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HOUSEHOLD ENVIRONMENTAL CONDITIONS AND DISEASE PREVALENCE IN UGANDA: THE IMPACT OF ACCESS TO SAFE WATER AND IMPROVED SANITATION ON DIARRHEA

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Abstract

Although governments in sub-Saharan Africa have increasingly devoted more resources to water and sanitation interventions, many households in the sub-region still do not have access to safe water and improved sanitation. We utilize data from the 2005/06 Uganda National Household Survey to investigate the impacts of inadequate access to safe water and improved sanitation. In addition, we examine the cost effectiveness of the provision of piped water by either a household connection or community standpipes, for a hypothetical poor urban town in Uganda. We find that only piped water within the household and access to private covered pit latrines significantly impact diarrhea prevalence. In addition, we examine the cost effectiveness of the provision of piped water by either a household connection or community standpipes, for a hypothetical poor urban town in Uganda. We find that providing community standpipes results in the largest reduction in the burden of disease. Overall, our results present a targeting dilemma because although water in Uganda is publicly provided, the construction of sanitation facilities is considered a private matter. Nonetheless, either health information campaigns, conducted to persuade households to construct personal latrines, or local government ordinances making toilet construction mandatory could go a long way toward reducing the burden of disease due to diarrhea in Uganda.

Key words: Water and sanitation; Diarrhea; Uganda

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Acronyms

ADB	Africa Development Bank
DALYs	Disability Adjusted Life Years
DHS	Demographic and Health Survey
EA	Enumeration Area
GDP	Gross Domestic Product
GoU	Government of Uganda
IDP	Internally Displaced Persons
IV	Instrumental Variables
IVPROBIT	Instrumental Variables Probit
LG	Local Government
LSMS	Living Standards Measurement Survey
MDGs	Millennium Development Goals
MoH	Ministry of Health
MWE	Ministry of Water and Environment
NGOs	Non Government of Organisations
PSU	Principal Sampling Unit
SSA	Sub Saharan Africa
UBoS	Uganda Bureau of Statistics
UNDP	United Nations Development Programme
UNHS	Uganda National Household Survey
UPE	Universal Primary Education
VIF	Variance Inflation Factor
VIP	Ventilated Improved Pit latrines
WHO	World Health Organisation
WSIP	Water Sector Investment Plan
YLD	Years of Life due to Disability
YLL	Years of Life Lost

1. Introduction/Background

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 and sanitation interventions. However, many households in the sub-region still do not have access to safe drinking water and improved sanitation. According to the 2006 Human Development Report, only 55 % of households in SSA have access to safe water, and 36 % of the households have access to improved sanitation (UNDP, 2006). Policy makers and researchers are increasingly concerned with the effects of such poor household environmental conditions, particularly those on human development outcomes such as health, education, and poverty. On the health front, the lack of access to safe water and sanitation is associated with increasing incidences of water-borne diseases—particularly diarrhea. According to the World Health Organization (WHO), diarrhea accounts for about 4 % 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 diarrhea is five times higher in children aged 5 years and below compared to the rest of the population (WHO, 2006).

In tandem with the focus in the developing world on human development outcomes, under the auspices of the Millennium Development Goals (MDGs), and with the support of multilateral agencies, 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$ 20.6 million in 2000/2001 to US$ 69.3 million in 2006/7—a sizable change from 1.3 to 3.3 % of the national budget (GoU, 2007b). Notwithstanding the enlargement of public resources available for water, the sector remains grossly underfunded in comparison to other social sectors such as education, which had a budget of US$ 412 million in 2006/7. Nonetheless, under the current Water Sector Investment 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 (Okidi, *et al*. 2002).

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* *0*
(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)

Although household access to safe water and improved sanitation has improved over time, especially after the 1990s, overall coverage rates remain inequitable. For example, although the proportion of households with access to safe water increased from 51 % in 1999/00 to 58 % by 2005/06, the coverage rates favored households at the top end of the welfare distribution. The inequities are more pronounced when access to improved sanitation is considered. For example, in 1999/2000, the proportion of the bottom quintile with access to an improved sanitation source was only 47 %, while that of the top quintile was about twice that at 85 % (GoU, 2007a). Overall, the official projection is that the country remains on course to meet the WSIP target of providing at least 77 % of the population access to safe water by 2015 (GoU, 2006b; World Water Assessment Program, 2006). Notwithstanding the increase in water sector investments in Uganda, there is little information on how the various water and sanitation technologies impact the prevalence of water-borne diseases in Uganda, due to paucity of the data. This is partly explained by the limited incorporation of monitoring and evaluation components into the design of interventions and is also due to the multiplicity of institutions handling water and sanitation issues in Uganda. For example, the benefits of improved sanitation are mainly reflected in the improved health status of the population, whose evaluation mandate falls under the Ministry of Health (MoH) and not under the parent Ministry of Water and Environment (MWE).

This study examines the impact of access to improved water and sanitation on diarrhea prevalence and the potential gains from undertaking various interventions. First, we estimate instrumental variables (IV) probit models for determinants of diarrhea morbidity and include various water and sanitation sources as independent variables. We find that access to the following facilities reduces diarrhea prevalence: having piped water within the dwelling, and having access to a private covered pit latrine. In addition, we examine the cost effectiveness of the provision of piped water by either a household connection or community standpipes, for a hypothetical poor urban town in Uganda. We find that providing community standpipes results in the largest payoff (in terms of the least cost per DALY averted).

A unique characteristic of the present study, in comparison to previous studies analyzing the impacts of water related investments on health in Uganda (e.g. Davis *et al.*, 2001 and Tumwine *et al.*, 2002), is the availability of a nationally representative household survey that captures information on ill health as well as on associated treatment expenditures over a 30-day recall period. We use the 2005/06 Uganda National Household Survey (UNHS). In terms of size, we have individual and household information on 8,882 children aged below 5 years. The UNHS survey collected information on household demographics and household access to safe water and sanitation. The survey also captures unique information that deals with the household's environmental situation, such as the household's distance from a water source, its travel and waiting time at the water source, and whether it has a separate room for the kitchen.

The paper is structured as follows. The next section describes the economic and political context in Uganda. Section 3 reviews the literature pertaining to the impacts of water and sanitation infrastructure on the health outcomes of children in developing countries. The dataset, econometric approach, and estimation issues addressed are discussed in Section 4. Section 5 provides the main results of the study, and Section 6 presents the conclusions and implications of the study.

