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Knowledge of measures to safeguard harvested rainwater quality in rural domestic households

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ABSTRACT

Given the possibility of waterborne diseases caused by inappropriate rainwater harvesting systems, a survey was conducted in Uganda to assess existing knowledge of both physical and non-physical measures that safeguard harvested rainwater. Households who had received rainwater tanks were assessed on issues related to harvested rainwater quality. The study shows that 84% of respondents were aware of various sources of rainwater contamination, but only 5% were aware that they needed to adjust use of rainwater, depending on whether they cleaned the tank or not. Most of the respondents were not aware that gutter cleaning was necessary to improve water quality. Indeed, as the water from the collection surface is channelled through gutters, a number of measures need to be taken to control the entry of contaminations and subsequent growth of pathogens in the tank, e.g. first flush diverts, installation of filters, chemical use and mesh cleaning. The majority, however, did not take adequate care of the gutters and this impacts on health and social livelihood. Overall, the findings emphasize the need to provide more information to households when installing water harvesting tanks to ensure that the harvested rainwater is of high quality.

Key words | gutter management, health, rainwater collection, rural knowledge, Uganda

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INTRODUCTION

Safe water for drinking should be available to every human being, now and in the future (Serageldin 2000). Unfortunately water resources are not uniformly distributed and are generally scarce (El-Fadel *et al.* 2000), so that about 880 million people still lack access to improved drinking water sources (WHO & UNICEF 2008), which affects their social lives and their health (Link & Phelan 1995; Kennelly *et al.* 2003; Kroenke 2008; Mansyur *et al.* 2008). Immediate attention needs to be given to the sustainable supply of water, particularly in remote rural areas, if the global target of halving the number of people without access to water and sanitation is to be achieved by 2015, as stated in the Millennium Declaration (United Nations Development Program [UNDP] 2000). Indeed, a number of countries were facing a serious water deficit before the declaration (Hamdy *et al.* 1995; Spulber & Sabbaghi 1998; Seckler *et al.* 1999).

Collecting rainwater for drinking and other domestic uses is practised by individuals in almost every country in the world. Most rainwater collection systems are modified forms of traditional technologies, and offer the potential to provide sustainable water supplies while having a low environmental impact (Gould & Nissen-Petersen 1999). Using rainwater to supplement other sources of water supply (Howard *et al.* 2002) has been demonstrated as a practical and promising solution to water shortage (Cheng *et al.* 2006). The central challenge to spreading this technology is the high cost of the tanks, which are often

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not affordable, given that in rural areas most households have low cash incomes (Gould 2006). Provision of rainwater harvesting tanks to support rural communities and reduce the water shortage problem is done by a number of governments, as well as international organizations (Kunze 2000; De Melo Branco *et al.* 2005). Households with rainwater harvesting tanks, however. seem not to have sufficient knowledge of water quality safeguard measures and water-related illnesses (Pinfold *et al.* 1993). Therefore, while the use of roof-collected rainwater can contribute to increasing the available water, it might at the same time introduce new health threats due to waterborne diseases (Leder *et al.* 2002).

Thus, improving the quality of collected rainwater remains a challenge (Zhu & Yuanhong 2006). Foltz (1999) also points out that the public perception of 'good water'– i.e. the expectations held of drinking water's cleanliness and taste–depends on the extent to which a society constructs the idea that clear water cannot be clean enough (Foltz 1999). People form knowledge based on past experiences and on the information received, e.g. from scientific sources, the media, family members and peer groups (Bianco *et al.* 2007). However, it seems that in a number of instances, rural rainwater harvesters lack the information needed to ensure high water quality through preventive measures, which would enable them to reduce the incidence of waterborne illnesses. For instance, it is common for funding agencies to subsidize tank-building while leaving gutter construction to the householder's discretion (Thomas & Martinson 2007). Households thus may still have to carry the relatively high cost of gutter construction, and might end up installing temporary gutters like banana stem files, royal palm leaves or semi-permanent gutters made, for instance, out of bamboo (European Commission 2001; Gould 2006).

