A novel community-based water recreation area for schistosomiasis control in rural Ghana
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ABSTRACT
Primary prevention of schistosome infection has received little attention of late. We describe a novel water recreation area (WRA) to reduce Schistosoma haematobium infection rates in Adasawase, Ghana. Urogenital schistosomiasis is a water-based parasitic disease that affects over 100 million people worldwide, primarily children in the rural tropics. The disease is contracted via dermal contact with contaminated water. Widespread distribution of praziquantel is presently used to control morbidity, but chemotherapy does not confer immunity and reinfection can have severe health impacts. In 2008, an estimated 44% of school-aged children in Adasawase had S. haematobium eggs in their urine. Recreational contact with water was the primary transmission route. In collaboration with community members, a novel WRA was constructed. The WRA is groundwater and rainwater fed and serves more than 100 children at any given time. It was constructed from local materials and labor, designed to last more than 30 years, and minimizes exposure to S. haematobium. One year after construction, the annual incidence of S. haematobium infection dropped from 18.6% in 2009 to 4.6% in 2010, respectively (p < 0.001). Given the promising evidence, the data will be examined more rigorously to characterize factors that influence water contact and infection risk.

Key words | primary prevention, public health engineering, recreation, Schistosoma haematobium, urogenital schistosomiasis, water

INTRODUCTION
Schistosomiasis is a group of diseases caused by blood flukes in the genus Schistosoma. Schistosomiasis is endemic in 76 countries (Engels et al. 2002). Urogenital schistosomiasis is caused by S. haematobium and affects an estimated 112 million people worldwide (van der Werf et al. 2003; King 2005). Collectively, Kenya, Ghana, Mozambique, Tanzania and Nigeria account for over 50% of the morbidity associated with the disease (van der Werf et al. 2003). Urogenital schistosomiasis has been reported in Ghana since 1895 (Doumenge 1897) and is the focus of the pilot intervention study described here.

Urogenital schistosomiasis is spread through dermal contact with tropical freshwater bodies that harbor the parasite and its intermediate host, Bulinus snails. The life cycle is perpetuated when an infected human host urinates directly into a surface water body and releases S. haematobium eggs into the environment or when excrement is washed into a surface water body during a precipitation event. In Adasawase, Ghana, children typically contract schistosomes in a local river where they play, bathe, and collect water.

Large-scale administration of praziquantel, the drug of choice, to a target population (ex. schoolchildren) can be highly beneficial to schistosome-infected individuals, but can strain local health care systems (WHO 2006). Despite short-term improvements in morbidity following treatment with praziquantel (Engels et al. 2002), it is generally agreed that chemotherapy as a single strategy is rarely sustainable (Tucker 1983; Utzinger et al. 2005, 2009; Gryseels et al. 2006; Singer & de Castro 2007). Primary prevention of schistosomiasis through the use of public health engineering techniques is preferable.
(Singer & de Castro 2007). Several researchers have argued that areas of safe water contact are needed (Jordan 1985; Kloetzel 1992; El-Katsha & Watts 2002). In theory, schistosomiasis in rural parts of Ghana could be effectively prevented if people had access to and used only uncontaminated water to meet their needs.

Recreational water contact is a known risk factor for schistosomiasis in endemic areas (Tucker 1985; Jordan 1985; Lima e Costa et al. 1987; Friedman et al. 2001; Gazzinelli et al. 2001; Ndyomugenyi & Minjas 2001; Opara et al. 2007). Recreational water use often yields a relatively large surface area of skin exposed to water for prolonged periods of time (Ndyomugenyi & Minjas 2001; Oladejo & Ofoezie 2006). No studies have been found in which researchers have examined specifically the effect of infrastructure targeted at reducing recreational exposure. A number of authors describe schistosomiasis and recreation (Jordan 1985; Kloos et al. 1986; Lima e Costa et al. 1987; Gazzinelli et al. 2001; Ndyomugenyi & Minjas 2001; Mafiana et al. 2003; Opara et al. 2007), but only one (Tucker 1985) specifically calls for interventions to be designed that address recreational exposure. Jordan (1985) mentions the use of swimming pools in St. Lucia to control S. mansoni, but the pools were not assessed apart from other water infrastructure changes. A larger group of papers discuss the need for water, sanitation, and education, but do not mention recreational water use (Polderman 1984; Chitsulo et al. 2000; WHO 2001; Engels et al. 2002; Utzinger et al. 2003; Clennon et al. 2004; King et al. 2004, 2006; Lancet 2004; Nsowah-Nuamah et al. 2004; Kabateriene et al. 2005; Singer & de Castro 2007; Utzinger et al. 2009).