2. The Ugandan Context

Uganda is located in East Africa, bordering Kenya to the east, Tanzania to the south, and the Democratic Republic of Congo and Rwanda to the west. In 2007, the country's estimated population was 28.2 million people, with 85 % of the population residing in rural areas (GoU, 2007b). Furthermore, Uganda is one of the poorest countries in the SSA, with an annual per capita gross domestic product (GDP) of US$

360 in 2007 (GoU, 2008). Nonetheless, the country has made significant progress in reducing income poverty, especially during the implementation of economic reforms. The national headcount poverty index reduced from 56 % in 1992/93 to 31 % by 2005/06; it was only during the period 1999/00 to 2002/03 that the country witnessed a reversal in poverty reduction (UBoS, 2007).

Apart from income poverty, the country has made noteworthy improvements in human capital outcomes, especially in education. For example, the primary school net enrollment rate increased from 52 to 85 % between 1992/93 and 1999/2000 as a result of the implementation of the Universal Primary Education (UPE) program. With regard to health outcomes, performance has been mixed. While the country managed to reduce the HIV/AIDS prevalence from 30 % at the beginning of the 1990s to 6 % by 2005 (GoU, 2006a), other indicators, particularly those relating to child mortality, have stagnated. For example, the infant mortality rate only marginally changed between 1995 and 2005—from 85 to 75 births per 1000 live births (UBoS, and Macro International, 2007).

In Uganda, water services are provided at a differentiated cost depending on the location of the user. In urban areas, all piped water, accessed either directly from the dwelling or through public standpipes, 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. In the rural areas, although all of the water services are free, communities make voluntary contributions for the maintenance of the water infrastructure. Furthermore, most of the water infrastructure in rural areas is provided under a public-private arrangement. The government provides each local government (LG) with a "District Water and Sanitation Conditional Grant," which finances either the establishment of boreholes, gravity flow schemes or latrine stances. The LGs have the freedom to decide what type of technology to employ and where to place the water points. Communities meet the cost of sourcing and acquiring the land where the service is to be located through the water users' committees. 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 utilizing 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 overhauling of boreholes.

Whereas the public provision of water services is geographically well distributed, the provision of latrine stances is restricted to public areas such as schools, hospitals, markets, and community centers.

Of Uganda's four geographical regions, Northern Uganda faces considerable challenges in accessing social services, and these inadvertently impact its human development outcomes. Since 1986, the region has been engulfed in a climate of civil war, and the war has in turn defined the availability and type of social services that can be provided in the region. Apart from the actual loss of lives, one of the other key consequences of the war has been the displacement of large populations into what are known as internally displaced persons (IDP) camps. Apart from the IDPs, the region is also home to nomadic pastoralists in the *Karamoja* sub-region who also practice cattle rustling. Consequently, due to the above conflict environment, households in Northern Uganda have the worst human development indicators, including indicators regarding access to water and sanitation services.

In summary, although expenditures on water related-interventions have increased since 2000, challenges remain. First, the earmarked funds are not adequate; as a result, interventions relating to the sanitation sub-sector have received minimal attention. Furthermore, interventions by other parties such as non governmental organization (NGOs) are not only few and thinly spread, but are also undertaken in an ad hoc manner. Second, providing services to a large population of displaced and nomadic people in Northern Uganda will for some time determine the national water and sanitation indicators. Third, limited attention is placed on preventing diarrhea diseases compared to the treatment of diarrhea. In the next section, we review the literature on the relationships between water and sanitation sources and diarrhea prevalence as well as overall childhood health status.

3. Literature Review

A number of studies have examined the effects of water and sanitation investments in developing countries on health status, poverty, and other human development outcomes. Examples of empirical studies in the recent past include Lee *et al*. (1997); Newman *et al*. (2002); Smith and Hanson (2003); Jalan and Ravallion (2003); Abou-

Ali (2003); Galiani et al. (2005); Kremer *et al*. (2006); Fuentes *et al*. (2006a, 2006b); and Gamper-Rabindran *et al.* (2009). Other studies such as Fewtrell *et al*. (2005) provide a recent review of the effects of environmental conditions on specific illnesses, notably diarrhea.[1] The main focus for most of the above studies is on the effect of access to water on three health outcomes—disease prevalence, child mortality, and malnutrition. Evidence from developed countries, particularly the United States (US), shows major health benefits from improved water and sanitation infrastructure. Cutler and Miller (2005), using historical data to study the adoption of water treatment by US cities, find that the provision of clean water was key to the observed declines in child mortality.

Although a few studies find no impact of water and sanitation investments on health outcomes, the majority find strong and significant effects. The study by Lee *et al*. (1997), based on survey data from Bangladesh and Philippines, is among the few that find no effect of water on child survival and nutrition. On the contrary, Jalan and Ravallion (2003), based on data from India and using two measures of health status—diarrhea prevalence and length of reported illness—find that having piped water in the household is associated with a 21.3 % reduction in the prevalence of diarrhea among rural households. Furthermore, the authors find that piped water is associated with a 29.4 % reduction in the length of illness. Galiani *et al*. (2005) also finds strong effects of water for Argentina; here, having a water connection is associated with a 6.7 % reduction in child mortality. On the other hand, Gamper-Rabindran *et al*. (2009), using panel data and a quantile regression approach for Brazil, find that the impact of piped water on infant mortality differ by socioeconomic status; expanding piped water benefits most children residing in areas with very high rates of child mortality.

Apart from water and sanitation infrastructure, individual hygiene behavior, point-of-use water treatment, and child care have been identified as important for reducing diarrhea prevalence. Individuals' hygiene behavior, especially frequent hand washing, which disrupts pathogen transmission, has also been shown to have a significant influence on reduction in diarrhea prevalence (Luby *et al*. 2004). Point-of-use water treatment is another behavioral strategy considered important for diarrhea reduction.

[1] The various environmental interventions considered include: hygiene, sanitation, water supply, water quality and a combination of any of the four stated interventions.

For example, in a study on Zambia, Quick *et al*. (1999) find a significant effect of point-of-use water treatment on diarrhea incidence, with reductions ranging between 20-30 %.

Due to the problems of establishing causal treatment effects, experimental studies that control for unobserved heterogeneity have been used to study the impact of water and sanitation infrastructure on diarrhea incidence. (See, e. g., Kremer *et al.*, 2006; Aziz *et al*. 1990; Clasen *et al*. 2004; and Newman *et al*. 2002.) For example, Newman *et al*. (2002) evaluate the impact of water supply investments as part of the Bolivian Social Insurance Fund in two rural areas of the country. Using a matched comparison design of beneficiaries and non-beneficiaries of water projects and applying the difference-in-difference method, the authors find that water supply investments were associated with a 42 % drop in child mortality rates. Although randomized experiments have a superior sample selection strategy (by effectively controlling for unobserved determinants of access to water sources), they are expensive to undertake, due to the requirement of surveying the same households more than once. Apart from experimental designs and matching methods, other methods such as contingent valuation methods have been used to investigate the impact of access to water on child health. Examples of the latter approach include the study by Abou-Ali (2003), which examines the impact of access to water on child mortality in Egypt.

