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COST-EFFECTIVENESS OF WATER INTERVENTIONS:

**The case for public stand-posts and bore-holes in
reducing diarrhoea among urban households in
Uganda**



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ABSTRACT

In Uganda, water-borne diseases, especially diarrhoea still remain a big challenge to attainment of water related Millennium Development Goals. Compared to adults, children below the age of 6 years face a higher burden of diarrhoea, with the incidence estimated at 51 per 1000. Uganda has earmarked large amounts of resources for water related interventions but still the current levels of spending are inadequate to ensure that everyone gets access to improved drinkingwater. Given that funding is limited, policy makers in the water sector are concerned with how best to allocate scarce resources. To address part of this concern, this paper analysed the cost effectiveness of public stand-posts and boreholes in reducing the burden of diarrhoea among infants. The analysis involved computation of the Disability Adjusted Life Years (DALY) and public and social costs per DALY. Findings revealed that the average public cost per DALY is remarkably lower for public stand-posts than for boreholes. Additionally, the net social cost per DALY is lower for public stand-posts than for boreholes. The implication is that public stand-posts are more cost effective than boreholes in reducing the burden of diarrhoea. However, given the currently limited level of funding to the water sector, expanding coverage of public stand-posts would require external budget assistance.

Keywords

Burden of diarrhoea, DALYS, water interventions, Uganda

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1. INTRODUCTION

During the implementation of reforms, under the Poverty Reduction Strategy Papers (PRSPs) framework, governments in sub-Saharan Africa (SSA) have devoted increasing resources to water interventions. About US\$ 25 billion has been allocated to water interventions during 1990-2008 (United Nations 2009). As a result of such resource allocations, the proportion of households with access to an improved water source increased from 48 percent in 1990 to 56 percent by 2004 (UNDP 2006). However, current spending on water and sanitation interventions remains low in comparison to requirements to meet the Millennium Development Goal (MDG) for water. According to the World Health Organization (WHO), countries in SSA require to increase per capita spending on water—between US\$ 150 to US\$700 per person in order to meet the water coverage rates of South Africa—country with highest coverage rates for improved water on the continent (Hutton and Bartram 2008). The benefits of increasing access to improved water sources are enormous—from short term benefits e.g. reducing the burden of disease water borne illness to long term benefits such as improved child school attendance and labour productivity.

Indeed, water-borne diseases such diarrhoea remain a big challenge to developing countries. According to the WHO, water-borne diseases—particularly diarrhoea accounts for about 4 percent of the total global burden of disease, and, worse still, the burden is unevenly distributed—the annual Disability Adjusted Life Years (DALYs) lost due to diarrhoea is five times higher in children aged 5 years and below compared to the rest of the population (WHO 2006). Furthermore, globally about 1.5 million children die annually due to the disease. Apart from mortality, diarrhoea illness can lead to long term health consequences such as malnutrition and affected cognitive development (Martorell and Habicht 1986). On the other hand, there is extensive evidence to show that diarrhoea illness is more likely than not to be a result of inadequacies in water, sanitation, and hygiene (WHO 2002; Pruss-Ustun *et al.* 2004). Keusch *et al.* (2006) provide global estimates for the cost effectiveness of different interventions for dealing with diarrhoea diseases in developing countries while Koseket *et al.* (2003) provide a comprehensive review of the diarrhoea burden of disease in developing countries.

The Government of Uganda (GoU) has earmarked significant resources to the water sector since 2000. For example, the annual budget for the water sector increased from US\$ 21 million in 2000/2001 to US\$ 82 million in 2010/11—a modest change from 1.3 to 3.3 percent of the national budget (GoU 2010).¹ Although Uganda has earmarked large amounts of resources for water related interventions, the current levels of spending fall short of the resources required to attain the water related MDGs². For instance, under the current Water Sector Investment

¹ The type of facilities promoted include: public stand pipes, bore holes, and protected well.

² The MDG 7 is halve, by 2015, the proportion of people without sustainable access to safe drinking water and sanitation.

Plan (WSIP), it is expected that at least US\$ 950 million will be earmarked for interventions within the sector over the period 2000-2015 (Table 1). Even then, the above commitments fall short of the resource requirements for Uganda to attain water related MDGs—projected at US\$ 1,430 million or US\$ 147 million per year (Okidiet *al.* 2002). Given that the water spending—of US\$ 82 million per year, Uganda appears to be under-spending on water interventions at tune of US\$60 million per year. As such, policy makers in the water sector are concerned with issues of how best to allocate scarce public resources.