In the Luwero District of Uganda, while some people can collect water from boreholes, wells and springs, a quarter of the households still use open water sources, which present a great risk to the health of the population (Uganda Bureau of Statistics [UBOS] 2002). Rainwater harvesting has two main advantages: it provides water directly to the homestead and thus reduces labour time to collect and transport water; and it is an alternative where other technologies cannot be implemented, e.g. owing to lack of ground water (Ministry of Water, Land and Environment 2007). It is thus necessary not only to install rainwater harvesting systems, but also to better understand public knowledge of the physical and non-physical features of these systems, as well as of measures to safeguard the quality of the water collected in the tanks. Indeed, there is often a lack of proper measures to prevent contaminants from entering tanks (Thomas & Martinson 2007), and waterborne diseases are widespread (Gould & McPherson 1987; Krishna 1989; Pitkänen *et al.* 2008).

This study assesses the knowledge of households in rural Luwero District regarding factors that can influence the quality of harvested rainwater and the various options available to the households to treat harvested rainwater. Knowledge about both physical and non-physical measures to safeguard water quality is modelled as well to determine the possible influence of demographic factors.

MATERIALS AND METHODS

The study was done in Luwero District, which is north of the capital city, Kampala (Figure 1). Rainfall is well distributed, with an annual average of 1,300 mm. The mean annual maximum temperature is between 27.5°C and 30°C, whereas the mean annual minimum temperature is between 15°C and 17.5°C. Luwero District was selected because both the government and international organizations provide households support to harvest rainwater in the area. In addition, accessing safe water for rural areas is more difficult compared to urban areas (UBOS 2002).

The questionnaire was developed in line with the objectives of this study and the relevant literature. Modifications were made accordingly based on the feedback received from the conducted pre-test on 15 respondents. The first section of the final questionnaire focused on background information on respondents (e.g. gender, age, family size, position in the household and number of years since the water harvesting tank had been installed). The current use of the water collected in the tank and the measures implemented to ensure water quality (e.g. gutter cleaning, tank cleaning and first flush diverts) were asked in the second section. The lack of wider discussion of the key issues from a social science perspective of bias and triangulation was acceptable, given the target audience