To determine whether avoidance of recreational exposure to infected river water could reduce S. haematobium infection in rural Ghana, a WRA was selected as a potential primary prevention technique. Adasawase was chosen as the intervention community based on (a) the high (18.6%) cross-sectional prevalence of urogenital schistosomiasis in 2008 among school-aged children, (b) an invitation from the Chief of Adasawase to work in the community, and (c) the small size of the town (approximate population 2000). After establishing baseline infection prevalence, the Chief and Council of Elders considered a number of infection control options including regular distribution of praziquantel and health and hygiene education. The idea of the WRA was also presented. Adasawase authorities chose to focus on the WRA.

The WRA was a community-based approach in which local demand was a critical factor in selecting the appropriate intervention; this is analogous to the approach taken by the South African Department of Water Affairs and Forestry (DWAF) (2002) on sanitation provision. The WRA was designed to effectively and sustainably reduce infection with schistosomes and to be replicable in other settings. This involved consideration of many constraints, including the following: WRA site location within the town, local construction methods and expertise, availability of materials, costs of operation and maintenance, and other demands on water resources. The WRA consists of a concrete pool with shallow and deep sections and a latrine; it is filled by a rainwater collection system and by two pre-existing hand pumped boreholes. To assess the structure’s effectiveness in lowering infection incidence, children were screened for S. haematobium eggs before and after the WRA was opened for use; behavior was characterized via interviews and direct observation.

MATERIALS AND METHODS

Construction methods

Design of the WRA was based on literature describing appropriate technology for community-level operations and maintenance (Schulz & Okun 1984; Cairncross & Feachem 1993; DWAF 2002), the local availability and cost of materials, and the collective experience of the implementation team and community members (Hopkins et al. 2004). In particular, input was collected from the Chief of Adasawase, the Council of Elders, community members including schoolchildren and particularly the community members on the construction team. Members of the construction team were hired for their demonstrated experience and knowledge of construction methods.

Selection of WRA site

The location of the WRA was chosen based on (a) proximity to two groundwater wells, (b) availability of open land, as
verified by the Chief, (c) slope of the land for drainage and (d) location between the town center and the previous water contact site at the Tini River (Figure 1). The aforementioned groundwater wells with handpumps have been in use for approximately 25 years. The WRA was sited between the town and the river to maximize the likelihood of behavior change (i.e. use of the WRA, compared with use of the Tini River) among schoolchildren.

**WRA site preparation**

Preparation of the construction site involved leveling the ground (75 m³ of soil) and excavating the soil (42 m³) that would be replaced by the WRA. To further enhance the potential for WRA translation to similar settings, this was accomplished solely with manual labor (Figure 2).

Labor for site preparation represents a community contribution to the overall cost of construction; at 750 person-hours, the contribution was substantial. In Adasawase,
adult community members are normally expected to contribute service hours to projects that benefit the town (e.g. health clinic construction, road maintenance). The community members who worked on this project chose to do so in partial fulfillment of this service requirement. The project was deemed by the Chief and Council of Elders to be a public good, based on projections that it would help reduce *S. haematobium* transmission and would be a resource for all local children.

**WRA design**

A WRA built with local labor and expertise out of local materials was chosen over installation of a prefabricated pool or hiring of an outside construction company. The pool was split into deep and shallow ends designed for water depths of up to 1.22 m and 0.30 m respectively, to accommodate children of a broad range of ages. The depths were chosen based on the depth of the river swimming site, safety, and the preferences of schoolchildren.