Table 1: Uganda: Projected expenditures under the WSIP 2000-2015 (US\$ millions)

Major Program	Financial Years			Total
	2001/2005	2005/2009	2009/2015	
(a) Water Supply	150.1	190.1	447.4	787.6
(b) Sanitation	10.4	21.4	70.1	101.9
(c) Environment Assessment, Mitigation, and Monitoring	-	6.5	14.6	21.1
(d) Capacity building for Local Governments	15.1	10.3	23.7	49.1
(e) Institutional Support and Capacity Building for Central Government	3.1	2.3	4.9	10.3
Total (US\$ Millions)	178.7	239.6	560.7	978.9

Source: Revised WSIP (2000-2015) and ADB (2005)

1.1 Research question

This paper attempts to address Uganda's limited water resources challenge by analyzing the cost effectiveness analysis of two water interventions (public stand-posts and boreholes)—in terms of reducing the burden of disease such as diarrhoea as captured by the Disability Adjusted Life Years (DALYs) avoided. The specific research question is: which of the two water interventions leads to least cost per DALY avoided among urban residents. As earlier mentioned, the benefits from water interventions go beyond the health sector; however, for the current study we stick to the specific health benefits due to data constraints. The choice of urban household is guided by the choice of water interventions selected—public stand-posts and boreholes—the two water technologies account for about 59 percent of the current water facilities used by urban residents in Uganda. Most important, public stand-posts can only be provided to geographically concentrated population—a key characteristic of urban households—compared to geographically dispersed population in rural areas. In section 2.2 we provide further justification for considering the two water technologies.

The choice of considering both children aged 5 years and below as well as adults is because infants face a higher burden of disease due to diarrhoea. According to the World Health

Organization, children under 5 years account for 90 percent of the 1.8 million people who die annually due to diarrhoea (WHO 2006). Indeed, in Uganda, although the diarrhoea disease incidence is only about 20 per 1000 in the general population, among children under 5 years, diarrhoea incidence is 51 per 1000 (UBoS 2010).

The rest of the paper is structured as follows: The next section provides a brief on the Ugandan context especially as it relates to access to water facilities and incidence of diarrhoea and in addition provides the justification for considering public stand-posts and boreholes as means of reducing water born-illnesses. This is followed by the methodology including the description of the datasets used in the analysis. Section 4 presents the cost effectiveness results while the conclusions are in section 5.

2. UGANDA CONTEXT

Although Uganda has registered tremendous progress in reducing the incidence of poverty, it nevertheless remains a poor country — if compared to other countries in SSA. The national headcount poverty index for Uganda reduced from 56 percent in 1992/93 to 24 percent by 2009/10; it is only during the period 1999/00 to 2002/03 that the country witnessed a reversal in poverty incidence (UBoS 2010). Despite the above changes, the population of poor persons has remained constant at about 7 million persons — partly due to a very high population growth rate — 3 percent per annum (UBoS 2002). On the other hand, Uganda remains one of the poorest countries in the SSA with an annual per capita Gross Domestic Product (GDP) of US\$ 500 in 2010—compared to US\$2,258 for sub Saharan Africa (International Monetary Fund 2011).

One of the reasons for Uganda's relatively low per capita GDP is the very large agricultural subsistence sector. Although agriculture accounts for less than 20 percent of the GDP, the sector employs more than 75 percent of the country's labour force. The large subsistence sector has ensured that the country's revenue mobilization efforts remain low. Uganda only collects about 13 percent of the GDP in taxes and as such there is competition among the various social sectors (e.g. education, water, and health) for the limited resources. With the significant external assistance availed to Uganda during the implementation of PRSPs, per capita expenditures of social sectors remains low.

