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Building Effective Drinking Water Management Policies in Rural Africa: Lessons from Northern Uganda

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ABSTRACT

While the need to provide clean drinking water is widely recognized as a priority in rural Sub-Saharan Africa, there is a lack of specific data on water quality to build effective drinking water management policies. This discussion paper describes a water quality study undertaken in Northern Uganda, to test the potability and potential contamination of water taken from wells, open water sources and households. Key lessons from the study include the fact that clean well water can be contaminated during transportation to, and storage in, homes. Building on the data from the water quality tests, this paper explores the policy implications for national governments, non-governmental organizations (NGOs) and individuals at the household level. In the absence of more specific, country-by-country studies, the results from this study are applicable across the region due to similarities in water sources and storage practices in rural Africa.

INTRODUCTION

Access to clean and safe drinking water is an important prerequisite for improved health and an essential investment in human capital. It makes a direct and immediate beneficial contribution to the health, quality of life, food security, poverty eradication and the long-term socio-economic development of a country (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2006).

While the need to provide clean and safe drinking water has been recognized as a priority by major multi-lateral organizations and policy makers (Wallace, Acreman and Sullivan, 2003), the quality of water consumed by people in most rural areas of Africa does not meet the UN's drinking water standards (UNESCO, 2006). According to the World Health Organization (WHO) and the UN Children's Fund (UNICEF), in developing countries the diseases causing diarrhea are most commonly attributed to dirty water, resulting in the deaths of 1.4 million children annually — more than AIDS, malaria and measles combined (WHO/UNICEF Joint Monitoring Program [JMP], 2010). Only 61 percent of Sub-Saharan Africans have access to clean water sources, compared with 90 percent or more in Latin America, the Caribbean, Northern Africa and large parts of Asia. Just under half of all people globally who lack access to drinking water live in Sub-Saharan Africa (WHO, 2012). For many countries, maintaining and improving the quality of water available for human consumption will become a major challenge, as surface water and ground water supplies are being depleted and are increasingly contaminated with toxic chemicals and organisms that contribute to water-borne disease (Cho, Ogwang and Opio, 2008; 2010; Gerba and Pepper, 2004).

Specific, country-by-country empirical studies of water quality are needed, therefore, to generate data that can be used to formulate drinking water management policies for African countries. A sound, realistic and meaningful drinking water policy should be based on accurate information, yet there is very little data derived from empirical field and laboratory studies on water quality in rural Africa. In the absence of more country-specific studies, this study provides data from Northern Uganda, the lessons from which can be generalized across rural Africa.

The Status of Uganda's Water Quality

In Uganda, many organizations have begun to focus efforts on water quality and delivery by financing the construction of boreholes to create freshwater wells. The NUDF, a Canadian-based humanitarian organization that works to improve the standard of living of rural people in Northern Uganda, financed and constructed 42 wells serving over 50,000 people in Oyam District, Northern Uganda. Out of concern for the health of well users, the NUDF undertook to test the water quality of these wells, comparing it with the open surface wells that rural people had been using to obtain their drinking water. A preliminary study conducted in July 2008 in Kamdini Parish in Oyam District (Opio, 2010), showed that water samples collected from NUDF wells had good bacteriological and satisfactory physical characteristics commensurate with Uganda's potable water standards and could be used for domestic consumption. The open water sources, on the other hand, showed less satisfactory characteristics, requiring settlement or simple water filtration treatment prior to direct domestic consumption. To build on these results, and in the interests of contributing to comprehensive, evidence-based drinking water policies for rural Africa, more extensive tests of water potability in rural Uganda were needed.

The study that informs this discussion paper was conducted in November 2011, in Kamdini Parish, Northern Uganda. The main research question was to identify whether the quality of water from NUDF-constructed wells was maintained during the collection and storage process at villagers' homes in Oyam District and how this compared to water taken from open sources. The study focused on field sampling and laboratory testing of drinking water quality from boreholes, open sources and storage facilities. The study compared the biological, chemical and physical properties of the water including pH, colour, turbidity, hardness, fecal coliforms and E. coli; determined if water from these two types of wells met Uganda's national standards; and tested the assumption that the quality of water from NUDF wells was maintained during storage at villagers' homes.

This paper first reviews the relationship between water quality and health, then presents the research methodology and water test results, followed by a discussion of these results. It closes by explaining the implications of this research for rural water policy in Northern Uganda and, by extension, rural Sub-Saharan Africa.