Due to SSA's large water-borne disease burden, a number of studies have investigated the impact of water and sanitation infrastructure investment on children's health in the subregion (See, e.g., Kremer *et al.*, 2006; Ashraf *et al.*, 2008; Quick *et al.*, 2002; Fuentes *et al.*, 2006a, 2006b).[2] In a study investigating the effects of water source protection in Kenya, Kremer *et al.* (2006) find mixed results. In particular, although the water-spring protection is associated with an improvement in household water quality, it has no significant impact on diarrhea prevalence among children. On the other hand, Fuentes *et al*. (2006a), using the Demographic and Health Survey (DHS) database, find that that water and sanitation infrastructure have significant impacts on

[2] A number of studies have examined the impacts of water sources on diarrhea prevalence in Uganda; however, they have mainly done so in a cross-country setting (see, e.g., Esrey *et al*. 1985; Sharma *et al*. 1996; Whittington *et al*. 2001; and Tumwine *et al*. 2002).

child health. Specifically, having an improved sanitation source, especially a flush toilet, is associated with a 30 % reduction in child mortality.

Notwithstanding the wealth of studies on water and sanitation on child health in SSA, we examine related issues, though we do so in a different way. We focus on diarrhea illness among young children in Uganda.[3] Fuentes *et al*. (2006b) is the work most closely related to this study, but we incorporate a number of improvements. First, unlike the above study, we investigate whether important determinants of child health such as income are endogenous. The study by Fuentes *et al*. (2006b) only estimates a logistic regression for the determinants of diarrhea prevalence without examining the suitability of the variables used. Indeed, studies such as Haddad *et al*. (2003) show that income is endogenous in child health regressions. We test for the endogeneity of income and estimate IV probit regression to account for the potential bias of income. Second, we account for the distance to water facilities in our estimation. As we explain later, distances and associated travel times can affect the quality and volume of the water collected. Finally, we examine the policy implications of our findings through the analysis of the cost effectiveness of the two water interventions.

4. Method of analysis

4.1 The Data

As mentioned earlier, we use the 2005/2006 Uganda National Household Survey dataset collected by the Uganda Bureau of Statistics. This survey, modeled along the lines of the World Bank's Living Standards Measurement Surveys (LSMS), was intended to track changes in the welfare status of Ugandans. The survey is nationally representative, covering 7,426 households with 41,211 regular household members. Furthermore, the 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.

In addition to the socioeconomic module, the 2005/06 surveys also contain a community as well as an agricultural module. The socioeconomic module captures

[3] We focus exclusively on children under five years old, since this age category suffers a disproportionate share of the burden due to diarrhea. According to the WHO, children less than 5 years old account for 90 % of the 2.2 million annual deaths due to diarrhea (WHO, 2006).

information on household demographics (i.e., age, sex, marital status, and position within the household), socioeconomic characteristics (educational attainment, household consumption, and access to communication facilities such as bicycles and mobile phones). Also, this particular section of the survey inquires whether an individual suffered illness or injury during the month prior to the survey interview. 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 data on housing conditions, especially those relating to the tenure status of the household, the structure of wall, floor, and roof; the source of drinking water, distance to the water source as well as the amount of time spent waiting at the water point; the type of toilet facility used; the method of waste/garbage disposal; and whether a household has a separate room/facility for cooking. On the other hand, the community module captures the availability of and access to social services in the locality. In the analysis, we match the individual child characteristics to the characteristics of the household and community in which the child resides. The data for the cost-effectiveness analysis and the sources are described in section 5.4. In the next sub-sub-section, we describe the empirical strategy adopted, while section 4.3 provides the particular survey variables we use and the justification for their selection.

4.2 Econometric Approach

We use the probit model in order to estimate the relation between the prevalence of child diarrhea and the access to improved water and sanitation, including background variables such as household consumption, education, and location variables. Some variables in such a relationship may not be exogenous. For example, piped water may only be available in affluent areas, and indicators of household welfare status may be endogenous to the diarrhea regression. Related, while the lack of an improved water or sanitation source may lead to diarrhea illness, it is also conceivable that exposure to diarrhea may force households to adopt particular preventive measures such as investing in either improved water or sanitation sources, leading to concerns of simultaneity bias.

Given the possibility of such an environment, comparing the effect of access to water and access to sanitation facilities on diarrhea is difficult because any observed differences could be due to the access to particular facilities or to factors that affect the child's household location. If the factors that influence a child's household characteristics also directly affect the child's health, then any observed differences in diarrhea prevalence between households with water and sanitation facilities and those without may be partly explained by unobserved differences between children rather than the access to improved water and sanitation; this may thus bias results. In order to deal with this potential bias, we adopt the IV approach as mentioned earlier. In particular, we estimate the following model:

$$D_{ij} = X_j\beta + Y_j\alpha + \varepsilon_{ij}, \qquad (1)$$

where D_{ij} is the prevalence of diarrhea by child i from household j, X are exogenous factors determining diarrhea prevalence, including household access to a particular water or sanitation facility, Y are other explanatory variables that may be endogenous, such as household consumption, and ε_{ij} is the error term. To account for the possibility that the Xs may be simultaneously determined with the dependent variable (D), we adopt the instrumental variables approach. In particular, we estimate the following model:

$$Y_j = X_j\beta_2 + Z_{ij}\varphi + \lambda, \qquad (2)$$

where Z represents instrumental variables that are correlated with the income (Y) but uncorrelated with the diarrhea prevalence (D).

In the literature examining the determinants of child health, wages and household assets are usually used to measure income (Attanasio *et al.*, 2004; Haddad *et al.*, 2003). Although the survey captures information on household wages, only one third of households have at least one member with wage information; consequently, this particular variable is not used as an instrument. Based on the assumption that household assets are acquired over a sufficiently long duration and as such can be reasonably assumed not to be correlated with diarrhea illness, we adopt the value of household assets as our preferred instrument. In particular, we use the value of household land holdings and non-land assets as our instrument for household income/consumption. In the literature for land, household land holdings, measured in acres or hectares, are used as the preferred instrument. However, our analysis revealed that this particular indicator was poorly correlated with income. This is because land values depend heavily with the location of the land; as such, the volume of land is a poor proxy of its value. For example, 10 acres in a rural area may not be worth half an acre in an urban area. Consequently, we use household land value as the instrument instead of land volume.[4]

We also use non-land asset holdings, including livestock, furniture, household appliances, electronic equipment, jewelry and watches, mobile phones and transportation equipment (i.e., bicycles, motor cycles, or cars). In particular, we use the per capita value of household non-land asset holdings as our second instrument.[5] Since our dependent variable is binary, we estimate the instrumental variables probit regression using the IVPROBIT routine in STATA 10. In addition to the IVPROBIT models, we also undertake marginal IVPROBIT estimation to aid in the interpretation of the impacts of covariates on diarrhea prevalence. In particular, the marginal effects measure the impact of change in the regressor at the mean on diarrhea prevalence. The tests undertaken to establish the validity of the instruments are described in section 5.2, while other estimation issues we deal with are explained in section 4.4.[6]

4.3 Variables Included in the Analysis

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

[4] For each parcel of land owned by the household, the survey gathers the value of the land, including the investments on the land, and this is used to generate an indicator of the total value of household land holdings.