In Uganda, water services are provided at a differentiated cost depending on the location of the user. In urban areas, all piped water — sourced either directly from the dwelling or through public stand-posts, is provided at a cost. On the other hand, access to other water schemes in urban areas such as boreholes and protected springs is free of charge.³ The government provides each local government (LG) with a “District Water and Sanitation Conditional Grant” which finances either the establishment of bore holes, gravity flow schemes or latrine stances. The LGs have the leeway to decide what type of technology to employ and where to locate the water points. Communities through the water-users committees meet the cost of sourcing and acquiring the land where the service is to be located. In addition, communities must recruit and recommend for training, local artisans who can serve as repair mechanics for the water source. For minor repairs, the community utilising the monthly contribution for water usage meets the costs of the repairs. On the other hand, LGs undertake all the other major repairs, e.g. the regular over-hauling of bore holes.

Diarrhoea illness remains a big health challenge for children aged 5 years and below in Uganda. Table 2 shows the incidence of diarrhoea in Uganda based on the latest national household

³ In the rural areas, water services are free; however, communities make voluntary contributions for maintenance of water infrastructure.

survey. It is indicated that while overall incidence is 20 per 1000 per year, for children below 6 years, the incidence is more than double — 51 per 1000 per year. The table also shows that wide geographical variation in diarrhoea incidence exists with Northern Uganda accounting for a disproportionately high share of diarrhoea illness. Due to a prolonged exposure to civil war, Northern Uganda faces a number of development challenges — including accessing basic social services. Apart from the actual loss of lives, one of the other key consequences of the civil war has been the displacement of large populations into congested Internally Displaced Person's (IDP) camps. For instance, Ssewanyana *et al.* (2006) shows that while households in Northern Uganda have better access to water facilities — especially boreholes, the quantity of water used is lower compared to other areas due to congestion at water facilities.

Table 2: Uganda: Diarrhoea prevalence per 1000, 2009/10

	Region				
	All	Central	Eastern	Northern	Western
All Households	20.3	11.4	28.4	29.4	12.6
Urban	9.1	6.5	12.7	19.1	6.4
Rural	22.4	14.0	29.7	31.1	13.0
By age category					
Infants 0-5 years	51.5	34.8	64.1	70.6	35.2
Children 6-14 years	12.5	4.9	18.8	16.4	8.3
Adults 15+ years	11.1	6.0	16.2	19.6	5.2

Source: Author's calculations from 2009/10 UNHS survey

2.1 Justification for considering public stand-posts and boreholes

This paper considers two types of water technologies—boreholes and public stand-posts. It is worth pointing out that both technologies have high risks of water contamination either at the water source, during transportation or storage at home. Nonetheless, there are important reasons for focusing on the two interventions given the Ugandan context. First, historically, the two technologies have been shown to be relatively inexpensive as they can be shared by a number of households leading to lower per-capita costs compared to household connections (International Reference Centre for Community water supply, 1979). Indeed, household connections despite being subsidized require significant co-payment from households to set up the infrastructure—which payments can only be afforded by the well-to-do, given Uganda's poverty levels.⁴ Furthermore, in a country like Uganda, characterized by limited urbanization (only 15 percent of the population is resident in urban areas); it may be very costly to run pipes to all households to benefit from an in-door connection. In addition, in an un-planned urban setting, public stand-posts may be a first step before eventual in-door house connection. As such, in Uganda, establishment of public stand-posts is considered part

⁴ In 2009/10, at least 7 million Ugandans are classified as living below the poverty datum line despite the significant decrease in the incidence of poverty during the past 20 years (UBoS 2010).

of the pro-poor strategies aimed at improving the lives of people living in poor settlements in the urban areas (Ministry of Water and Environment 2011). Finally, the overall resources available for water and other social service is low in Uganda and this makes massive roll-out of in-door house connection unfeasible.⁵ Also, in-door piped water cannot be considered to most effective technology as highlighted by previous authors who show that providing piped water alone without improved sanitation can still encourage the spread of diseases (Whittington *et al.*, 2008). Consequently, public stand-posts and boreholes are a low cost alternative of providing safe water—especially if such facilities are combined with hand washing which has been demonstrated to reduce diarrhoea prevalence by as much as 48 percent (Curtis and Cairncross 2003).