The pool was sized based on a variety of constraints. It had to be sufficiently large to accommodate up to 100 children at a time. Simultaneously, it had to be sufficiently small to contain costs and minimize water use. Sizing the pool for routine flushing and draining was a key factor, as this eliminated the need for chemical treatment of pool water. An attempt was made to maximize the surface area to volume ratio while still keeping the pool rectangular in shape for ease of construction. The dimensions of various pool sections and the required concrete and rebar materials are listed in Table 1.

The pool is made from durable materials that require minimal maintenance. The concrete mix was designed for high strength while still being workable without power tools. The recreation area and surrounding area were fitted with terraces and proper sloping for drainage to prevent erosion (Figure 3). The rainwater collection system is automatic and contains an overflow outlet so that during a rain event, no adjustment to valves is necessary. These design features were chosen to simplify operations and maintenance and to promote sustained use without burdening the community. The WRA was rendered in an aesthetically pleasing manner to encourage use by children; for example, the pool was waterproofed with blue paint, curved concrete walking paths were poured, and flowering plants border the area.

The unintended increase of other infectious diseases was considered. The pool is flushed at least once every three to four days and water is drained completely when it will be out of use for more than a few days. Bacteriological testing was not conducted on pool water. Transmission of *S. haematobium* to children using the pool is not possible without snails present in the pool. There is no reason to believe that snails will colonize the pool, which lacks vegetation.

**Table 1** Details of the components of the water recreation area (WRA) are listed with accompanying specifications

<table>
<thead>
<tr>
<th>Component</th>
<th>Details</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow end</td>
<td>Interior wall/floor dimensions</td>
<td>5.3x2.3x0.6 m</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Volume of water contained</td>
<td>3.6 m³</td>
<td></td>
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<tr>
<td></td>
<td>(~0.3 m depth)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep end</td>
<td>Interior wall/floor dimensions</td>
<td>5.3x3.8x1.4 m</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Volume of water contained</td>
<td>22 m³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(~1.1 m depth)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete</td>
<td>Footings, volume</td>
<td>0.1 m³</td>
<td></td>
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<tr>
<td></td>
<td>Walls, volume</td>
<td>2.6 m³</td>
<td></td>
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<tr>
<td></td>
<td>Floor slabs, volume</td>
<td>3.3 m³</td>
<td></td>
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<tr>
<td></td>
<td>Exterior skirt, volume</td>
<td>2.8 m³</td>
<td></td>
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<tr>
<td></td>
<td>Total volume</td>
<td>9.5 m³</td>
<td></td>
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<tr>
<td>Rebar</td>
<td>Size (diameter)</td>
<td>0.013 m</td>
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<td></td>
<td>Vertical spacing in walls</td>
<td>0.15 m</td>
<td></td>
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<tr>
<td></td>
<td>Grid spacing in floor slabs</td>
<td>0.46 m</td>
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<tr>
<td></td>
<td>Total length</td>
<td>600 m</td>
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</table>

**Figure 3** Schematic of the water recreation area (WRA) in Adasawase, Ghana is shown with erosion-control terraces, a 7.0 m³ rainwater collection tank, and walking paths; the latrine, two borehole wells; most components of the rainwater collection system are located outside the scope of this figure.
Local availability of construction materials

Available materials included 1.27 cm iron rod (rebar), cement, 1.91 cm crushed stone, ‘quarry dust’ (bluestone sand) and low-silt sand from a riverbank deposit. Hollow blocks were commissioned for construction of the walls of the WRA, but the final blocks were weak because they were made with poor quality sand and had been dried in the sun instead of cured under damp conditions. The final block dimensions were incorrect (31.12 cm × 20.32 cm × 10.16 cm instead of 30.48 cm × 20.32 cm × 10.16 cm), causing significant delays in construction and considerable additional expense. The additional expense resulted from the use of unexpected additional labor and materials (sand, gravel, cement, rebar) when both cells in each block had to be filled with reinforced concrete to render the walls of the pool structurally sound (Figure 4). The joints of polyvinyl chloride (PVC) pipes did not always fit together. Joints frequently were softened over open flame before they were glued.