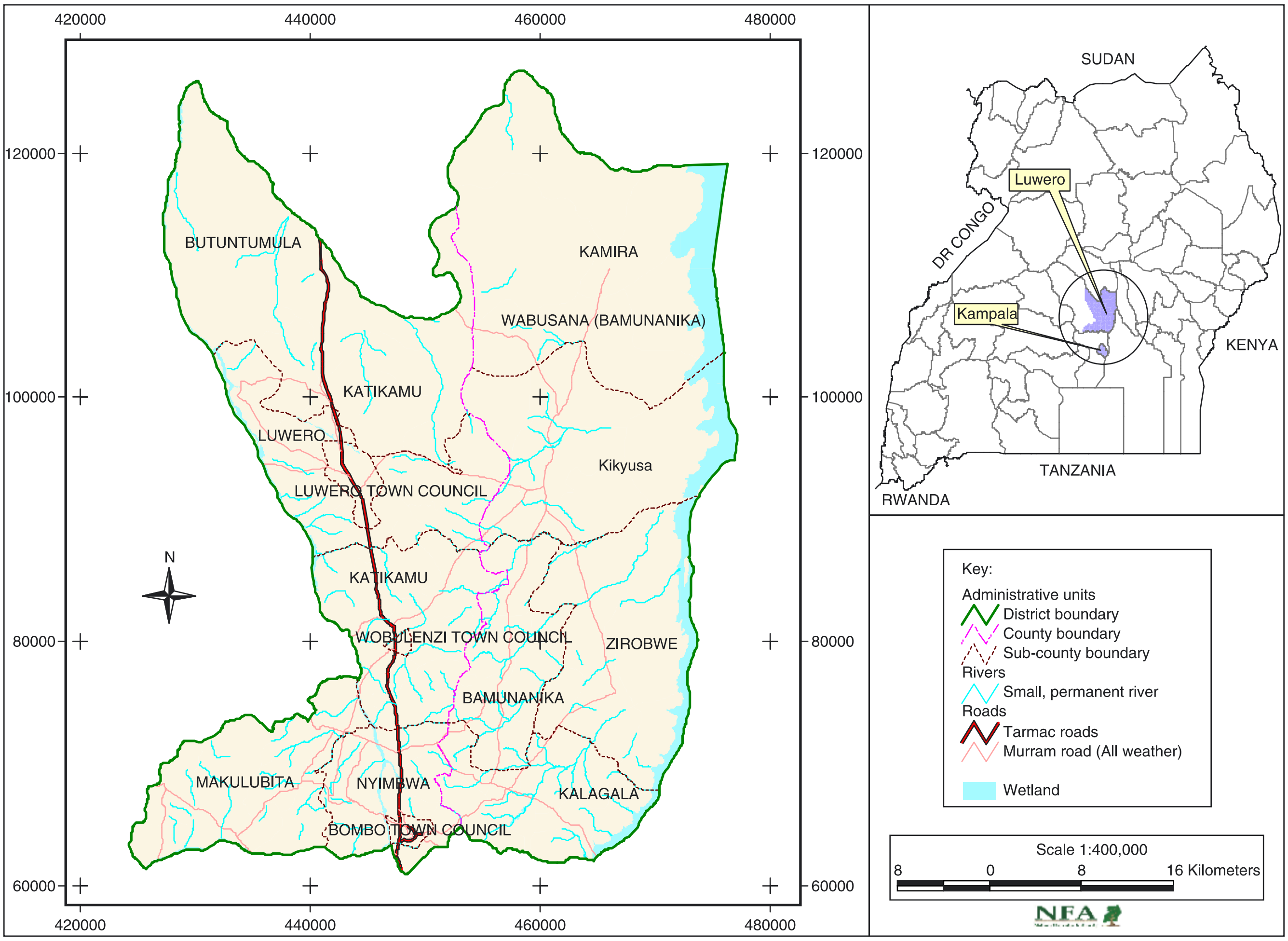

Figure 1 | Map of Luwero District in Uganda. Source: Uganda Mapping and Inventory, National Forestry Authority, April 2008.

addressed. The questionnaire then explored knowledge about water quality issues (e.g. knowledge of biological water contaminants), existence of local rainwater associations and treatment options (e.g. use of chemicals to treat the water) by asking the respondents if they agreed or disagreed with a list of statements.

With the support of donor funds, a total of 90 households had received rainwater harvesting tanks in Luwero District. As the results were to be analysed using logistic regression models, at least 50 cases per independent variable are required for accurate hypothesis testing (Grimm & Yarnod 1995). To ensure sufficient data, even if some respondents chose not to participate or were absent, all 90 households were included in the study. The data were collected between June and October 2007. Each household was interviewed after the purpose of the study was explained to them and after the interviewees were assured that all data would remain confidential. As the questionnaire was in the form of face-to-face interviews, the researcher was able to provide clarifications on questions if necessary.

The data were analysed using the Statistical Package for Social Scientists (SPSS 2006). Two models were built: the first model assessed the factors influencing knowledge of non-physical features as being able to safeguard water from contamination; the second model assessed the factors influencing knowledge of the use of physical features as safeguards. The explanatory variables that were originally included in the model-building process were age, gender, educational level, household size, occupation and years with tank. To determine whether there were correlations between the explanatory and the response variables or correlations among the explanatory variables, a bivariate analysis was made. To build the models, a stepwise binary logistic regression with backward elimination was used. This approach was selected as the dependent variable was dichotomous and the method allows for the use of an α-level to judge the importance of variables. Odds ratios (OR) and 95% confidence intervals (CIs) were calculated. Following Hosmer & Lemeshow (1989), we ensured that the goodness-of-fit test statistic was greater than 0.05. As the *p*-value was not significant ($0.460 > 0.05$), we failed to reject the null hypothesis. That is, there is no difference between the observed values and those predicted by the model. Thus, the models' estimates fit the data at an acceptable level (Garson 1998).