On the other hand, despite the apparent similarities of boreholes and public stand-posts in terms of the risk of water contamination, the two types of water technologies are different in a number of respects including methods of access. First, public stand-posts offer significant time savings and are associated with increased water use in developing countries (Whittington *et al.* 2008). In addition, to time savings, public stand-posts are more convenient in use since they do not require hand pumping. Furthermore, boreholes do not require water treatment compared to public stand posts—which require treatment and energy for distribution to the pipe system. Finally, apart from water committee contributions, in Uganda, water from boreholes is accessed free of charge while public stand-posts charge depending on the amount of water used. As such, the two technologies have a number of differences. As earlier mentioned, the two technologies are currently the most widely used water sources in urban Uganda and as such warrant an examination with regard to effectiveness in reducing illnesses.

⁵ During 2000/1-2010/11, Uganda allocated on average 3% of the national budget to water and sanitation interventions (MFPED2011) and this partly due to the very low resource base.

3. METHODOLOGY

3.1 The Data

The study used the 2009/10 Uganda National Household Survey (UNHS) to generate demographic and epidemiological data on diarrhoea among urban children in Uganda. The survey was conducted between May 2009 and June 2010 by the Uganda Bureau of Statistics (UBoS). This survey is a multi-topic survey modelled along the lines of the World Bank's Living Standard's Measurement Surveys (LSMS). This survey is based on a two-stage simple random sampling design. In the first stage, the Enumeration Area (EA) is the principal sampling unit, and at the second stage, 10 households are randomly selected from each EA. The survey is nationally representative covering 6,800 households with 34,800 individuals of which 22 percent are children aged 5 years and below.

The health module of the survey inquires from all household members whether they were ill in the past one month prior to the survey. For individuals reporting illness, the survey captures the major illness. This particular module was used to generate the epidemiological data for diarrhoea among children in urban Uganda. At the same time, the socio-economic module captures information on household demographics (i.e. age, sex, and marital status) and socio-economic characteristics (education attainment, and household consumption). Furthermore, for individuals reporting illness and seeking health care, the survey collects cost information relating to expenditures on treatment or transportation to the health facility. The survey also captures information on the housing conditions especially relating to the source of drinking water, distance to water source as well as waiting time at the water point.

3.2 Outcome measure and cost-effectiveness analysis

Diarrhoea Prevalence: As earlier mentioned, the survey inquires about the symptoms of illness for household members who report illness over the past 30 days prior to the survey. Diarrhoea is one of the listed symptoms and we use its incidence among children aged 5 years and below as our indicator of diarrhoea prevalence.

Disability Adjusted Life Years (DALYs): We adopt the cost-effectiveness method used by Cook et al., (2008) to examine the cost effectiveness of typhoid vaccination programs in developing countries. This method is fairly standard as it has been advocated for by the global Disease Control Priorities (DCP) for Developing Countries Project as well as the World Health Organization (WHO, 2003). Specifically, the methods entails: first, the assessment of baseline burden of disease for diarrhoea to generate an aggregate of health outcome measure. The particular information relates to estimates for: cases of diarrhoea; and deaths for childhood diarrhoea. This information is used as our outcome measure — the disability-adjusted life years (DALYs) due to childhood diarrhoea. DALYs captures the (non-monetized) morbidity and

mortality from diarrhoea illness before and after the interventions. In the calculation of DALYs, we used Uganda life tables with life expectancy of 53 years (WHO, 2006). Other information, relating to the epidemiological profile of our target population was from the 2009/10 UNHS (UBoS 2010).

DALYs avoided: We estimate DALYs avoided by a child accessing our two choice interventions — public stand-posts and boreholes. This entails estimating the number of cases of diarrhoea and deaths avoided as result of the two interventions; discounting for life years over the duration of the water facilities. Following Cook *et al.* (2008), we assume a uniform discount rate of 3 percent for both water interventions. Below is an outline of how the DALYs are defined and calculated:

(1) DALYs avoided = (YLD avoided) + (YLL avoided)

Where YLD is years of life lost to disability and YLL is the years of life lost. Both these variables as well as the total DALYs avoided are calculated and defined as:

(2)
$$YLD \text{ avoided per year} = \frac{((1 - CFR) * (Effectiveness * Coverage) * N * I) * Length}{DALY_weight}$$

(3)
$$YLL \text{ avoided per year} = \left(\frac{CFR * Eff * Coverage * NI}{0.03} \right) * [1 - \exp(-0.03LE)]$$

(4)
$$\text{Total DALYs avoided} = \sum_{t=0}^{Dur} \frac{DALYs_avoided_per_year}{(1 + 0.03)}$$

Where *CFR* is the diarrhoea Case Fatality Rate (CFR), *Effectiveness* refers to the effectiveness of the water interventions in reducing diarrhoea, *Coverage* refers to proportion of children who would receive the intervention, *N* is the number of children aged 5 years and below, *I* is the incidence of diarrhoea among children; *Length* is the number of days ill with diarrhoea, and *E* is the life expectancy of Ugandans.