The Serious Health Effects of Drinking Unsafe Water

The results of empirical studies conducted in Africa and in other developing regions show a clear linkage between water quality and human health. Ashbolt (2004) provides an overview of the diseases that result from unsanitary water in developing countries, including cholera, typhoid fever, bacillary dysentery, infectious hepatitis, leptospirosis, giardiasis, gastroenteritis, aseptic meningitis, poliomyelitis, acute respiratory illness, salmonellosis, hookworm, amoebic dysentery, bilharziasis, leptospirosis,

"THERE IS A LACK OF SPECIFIC DATA ON WATER QUALITY TO BUILD EFFECTIVE DRINKING WATER MANAGEMENT POLICIES"

"CHILDREN WHO DRANK CLEAN WATER EXCLUSIVELY SHOWED LESS PREVALENCE OF BACTERIA IN THEIR SYSTEM AND SIGNIFICANTLY BETTER GROWTH TO AGE FIVE"

encephalitis and gastrointestinal illness. In studying the relationship between clean water and child growth in Lesotho, Esrey et al. (1988) found that children who drank clean water exclusively showed less prevalence of bacteria in their system and significantly better growth to age five, likely due to decreased incidences of diarrhea, relative to children who consumed mixed or unsafe water. Tumwine et al. (2002) studied the prevalence of diarrhea, based on different water sources in East Africa and found that from 1967 to 1997, Uganda had the highest household incidence of diarrhea in the region. In their study, they concluded that water from open pits and surface sources was significantly more likely to cause diseases leading to diarrhea than piped water. One study suggests that more and better data, specifically on child mortality rates with respect to diarrhea, is required from these and other developing countries (Boschi-Pinto, Velebit and Shibuya, 2008).

WHY WATER CAN BE UNSAFE

There are a number of different factors that can make water unsafe for drinking. While Ashbolt (2004) shows that the quality of drinking water is affected by factors such as poor sanitation and personal hygiene, in central Ethiopia, unhealthy concentrations of elements such as fluoride and uranium in drinking water, instead of bacteriological contamination, are a major concern. Results of Reimann et al.'s 2003 study showed that 78 percent of all water samples from the Rift Valley would fail current European Union drinking water regulations due to high concentrations of potentially harmful elements.

EVIDENCE-BASED SOLUTIONS

Gundry, Wright and Conroy (2004) conducted a study that focused on cholera and diarrhea. In their estimation, studies have not been able to make a definitive link between diarrhea and the amount of bacteria in water for several reasons: different types of bacteria are responsible for infections causing diarrhea, therefore, it is not easy to point out a single bacterium; there is a lack of data derived from empirical field and laboratory studies on water quality; and poorly designed studies impede conclusive results. They suggest that studies of water quality at point of use are necessary, as is the need to look at post-source contamination. The author's own initial study of Uganda's drinking water supports this suggestion.

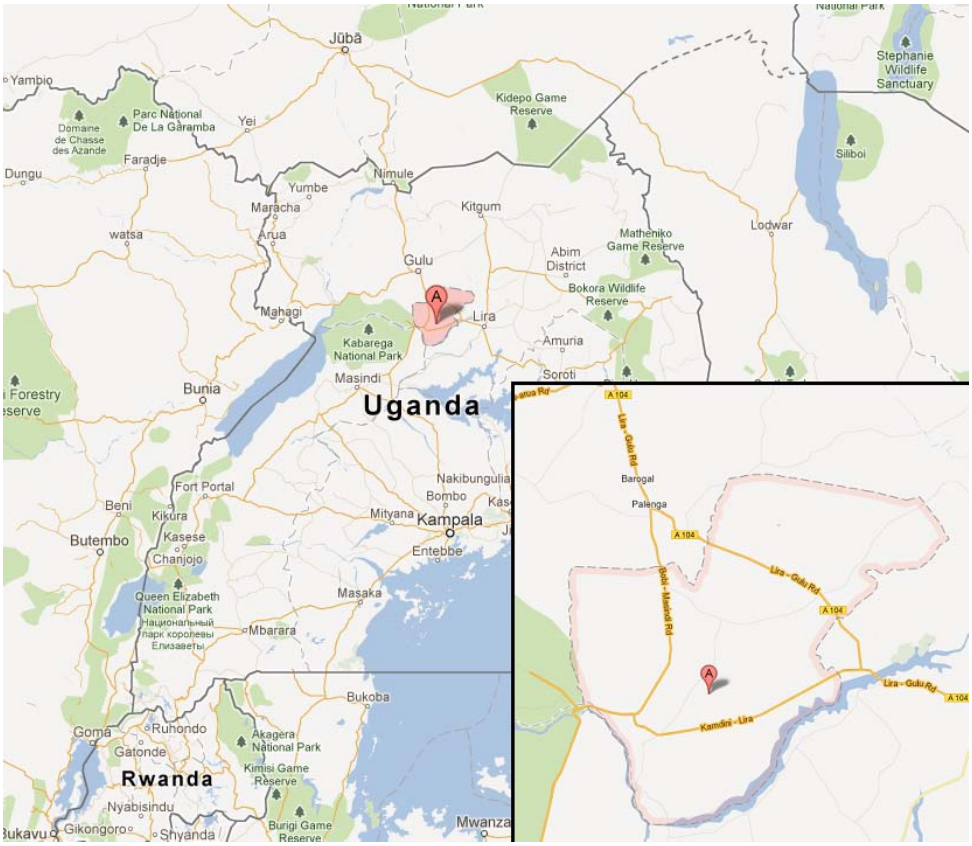
Overall, empirical, field-based sampling and laboratory analyses of drinking water from all sources (point source, handling and storage systems) in every African country are critical. Drinking water management policies for Africa, developed in the absence of empirical data, will likely be ineffective.