[5] This differs from the first instrument given the fact that about 25% of the households do not have land-based assets (mainly those who rent their homes) and as such have zero land ownership. However, all households have non-land-based assets.

[6] We do not claim to account for all potential endogeneity in our sample. For example, it is possible that every child who contracts diarrhea contributes to the contamination of the community in which he or she resides, further increasing the chance that other children will contract the same disease. This particular example would present a public good or environmental externality aspect to the health of children. Nonetheless, due to data limitations, we are unable to pursue this line of inquiry further.

Demographics: In order to capture household demographic composition, the following household characteristics were considered: sex, age in years, the gender of the household head, and the proportion of females among adults in the household.[7] The age of a child can account for the extent of the vulnerability of a child's immune system, given that children's susceptibility to illness reduces with age. Finally, the gender variables not only account for possible discrimination against the female child with regard to access to health care but also capture the availability of mature female caretakers in the household—as caregiving for children and the sick is predominantly undertaken by women.

Socioeconomic characteristics: In line with other studies analyzing socio-behavioral outcomes in developing countries, consumption expenditure is used as the household welfare measure. Although the survey captures both income and consumption, consumption expenditures were preferred due to being more stable than income, which fluctuates from year to year. In addition, with Uganda being a predominantly agricultural country, the likelihood of understating income was high. Thus, consumption expenditures adjusted for intra-household inequalities (household age and composition effects) using adult equivalence scales are our measure of household socioeconomic status. Other socioeconomic characteristics used relate to the highest female education of the household. Apart from representing the accumulated human capital of the household, the education variables may also signal a household's ability to receive and process health-related information.

Household environmental conditions: In order to capture the atmosphere faced by the child, we considered a number of variables related to the housing conditions of the child. These included whether the household has a separate room/facility for the kitchen. Apart from partially signaling the welfare status of the household, most of the above variables indicate the level of cleanliness one should expect in a dwelling. With regard to access to drinking water, the following sources were considered: piped water, boreholes, protected springs, unprotected springs, and open water sources (streams,

[7] We also experimented with the age and marital status of the household head as well as the number of children within the household, but we found these two particular variables to be highly correlated with other household level indicators; consequently, they do not feature in our estimations.

rivers, and lakes). For the toilet facility used, we considered flush toilets, private covered Ventilated Improved Pit (VIP) latrines, shared covered VIP latrines[8], uncovered pit latrines[9], and the use of the bush. Due to data limitations, we only focus on household access to particular water and sanitation facilities and not on the quality of services provided by the identified facilities.

Community/Village level variables: We account for the community access to key infrastructure utilizing the following variables: having a primary school in the locality, and having either a general consumer goods or product market in the village. Table 2 provides the means of the variables used in the study for children suffering from diarrhea and children who are not.

[8] Sharing of a pit latrine refers to a household using a latrine in conjunction with one or more other households.

[9] In the surveys, an uncovered pit latrine refers to a makeshift latrine structure that lacks a wall or a roof.

Table 2: Means of the variables used (%)

	Combined Sample	Children suffering from diarrhoea	Other children
Variable			
Demographic			
Age of the child (months)	34.4	28.6	38.5
Child is female	0.506	0.502	0.506
Household Head is female	0.195	0.198	0.195
Share of female adults in the household	0.306	0.302	0.307
Household			
Highest female Educaion (years)	4.5	4.7	5.6
Incidence of Poverty (PO) %	0.332	0.439	0.324
Consumption per adult equivalent (Ushs)	35,421	29,206	35,867
Household has a kictchen for cooking	0.568	0.540	0.571
Value of household land owned (Ushs)	2,684,383	1,203,281	2,790,494
Value of household non-land assets (Ushs)	5,813,303	3,233,111	5,998,468
Community			
Community with a primary school	0.473	0.403	0.478
Community with a consumption goods market	0.573	0.513	0.577
Community with a product goods market	0.207	0.137	0.212
Location			
Urban area	0.135	0.104	0.137
Rural area	0.865	0.896	0.863
Central Uganda	0.278	0.133	0.288
Eastern Uganda	0.268	0.359	0.262
Northern Uganda	0.213	0.342	0.204
Western Uganda	0.241	0.166	0.246
Water and Sanitation			
Household has access to an improved water source	0.556	0.602	0.553
Household has access to an improved sanitation source	0.472	0.370	0.479
Household uses piped water for drinking	0.125	0.068	0.129
Household uses water from bore holes for drinking	0.272	0.358	0.266
Household uses water from protected springs	0.179	0.170	0.179
Household uses water from unprotected spring	0.145	0.122	0.147
Household uses a covered pit latrine	0.445	0.342	0.453
Household uses a shared covered pit latrine	0.291	0.344	0.287
Household uses an uncovered pit latrine	0.131	0.135	0.131
Household uses the bush as the toilet	0.100	0.141	0.097
Household uses a flush toilet	0.006	0.001	0.006
Number of observations	8,820	592	8,290

Source: Author's calculations from the 2005/06 UNHS surveys

4.4 Other Estimation Issues

Previous studies investigating the impact of water and sanitation intervention on diarrhea prevalence (e.g., Kremer *et al*. 2006; Jalan and Ravallion, 2003) point to a number of problems in the regression estimation of the determinants of diarrhea morbidity. These include: omitted variable bias, simultaneity bias, and sample selection bias. Below, we discuss how we addressed the above problems during estimation.

Omitted variable bias arises from the fact that it is not possible to capture all of the factors that affect diarrhea prevalence utilizing the regular household surveys. For example, the frequency of hand washing, a key hygienic behavior, is rarely captured in multipurpose surveys. If such omitted variables are correlated with observed independent variables, then the estimated coefficients could be biased upwards or downwards depending on the sign of the correlation. One possible solution to minimize omitted variable bias is to include as many household environment variables as possible. In this study, we include a number of variables relating to the structure of the home and demographic variables that may indicate congestion within the household. However, the use of more household-level variable can bring about the problem of multicollinearity. We test for the presence of multicollinearity using the variance inflation factor (VIF) method and drop variables such as the household roof and wall structure and availability of secondary school in the community—these are highly correlated with water and sanitation sources. Furthermore, we have a sufficiently large sample (8,882 children), which limits the extent of multicollinearity as a problem in our estimations.