Costs of water interventions: We include the cost of setting up the water infrastructure. Specifically, these included the intervention costs i.e. capital costs of installing either public stand-posts or boreholes as well as the associated maintenance costs of the facility. For both public stand-posts and boreholes, we use the average per capita costs of providing different water technologies as reported in 2011 Uganda Water and Environment Sector Performance Report (Ministry of Water and Environment 2011). For the proposed water interventions, we assume that the coverage rate for public stand-posts increases by 10 percentage points (hence a new population of about 520,000 receive the intervention) while the coverage rates for boreholes increases by 12 percentage points (equivalent to a new benefiting population of about 620,000).⁶ Finally, we generate our cost-effectiveness ratios as the total cost per DALY

⁶ These assumed policy changes are based on the prevailing coverage rate of 46% for public stand-posts and 12% for boreholes in urban Uganda (UBoS, 2010).

avoided and are used to gauge which intervention is most cost-effective. Other details relating to the parameters used are provided below.

Other parameters: Other epidemiological parameters used relate to: diarrhoea incidence, the CFR, duration of illness, and DALY weight. As earlier mentioned, data on baseline diarrhoea incidence is based on the most recent 2009/10 UNHS (UBoS 2010). The estimated diarrhoea incidence is generally highest in infants-aged 5 years and below (51 cases per 1000) and ranging from 35 cases per 1000 in Central Uganda to 71 cases per 1000 in Northern Uganda (Table 2). Based on previous studies conducted in developing countries e.g. WHO (2002) and Cook et al (2008)—who examine the burden of disease due to diarrhoea, we assume CFR of 0.08 percent, with lower and upper bounds of 0.04 percent–0.12 percent for the sensitivity analysis. Similarly, for diarrhoea illness, we assume an average duration per case of 9 days, with lower and upper bounds of 2 days and 14 days respectively and we adopt a mean DALY weight of 0.27. The details and sources of the various information used in the calculations are presented in Table 3.

Table 3: Data used in the CEA for water interventions for diarrhoea (Public stand posts and boreholes)

Demographics of Study Area (Uganda)				
	Lower limit	Base	Upper limit	Source/Notes
Total population	28,162,315	31,800,000	34,351,083	2002 Census population of Uganda was 25.4 million. Based on a per annum population growth rate of 3.2%, this gives a 2010 population of 31.8. The upper and lower limits of the population growth rates are 2% and 3.5% respectively.
Population Growth Rate (% Growth per Year)		3.2%		See above
Age structure in Uganda				Calculated from the UNHS 2009/10
Children 0-1	0.071	0.071	0.071	
Children 2-3	0.073	0.073	0.073	
Children 4-5	0.074	0.074	0.074	
Children 6-14	0.2830	0.2830	0.2830	
Adults 15+	0.4990	0.4990	0.4990	
Epidemiological Information - Diarrhoea				
Overall incidence (per 1000)	10.15	20.30	40.60	From Uganda National Household Survey (UNHS) 2009/10
Incidence by age group (per 1000)				
Children aged 0-1 years	46.65	93.30	186.60	
Children 2-3 years	18.70	37.40	74.80	
Children aged 4-5 years	12.80	25.60	51.20	
Children 6-14 years	6.25	12.50	25.00	
Adults 15+	5.55	11.10	22.20	
DALY weight	0.0800	0.105	0.2700	For diarrheal disease (<u>not specific to cholera</u>). Low and high ranges are dengue and upper respiratory infections, respectively. Annex Table 5a of: Mothers CD, Bernard C, Iburg K, Inoue M, Ma Fat D, Shibuya K, Stein C, Tomijima, N (2003). The Global Burden of Disease in 2002: data sources, methods and results. Geneva, World Health Organization (GPE Discussion Paper No. 54). Online at: http://www3.who.int/whosis/discussion_papers/pdf/paper54.pdf . For general discussion of calculating QALYs: http://www.who.int/healthinfo/boddaly/en
Average duration of case (years)	0.005	0.025	0.038	Lower bound is two day, mean is nine days, upper bound is 2 weeks
Case fatality rate < 5 years (%)	0.04%	0.08%	0.12%	Revised Global Burden of Disease (GBD) Estimates (WHO, 2002). Available at http://www.who.int/healthinfo/bodgbd2002revised/en/index.html . Diarrhea CFR for Africa is about 0.08%.
Case fatality rate 5-14 years (%)	0.04%	0.08%	0.12%	
Case fatality rate > 15 years (%)	0.04%	0.08%	0.12%	
Costs and effectiveness of water interventions for diarrhoea control				
Public stand-posts - Effectiveness, Duration and Costs				
Effectiveness (Percent)	10%	30%	50%	Whittington D et al (2008).
Duration (Years)	7.5	15	19.5	Guess
Total cost per capita	\$20.00	\$40.00	\$72.00	Average per capita cost of establishing energy supported public standpipes and pro-poor water kiosks in Uganda (Based on the 2011 Water and Environment Sector performance report).
Boreholes - Effectiveness, Duration and Costs				
Effectiveness (Percent)	10%	20%	50%	Average effectiveness based on a review studies by Fewtrell et al (2005)
Duration (Years)	6	12	15.6	Guess
Total cost per capita	\$22.50	\$25.50	\$28.50	Average per capita cost of establishing boreholes in Uganda (Based on the 2011 Water and Environment Sector performance report).