Local knowledge and capacity building

Two senior and two junior masons were hired in addition to four general laborers; these individuals, along with one translator from a nearby community, comprised the Ghanaian members of the construction teams, which operated from June–August 2008 and June–August 2009. The construction team, especially the senior masons, provided context for the project by supplying knowledge of local environmental conditions and appropriate materials and construction methods (Hopkins et al. 2004). For example, erosion in Adasawase can render buildings structurally unsound and walls may cave; therefore, concrete and earthen terraces were constructed on the hill slope near the WRA to prevent erosion and to control overland flow of rainwater during heavy precipitation events. Also, to minimize the opportunity for erosion and vandalism to damage PVC water pipes buried in the subsurface, the pipes were buried between 0.33 m and 1.0 m deep. Finally, Ghanaian team members were familiar with cyclic, seasonal changes in the geomorphology of nearby drainage canals and the local river and were able to provide information about seasonal water flow, sediment load, and the corresponding changes in drainage canal locations and depths. The construction team selected the depth and location of water inflow and outflow pipes that connect to the WRA to prevent them from being exposed and damaged or removed.

A hollow-block method was selected for construction of the pool walls. Milled lumber to create forms for poured concrete slabs was not available near Adasawase and is unlikely to be available or affordable in other rural schistosomiasis-endemic sites. A hollow-block construction method allowed the construction team to apply local construction techniques; moreover, the method translates easily to similar settings. It also makes possible reinforcement of the pool walls with 1.27 cm iron rod (rebar). This strengthening technique was employed in the WRA.

Appropriate and sustainable use of materials and community resources

Adasawase is predominantly a subsistence farming community. Cash for electricity and chemicals for the pool are not available, and chemical treatment of the water was not considered an environmentally sensitive option for pool maintenance. Instead, groundwater from a pair of hand-pumps located approximately 25 m from the pool is used to supply about 50% of the pool water. The approximate pumping rate is 20 L/min and only one pump is connected to the pool at any given time, leaving the second pump available for domestic water collection. The remainder of the pool water is obtained from a rainwater collection system. Three roof sections (each approximately 5 × 12 m) were guttered and
connected to the WRA via 2.54 cm PVC piping laid underground; the expectation is that the gutters will collect approximately 250 m$^3$ of rainwater per year. The pool was situated so as to utilize pre-existing natural drainage systems for periodic cleaning purposes. Gravity is sufficient to drain and re-fill the pool with the rainwater collection system. In the dry season, the pool remains empty so as not to deplete groundwater that is valuable for meeting domestic needs.

Assessment of WRA impact on *S. haematobium* incidence

The objective of this paper is to describe the design, construction, operations and maintenance of a novel WRA; a complete discussion of the impact of the WRA on the incidence of schistosomiasis is outside the scope of this paper, but is addressed fully in a follow-up publication. The materials and methods used to assess the prevalence of *S. haematobium* in 2008, and the incidence of *S. haematobium* infection in 2009 and 2010, are briefly described.

Consent: institutional review boards

This study was approved by the Institutional Review Boards (IRBs) of Tufts University and the Noguchi Memorial Institute for Medical Research (NMIMR) and verbal assent was obtained from each child who participated. Permission to carry out the study was also obtained from the Chief of Adasawase and from the head of each school; these same individuals communicated the nature of the study to the larger community.

Study population and study design

In 2008, all school-aged children aged 8 years and older who were enrolled in school in Adasawase were invited to participate in this longitudinal study. Recruiting and data collection took place in June of 2008. After screening, Ghana Health Services treated study participants with praziquantel (40 mg/kg) in late June 2008 and participants were rescreened for *S. haematobium* eggs in July 2008. In June/July 2009, data about *S. haematobium* infection were again collected; participants were treated with praziquantel and rescreened in July 2009. At the same time, the WRA was opened for public use. In June/July 2010, data about *S. haematobium* infections were collected for the final time; due to the very small number of infections in 2010, egg-positive participants were treated with praziquantel along with other children who wished to be treated, but praziquantel was not given to consistently egg-negative schoolchildren.

Based on official school rosters, approximately 450 to 500 children were over 8 years of age and enrolled in school in any given year. During the 3 years of the study, nearly every child agreed to participate in the study and to provide urine samples for *S. haematobium* screening if (s) he was in school during a screening visit. In any given year, over 90% of school-enrolled children provided at least one urine sample for screening and at least 50% of the children provided three or more urine samples.