At the same time, non-random placement or sample selection bias is highly unlikely to occur in the present case, given the nature of the survey design. In particular, the principal sampling unit (PSU) is the enumeration area (EA) and not the household or the individual. According to UBoS, all of the selected EAs were enumerated and as such there is no attrition at the level of PSU (UBoS, 2007). Furthermore, each of the 10 randomly selected households in each EA is visited at least twice (in order to complete the consumption module); this minimizes non-response at the household level. Also, all the estimated models are weighted using the sampling weights to take into account the survey sampling design. Finally, in order to control for heteroskedasticity, our regressions are estimated using robust consistent stand errors.

5. Research findings

5.1 Descriptive Results

As a precursor to our regression analysis, we present descriptive results relating to the type of water and sanitation facilities used by households in Uganda as well as the prevalence of diarrhea.

Types of water sources used. Panel A of Table 3 shows the main sources of drinking water for households; boreholes emerge as the most predominant source. At least 30 % of households in 2005/06 indicate boreholes as the main source of drinking water; these are predominantly in rural areas. On the other hand, piped water is mainly used in urban areas, with at least 56 % of urban households using tap water. Furthermore, at the regional level, the use of tap water is highest in central Uganda (24 %), followed by Western Uganda (15 %). Also worth noting is that fact that at least 6 % of households in rural Uganda have tap water. The use of unsafe water sources, i.e., unprotected springs/wells and opens water sources (streams, rivers, lakes etc), is most common in Western and Central Uganda (42 % and 30 %, respectively). The variation in the use of such unsafe sources may be partly explained by the diverse topography of Uganda's regions. Indeed, in mountainous areas and areas close to rivers and lakes, households close to such sources may ultimately use them regardless of the quality of water.

Table 3: Uganda household characteristics for water, sanitation, and diarrhea (2005/06)

	All households	Location		Region			
		Rural	Urban	Central	Eastern	Northern	Western
(A)	Source of household water (%)						
Tap water	15.1	6.4	56.2	24.7	8.8	7.0	15.0
Bore Hole	30.0	33.8	12.2	16.5	50.0	51.2	12.0
Protected well/spring	21.3	22.0	17.6	21.4	21.0	16.1	25.4
Unprotected well/spring	19.0	22.0	4.7	17.5	12.0	19.8	26.6
Rivers,steams, lakes,and ponds	9.8	11.6	1.7	12.0	5.1	4.4	15.7
Other sources*	4.9	4.2	7.8	7.9	3.0	1.5	5.3
Total	*100*	*100*	*100*	*100*	*100*	*100*	*100*
(B)	Average distance to water source (kilometers)						
Tap water	1.12	1.90	0.70	0.63	0.93	1.12	2.23
Bore Hole	3.22	3.33	1.85	4.20	3.33	2.45	3.68
Protected well/spring	3.41	3.60	2.27	3.05	3.08	3.05	4.23
Unprotected well/spring	4.04	4.10	2.86	4.69	3.64	2.94	4.32
Rivers,steams, lakes,and ponds	3.95	3.99	2.54	3.72	3.91	3.09	4.37
Other sources*	2.53	2.79	1.86	1.86	1.89	2.93	4.03
Average distance for all categories	3.14	3.52	1.34	2.91	3.09	2.58	3.90
(C)	Average queueing time at the water source (minutes)						
Tap water	12.7	20.6	8.5	5.7	10.6	35.2	20.1
Bore Hole	49.4	49.7	46.8	32.7	42.5	71.0	33.1
Protected well/spring	24.4	24.0	26.6	20.9	18.7	42.8	23.4
Unprotected well/spring	11.3	10.7	25.2	6.8	13.0	23.8	7.1
Rivers,steams, lakes,and ponds	4.7	4.6	8.3	3.0	2.4	7.6	6.4
Other sources*	12.3	13.9	8.1	5.0	11.3	56.9	16.5
Average time for all categories	25.2	26.9	17.1	13.2	28.2	51.6	16.7
(D)	Sources of household sanitation (%)						
Covered pit latrine private	40.8	44.3	24.0	39.2	37.8	20.5	61.4
Coverd pit latrine shared	33.2	27.6	59.5	35.9	24.1	49.0	25.6
Uncovered pit latrine	11.9	13.9	2.6	14.2	19.6	6.1	6.5
Bush	9.7	11.4	1.8	3.5	15.1	20.7	4.0
Other sources**	4.4	2.8	12.0	7.2	3.4	3.7	2.5
Total	*100*	*100*	*100*	*100*	*100*	*100*	*100*
(E)	Occurrence of diarrhea among children aged below 5 years (%)						
All	6.7			3.2	8.9	10.7	4.6
Rural	6.9			3.1	8.8	11.2	4.7
Urban	5.1			3.4	10.5	7.6	2.9
Number of households	*7,426*	*5,727*	*1,699*	*2,100*	*1,932*	*1,624*	*1,770*

Source: Authors's calculations from 2005/06 UNHS
Notes: *Other sources contain: vendor/tanker truck, gravity flow schemes and rain water
Other sources** contain: VIP latrines (both private and shared) and Flush toilets (both private and shared)

Distance to and waiting time at water source. Panel B of Table 3 shows the average distance in kilometers (km) by water source, and it is indicated that on average Ugandan households are 3.1 km away from their main source of drinking water. Unprotected springs/wells and open sources are the most distant sources (about 4 km). This fact combined with previous results suggests that for households that use these unsafe water sources, they may in fact be the only sources available. A picture different from what was previously observed emerges when distances by regions are considered. Households in western Uganda travel the greatest distance to collect drinking water. Indeed, the average distances are more than 4 km for four out of the six water sources considered in the region. Among households utilizing boreholes, those in northern Uganda exhibit the shortest distances (2.4 km). However, as we show later, the above scenario may not confer significant advantages in terms of either cost/time savings in water collection or health benefits as compared to households in other regions.

Even when a water source is within a reasonable distance, households may face other costs in terms of longer durations spent waiting to collect water, depending on the population in the area and the type of water technology. Panel C considers the average waiting time by water source (these particular durations do not include travel times to and from the source). On average, households report spending 25 minutes waiting to collect water (27 minutes in rural areas and 17 minutes in urban areas). Based on the water source, the highest average waiting time was estimated for households using boreholes—about 49 minutes. More importantly, there are no significant differences in waiting time at boreholes between rural and urban areas; this suggests that boreholes are heavily congested places regardless of spatial location. Also worth noting is the fact that waiting times are lowest at open water sources, on average amounting to only about 5 minutes. The above result and the relatively higher waiting time at other water sources implies that open water sources may be the preferred choice, particularly in areas where they co-exist with other alternative water sources.