Benefits of water improvements: avoided costs of illness				
Cost-of-illness: Diarrhoea				
Private COI: 0-5 yrs	\$2.00	\$6.00	\$10.00	Whittington D et al (2008).
Private COI: 6-14 yrs	\$2.00	\$6.00	\$10.00	
Private COI: >14 yrs	\$2.00	\$6.00	\$10.00	
Public COI: 0-5 yrs	\$2.50	\$7.50	\$12.50	
Public COI: 6-14 yrs	\$2.50	\$7.50	\$12.50	
Public COI: >14 yrs	\$2.50	\$7.50	\$12.50	
Other information	Lower limit	Base	Upper limit	
Discount rate for life years saved	3%	3%	3%	WHO, Global Burden of Disease Studies, NATIONAL BURDEN OF DISEASE STUDIES: A PRACTICAL GUIDE, v2.0, p.115. Online at www.who.int
Facility coverage rate - the percent of households with access to public stand-posts		46%		UNHS 2009/10
Public stand-post coverage after intervention		56%		An increase of 10 percentage points from the 2009/10 baseline
Facility coverage rate - the percent of households with access to a borehole		12%		UNHS 2009/10
Borehole coverage after intervention		24%		An increase of 12 percentage points from the 2009/10 baseline
Per capita GDP, 2010US\$		\$501		Not adjusted for PPP, from IMF's World Economic Outlook, April 2011.
Cost effectiveness threshold		\$1,503		Cost/DALY avoided < 3*mean income per capita
High cost effectiveness threshold		\$501		Cost/DALY avoided < mean income per capita (IMF, 2010)
Child diarrhoea hospitalization rate		2.75		Based on calculation from the UNHS
Adult diarrhoea hospitalization rate		1.17		Based on calculation from the UNHS
Percent enrolment in primary school		88.2		Based on Net Enrolment Rates for 2009/10 (UNHS)
Average daily wage (\$2006)		\$ 0.88		Based on the wage questionnaire of the UNHS 2005/06
Travel/time costs		\$ 0.22		Based on the median wage above

Water interventions and reduction in cost of illness: As one of the quantifiable benefits of the water interventions, we estimate the public and private costs of illness at the baseline as well as over the duration of the interventions (15 years for public stand-posts and 12 years for boreholes) to generate the cost avoided as result of reduction in diarrhoea morbidity arising from accessing either public stand-posts or boreholes.⁷ In addition, we incorporate the travel costs in estimating the private costs avoided due to illness—based on the median wage rate in Uganda.

⁷ The public and private cost of illness for treating diarrhoea—including costs of travel time are based on regional averages for Africa (Kiri-gaet *al.*, 2009).

