

COST-EFFECTIVENESS OF HOME-BASED CHLORINATION AND SAFE WATER STORAGE IN REDUCING DIARRHEA AMONG HIV-AFFECTED HOUSEHOLDS IN RURAL UGANDA

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Abstract. Safe water systems (SWSs) have been shown to reduce diarrhea and death. We examined the cost-effectiveness of SWS for HIV-affected households using health outcomes and costs from a randomized controlled trial in Tororo, Uganda. SWS was part of a home-based health care package that included rapid diarrhea diagnosis and treatment of 196 households with relatively good water and sanitation coverage. SWS use averted 37 diarrhea episodes and 310 diarrhea-days, representing 0.155 disability-adjusted life year (DALY) gained per 100 person-years, but did not alter mortality. Net program costs were \$5.21/episode averted, \$0.62/diarrhea-day averted, and \$1,252/DALY gained. If mortality reduction had equaled another SWS trial in Kenya, the cost would have been \$11/DALY gained. The high SWS cost per DALY gained was probably caused by a lack of mortality benefit in a trial designed to rapidly treat diarrhea. SWS is an effective intervention whose cost-effectiveness is sensitive to diarrhea-related mortality, diarrhea incidence, and effective clinical management.

INTRODUCTION

Persons with HIV and their families could potentially benefit from basic health care interventions providing an inexpensive, easily implemented, evidence-based package of services. These services often include treatment of diarrhea and malaria and hygiene education, which particularly benefit individuals with HIV, regardless of their access to antiretroviral therapy (ART). Point-of-use disinfection and storage of water using safe water systems (SWSs) are basic components of the primary health care package for HIV-affected households, which are effective in reducing diarrheal incidence.¹ Such interventions could not only help slow disease progression in individuals with HIV/AIDS, but could also help ensure basic preventive care services for the majority of persons living with HIV/AIDS in Africa who do not have access to ART.

SWS is a household-based water quality intervention developed by the Centers for Disease Control and Prevention (CDC) and the Pan American Health Organization.^{2,3} It consists of the disinfection of household drinking and cooking water immediately after collection and storage of disinfected water in a narrow-mouthed closed vessel designed to prevent recontamination. SWS has been considered an inexpensive and reliable alternative to safe water supply and sanitation that prevents diarrheal diseases.^{2,4} In a randomized controlled trial among people with HIV in rural Uganda, the household-level provision of SWSs was found to reduce the frequency of diarrhea episodes by 25%, days with diarrhea by 33%, and the frequency of dysentery by 28%.¹ SWS was similarly effective whether people with HIV were taking cotrimoxazole prophylaxis, which is recommended for reducing

morbidity and mortality among people with HIV/AIDS.^{5–9} In addition, recent studies have shown that point-of-use disinfection and safe storage of water using SWSs in the general populations of Malawi, Bolivia, and Zambia reduced diarrheal disease risk for individuals by 31–48%.^{10–12} While diarrhea is an important cause of morbidity and mortality in people living with HIV/AIDS and the intervention is effective, the cost-effectiveness of SWSs in preventing diarrhea among HIV-affected households has not previously been studied.

An earlier study of population-level water supply and sanitation interventions in developing countries showed that oral rehydration therapy and basic hygiene education can be cost-effective in reducing diarrheal incidence and mortality among children (\$2.93 per diarrheal case averted, \$689 per death averted, and \$20 [1996 US dollars] per disability-adjusted life year [DALY] gained).¹³ However, these favorable cost-effectiveness findings depended on the assumption of an existing physical infrastructure for potable water supply and sanitation. Furthermore, the study focused on children less than 5 years of age, who tend to have higher diarrhea incidence and mortality (i.e., five episodes of 8 days each per person-year and mortality of 5 per 1,000 person-years).¹³ Other studies of interventions that included water and sanitation infrastructure or personal hygiene education reported far less favorable cost-effectiveness. A study conducted in Guinea of pit latrine construction and provision of drinking water estimated cost-effectiveness to be \$343 (1994 US dollars) per unadjusted life year saved assuming a mortality risk of 13 per 1,000 person-years.¹⁴ Results from Malawi found a cost-effectiveness of \$433 (1990 US dollars) per DALY gained from a drinking water and sanitation intervention with construction and maintenance of deep-well water system and pit latrine and public hygiene in a population at risk of endemic cholera.¹⁵ The study assumed diarrhea incidence of 0.2–2.6 episodes of 3 days each person-year and a mortality rate of 1.4–7 per 1,000 person-years.

