over considerable stretches of streams and canals and after being washed over a waterfall (Upatham 1973, 1974). Similarly, aquatic snails have been found in drinking water pipes (Evins 2004) and *B glabrata* was found in wells and tanks in another two rural communities in Minas Gerais State (Kloos *et al.* 2001).

However, lower infection rates in persons with access to well-water suggest that electrified wells may reduce transmission. This may be due to the potentially negative effect of water storage in tanks on cercarial survival and reduced human contact with water in wells after the installation of pumps. Nevertheless, existing data do not permit an assessment of the epidemiological impact of well water in Virgem das Graças. This is due to other potential sources of *S. mansoni* transmission besides wells, limited information on the transmission potential of well water, widespread sharing of pumped water with neighbours, and possibly socioeconomic factors. There are also unconfirmed reports that some rural households in northern Minas Gerais State have installed electric pumps directly in streams and canals to obtain domestic water, a practice that would increase the risk of *S. mansoni* transmission.

Further studies are required to determine the extent of electric pump use in Brazilian wells and the infectivity of *S. mansoni* cercariae passing through electric pumps, pipes and storage tanks. Sentinel mice (Upatham 1973; Wang *et al.* 2009) and filtration methods (Aoki *et al.* 2003) have been widely used to determine the infectivity of cercariae. Recent development of rapid, sensitive and less labor intensive and costly quantitative PCR assays to measure *S. mansoni* cercariae concentration in water yielded promising results. A quantitative PCR assay specific for *Schistosoma japonicum* that has a detection limit below the DNA equivalent of half of 1 cercaria was developed by Huang and Remais (2008). Another technique of molecular monitoring of schistosomiasis transmission, using DNA amplification techniques to detect schistosome infection in snails, may be also suitable, not only in determining well water safety but also in monitoring residual post-control schistosomiasis transmission, highly relevant in the low-transmission areas of Brazil (WHO 2009).

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