4. RESULTS

Table 4 shows both the baseline analysis prior to interventions and the program outcomes after interventions. Baseline diarrhoea disease burden estimates are 45,698 cases per year and 36 deaths per year for residents of urban areas (estimated population is 5.2 million). The expected DALYs per year due to diarrhoea and hospitalization rates are 1,836 and 1,018 respectively while the total cost of illness is about US\$0.6 million per year. With regard to the effectiveness in reducing the burden of disease due to diarrhoea, Table 4 shows that the average net public cost per DALY is US\$ 25,672 for public stand-posts compared to US\$ 40,477 for boreholes. Consequently, we can conclude that public stand-posts are more cost effective than boreholes—if the overall objective of establishing water facilities is only to reduce the burden of disease due to diarrhoea. Similarly, the net social cost per DALY is lower for public stand-posts than boreholes (US\$ 25,551 vs. US\$40,446). Perhaps, public stand-posts have a lower cost-effectiveness ratio due to higher efficacy in controlling diarrhoea and a longer operation duration for the water facility—notwithstanding the fact that both types of water technologies have challenges with regard to water contamination at source or during transportation.

Table 4: Cost effectiveness results for the water interventions

	Base case analysis	
Population	5,125,767	
Baseline disease burden (no water intervention: Urban population children and adults)		
Expected cases of diarrhoea per year	45,698	
Expected deaths from diarrhoea per year	37	
Expected DALYs per year (Discounted)	1,838	
Expected hospitalizations per year	1,018	
Publicly borne cost of illness per year	\$342,733	
	\$274,186	
Types of interventions Considered	Public Stand-posts	Bore Holes
Population currently using the facility (based on 2009/10 coverage rates)	2,392,000	625,000
Population receiving the intervention	512,600	615,000
Program Outcomes		
Cases Avoided over duration	205,939	109,674
Deaths avoided over duration	165	45
Hospitalizations avoided over duration	9,164	4,888
YLL avoided over duration	865	590
YLD avoided over duration	160	163
DALYs avoided over duration	1,025	753
Public COI avoided over duration	\$270,600	184,600
Private COI avoided over duration	\$216,500	147,700

Total Program Cost	\$22,143,300	16,342,911
Average per capita cost for accessing water facility	\$43	27
Total travel/time costs	\$0.22	\$0.22
Net public cost	\$21,872,692	\$16,158,400
Net public cost per DALY avoided	\$25,672	\$40,477
Net social cost	\$21,768,692	\$16,146,000
Net social cost per DALY avoided	\$25,551	\$40,477
Net social cost per DALY avoided with standard age weighting*	\$7,848	\$12,588
Notes: YLLs, YLDs, and DALYs are calculated based on homogenous age-weights and discounted at 3%. Results for travel time and costs of interventions are converted to US\$ based on the market exchange rate.		

According to the Disease Control Priorities Project, for a given country, an intervention is cost effective if the cost effectiveness ratio is below the national per capita GDP (Keusch *et al.* 2006). This implies that the country can afford to meet the costs of the intervention. Based on this criteria, one can argue that both sets of water interventions are not cost effective given that the average cost per DALY averted is several times higher than the per capita GDP for Uganda—US\$ 501 in 2010 (International Monetary Fund 2011). However, some of the above interventions may not be financed by national resources; it is possible that donors can finance such large expenditures. Indeed, during 2001/2-2010/11, the share of Ugandan budget externally financed averaged 25 percent (MoFPED 2011).

Sensitivity analyses

We also conducted some sensitivity tests on the key assumptions used in the cost effectiveness analysis. First, we explore the effects of non-uniform age weights. The parameters used in this specific analysis ($\beta=0.04$) are from by global burden of disease study by Murray and Lopez (1996) reported in Cook *et al.* (2008). Our results reported at the bottom of Table 4 reveal that the cost effectiveness ratios improve. In particular, the net social cost per DALY avoided reduces to US\$7,848 for public stand-posts (from US\$ 25,551) while that for boreholes reduces to US\$12,588 (from US\$ 40,446).