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SWS differs from population-level potable water and sanitation interventions in that it is not based on infrastructure, is targeted to households, and complements local interventions of sanitation, health education, and personal hygiene. We examined the costs and cost-effectiveness of SWSs for HIV-affected households in rural Uganda.

MATERIALS AND METHODS

We evaluated the costs and cost-effectiveness of the SWS intervention delivered in the context of a basic home-based care program for HIV-affected households. Home-based care services consisted of diagnosis and treatment of diarrhea and malaria, clinical care at the study clinic at Tororo District Hospital, and educational interventions to improve hygiene. All services were provided to participating individuals free of charge. Our analysis reflects the cost-effectiveness of the SWS intervention added to an array of basic health care services for HIV-affected households.

Because SWS is a household-based intervention, all individuals in the household would benefit from the program. In the base-case analysis, we included in our calculation the benefits accruing to the entire household. The cost-effectiveness of SWSs specific to HIV-infected persons was evaluated in a sensitivity analysis.

Description of intervention. The SWS intervention was implemented as part of a randomized clinical trial described elsewhere.¹ Briefly, the SWS intervention consisted of the provision of a 20-liter polyethylene vessel with a narrow mouth and a spigot, one 500-mL bottle of 0.5% sodium hypochlorite solution, and a cloth through which visibly dirty water could be filtered. Field workers provided basic hygiene education to both intervention and control households. They also provided training to participants in the intervention group on operating the SWS and replenishing the sodium hypochlorite solution in the water. Field workers inspected the SWS vessel at weekly visits during the study period.

At baseline, participants were randomly assigned to the SWS intervention or control (Figure 1). After 5 months, both intervention and comparison households received cotrimoxazole prophylaxis (160 mg of trimethoprim and 800 mg of sulphamethoxazole) and were followed until the end of the study. Because cotrimoxazole prophylaxis prevents diarrhea, the results reported here are based on data collected during the period after the addition of cotrimoxazole prophylaxis, although our previous analyses showed that there was no interaction between cotrimoxazole and the absolute effect of SWS on diarrhea incidence.^{1,6}

During the study, program participants were visited weekly by trained lay field workers who administered a questionnaire to record diarrhea episodes, days with diarrhea, days of school or work lost, hospitalization, clinic visits, and death of the household member within the past 7 days. Seriously ill participants were encouraged to come to the clinic or hospital to be treated. The program participants were offered field-based services for prompt diagnosis and treatment of diarrhea using a standard clinical algorithm. During routine weekly home visits, patients with diarrhea were examined, and stool specimens were collected. All samples were transported to the project laboratory and tested for *Salmonella*, *Shigella*, *Campylobacter*, *Vibrio cholerae*, *Pleisiomonas*, and *Aeromo-*

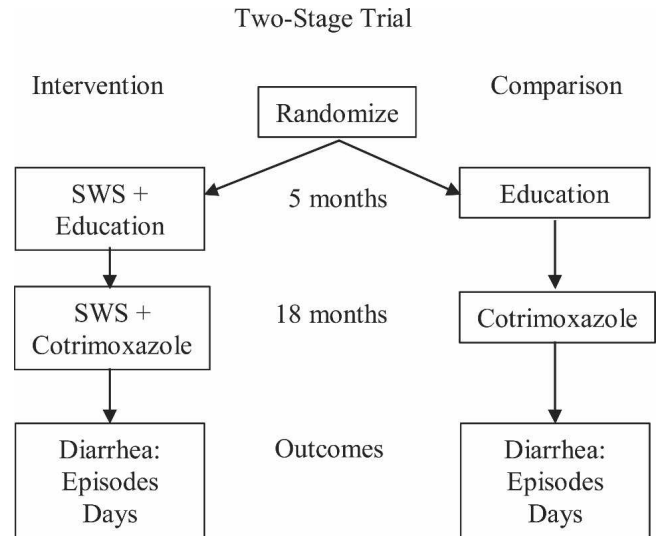


FIGURE 1. Two-stage randomized trial of households participated in the safe water systems in the context of a basic home-based care program for HIV-affected households in Tororo, Uganda.