Water quality was defined in terms of contamination by chemical and microbiological agents (Safe Water and Waste Disposal for Rural Health (SDRH) 1982; Evans *et al.* 2005). The study considered microbiological agents that cause diseases transmitted through the consumption of contaminated water, and reviewed outpatient records from Uganda Ministry of Health from 526 health units in Luwero District out of the 711 that had participated. The outpatient records were linked to rainwater harvesters by examining records from seven sub-counties health units in the area. Laboratory water tests were conducted on samples from ten rainwater tanks in the area to reduce gaps in the data that could be created due to the fact that most local rural people turn to traditional herbal remedies for primary health care needs without visiting recognized hospitals (Anokbonggo *et al.* 1990; Hamill *et al.* 2003; Jain *et al.* 2005; Njoroge & Bussmann 2006) and that records may have been for other water sources.

Samples were selected using a simple random sampling technique, whereby each sample was chosen at random, such that each sample had the same probability of being chosen at any stage during the sampling process (Yates *et al.* 2008). Samples were collected in 200-ml sterilized glass bottles, immediately stored in the dark inside a cool box, and processed in the laboratory within six hours of collection. To ensure easy identification of samples, sterilized glass bottles were marked with the letters A, B, C, D, E, F, G, H, I and J before the specimens were collected.

Analysis of water samples for faecal coliform bacteria was done using the Membrane Lauryl Sulphate Broth (MLSB) media and Membrane Filtration Method. Faecal coliforms were selected for testing because they are mostly appropriate indicators of cistern water quality (Krishna 1993; Simmons *et al.* 2000), are simple and relatively cheap to determine and give a good indication of microbiological contamination (Foppen *et al.* 2008). The MLSB media were used to culture the coliform bacteria. Water samples were drawn through a membrane filter paper (0.45 μm pore size) by the use of a vacuum pump. The filter paper placed on a Petri dish contained MLSB. The Petri dishes were then incubated at 44°C for 20 hours. The number of cells was then enumerated by counting yellow colonies and reported as colony-forming units (cfu)/100 ml, following standard UK methods based on membrane filtration (Environment Agency 2000). The colonies appeared yellow owing to a reaction between a by-product of lactose breakdown that produces acid and an indicator phenol red present in the MLSB. The findings were grouped in a three-tier classification (Gould & Nissen-Petersen 1999): zero faecal coliform/100 ml for class one (the highest and ideal water quality), one to ten faecal coliform/100 ml for class two (water of marginal quality) and more than ten for faecal coilform/100 ml for class three (water unacceptable for drinking purposes).

RESULTS

From the 90 respondents who participated, 77 could be interviewed (the remainder were absent or chose not to participate), which is an 85.6% response rate. The mean family size was 7.91 persons in a household. The mean age was 46 years. Approximately 14% of the respondents had completed higher education, while 40% had not completed high school, and some of them were illiterate (see Table 1).

The answers to the questions regarding the respondents' knowledge of measures that can be used to safeguard the quality of the harvested water are presented in Table 2. Over 84% of the respondents knew about the risk of biological contamination of the harvested water. However, only 5% stated that use of the harvested water within the household depended on whether or not the tank had been cleaned.

Table 1 | Selected characteristics of the interviewees in Luwero district

Characteristic	Description	N	%
Gender	Male	39	50.6
	Female	38	49.4
Age group	<18	4	5.2
	19–64	64	83.1
	>65	9	11.7
Education	<13 years in school	31	40.3
	13 years in school	35	44.5
	>13 years in school	11	14.2
Household size	1–4 people	8	10.4
	>5	69	89.6
Occupation	Agricultural	62	80.5
	Other employments	15	19.5
Years with tank	1–3 years	4	5.2
	4–5 years	56	72.7
	>5	17	22.1

Although 77% of respondents stated that they knew about chemicals used to treat harvested water, 80% reported that they had never used chemicals (Table 2). For the answers to the item regarding association of rainwater harvesters, respondents indicated that they did not have any membership and there were no associations.

The multivariate analysis of the responses for respondents who knew that the physical features of the tank influence the quality of the harvested rainwater, and those respondents who were not aware of this, indicates that knowledge of gutter cleaning as a means of safeguarding drinking rural rainwater was significantly associated with rainwater quality.