Determination of infection status

In 2008, 2009, and 2010, a single urine sample per day on at least three different days was requested between 10:00 and 14:00 hours. Children were given 50 ml plastic containers for urine collection. After sample collection, urine was tested for microhaematuria via a semi-quantitative dipstick test (Mott et al. 1988) (U-11 Urinalysis Reagent Strips, Mindray Co. Ltd., China) and for the presence of eggs via filtration through Nucleopore membranes (25 mm diameter, 12.0 μm pores). Urine was filtered for eggs as follows: urine containers were shaken and at least 10 ml of urine were drawn into a plastic syringe and then discharged through a Nucleopore membrane. Membranes were placed on glass slides and eggs were counted under a microscope at 10× power. For the purposes of this study, only *S. haematobium* eggs in urine were considered for determination of *S. haematobium* infection status (i.e. microhematuria was not considered definitive). The absence of eggs in multiple urine samples does not guarantee that a person is uninfected (Kosinski et al. 2011). A single certified laboratory technician from NMIMR read all slides within 2 weeks of sample processing. The technician was blinded as to the identities of study participants and to the results of each participant’s previous screenings. Data were entered into SPSS 14.0...
(SPSS Inc., Chicago, IL) as total egg counts per 10 mL of urine and were then reduced to binary data (presence/absence). Microhaematuria data were entered into SPSS 14.0 as a score, but were not used for this analysis.

RESULTS AND DISCUSSION

Construction of concrete structural elements of the pool lasted approximately 8 weeks and took place during June, July, and August of 2008. Between June and early August 2009, waterproofing was completed and other components of the WRA, such as the terracing, latrine, and rainwater collection system were added. Community overseers and maintenance workers were trained, and upon completion of the WRA, children were encouraged by the local Assemblyman to use the water collection facilities and to recreate at the WRA instead of at the Tini River. The Assemblyman undertook a word-of-mouth campaign over the course of several weeks to inform children and their parents about the nature of the pool and its purpose as a form of schistosomiasis-transmission control.

Recreational water contact at the Tini River

One community member from Adasawase was trained to directly observe behavior at the Tini River. He was stationed at the river from 06:00 to 18:00 hours for 14 days between July 5 and July 31, 2009. From August to November of 2009, the same individual observed the river from 06:00 to 18:00 hours 7 days per week (84 hours/week) and was compensated for his time. He recorded the names, ages, school affiliations, types and durations of water contact activities, and time of day that each child visited the river. Data show that 17 girls and 42 boys visited the river at least once during this period. It is important to note that even among children who did visit the Tini River, the cumulative contact time over the 4.5 month period was minimal. Of the 17 girls who visited the river, mean contact time was 4.49 h per 4.5 months (range: 0.17 to 11.42 h); of the 42 boys, mean contact time was 3.37 h per 4.5 months (range: 0.08 to 13.87 h). ‘Risky’ contact was defined as swimming or bathing in the Tini River; on average, girls had 0.78 h (range: 0.00 to 3.00 h) of ‘risky’ contact and boys had an average of 0.89 h (range: 0.00 to 3.78 h) of ‘risky’ contact during the 4.5-month period. Water contact data are presented in additional detail in a companion publication.

The WRA

The recreation area is open for use 3 to 4 days per week in order to periodically flush the pool water and maintain water quality in the absence of chemicals and filtration. This management scheme was selected by the community as a feasible and sustainable way of meeting the needs of the end users (i.e. schoolchildren). The WRA was operational between August 2009 and August 2010 under town management. Because chemicals and electricity are not necessary for operation, the community has all the resources required for use: water and manual labor. Children of all ages play in the shallow end on a regular basis, and when a rain event occurs, the deep end is also opened (Figure 5). Rain events typically dictate the frequency with which the deep end of the WRA is open; even when open, the deep end often does not fill to capacity before used water is discharged in favor of clean water. In June 2010, the WRA was visited by our study team to assess wear and to consider design components that required improvement. The drainage system of the pool in the deep end had to be unearthed due to clogging; the problem was effectively remedied by inserting a solid 10.16 cm PVC solid cap into the drain and drilling into it a series of holes, thereby allowing the cap to act as a strainer for organic material. This was the only aspect of the pool that required redesign.