nas using standard procedures.¹ A physician reviewed field reports and laboratory test results and prescribed appropriate medications and oral rehydration solution (ORS). Cases of diarrhea were diagnosed as dysentery if visible blood or mucous was detected by patients in their stool. Medications were delivered at home by field workers. Diarrhea was treated with loperamide and ORS; if fever or dysentery were present, diarrhea was treated with ciprofloxacin and ORS.

Description of the model. We analyzed health outcomes and costs using a model programmed in Excel. We adhered to the reference case scenario recommended by the Panel on Cost Effectiveness in Health and Medicine, except that we took the perspective of the health care payer who would finance the SWS intervention rather than a societal perspective.¹⁶ Outcome measures included diarrhea episodes and days with diarrhea averted and DALYs gained. Number of work and school days lost were not found to be associated with SWS and thus were excluded from this analysis.¹ Costs and outcomes were standardized to 1 year for a cohort of 100 HIV-affected individuals and their households.

Health outcomes. Data on health outcomes were derived from the clinical trial (Table 1). The trial was designed to assess the effect of SWS on diarrhea incidence and severity, not mortality, because episodes of diarrhea were rapidly treated in the field. In the analysis of the trial data, the reductions in diarrhea episodes and days with diarrhea were estimated controlling for age, sex, household wealth, presence of latrine or soap at home, time of the year, cotrimoxazole use, CD4 counts, and World Health Organization clinical stages.

Health state utility estimates for diarrhea were derived from community-based studies and population surveys in developing countries.¹⁷ Diarrhea as defined in these studies included acute watery diarrhea, persistent diarrheal episodes, and dysentery. Diarrhea in our clinical trial was defined as at least three loose or watery stools within 24 hours, and dysentery with stool specimens contained visible blood or mucous. In calculating DALYs, we used the median productivity-

TABLE 1

Base-case values and input ranges used in cost-effectiveness analysis of safe water system in the context of a clinical trial of a basic home-based care program for HIV-affected households in Tororo, Uganda

Input parameters	Base case	Range*	Source
Household composition			
HIV-infected household members	1.28	—	Trial
HIV-uninfected household members	3.88	—	Trial
Program efficacy in reducing diarrhea incidence†			
Diarrhea episodes per person-year	0.20	0.48	Trial ^{10–12}
Days with diarrhea per person-year	0.26	0.48	Trial ^{10–12}
Mortality reduction (100 person-years)‡	—	1.60	22
Diarrhea incidence			
Diarrhea episodes per household-year	2.12	1.06–3.50	Trial ¹²
Days with diarrhea per household-year	13.12	9.84–21.00	Trial ¹²
Age-related productivity weight	1.30	0.65–1.96	Trial ¹⁸
Disutility from diarrhea	0.11	0.06–0.17	17
Program cost per person-year (US \$)			
Personnel	0.29	0.14–0.43	Trial
Office maintenance and supplies	0.21	0.11–0.32	Trial
Water chlorination	0.69	0.27–1.03	Trial ⁴
Water vessel	0.55	0.27–1.20	Trial
Spigot replacement	0.19	0.10–0.30	Trial
Capital cost	0.26	0.13–0.39	Trial
Averted cost of field clinical algorithm per person-year	0.09	0.05–0.14	Trial

* Ranges are used in sensitivity analyses. All parameters are varied using low or high estimates available in the literature or using $\pm 50\%$ of the base-case values.