METHODOLOGY

Study Area

The study, which took place from November 18–25, 2011, was conducted in five villages (Adebe, Atapara, Dog Abam, Lela and Pida Alyec) in Kamdini Parish, Oyam District, Northern Uganda (2°14'45"N, 32°19'55"E) (Figure 1).

Figure 1: Uganda and Oyam District (inset)



Source: Google Maps, 2012.

Data Collection and Analysis

The methodology was adapted from a previous study (Opio, 2010). Five wells, from a total of 10 NUDF wells established in Kamdini Parish, were randomly selected for sampling. For comparison, five open wells were also randomly selected from a total of 10 open wells that villagers had been, or were currently using for drinking water in the same parish. All of the wells — both NUDF wells and open water supplies — are located in areas with similar geological characteristics.

Five samples of stored water collected from NUDF wells were also obtained from randomly selected households where the water had been kept in commonly used clay pots for an average of one week. Bottles used to transport the water samples were obtained from the UNBC in Canada. They were pre-washed with hot, soapy water, soaked in a three-percent nitric acid solution and were then rinsed with tap water, followed by distilled water, as outlined by the City of Boulder's Drinking Water Sampling Methods (2005).

Samples were collected from the sites on November 18, 2011 and transported following recommended protocols (American Public Health Association [APHA], American Water Works Association [AWWA] and Water Environment Federation [WEF], 1992). Samples were poured into bottles, labelled by well source, household source and sample number.

"EMPIRICAL, FIELD-BASED SAMPLING AND LABORATORY ANALYSES OF DRINKING WATER FROM ALL SOURCES IN EVERY AFRICAN COUNTRY ARE CRITICAL"

They were then packed in an ice-filled cooler and transported to the NWSC laboratory in Kampala, Uganda. Samples that required filtration were filtered immediately upon arrival at the laboratory, approximately a five-hour drive from the sampling sites. Samples were acid-preserved or refrigerated, as required (City of Boulder, 2005). Due to cost constraints, only 15 water samples (one from each well and storage household) were collected for analysis. For field blanks,[1] laboratory millipore water (also referred to as deionized water) was transported to the field in a sealed container. All field blank bottles were then filled from the blank water in the field as a test of sampling integrity (City of Boulder, 2005).

The analytical methods used are those described in the APHA, AWWA and WEF joint publication, "Standard Methods for the Examination of Water and Wastewater" (1992) and are outlined in Table 1. Fecal coliforms and E. coli levels in the water were determined using Method 1604 that involves membrane filtration using simultaneous detection technique (MI medium) (Oshiro, 2002). Water samples (100 mL) were filtered through a 47 mm, 0.45 µm pore size cellulose ester membrane filter that retains bacteria present in the water sample. The filter was placed on a 5 mL plate of MI agar (a special kind of agar for E. coli) on an absorbent pad saturated with 2 to 3 mL of MI broth. The plate was then incubated at 35^{o} Celsius for 24 hours. Bacterial colonies that grow on the plate were then observed for the presence of blue colour from the breakdown of IBDG (indoxyl-p-D-glucuronide) by CPU enzyme β-glucuronidase and fluorescence under long wave ultraviolet light (366 mm) from the breakdown of MUGal by TC enzyme β-glucuronidase (Oshiro, 2002). CFU (colony-forming units in 100 mL of well water) was calculated as follows: CFU/100 mL = [number of fluorescence colonies + number of blue, non-fluorescence colonies (if any) / volume of sample filtered (mL)] x 100 (Oshiro, 2002).