Specifically, knowledge of gutter cleaning as a means of safeguarding drinking water (OR = 0.129; CI 95%; 0.042–0.395) was significantly associated with rainwater quality. Other variables, such as occupation (OR = 0.476; CI 95%; 0.126–1.822), household size (OR = 0.378; CI 95%; 0.070–2.053) and knowledge of the different measures to safeguard drinking rainwater (OR = 4.172; CI 95%; 0.429–40.619), were not statistically significant in the model build-up (Model 1, Table 3).

Table 4 shows the Pearson correlation between each pair of variables and associated significance tests. Knowledge of rainwater quality and household size were positively correlated ($r = 0.337$, $p = 0.001$), while knowledge of biological contamination and position in the household were negatively correlated ($r = -0.236$, $p < 0.05$). There was also a negative correlation between household size and knowledge of gutter cleaning ($r = -0.230$, $p < 0.05$). The analysis of variance (ANOVA) to evaluate pair-wise differences did not show a statistically significant correlation between the other variables.

The overall value of 63.6% in Table 5 shows well that the model explains the variability between households' knowledge of rainwater quality and safeguard measures. Predictor variables are occupation, household size, knowledge

Table 2 | Respondents' knowledge of measures to ensure rainwater quality

	Know		Don't know		Not valid
Knowledge of rainwater quality and treatment	N	%	N	%	%
Gutter guards prevent items entering tank	34	44.2	42	54.5	1.3
First flush diverts prevent items entering tank	18	23.7	58	76.3	
Rainwater quality affects water use	8	10.4	69	89.6	
Gutter cleaning safeguards drinking water	41	53.2	35	45.5	1.3
Access to information on tank cleaning	26	33.8	51	66.2	
Have you ever cleaned the tank?	31	40.3	45	58.4	1.3
Does tank cleaning affect water use?	4	5.2	62	80.5	14.3
Do you know water biological contaminants?	65	84.4	12	15.6	
Do rainwater contaminants affect the water use?	23	29.9	53	68.8	1.3
Do you know water chemicals?	60	77.9	17	22.1	
Have you ever used water chemicals?	15	19.5	61	80.5	

Table 3 | Results of the two Logistic Regression Models. Model 1 focuses on the knowledge of non-physical technical measures to safeguard against contamination. Model 2 focuses on the knowledge of the use of physical measures

Variable	Model 1 LR $\chi^2(4) = 79.632$ $p < 0.001$ EXP (B) upper	95% CI for EXP (B) lower–upper	Model 2 LR $\chi^2(4) = 49.927$ $p < 0.001$ EXP (B) upper	95% CI for EXP(B) lower–upper
Age	–		–	
Sex	–		2.024	0.411–9.960
Household size	0.260*	0.070–2.053	0.647*	0.94–4.458
Education level	–		18.124*	1.773–185.26
Occupation	0.476	0.126–1822	–	
Number of years with tank	–		–	
Knowledge of first flush diverts to prevent items entering tank	#		#	
Knowledge of gutter guards to prevent items entering tank	#		–	
Knowledge of mesh used to prevent items entering tank	#		0.355*	0.058–2.163
Knowledge of rain catch filters used to prevent items entering tank	#		0.395*	0.052–2.987
Knowledge and existence of out–flow valve	#		0.852*	0.080–9.019
Knowledge of tank top cover to prevent contaminants	#		–	
Knowledge of type of roof cover with less pathogen growth	#		–	
Knowledge of any waterborne diseases	–		–	
Knowledge about tank washing and cleaning	–		–	
Knowledge of gutter cleaning	0.129*	0.042–0.395	0.794	0.136–4.633
Knowledge of chemical use	–		–	
Knowledge of different measures of safeguarding water	4.172*	0.429–40.619	–	

Notes: *$p < 0.05$; #, Not included in the model; –, Excluded by the stepwise model building strategy; Exp (B) implies odds ratio (OR). CI, confidence interval.

of gutter cleaning as a means of safeguarding drinking water and knowledge of the different measures to safeguard drinking rainwater. The significant factor is knowledge of gutter cleaning as a measure to safeguard drinking rainwater.