† Program efficacy in reducing diarrhea episodes and diarrhea days were 0.25 and 0.33 among HIV-infected persons. Diarrhea incidence by age group and serostatus are reported in Lule et al.¹

‡ The SWS trial in Tororo did not detect mortality; thus, we used the mortality data from a recent SWS study in Kenya for sensitivity analysis.²²

related age-weight from each decile of the distribution of ages of the members of the participating households.¹⁸

Program costs. Program costs were obtained from the intervention component of the clinical trial. We conducted a comprehensive accounting of incremental program costs using standard techniques.^{19,20} Costs of research-related activities and the costs of delivering basic care services other than the SWS intervention were excluded. Where personnel resources such as field workers' time were used both for SWS and for other program activities, we allocated costs according to the percent of time that SWS constituted of the total time for program activities recorded in log books when services were delivered. We obtained these allocations as retrospective estimates provided through structured interviews of field operations managers. For example, field workers offered an initial training for each household on the operation and maintenance of the water vessel and helped replenish chlorine in the vessel periodically. The initial training took 15 minutes on average, and chlorine replenishment required 10 seconds once every 3 months. Personnel costs reflected the prevailing local wage rates.²¹

Cost data for capital items and recurring goods were obtained from program expenditure records and were allocated to SWSs entirely if dedicated (e.g., water vessel) or in proportion to overall SWS personnel cost allocation. Chlorine

cost was \$0.30 for a 500-mL bottle of 0.5% sodium hypochlorite solution, (Mukwano Industries, Kampala, Uganda). The cost of water vessel was \$3.50 (Multiple Industries, Kampala, Uganda). This included the 20-liter polyethylene vessel with a spigot and the cost of delivery to the program site, spread over 5 years. In addition, based on empirical data from the trial, we assumed a 13% annual failure and replacement rate for the spigot.

Costs of the field-based clinical services consisted of travel, medication, field worker time, and medical officer time. Because these cases would otherwise have entailed treatment costs in outpatient clinics, the diarrhea clinical algorithm costs were deducted from program expenses. Cost details of the algorithm are available from the authors on request.

We adjusted all costs for inflation to January 2004 using the Uganda Consumer Price Index (<http://www.ubos.org>). Currency was converted to US dollars at a rate of \$1 = 1935 Uganda Shillings using the interbank exchange rate on January 1, 2004 (<http://www.oanda.com>). Capital costs were straight-line amortized over 5 years. We did not discount, because the analysis was standardized to a single year.

To understand which input values exert the greatest influence on cost-effectiveness, one-way sensitivity analyses were performed on key model input parameters as shown in Table 1. In addition, we conducted selected two-way sensitivity analysis and threshold analyses, to describe the conditions that would need to be present to significantly alter our conclusions.

RESULTS

Base Case Analysis. The SWS program averted 37 diarrhea episodes and 310 diarrhea days and gained 0.155 DALYs for the entire household per 100 person-years of participation by HIV-affected households (Table 2). The program did not alter mortality. The expected gross cost of the SWS program and cost saved from preventing the need for diarrhea treatment were \$219 and \$25 per 100 person-years, respectively. Thus, the net program cost was \$194 per 100 person-years. The SWS program cost \$5.21 and \$0.62 for each diarrhea episode and day with diarrhea averted, respectively. The cost per DALY gained was \$1,252. Program delivery costs other than the water vessel and chlorine itself constituted 35% of the total. The costs of the water vessel and chlorine were 34% (vessel cost plus replacement spigot) and 31% of the total cost, respectively (Figure 2).

TABLE 2

Health outcome, costs, and cost-effectiveness of safe water system in the context of a clinical trial of a basic home-based care program for HIV-affected households in Tororo, Uganda (results are reported per 100 person-years)

Description	Cost-effectiveness results*
Diarrhea episodes averted	37
Diarrhea days averted	310
DALYs gained	0.155
Net program cost	\$194
Cost per diarrhea episode averted	\$5.21
Cost per diarrhea day averted	\$0.62
Cost per DALY gained	\$1,252

* Costs are reported in 2004 US dollars.