> **"WATER SAMPLES FROM THE NUDF WELLS SHOWED THAT ELEMENTAL AND PHYSICAL CHARACTERISTICS MET BOTH UGANDAN AND CANADIAN POTABLE WATER STANDARDS"**

Field sampling was done by a trained NUDF scientist in Uganda and the water sample laboratory analysis was performed by a trained and certified technician. The report detailing the results of the analysis was certified by two scientists at the NWSC in Kampala, in accordance with its established regulations.

1 A field blank is a water sample used to identify errors or contamination in samples used in the water analysis process. See: http://water.epa.gov/type/rsl/monitoring/132.cfm.

Table 1: Methods Used in Potable Water Sample Analysis in Kamdini Parish, Oyam District, Uganda

Type of Concern	Parameter	Unit	Method
Aesthetic	pH	-------	Glass Electrode
	Colour	PtCo[a] scale units	Spectrophotometric
	Turbidity	NTU[b]	Turbidimetric
	Alkalinity (as $CaCO_3$)	mg/L	Titrimetric
	Hardness (as $CaCO_3$)	mg/L	Titrimetric
Health Danger	Fecal Coliforms	CFU[c]/100mL	Membrane Filtration
	E. coli	CFU[c]/100mL	Membrane Filtration

[a] PtCo scale units are a measure of apparent colour of the well water, based on the standard platinum-cobalt (PtCo) method (APHA, AWWA and WEF, 1995).
[b] nephelometric turbidity unit.
[c] colony-forming units in 100mL of well water.

RESULTS AND DISCUSSION

Water samples from the NUDF wells showed that elemental (chloride, fluoride, iron and nitrate) and physical (alkalinity and hardness) characteristics met both Ugandan and Canadian potable water standards and are safe to use for domestic consumption (Tables 2 and 3). This section explains the results for each of the characteristics of water listed in Table 1: pH, colour, turbidity, hardness, fecal coliforms and E. coli, from both the NUDF wells and open water sources. First, the well water's aesthetic concerns — factors such as pH, colour, turbidity and hardness, that do not necessarily adversely affect a drinker's health — are discussed, followed by the analysis of fecal coliforms and E. coli bacteria found in the water and their serious potential health ramifications. The section closes with the results for water stored in households.

> OPEN WATER WELLS SHOWED LESS THAN SATISFACTORY PHYSICAL CHARACTERISTICS FOR pH, COLOUR AND TURBIDITY

Aesthetic Concerns

Both the NUDF and open water wells showed less than satisfactory physical characteristics for pH, colour and turbidity (see Table 3), therefore, a simple filtration treatment prior to direct domestic consumption may be required. Results of the field blanks were not provided to the researcher.

pH

The pH value of water is a measure of its hydrogen ion concentration. Pure water (with no dissolved species) has a pH value of 7. Water with a pH value lower than 7 is considered acidic; water with a value greater than 7 is considered basic (Manahan, 2005). The normal range for pH in potable water is 6.5–8.5, equivalent to the Ugandan standard. Water from both NUDF wells and open sources are considered acidic (Table 3), soft and corrosive because their pH values are low (<6.5). The low pH values might be partly attributed to the presence of dissolved metal ions such as aluminum, iron, zinc and manganese in the aquifer that contribute to acidity through hydration reactions (Manahan, 2005). These metal ions can cause premature damage to metal piping and have associated aesthetic problems such as a metallic or sour taste and staining of laundry. Low pH in water can be treated with the use of a neutralizer such as soda ash (Manahan, 2005); however, soda ash increases the sodium content of water. While the ideal pH level of drinking water should be in the range 6.5–8.5, the human body maintains pH equilibrium on a constant basis and is not harmed by consumption of waters exhibiting mild acidity (Health Canada, 1995).

Table 2: Elemental Characteristics of Water Samples Collected from NUDF Wells and Open Sources in Kamdini Parish

Parameter	Unit	Well Site										Ugandan standard for potable water	Canadian drinking water guideline
		Adebe		Atapara		Dog Abam		Lela		Pida Alyec			
		NUDF Well	Open Source	NUDF Well	Open Source	NUDF Well	Open Source	NUDF Well	Open Source	NUDF Well	Open Source		
Chloride (Cl^-)	mg/L	4	2	2	3	8	2	1	14	4	2	500	≤250
Fluoride (F^-)	mg/L	0.06	0.02	0.03	0.05	0	0	0	0.175	0.03	0	1.5	1.5
Iron	mg/L	0.048	0.209	0.053	0.012	0.272	0.573	0.096	0.58	0.074	0.277	1	≤0.3
Nitrate	mg/L	0	0.01	0.03	0.02	0.02	0.05	0.01	0	0.01	0.07	5	45