Although households in Northern Uganda are closer to most water sources, especially boreholes, they face the longest queues at the water points. In particular, the average time spent at a borehole in the region is over an hour, while it takes 43 minutes on average to wait for water from a protected spring/well. Even when the source is a public standpipe, the waiting times in northern Uganda are considerably much higher compared to the rest country—36 minutes, which is one and half times the average for western Uganda, three times the average for eastern Uganda and 6 times the average for central Uganda. The above results may be partly explained by the residence of a large population in northern Uganda at internally displaced person (IDP) camps as a result of the civil war (Ssewanyana *et al*., 2006).

Types of sanitation infrastructure used. Panel D examines the main source of sanitation facility used by the household.[10] The majority of households use covered pit latrines that are private (41 %), followed by covered pit latrines that are shared (33 %). The phenomenon of sharing latrines is most common in urban areas where at least 65 % of households share sanitation facilities with other households compared to only 29 % in rural households. This may be partly explained by the household tenure status of most urban households—at least 60 % of urban households are tenants compared to less than 10 % for rural households. Also worth noting is the fact that about 10 % of households in Uganda use the bush as the method of disposing human excrement. The highest rate of using this particular method is found for northern Uganda and, to a lesser extent, in Eastern Uganda. Overall, the covered pit latrine remains the most prominent sanitation facility in Uganda.

Incidence of diarrhea among children. Childhood diarrhea is concentrated in the poorest regions of Uganda. Panel E of Table 3 shows that eastern and northern Uganda have the highest diarrhea prevalence rates among children—8.9 % and 10.7 %, respectively. A number of reasons can be advanced to explain the dire situation observed in northern and eastern Uganda with regard to diarrhea. First, the two regions are the poorest in the country. In 2005/06, the head count indices for poverty in northern and eastern Uganda were 61 % and 36 %, respectively while the corresponding rates for central and western Uganda were 16 % and 21 %, respectively.[11] As noted earlier, specific to northern Uganda, the above results may be explained by the prolonged civil war and the associated displacement into IDP camps. IDP camps are congested places and are consequently a fertile ground for breeding and transmitting diseases (Ssewanyana *et al*., 2006).

[10] Similar to the consideration for access to water sources, the question regarding the type of toilet facility used in the surveys does not take into account the actual ownership of the structure.

[11] The incidence of diarrhea in Uganda has been on the increase, and the poorest households are the most afflicted by the disease. For example, between 1999/2000, and 2005/06, the diarrhea prevalence among children aged 5 years and below increased from 4.7 % to 6.7 %. The increase may be partly explained by the increase in cholera outbreaks observed in Uganda; cholera is one of the main diseases associated with diarrhea. Indeed, according to the Ministry of Health Annual Health Performance Report (2006), Uganda experienced severe cholera outbreaks in 2005. Other reports such as Griffith *et al*. (2006) also show that parts of northern Uganda and western Uganda, especially those bordering the Democratic Republic of Congo, have witnessed a high frequency of cholera outbreaks over the 1995-2000 period.

5.2 Specification Test Results

We tested to establish whether our choice of instruments was valid and whether it also passed the overidentification tests (Table 4). The instruments were highly predictive of household income (e.g., the *F*-statistic of 359.6 in the first stage). These instruments also passed the test of overidentification in all models (i.e., the null hypothesis using chi-square tests were rejected in each case). Furthermore, the explanatory power of the first-stage regression was high, (adjusted-$R2$ of 0.39) but was not reported in the table. A Wu-Hausman test of the exogeneity of household consumption in the first-part model showed that household consumption was endogenous to children contracting diarrhea. Accordingly, we report instrumental variable results for all models.

Table 4: Strength of the instruments and tests of the exclusion restriction and exogeneity of income

Dependent variable	Strength of the instruments	Test of exclusion restriction	Wu-Hausman F- exogeneity test--regression form
Household having access to piped water	F(17,8864)=359.60***	X22=2.257(p-value=0.133)	F(1,8864)=7.52***
Household having access to Bore Hole	F(17,8864)=330.54***	X22=2.296(p-value=0.129)	F(1,8864)=8.51***
Household having access to a protected spring	F(17,8864)=327.25***	X22=2.308(p-value=0.129)	F(1,8864)=8.08***
Household having access to an improved water source	F(17,8864)=327.38**	X22=2.257(p-value=0.133)	F(1,8864)=7.93***
Household having access to covered private pit latrine	F(17,8864)=326.36***	X22=1.751(p-value=0.186)	F(1,8864)=6.36**
Household having access to covered shared pit latrine	F(17,8864)=333.43***	X22=1.595(p-value=0.207)	F(1,8864)=6.91***
Household having access to VIP pit latrine	F(17,8864)=330.44**	X22=2.109(p-value=0.147)	F(1,8864)=7.64***
Household having access to an improved sanitation source	F(17,8864)=344.43***	X22=2.297(p-value=0.129)	F(1,8864)=8.11**

Notes: *Significant at the 10 percent level. **Significant at the 5 percent level. ***Significant at the 1 percent level and X22 is the respective Chi-square statistic.

5.3 Regression Results

The upper panel of Table 5 reports the results from the IV regressions. Results from the piped water regression are in column 1, while those from the interaction of piped water with travel time are in column 2. The other columns show regression results for boreholes, protected spring, and access to an improved water source. All regressions include controls for the child (age, age squared, and gender) and household (gender of the head, the share of female adults in the household, the highest female education attained in the household, having a separate kitchen for cooking and location variable). In the following discussion, we focus exclusively on either water or sanitation variables, the main interest of this study. The interpretation of the coefficients is as follows: the coefficient of either access to water or sanitation captures the impact of household environmental conditions on diarrhea prevalence through the reduced risk of morbidity from diarrhea.

The coefficient for piped water alone (column 1) is insignificant; however, in the presence of the interaction with travel and queuing time, the piped water coefficient is significant at the 5 % level (column 2).[12] In particular, the increased access to piped water within the dwelling reduces diarrhea prevalence by about nine percentage points.[13] Nonetheless, the table shows that none of the other water sources (i.e., boreholes, protected springs, and improved water) has any significant impact on diarrhea prevalence in infants, even in the presence of interactions with travel and queuing time. Furthermore, the diarrhea prevalence rate for children with access to an improved water source is not significantly different from zero.[14]

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[12] We include interaction terms based on the assumption that the duration that households spend traveling and lining up for water is a good proxy for the amount of water they can collect. For instance, if it takes an individual two hours for each trip of water collection, then the total amount of water collected and used will be considerably less than when the travel and waiting time takes, e.g., 20 minutes.