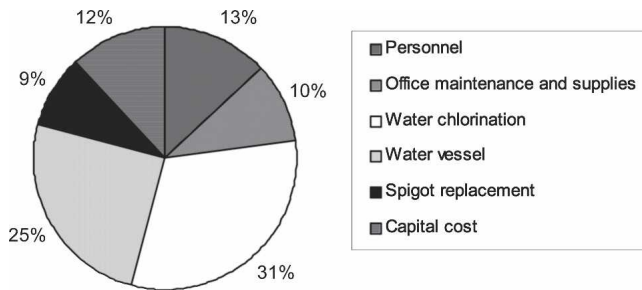


FIGURE 2. Distribution of program costs of the safe water system trial conducted in the context of a basic home-based care program for HIV-affected households in Tororo, Uganda.

Sensitivity Analyses. The SWS intervention was in addition to the basic care services for HIV-affected households. The absence of mortality benefits detected for SWSs was likely caused by the aggressive diagnosis and treatment of diarrhea that was delivered in the field. Prior studies suggested mortality reduction of 0.2–1.3 per 100 person-years from diarrhea prevention through water supply and sanitation-related interventions.^{13–15} A recent study in rural western Kenya showed that SWSs reduced mortality by 1.6 per 100 person-years.²² We conducted sensitivity analysis using the mortality effects found in Kenyan study, which would be comparable with rural settings in Uganda or similar settings in sub-Saharan Africa. The results indicated that SWSs would cost \$11/DALY, assuming 3% annual discount rate and 10 years of added life (Table 3). Furthermore, we conducted a threshold analysis to determine the level of mortality benefit that would be required to yield an SWS cost-effectiveness ratio of \$75/DALY. We found that SWSs would need to avert 0.22 deaths per 100 person-years to reach this level of cost-effectiveness, assuming a 3% annual discount rate and 10 years of added life. If SWSs added 20 life-years, 0.164 averted deaths per 100 person-years would be sufficient to yield a cost-effectiveness of \$75/DALY.

Diarrhea incidence and duration in our study might be lower than it would have been in the absence of the other basic care services and aggressive field management of diarrhea. The provision of hygiene education in particular might

have averted some of the diarrhea cases that otherwise would have been averted by SWSs. Diarrhea days in the study area before SWSs were thought to be higher than base-case rate of 13.12 days per household-year used in this analysis. Our clinical trial in Tororo showed that the diarrheal incidence among HIV-infected persons was six times higher compared with the HIV-uninfected cohort.¹ Based on the diarrhea incidence of an earlier study in a refugee camp in Malawi, we estimated diarrhea days for HIV-affected household without SWS to be 21 days per household-year.¹² Sensitivity analysis of the base case (not taking into account estimated mortality benefits) showed that with diarrhea incidence as high as 21 days (3.50 episodes) per household-year, the SWS intervention would cost \$782 per DALY gained (\$2.89 per episode averted; Figure 3a).

The cost of the vessel could vary by geographic location and by the size and the type of vessel used in the program. The retail cost of vessel could approach \$8.00.⁴ For example, when the SWS program in Tororo imported the vessel from outside the country, the cost of vessel including transportation cost was \$7.68 (Nampak Co., Johannesburg, South Africa). The corresponding amortized vessel cost would be \$1.20 per person-year (Table 1). At this high-end vessel cost per person-year, the incremental cost per DALY gained would be \$1,673 (\$6.96 per episode averted; Figure 3b). In some cases, the SWS program may use locally available vessels, buckets, or clay pots, which would essentially eliminate program cost on vessel.²³ Assuming no change in program efficacy in using these alternatives and eliminating vessel and spigot replacement costs, we estimated the SWS cost of \$774/DALY. In the base-case results, we estimated an annual rate of 13% for spigot replacement in water vessels (\$0.19 per person-year). Because the spigot replacement rate may increase over the expected life of the vessel, we used replacement rate of 20% in a sensitivity analysis, which increased the cost-effectiveness ratio to \$1,319/DALY. If we assume that spigot replacement cost reduced by 50% (\$0.10 per person-year; Table 1) from base-case estimate instead, the incremental cost per DALY would be \$1,192.