“THE COLOUR IN DRINKING WATER CAN BE IMPROVED BY USING SIMPLE WATER TREATMENT OPTIONS SUCH AS SAND FILTRATION”

Table 3: Physical Characteristics of Water Samples Collected from NUDF Wells and Open Sources in Kamdini Parish

Parameter	Unit	Well Site										Ugandan standard for potable water	Canadian drinking water guideline
		Adebe		Atapara		Dog Abam		Lela		Pida Alyec			
		NUDF Well	Open Source	NUDF Well	Open Source	NUDF Well	Open Source	NUDF Well	Open Source	NUDF Well	Open Source		
pH	-----	5.81	6.01	5.21	5.38	5.43	6.11	5.30	6.00	5.10	5.76	6.5 – 8.5	6.5 – 8.5
Colour	PtCo[a]	27	130	22	13	170	329	75	447	86	462	15	≤15
Turbidity	NTU[b]	7.74	28.16	4.11	3.68	45.56	98.66	22.06	84.26	31.95	169.9	5	0.3/1.0/0.1[c]
Alkalinity (total as $CaCO_3$)	mg/L	76	56	24	32	76	76	56	68	32	52	500	500
Hardness (total as $CaCO_3$)	mg/L	56	48	6	28	52	28	36	60	16	88	500	n.a.

[a] PtCo scale units are a measure of apparent colour of the well water, based on the standard platinum-cobalt (PtCo) method (APHA, AWWA and WEF, 1995).
[b] nephelometric turbidity unit.
[c] Based on conventional treatment/slow sand or diatomaceous earth filtration/membrane filtration (Health Canada, 2008).
n.a. = not available. Health Canada Guidelines for maximum acceptable levels of hardness have not yet been established.

COLOUR

“Apparent colour” is water that contains visible suspended matter, while “true colour” is measured in water samples from which particulate matter has been removed by centrifugation (Health Canada, 1995). The Ugandan standard is 15 true colour units (TCUs) (Opio, 2010). In Canada, the drinking water quality guideline for colour is an aesthetic objective of ≤15 TCUs (Health Canada, 2003).

Water from both NUDF wells and open sources had higher TCUs than the established standards, but the colour units from open well water was considerably higher than the NUDF wells (Table 3).

While the presence of colour in drinking water may be indirectly linked to health, its primary significance is aesthetic (Nova Scotia Environment, 2008). Colour in well water may indicate the presence of natural substances, such as dissolved organic matter (humic substances, tannin, lignin or coal) and inorganic materials, such as iron, manganese, copper and zinc (Nova Scotia Environment, 2008). Colour in well water may also indicate insufficient water treatment or the presence of surface or sub-surface contaminants in the water supply that include surface-water containing dissolved organic matter and suspended matter or industrial wastes (Nova Scotia Environment, 2008). The colour in drinking water can be improved by using simple water treatment options such as sand filtration.

TURBIDITY

Turbidity is defined as "a measure of the degree to which the water loses its transparency due to the presence of suspended particulates" (Lenntech, 2010). Uganda has established that the turbidity of drinking water should not exceed 5 nephelometric turbidity units (NTUs). This is also the standard that has been established by the WHO, which further states that the ideal standard for turbidity should be below 1 NTU (Lenntech, 2010). In Canada, turbidity of drinking water should not exceed 0.3 NTU based on conventional treatment (see Table 3).

Except in Atapara village, water from all NUDF wells and open sources has turbidity levels >5 NTUs. According to Lenntech, the "main impact" of turbidity on humans is aesthetic: "nobody likes the look of dirty water" (2010). The turbidity of drinking water can be reduced by simple filtration to remove suspended particles. Studies involving the seed extract of the Moringa tree (*Moringa oleifera*) and alum, or alum with Moringa seed extract as a coagulant aid showed that the extract, either alone or with alum, decreased the turbidity of surface water very significantly (Muyibi and Alfugara, 2003; Liew et al., 2006). Nonetheless, suspended particles enhance the attachment of heavy metals and many other toxic organic compounds and pesticides, thus increasing or decreasing the risk of exposure to these toxins (Lenntech, 2010).