[13] Apart from the reduced travel and waiting time, access to piped water within the dwelling may reduce the possibility of contamination during the transportation of water.

[14] We feel that improved water is an important ingredient in the child health relationship, but we have a situation where we are unable to capture key complementarities with the combined water sources variables. Previous research shows that the health benefits of water facilities are only achieved with proper use (Carr and Strauss, 2001). For example, if we were able to capture variables relating to the method of storage and preservation of water (e.g., boiling water before drinking), we feel that our results above would be different. Also, we are unable to control for the possibility of ground water contamination in the case of the pit latrine, another important issue. On a related note, without information on behavioral information such as hand-washing with soap after toilet use, we believe that our improved water source variable is not capturing the information that makes us interested in it.

It is somewhat surprising that key water facilities such as boreholes and protected springs have no appreciable impact on diarrhea in children. These particular results may be explained by the issue of water quality. Studies such as Kremer *et al*. (2006) show that community-based water facilities (e.g., protected springs) do not have significant health impacts due to poor maintenance, and as a consequence, poor water quality. Even when the community water points are regularly maintained and as such can be assumed to produce good-quality water, another issue regarding the recontamination of water during transportation arises. Indeed, interventions such as point-of-use water treatment are based on the realization that water can be re-contaminated during transportation (Ashraf *et al*., 2008).

Similar to water sources, Panel B of table 5 reports the results for IVprobit regressions for sanitation sources. In this case, only having either a private covered pit latrine or a flush toilet significantly reduces diarrhea among infants at the 10% level. Specifically, having a private pit latrine reduces diarrhea prevalence by 20%, while having a flush toilet reduces prevalence by 5%. The lower magnitude of flush toilets (considered the most technologically advanced and consequently the most hygienic sanitation infrastructure) may be partly explained by the fact that only a small proportion of households and consequently children have access to this specific type of facility (Table 2). Also, we find evidence that having an improved water source as well as an improved sanitation source significantly reduces diarrhea. In particular, children from households with both sources improved have on average a 13% lower diarrhea prevalence rate than children with only improved sanitation (Panel B column 6).[15]

[15] A number of previous studies also find that improved sanitation alone does not lead to improved health (Kremer *et al*., 2006; Luby *et al*., 2006).

Table 5: Instrumental variables specification

Dependent Variable: 1 if a infant suffered from diarrhoea in the past one month; 0 if no diarrhoea illness								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Water Sources								
Household uses piped water for drinking	-0.003	-0.089						
	[1.03]	[-2.03]*						
Interaction: [Piped water]X[Travel and queining time at water source]		-0.179						
		[1.63]						
Household uses water fom bore holes for drinking			-0.117	-0.156				
			[1.15]	[0.72]				
Interaction: [Bore Hole]X[Travel and queining time at water source]				0.035				
				[0.70]				
Household uses water from protected springs					-0.156	-0.354		
					[0.29]	[1.39]		
Interaction: [Protected Spring]X[Travel and queining time at water source]						0.089		
						[1.37]		
Household has access to an improved water source							-0.12	-0.06
							[0.27]	[1.75]*
Interaction: [Improved Water Source]X[Travel and queining time at source]								0.16
								[0.46]
Individual Controls	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]
Household Controls	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]
Observations	8,882	8,882	8,882	8,882	8,882	8,882	8,882	8,882
R2	0.408	0.412	0.388	0.388	0.386	0.385	0.385	0.391
Panel B: Sanitation Sources								
Household uses a private covered pit latrine	-0.207							
	[1.97]*							
Household uses a shared covered pit latrine		0.098						
		[1.54]						
Household uses an uncovered pit latrine			0.23					
			[0.62]					
Household uses a flush toilet				-0.052				
				[1.82]*				
Household has access to an improved sanitation source					-0.085	-0.095		
					[1.48]	[1.18]		
Interaction: [Improved Water]&[Improved Sanitation]						-0.128		
						[2.39]**		
Individual Controls	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]		
Household Controls	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]		
Observations	8,882	8,882	8,882	8,882	8,882	8,882		
R2	0.385	0.389	0.403	0.388	0.398	0.386		

Notes: Individidaul controls included are: gender, age, and age squared. Household controls included are: household consumption, gender of the household head; share of female adults in the household, highest female education in the household, community indicators for presence of primary school, consumption and product markets, and location variables for urban, central, eastern, and western Uganda

5.4 Cost effectiveness of water interventions

In order to place our results in a policy context, we consider a hypothetical poor urban town in Uganda with a population of 50,000. Based on the demographic profile in the UNHS dataset, such a town would have at least 15 % of the population aged 5 years and below. The policy objective is to provide improved water as means of reducing diarrhea prevalence among young children. For simplicity and due to the fact that piped water returned significant results in our estimations, we assume that this town can be provided with piped water, either by direct household connections or by community standpipes. Faced with such a situation, Cook *et al.* (2008) suggest estimating the water-borne disease burden using disability-adjusted life years (DALYs). We employ their approach in choosing the most cost-effective piped water intervention.[16] DALYs is measure of the shortfall in good health an individual suffers due to illness. It is computed as sum of Years of Life Lost (YLL) due to premature mortality and Years of Life due to Disability (YLD). DALYs is widely used measure of overall disease burden (World Bank, 1993; Murray and Lopez, 1996).

In summary, we calculate the reduction in diarrhea cases among young children as a result of having either a household connection or access to a community standpipe. These are converted into DALYs avoided for any of the two interventions.[17] In the estimations, we consider a number of costs. First, we consider the private and public cost of illness based on averages for Africa in Whittington *et al.* (2008). Next, we consider the fixed cost of providing piped water infrastructure[18] and the operational costs of providing water services.[19] For households that access water through community standpipes, we estimate the travel costs.[20] All costs are converted into 2006 US dollars and are discounted for the duration of the intervention using a

[16] The authors thank Joseph Cook for sharing the cost effectiveness model and suggestions for this procedure.

[17] In the analysis, we only consider one type of benefit—reduction in childhood diarrhea as it is the focus of the study. Indeed, the provision of water has other benefits e.g. reduction in dysentery among adults and other life threatening water borne diseases. Consequently, our cost effectiveness analysis should be interpreted with the above limitation in mind.

[18] We use the median construction cost of water supply facilities for Africa by WHO/UNICEF 2000 quoted in Cairncross and Valdmanis (2006)—second Edition of the Disease Control Priorities in Developing Countries (DCP) project report.

[19] From the Whittington *et al*. (2008) for low-income countries.