In some situations, sodium hypochlorite may be bottled locally, which might reduce the cost of the solution to about \$1.36 per household per year or about \$0.27 per person-year

TABLE 3
Results from sensitivity analysis of important parameters used in the SWS cost-effectiveness model*

Parameter description	Base case value	Sensitivity value	Cost per diarrhea episode averted (\$)	Cost per DALY gained† (\$)
Mortality reduction per 100 person-years‡	—	1.6	—	11
Threshold mortality per 100 person-years§	—	0.22	—	75
Diarrhea episodes per household-year	2.12	3.50	2.89	695
Diarrhea days per household-year	13.12	21.00	—	782
Disutility from diarrhea	0.11	0.17	—	1,075
Program efficacy in reducing diarrhea episodes	0.20	0.48	1.55	520
Program efficacy in reducing diarrhea days	0.26	0.48	—	733
Program efficacy and diarrhea days	0.26; 13.12	0.48; 21	0.68	459
Spigot replacement rate	0.13	0.20	5.49	1,319
Cost of water vessel per-person year (\$)	0.55	0.27–1.20	4.46–6.96	1,073–1,673
Spigot replacement cost per-person year (\$)	0.19	0.10	4.96	1,192
Water chlorination cost per-person year (\$)	0.69	0.27	4.09	982
Program delivery cost (% of total cost)	0.35	0.10–0.50	3.75–6.12	902–1,470
Program targeted to HIV-infected persons	—	—	4.28	1,037

* Cost-effectiveness model was constructed using the clinical trial data. The base-case cost-effectiveness ratio is \$1,252 per DALY (\$5.21 per episode) averted.

† See text for interpretation of the sensitivity analysis results.

‡ Sensitivity analysis on mortality reduction was based on the data from SWS randomized controlled trial in rural western Kenya.²²

§ Threshold analysis was based on the estimate of mortality rate that would be required to yield a cost-effectiveness ratio of \$75 per DALY gained.

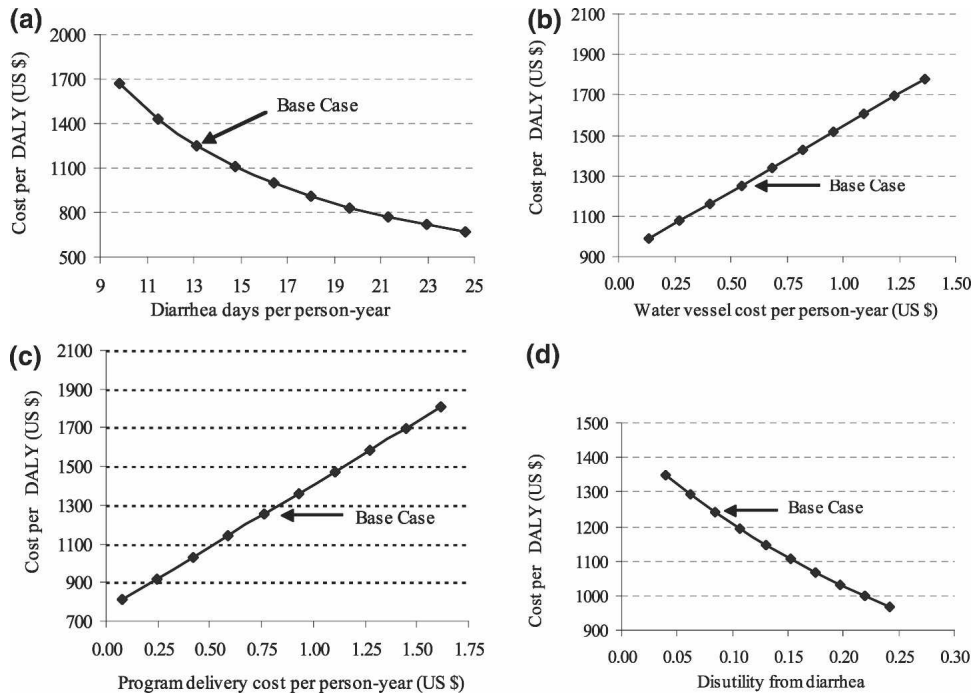


FIGURE 3. (a–d) Sensitivity of the cost-effectiveness results of safe water system trial conducted in the context of a basic home-based care program for HIV-affected households in Tororo, Uganda. The figures represent cost per DALY gained from SWS intervention as function of background diarrhea days; cost for water vessel; program delivery cost (all costs excluding vessel and chlorine); and disutility from diarrhea (without mortality effects).

including bottling and distribution costs,⁴ which is 39% of our base-case estimate of chlorine cost. With this change, the cost per DALY gained was estimated to be \$982 (\$4.09 per episode averted). Because chlorine cost is 31% of total program cost, the results are sensitive to chlorine cost.