Figure 5 | Children recreating at the water recreation area (WRA) in August 2009.
Changes in S. haematobium infection incidence

The cross-sectional prevalence of S. haematobium infection in 2008 was estimated to be 44.2% among school-aged children who were screened at least three times that year ($n = 249$). Among children who were screened at least three times in 2009 ($n = 221$), annual incidence was estimated to be 18.6%, demonstrating ongoing disease transmission between June 2008 and June/July 2009. It is important to emphasize that children received praziquantel in 2008 and in 2009 from Ghana Health Services after screening was complete. Praziquantel usually kills all adult worms in 60 to 90% of those infected and reduces the egg counts by 85% to 95% among those who are not cured (WHO 1993; Cioli 2005). Among children screened at least three times in 2010 ($n = 260$), annual incidence was estimated to be 4.6%. Thus, based on identifying S. haematobium eggs in urine, the incidence of S. haematobium infection in 2009 is significantly higher than the incidence of infection in 2010 ($p < 0.001$). However, a number of variables are relevant with respect to varying incidence rates and a more nuanced statistical analysis is necessary before definitive conclusions can be drawn. In particular, the effects of sex, nutritional indicators, house location, water contact behavior, school attendance and previous infection status will be assessed.

CONCLUSIONS

Annual incidence of infection with S. haematobium decreased significantly between 2009 and 2010 in Adasawase with the introduction of the WRA, when compared with incidence between 2008 and 2009 when no WRA was present. To our knowledge, the presence of the WRA is the only community-wide factor that changed during this time period that could affect incidence to this extent. While the data cannot demonstrate causation, they strongly suggest that the WRA contributed to a reduction in S. haematobium infection incidence. Although the evidence is suggestive, the data will be examined more rigorously to characterize factors that influence water contact and infection risk. The WRA should be constructed and evaluated in other rural communities where S. haematobium is endemic to determine whether the results are reproducible.

In general, primary prevention of schistosomiasis receives very little attention in the literature, with some notable exceptions (Jordan 1985; King et al. 2006; Singer & de Castro 2007; King 2009, 2010; Utzinger et al. 2009), and in particular, there is very little focus on preventing recreational contact with contaminated surface water. Jordan (1985) discusses effective primary prevention of S. mansoni infection on St. Lucia. In Japan, diminished river contact has been shown to decrease reinfection with and severity of disease caused by schistosomes (Minai et al. 2005) since, in the absence of acquired immunity, parasite burden is proportional to the frequency and duration of contact with infected waters. In a more recent paper, Wang et al. (2009) found that in The People’s Republic of China, the use of infrastructure plus an integrated package of disease control tools (education, chemotherapy, alternative agriculture methods, control of animal reservoirs, etc.) was effective in reducing S. japonicum transmission. Chemotherapy had
been used previously, but had proved ineffective at reducing parasite transmission below an unyielding endemic level. To our knowledge, ours is the first paper discussing the use of infrastructure to alter recreational water contact behavior in the context of urogenital schistosomiasis in West Africa.

Our work has several limitations. First, it is recognized that lack of disinfection (chlorine) may permit some pathogenic microorganisms to grow in the WRA; however, given the use of the contaminated Tini River swimming area prior to WRA implementation, we believe that the pool represents a net improvement over the quality of water at the river, which is functionally stagnant for much of the year. Further studies are needed to confirm that water quality at the WRA is consistently free of unacceptably high levels of bacteria or other undesirable organisms. Second, there are confounding variables such as school attendance, children’s house locations and frequency of contact with the river, that warrant further in-depth statistical analysis to elucidate precisely which risk factors contribute to S. haematobium infection. Another key issue is the impact of regular treatment with praziquantel; river contact has been reduced in the presence of the WRA, but regular drug administration is a critical variable to examine in future studies. These shall form the basis of future publications. Here, details concerning the construction of the WRA are provided. Based on preliminary data analysis, the WRA appears to be a new potential tool for integrated schistosomiasis control.

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REFERENCES


Schulz, C. R. & Okun, D. A. 1984 Surface Water Treatment for Communities in Developing Countries. John Wiley & Sons, New York, USA.


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