> "SUSPENDED PARTICLES ENHANCE THE ATTACHMENT OF HEAVY METALS AND MANY OTHER TOXIC ORGANIC COMPOUNDS AND PESTICIDES, THUS INCREASING OR DECREASING THE RISK OF EXPOSURE TO THESE TOXINS"

WATER HARDNESS

Hard water is not a human health risk, but it can become a nuisance because of mineral buildup on fixtures and poor soap and detergent performance (Oram, 2012c). Water hardness is commonly associated with dissolved minerals such as calcium, magnesium and sometimes with iron. The most common observation of hard water is the precipitate formed by soap (Manahan, 2005; Oram, 2012c; Health Canada, 1995). In Uganda, the maximum acceptable level of hardness is 500 mg/L (Opio, 2010). Levels of water hardness from both NUDF wells and open sources are much lower than the standard used in Uganda (Table 3). In Canada, a maximum acceptable level of hardness has not yet been established because public acceptance of hardness varies according to local conditions (Health Canada, 1995). However, water supplies with hardness greater than 200 mg/L are considered poor and those in excess of 500 mg/L are unacceptable for most domestic uses (Health Canada, 1995). Health Canada suggests that a hardness level of 80 to 100 mg/L (as $CaCO_3$) provides an acceptable balance between corrosion of well pipes and incrustation (Health Canada, 1995).

Characteristics with Serious Health Implications

COLIFORM BACTERIA

Coliform bacteria (fecal coliforms and E. coli) are indicator organisms whose presence suggests that water-borne pathogens of fecal origin may be present (Gerba and Pepper, 2004). In both Canada and Uganda, the maximum acceptable concentration of total coliforms in potable drinking water is zero detectable colonies per 100 mL (Health Canada, 2003; Opio 2010).

> "NO TRACES OF E. COLI WERE FOUND AT THE NUDF WELLS AT ANY OF THE FIVE SITES. FECAL COLIFORMS, HOWEVER, WERE FOUND AT THREE OF THE FIVE SITES"

No traces of E. coli were found at the NUDF wells at any of the five sites. Fecal coliforms were found at three of the five sites — Adebe, Atapara and Dog Abam — but the levels were low, thus this water is still potable (Figure 2). Overall, water from NUDF wells was found to be clean and suitable for domestic consumption, while water from open sources contained unacceptable levels of fecal coliforms (Figure 2) and E. coli (Figure 3). In fact, the fecal coliform levels in open source water are at least twice that found in NUDF wells. Moreover, E. coli was found in two open water sources, most likely due to surface contamination sources such as animal feces (Figure 3).

IMPORTANT FINDINGS ON WATER STORED IN HOUSEHOLDS

Despite the low-level findings of coliform bacteria in the NUDF wells and the moderate levels of contamination in the open sources, water that was stored in households at three of the sites contained highly unsafe levels of fecal coliforms (Figure 2) and, in one case, E. coli (Figure 3). Similar studies conducted in South Africa (Genthe et al., 1997; Jagals, 2006) have also shown unacceptable levels of coliforms in stored water. Households at the Adebe site showed the highest level of fecal coliform, despite relatively low levels at the well sites. These results confirm that, after transportation and storage, clean well water can become tainted with over 10 times more bacteria than water drawn from the contaminated open source. Moreover, there was no presence of E. coli in the water at any NUDF well sites, however, after storage, small amounts were detected in the water obtained from the Adebe well site, suggesting that bacteria are being introduced by villagers handling the domestic water (Figure 3). Water was contaminated by handling in some sites, but not in others, due to differences in handling practices. Residents in some sites wash their hands, containers and cups in their stored water, while others do not. Leaving storage container lids open or closed also affects potential contamination, as does the frequency with which storage containers are cleaned.

Figure 2: Levels of Fecal Coliform Present in NUDF Wells, Open Water Sources and After Transport/Storage by Well Users in Kamdini Parish, Oyam District, Uganda