We conducted sensitivity analysis on program costs excluding the vessels and the chlorine itself to reflect the potential variability in these costs in different contexts. If it were possible to reduce program delivery costs to 10% from its base-case cost of 35% of the total program cost, that is, to \$0.22 per person-year, the program would assume a cost-effectiveness of \$902 per DALY gained (\$3.75 per episode averted; Figure 3c). Similarly, if program delivery costs were 50% of base-case total cost (\$1.10 per person-year), the cost-effectiveness ratio would increase to \$1,470 per DALY gained (\$6.12 per episode averted).

The relationship between the disutility from diarrhea and incremental cost per DALY gained was nonlinear, as revealed in Figure 3d.¹⁷ In other settings, diarrhea episodes could be longer and more severe in HIV-infected persons than they were found to be during the trial in Tororo. In such cases, disutility from severe diarrhea or dysentery would increase. Sensitivity analysis showed that with the upper-bound disutility value of 0.17, cost-effectiveness was \$1,075/DALY.

We also examined the effect of including only those diarrhea benefits specific to HIV-infected persons, even though it could be difficult to deny other household members' access to SWSs. We reduced costs to reflect lower use of chlorine, and diarrhea days averted to reflect lower absolute (although higher relative) effectiveness of SWSs. The adjusted cost-effectiveness ratios was \$1,037 per DALY gained (\$4.28 per episode averted).

We simultaneously varied base-case diarrheal incidence

and SWS efficacy (Figure 4). With the base-case incidence of 13.12 diarrhea days (1.12 episodes) per household-year but high efficacy (0.48) based on SWS efficacy trials in Malawi, Bolivia, and Zambia, the cost per DALY gained was \$733 (\$1.55 per episode averted). When we varied both base-case diarrhea days and efficacy to the upper bound values of 21 and 0.48, respectively, the DALY gained was \$459 (\$0.68 per episodes averted).

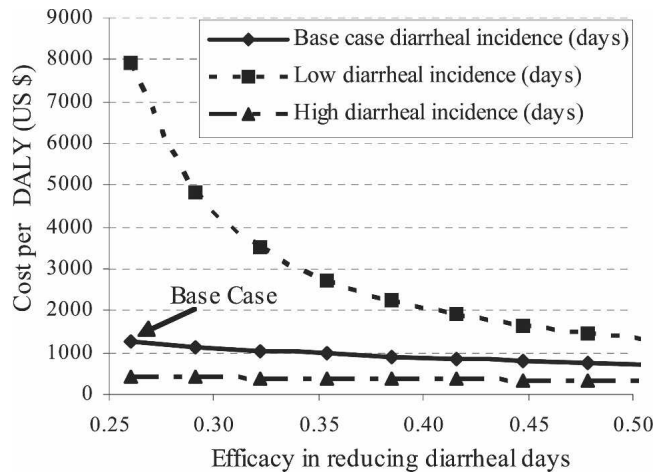


FIGURE 4. Sensitivity analysis on cost per DALY gained from SWS intervention in the context of a clinical trial of a basic home-based care program for HIV-affected households in Tororo, Uganda, as function of program efficacy (higher than base case only), and diarrhea incidence (without mortality effects).

DISCUSSION

The SWS trial in Tororo cost \$5.21 per diarrhea episode averted and \$0.62 per diarrhea-day averted, which were similar to values found in other studies shown to prevent diarrhea using potable water and sanitation-related interventions.¹³ The incremental cost-effectiveness was \$1,252 per DALY gained, and sensitivity analysis showed that the base case SWS cost-effectiveness ratio is above the threshold generally considered cost-effective for public health programs in developing countries: \$50–150/DALY.^{24–26} However, the high SWS cost per DALY gained was caused by a lack of mortality benefit. Because we used the data from clinical trial not designed to detect mortality and delivered intensive clinical services in the field, caution must be taken when generalizing the results to larger-scale programs without those clinical services, in which mortality benefits may be obtained.