Records from outpatients of 526 health units (Table 6) on different microbiological diseases (Safe Water and Waste Disposal for Rural Health 1982) showed the prevalent diseases in 2006 and 2007. The results from records of village health units close to the residence of some rainwater harvesters also showed prevalence of water-related diseases (Table 7). Faecal coliforms were detected in the rainwater samples tested. There were no results for classification one, i.e. zero colony counts; while both classification two (1 to 10 colony count) and classification three (>10 colony counts) had five samples each with faecal coliforms. The results from the rainwater test did not match the WHO standard on safe water for drinking, which is zero colony count for faecal coliform in 100 ml of water (WHO 2006).

DISCUSSION

The goal of the study was to assess existing knowledge of both physical and non-physical measures that safeguard harvested rainwater. The multiple logistic regression model allowed the evaluation of household knowledge and awareness of rainwater quality, treatment and the influence of demographic factors, as some of the possible determinants of rainwater utilization in domestic households with rainwater harvesting tanks in Luwero District. The lack of awareness of the importance of knowledge of gutter cleaning in influencing water quality is indicated in Table 2. This means that if the surfaces used to harvest

Table 4 | Results of the bivariate analysis on demographic variables and knowledge of rainwater quality and treatment

Variables	r Significance	N	Age	Sex	Education level	Home position	Household size
Tank cleaning	r		−0.147	−0.133	−0.167	0.098	0.147
	Sig. (2-tailed)	76	0.206	0.253	0.150	0.402	0.204
Gutter cleaning	r		0.060	0.000	−0.034	−0.136	−0.230*
	Sig. (2-tailed)	74	0.612	1.000	0.777	0.248	0.049
Biological contamination	r		0.123	0.029	0.029	−0.236*	0.114
	Sig. (2-tailed)	76	0.289	0.806	0.806	0.040	0.326
Treatment use	r		−0.045	0.050	−0.113	−0.030	0.043
	Sig. (2-tailed)	75	0.701	0.671	0.336	0.800	0.715
Water quality	r		0.150	0.017	0.071	0.208	0.337†
	Sig. (2-tailed)	76	0.196	0.886	0.543	0.072	0.003

*Correlation significant at the 0.05 level (2-tailed).
†Correlation significant at the 0.001 level (2-tailed).
Notes: *r*, Pearson correlation; $p < 0.05$.

rainwater, which deposit waste material in gutters, were cleaned regularly, the contamination of the harvested water, and thus the incidence of waterborne diseases, could be reduced. These findings are similar to those of Thomas & Martinson (2007), which showed that many gutters are never cleaned, especially if they are more than two metres off the ground and waste is left to accumulate in them.

> 'We observed a pack of rotting waste at the extreme end of the gutter where rainwater from the roof collecting surface begins to flow to the tank. This occurs because collected water at the starting part of the gutter has a slow speed, and water has not gained enough energy to carry all the waste. In addition, the shade from the trees prevents some raindrops from falling on the harvesting surface at the far end of the roof, allowing little rainwater to flow in the gutter at the starting point. Therefore, more often waste accumulates in the gutters.'

The study demonstrates that knowledge of gutter cleaning and awareness of its intrinsic interconnections with other features (e.g. first flush diverts, harvesting surfaces, mesh and filters) are important in influencing the treatment and use of rainwater. Therefore the practice by donor or government agencies of subsidizing the construction of rainwater collection tanks without ensuring adequate

Table 5 | Classification table *,†

Observed			Predicted: Knowledge of non-physical technical measures to safeguard against contamination — Use safeguard	Not use	Percentage correct Use safeguard
Step 0	Knowledge of non-physical technical measures to safeguard against contamination	Use safeguard	0	28	0
		Not use	0	49	100, 0
Overall percentage					63.6

*Constant is included in the model.
†The cut value is 500.