We also undertake sensitivity analysis for five key parameters in our model i.e. cost of water intervention; case fatality rate; duration of water facility; incidence of diarrhoea prevalence and the efficacy of water facility in preventing diarrhoea. Specifically, we vary one parameter at time while keeping the rest constant based on lower and upper limits detailed in Table 3. In

Table 5, we present the results how the effectiveness of the water facilities varies with changes in parameters as we undertake this separately for children alone as well as when children are combined with adults. The results show that our estimates are most sensitive to the efficacy of facility in preventing diarrhoea followed by the incidence of diarrhoea prevalence. The least sensitive parameter is the duration of the water technology. The above results have major policy implications—in an environment of high water contamination rates leading to the lower efficacy rates, the technologies are not cost effective. Consequently, the implementations of the water interventions require to be accompanied by vigorous public health campaigns. As such, the cost of such complimentary factors should be given due consideration when considering the overall cost of the interventions.

Table 5: Results for sensitivity analysis for key parameters

	Cost		Case Fatality Rate		Duration		Incidence of diarrhoea		Effectiveness of intervention	
	Best	Worst	Best	Worst	Best	Worst	Best	Worst	Best	Worst
Social costs										
Net social costs/DALY Public stand posts										
Infants	\$3,699	\$13,001	\$5,275	\$11,725	\$6,008	\$9,882	\$3,393	\$15,044	\$2,725	\$8,132
All children	\$7,191	\$23,704	\$9,818	\$21,816	\$11,290	\$18,167	\$6,648	\$27,331	\$18,460	\$50,097
All children and adults	\$18,341	\$44,802	\$18,174	\$43,008	\$21,284	\$34,313	\$12,489	\$51,673	\$5,198	\$33,459
Net social costs/DALY Boreholes										
Infants	\$5,639	\$7,185	\$5,756	\$12,793	\$6,412	\$11,030	\$2,960	\$13,315	\$7,198	\$22,633
All children	\$10,634	\$13,379	\$10,671	\$23,711	\$12,067	\$210,204	\$5,890	\$24,260	\$50,156	\$151,512
All children and adults	\$18,341	\$23,099	\$18,536	\$42,139	\$20,720	\$34,931	\$10,095	\$41,693	\$22,747	\$69,350
Net Public costs/DALY Public stand posts										
Infants	\$3,878	\$13,180	\$5,405	\$12,013	\$6,193	\$10,048	\$3,591	\$15,184	\$2,939	\$8,319
All children	\$7,231	\$23,744	\$9,847	\$21,850	\$11,341	\$18,184	\$6,722	\$27,301	\$18,581	\$5,033
All children and adults	\$13,640	\$44,924	\$18,260	\$43,213	\$21,427	\$34,390	\$12,677	\$51,662	\$12,375	\$33,552
Net Public costs/ DALY Boreholes										
Infants	\$5,800	\$7,346	\$5,864	\$13,033	\$6,573	\$11,153	\$3,150	\$13,419	\$7,366	\$22,673
All children	\$10,644	\$13,888	\$10,662	\$23,690	\$12,016	\$20,146	\$5,939	\$24,169	\$49,909	\$150,307
All children and adults	\$18,399	\$23,157	\$18,550	\$42,172	\$20,778	\$34,873	\$10,244	\$41,847	\$13,539	\$69,023

Notes: This table shows the result of changing each parameter, one at a time, to its lowest and highest value

5. CONCLUSIONS AND POLICY IMPLICATIONS

The results indicate that public stand-posts are the most cost effective interventions if the goal is to reduce the burden of disease from diarrhoea among urban households in Uganda. Although the cost effectiveness ratios are above Uganda's per capita GDP, both types of water interventions can be expanded with the help of external assistance. The results for the sensitivity analysis show that the estimates are sensitive to efficacy of the water technology in preventing diarrhoea. There are several important limitations of the analysis. First, we assume that the costs of accessing water facilities are minimal. While this is the case for boreholes in Uganda, for public stand-posts, charges are levied for using the facility. In low income settings, households may elect to reduce the amount of water consumed in order to minimize user charges. Second, we do not account for the opportunity cost of time spent waiting to receive diarrhoea treatment. Furthermore, we do not address the key policy challenge of financing water interventions. As earlier noted, national spending on water interventions is only about 3 percent of the budget and attempts to only double this share would be met with resistance—since other sectors have to reduce their shares. At the same time, external financing is not sustainable in the long run while it may be very difficult to recover costs from users of boreholes—given the perception that the quality of water from boreholes is of inferior quality compared to piped water.

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