The SWS trial in Tororo was delivered in the context of a basic home-based care program for HIV-affected households. During the intervention, households were visited weekly by trained field workers and offered services for prompt diagnosis and treatment of diarrhea in the field. Persons with diarrhea were diagnosed and treated within hours to a few days of illness onset, and all had free access to clinic care. Because of the aggressive field management of diarrhea, the chances of a mortality effect of Tororo trial were reduced. Thus, incremental cost-effectiveness ratio in terms of cost/DALY computed without mortality benefit in our study were likely inflated compared with more representative settings in rural Uganda or sub-Saharan Africa, where SWSs might reduce diarrheal mortality, as shown in a recent study in rural Kenya.²² Under these conditions, the cost per DALY gained was considerably lower; in our sensitivity analysis using the mortality data from this study, the incremental cost per DALY gained was reduced to \$11/DALY.²² Sensitivity analysis also indicated that the SWS cost-effectiveness ratios in averting diarrhea episodes, even without a mortality effect, were within the range found in other safe water and sanitation interventions.¹³

While the home-based care intervention was delivered with intensive weekly home visits, only a portion of the program costs was allocated to SWSs. In other settings, the frequency and cost of travel and supervision by field workers would likely be further reduced. However, our analysis shows that even with a 90% reduction in all costs other than the vessel and chlorine itself, and assuming no concomitant loss of program effectiveness and no mortality benefit, the cost-effectiveness ratio remains high in terms of cost per DALY gained.

Poor water quality may cause a wide range of diseases including cholera, typhoid, hepatitis, dysentery, giardiasis, and other gastrointestinal infections in rural communities in Uganda. However, households that participated in the SWS trial in Tororo had relatively high levels of coverage of improved water and sanitation facilities (i.e., 61% used high-quality water from a borehole, 79% had latrines, and 86% possessed soap).¹ In other settings with poorer environmental health conditions, the SWSs may provide greater health benefits and a more favorable cost-effectiveness ratio.

It is possible that SWSs could provide other health benefits beyond the health outcomes considered in our cost-effectiveness analysis. We did not account for some of the potential benefits of SWS in terms of providing safe water for

preparing infant formula, weaning foods, and taking ARV medication because replacement feeding and ARV treatment programs were not in place in Tororo at the time of the clinical trial.

Diarrhea is one of the leading causes of mortality among children in Africa,⁵ and morbidity among adults and children with HIV.⁶ The few studies of SWS effectiveness currently available only involved HIV-negative or untested participants and were not powered to detect mortality benefits.^{2,10,11} Ethical considerations probably preclude further evaluations of the efficacy of SWS among persons with or without HIV, and therefore the judgment of whether SWS is ultimately as a useful intervention for a particular program may depend on local assessments of the frequency of diarrhea, the mortality rates associated with diarrhea, and the comprehensiveness of HIV care programs.

Cost-effectiveness of health care interventions in developing countries might be interpreted within the context of the data used and cost-effectiveness threshold used. The base-case SWS intervention in our study is evaluated based on micro-level clinical trial data and cost-effectiveness thresholds implied by similar interventions reviewed in the literature. The World Health Organization Commission on Macroeconomics and Health suggested that the interventions in developing countries costing less than one to three times the GDP per capita per DALY gained are cost-effective.²⁷ Incremental cost per DALY gained in the base case of our study is greater than three times the 2002 Uganda GDP per capita of \$236, although it is less than the GDP per capita of \$1,390 based on purchasing power parity.²⁸ When mortality benefits are considered, the cost-effectiveness ratios may be substantially lower than the GDP per capita. Further evaluation of the cost-effectiveness of the SWS will help better define its relative priority among interventions used to reduce morbidity and mortality, and improve the quality of life in HIV-affected households.

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