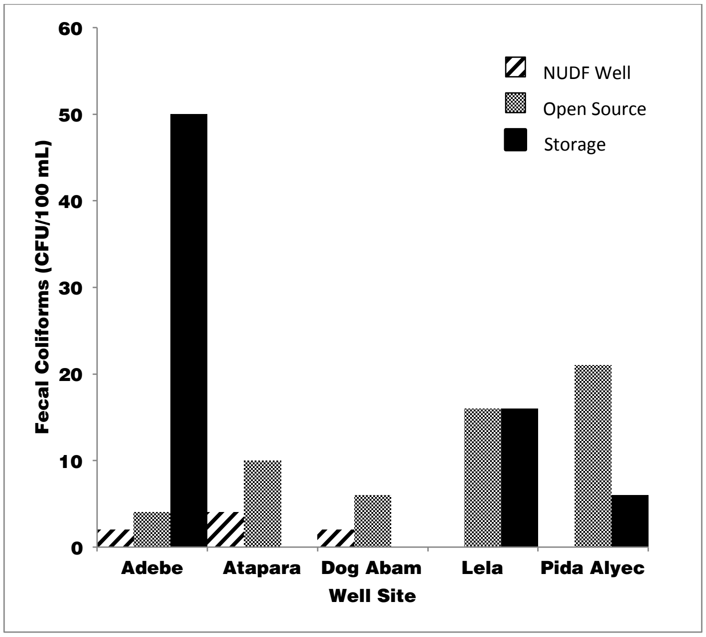
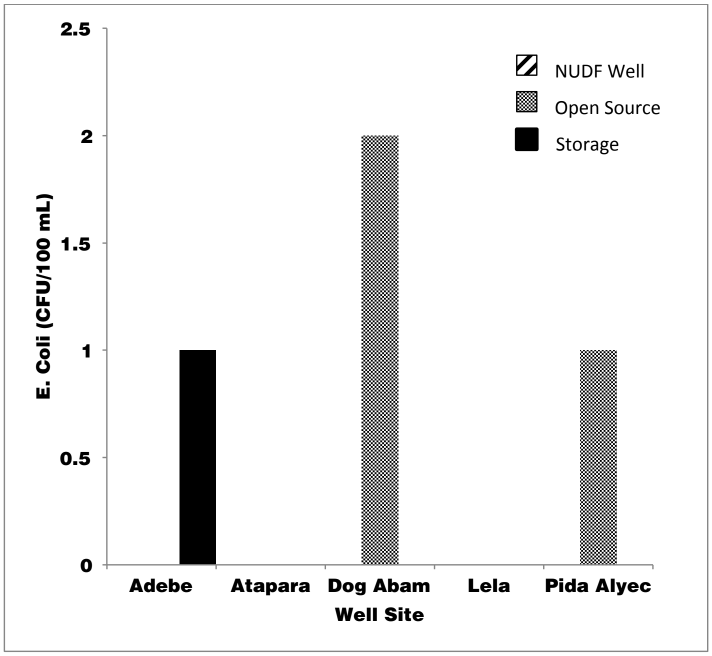


Figure 3: Levels of E. coli Present in NUDF Wells, Open Water Sources and after Transport/Storage by Well Users in Kamdini Parish, Oyam District, Uganda



> WATER WAS CONTAMINATED BY HANDLING IN SOME SITES, BUT NOT OTHERS, DUE TO DIFFERENCES IN HANDLING PRACTICES

CONCLUSION

The primary issue here is whether or not the quality of water from constructed wells is maintained during the collection and storage process at households in Oyam District and how this compares to water taken from open sources. The test results from the NUDF wells (clean, potable water) show that a properly constructed and situated well can become a reliable source of clean and safe water for rural inhabitants. Testing shows that water from NUDF wells contain half the unsafe bacteria and had far fewer "aesthetic" issues, such as pH, colour, turbidity and hardness than water from open sources. Data also showed that clean water became unsafe to drink as a result of transportation and storage practices in some households, and that levels of harmful bacteria were significantly higher in stored water that had been safe when taken from wells.

These lessons can inform a comprehensive rural drinking water strategy for Northern Uganda and other rural areas of Sub-Saharan Africa. Efforts by governments, NGOs and other institutions to provide clean and safe drinking water to rural populations in Africa are less effective if unsafe handling and storage practices are not addressed.

> "A PROPERLY CONSTRUCTED AND SITUATED WELL CAN BECOME A RELIABLE SOURCE OF CLEAN AND SAFE WATER FOR RURAL INHABITANTS"

Policy Implications[2]

The study results described in this paper identify key areas for policy action on rural water quality in Africa, contributing to sound, evidence-based policy recommendations and showing the many benefits to be gained from consistent water quality monitoring. The lessons from this data have policy implications for national governments, NGOs and for individuals at the household level.

GOVERNMENTS

At the national level, the insights from this data demonstrate the need for the following measures to be taken:

- Develop strong national rural drinking water quality monitoring and surveillance programs to ensure that water quality is maintained. The purpose of such a strategy would be to guarantee that all water sources are free from human, industrial and farm wastes and that wells are properly situated. Measurable potable water standards should be included and water from new wells should conform to those standards prior to being declared fit for consumption. Any national program should also include regulations that ensure water is purified prior to consumption, most commonly achieved through chlorination and shock chlorination (Oram, 2012a; 2012b).