[20] This is based on the mean hourly wage for Uganda using the UNHS 2005/06 dataset.

uniform discount rate of 3.[21] The other information considered include the case fatality rate for diarrhea[22], the life expectancy of Ugandans[23], the hospitalization rate due to diarrhea illness, the length of illness[24], the duration of piped water intervention and the DALY weight. The estimated parameters for some of the above indicators are provided in upper part of Table 6. Having established the costs and DALYs with and without the interventions, we estimate the incremental cost effectiveness ratios based on the following equation:

$$ICER = \frac{(Intervention - \cos ts) - (Costs - averted)}{DALYs - averted}\,. \qquad (3)$$

We simulated the two interventions in the model for small towns, assuming that for both cases, the water system would last on average 16 years without additional capital costs. The simulations are for the following cases: no water intervention, household connection, and standpipe access. Table 6 shows that the estimated program cost for a household connection would amount to US$816,000 compared to US$367,000 for a community standpipe (however, the average cost of a household connection is more than three times that of a standpipe). The bottom part of the table shows that the cost per DALY averted for a household connection is $1090 while that of a standpipe is US$650. This suggests that standpipes are the more cost effective of the two interventions.

[21] This based on World Health Organization's Global Burden of Disease Studies, National Burden of Disease Studies: A Practical Guide, v2.0, p.115. Online at www.who.int
[22] Based on Fischer *et al*. (2005), I assume a case fatality rate of 3.7 per 1000.
[23] Source: WHO, Life Tables for Uganda in 2006. Online at http://apps.who.int/whosis/database/life_tables/life_tables.cfm
[24] This is median length of illness for diarrhea calculated from the UNHS 2005/06

Table 6: Cost effectiveness of water interventions (for a hypothetical urban poor town in Uganda)

Population		50,000
Demographic characteristics: 15 % children aged below 5 years		
Baseline disease burden (no water intervention)		
Expected cases per year	72	
Expected deaths per year	0.70	
Expected DALYs per year (Discounted, age weighted)	24.00	
Expected hospitalizations per year	16.00	
Publicly borne cost of illness per year	$5863	
Privately borne cost of illness per year	$14,658	

Types of interventions considered	**House connection**	**Stand pipes**
Program Outcomes		
Diarrhea cases avoided over duration	139	93
Diarrhoea deaths avoided over duration	0.11	0.3
Hospitalizations avoided over duration	4	2.6
Cases avoided per 1000 receiving water	5.79	8.68
Deaths avoided per 1000 receiving piped water	0.02	0.01
YLL avoided over duration	33	103
YLD avoided over duration	3	5
DALYs avoided over duration	38	106
Public cost of illness avoided over duration	$64,866	$65,643
Private cost of illness avoided over duration	$97,298	$164,107
Total program costs	$816,024	$367,661
Average cost per person receiving water	$103	$33
Total travel/time costs	$0	$24,832
Cost effectiveness ratios		
Cost per DALY averted	$1,090	$654

Notes: YLLs, YLDs, and DALYs calculated using uniform age-weights and discounted at 3%. All currency values are in 2006 US$. It is assumed that the children receive the water in the same environment as the rest of other household members

However, the above results should be interpreted in context. First, the DALYs averted by either intervention are relatively small in number. This is partly explained by the water-is-life hypothesis (Whittington et al., 2008): even in the absence of the above or other water interventions, households are still able to access water facilities regardless of the water quality. As such, the cost per DALY averted is considerably high, at least compared to the per capita income of Uganda (US$360 in 2007).[25] The high cost is due to the relatively higher fixed costs of infrastructure interventions and the

[25] According to Podewils *et al.* (2005), health-related interventions are not considered cost effective if they exceed the per capita GDP of the country.

associated duration of service compared to other interventions e.g., child vaccinations.[26] Second, as pointed out by earlier studies e.g., Shrestha *et al*. (2006) the high cost per DALY averted may be partly explained by the relatively low mortality and morbidity caused by diarrhea—diseases such as cholera have a relatively higher economic burden of disease than diarrhea.

Finally, our costs per DALY averted do not consider all the potential gains from having an improved water system. Specifically, unlike other interventions, for water interventions, it is not possible to target only young children and exclude other household members from using the facility. Furthermore, as noted by Whittington *et al*. (2008) the benefits of water infrastructure go beyond reducing the cost of illness; the extend to issues such as reducing coping costs and generating time savings. Consequently, considering only the DALYs averted underestimates the total benefits of water interventions. As such, our results should be interpreted with this limitation in mind.

6. Conclusions and implications

This study investigated the effects of the lack of access to safe water and improved sanitation on diarrhea morbidity among infants in Uganda. We find that access to a private covered pit latrine has the greatest effect on the burden of diarrhea among children. Furthermore, diarrhea incidence is highest among households without any established toilet structure, mainly in northern Uganda and to a lesser extent in eastern Uganda. Consequently, national policies that address the lack of toilets have the potential to reduce diarrhea-related diseases among children.

There are a number of ways through which government can encourage the use of proper toilets. First, the government needs to publicize the risks associated with diarrhea through health information campaigns, and the main target groups should be mothers. These can be effected either through the electronic media, especially radio, or through health workers. Previous national health promotion campaigns, e.g., those relating to the immunization of children during the “child days,” have shown that

[26] Based on earlier studies examining policy alternatives for combating water-borne diseases (see, e.g., Fischer et al, 2005), the total costs of children vaccinations range from $2-15.

women respond more to health conditions that affect their children (GoU, 2006c). The second option is to enforce the mandatory construction of toilets at the district level. Although this appears radical, there is evidence from other social services that ordinances work. For example, during the implementation of the UPE program, a number of local governments came up with ordinances targeting parents who refuse to enroll their children in school. In some districts, this has worked, leading to remarkable performance on national exams (Ssewanyana *et al*. 2008). Thus, without related ordinances in the water sector, a number of households will remain without an established toilet facility out of choice, to the detriment of the health of household members. However, studies from other developing countries show that there are constraints to acquiring proper sanitation, even for households willing to adopt improved sanitation. For example, in West Africa, misunderstandings about how latrines function, coupled with cost issues, are major obstacles to acquiring improved sanitation (Water and Sanitation Program, 2004).

Our results for the cost-effectiveness analysis show that for a poor urban town, providing community standpipes provides the largest gains in terms of reducing the prevalence of diarrhea at the lowest cost; this cost effectiveness is higher than that found for the use of a household water connection. Even then, the estimated costs per DALY averted suggest that other interventions, e.g., vaccinations, may be cheaper if the government's goal is only to control diarrhea illness among children. Nonetheless, the provision of water sources offers benefits beyond controlling the spread of diarrhea illness; indeed, water is essential to life. Also, because of the high costs of water infrastructure, the potential for cost sharing in providing water interventions is minimal. As such, faced with tight budgets, countries like Uganda will increasingly have to rely on development partners in order to meet such great infrastructural costs.

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