- Implement education programs to promote sound water management practices, with an emphasis on the importance of proper sanitation and hygiene in the handling of water containers and storage facilities. Education programs should target two types of individuals: those who

2 For more detailed policy recommendations emerging from this research, please see the accompanying policy brief at www.africaportal.org/africa-initiative/research/Policy%20Brief.

are not aware of proper sanitation techniques or the potential health hazards of drinking contaminated water and those who are aware of proper techniques but who choose not to exercise them for a variety of reasons, such as the time it takes to boil water.

NGOs

In their capacity as service providers, NGOs can play a crucial role in supporting government initiatives to provide clean and safe drinking water to rural inhabitants. To maximize the potential benefits of cooperation, NGOs should:

- consult with appropriate technical staff when siting new wells in order to avoid contaminated areas. These include public health authorities and hydrogeologists;
- undertake regular testing initiatives at well sites; and
- play a role in organizing and facilitating workshops to ensure that communities are capable of testing their own water, from both wells and households, for contamination. While in the past, water testing equipment and facilities were commonly unaffordable or unavailable to communities of this nature, the Colilert® MPN testing method, which is simple, fast and low-cost, has already proven effective in Tanzania and Kenya (Klink, 2007).Villagers can conduct this test themselves, without technical assistance, to determine whether or not their water is contaminated with bacteria that can be very harmful to their health.

HOUSEHOLDS

The study data shows that household behaviour can impact whether or not water becomes contaminated. Household members should:

- regularly clean and disinfect water storage and collection facilities using commercial bleach;
- close the lids of water collecting cans and storage pots when not in use; and
- organize management committees to ensure that well sites are kept clean and free from human, farm and industrial waste so that clean water remains clean.

> **“EFFORTS TO PROVIDE CLEAN AND SAFE DRINKING WATER TO RURAL POPULATIONS IN AFRICA ARE LESS EFFECTIVE IF UNSAFE HANDLING AND STORAGE PRACTICES ARE NOT ADDRESSED”**

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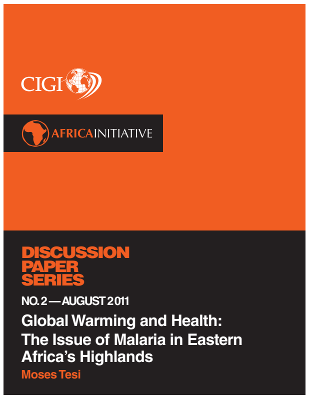
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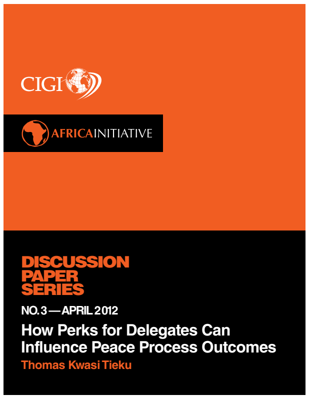
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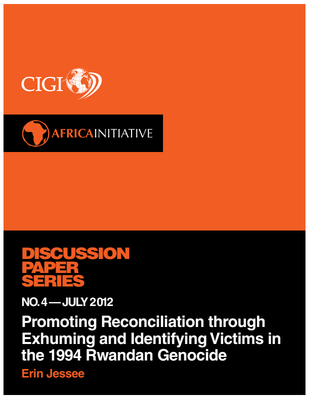
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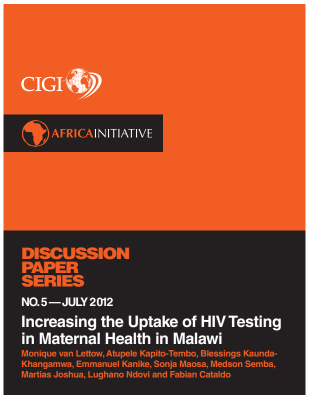
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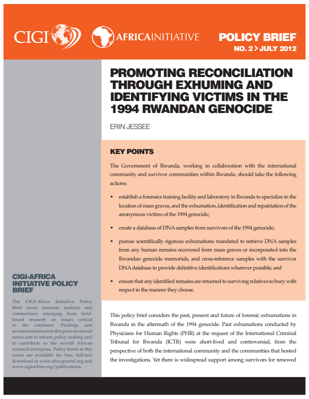
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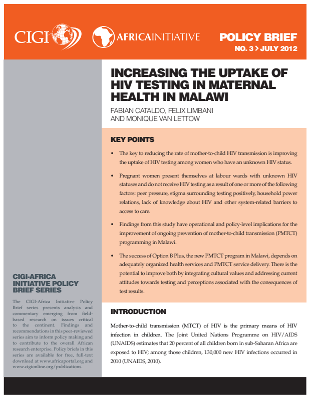
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