Table 6 | Outpatient records on different microbiological diseases: Uganda Ministry of Health, Luwero District—2006/2007

Microbiological disease	2006 <5 yrs	>5 yrs	Prevalence in 2006	2007 <5 yrs	>5 yrs	Prevalence in 2007	Total/Aver
Cholera	0	0	0	0	0	0	0 (0%)
Typhoid	186	930	1,116	105	1,687	1,792	1,454 (13%)
Diarrhoea-acute	1,336	1,816	11,152	105	1,687	5,786	8,469 (73%)
Diarrhoea-persistent	183	470	653	570	703	1,273	963 (8%)
Dysentery	166	386	548	233	523	746	746 (6%)
Guinea worm	0	0	0	9	6	15	7.5 (0.001)

gutter construction and the inclusion of physical devices (e.g. filters, diverts) are problematic (see also Thomas & Martinson 2007). This finding does not exclude the notion that the harvested rainwater might not be perceived as 'clean enough' (see Foltz 1999). Nor does it contradict the finding that in water collected directly from a roof and stored above the ground, bacterial contamination should be minimal or absent, unless the roof is accessible to humans or animals (Gould & McPherson 1987; Xijing *et al.* 1995; Bambrah & Haq 1997; Zobrist *et al.* 2000; Sazakli *et al.* 2007; Pitkänen *et al.* 2008). Besides, to achieve broad health impact, greater attention should be given to proper use of

Table 7 | Average number of patients attending village health units in some areas where rainwater harvesters reside in August and July 2007

Water-related diseases	Sub-county health centres where village data were collected: Kattugo	Bishop	Kyenzuze	Kabakenda	Luwero	Kigombe	Kikubo
Water-site insect carried							
Sleeping sickness	0	0	0	0	0	0	0
Malaria	312	148	39	297	577	155	417
Yellow fever (Arboviruses)	0	0	0	0	0	0	0
Filariasis i.e. Elephantiasis	0	0	0	0	0	0	0
Malaria in pregnancies	3	5	0	0	15	0	0
Water contact							
Bilharzias (Schistosomiasis)	0	0	0	0	0	0	0
Water quality							
Cholera	0	0	0	0	0	0	0
Typhoid	#	33	5	#	#	#	#
Diarrhoea-acute	12	2	8	1	7	27	14
Diarrhoea-persistent	#	#	#	#	21	5	7
Dysentery	1	4	#	2	2	1	4
Guinea worm (Dracontiasis)	0	0	0	0	0	0	0
Sanitation/water hygiene							
Bacillary dysentery	18	6	4	6	90	7	12
Trachoma & conjunctivitis	#	#	#	#	27	20	29
Round worm (Ascariasis)	0	0	0	0	0	0	0
Scabies	0	0	0	0	0	0	0
Intestinal parasites	#	8	2	5	#	#	#

Notes: 0, No patients recorded; #, Records not available.

water for person and domestic hygiene in addition to drinking-water quality (Briscoe 1984; Clasen & Cairncross 2004; Wright *et al.* 2004).

The size of the household, its economic status and, to a lesser extent, the gender of the household head, are all strong predictors of households that obtain water from a safe source (Dungumaro 2007). A model developed by Piper (2003) shows that water demand is significantly influenced by household size. In this study in rural Luwero District, household size did not significantly affect knowledge about physical and non-physical features that can safeguard the quality of the harvested rainwater. Indeed, regardless of the size of the household, respondents were not aware of the physical and non-physical features that can be used to prevent rainwater contamination. Differences in family size between rich and poor have an impact on widening inequality in Uganda (Lawson *et al.* 2003). Indeed, Uganda's Poverty Eradication Action Plan states that a large family is the most important cause of poverty (MFPED 2003). At the same time, poverty is synonymous with lack of water, which affects health (Zaidi 1988; Lister 1995).

Occupation referred to the work that the respondent did, whether it was paid employment or unpaid family worker (UBOS 2002). As agriculture is a crucial source of income for rural Uganda, two categories were included in this survey: agriculture-oriented occupation and 'other' employment activities. Agriculture-oriented employment accounted for 80.5% of the respondents, and other employment for 19.5%. However, occupation was not statistically significant to affect knowledge about physical and non-physical features that can safeguard the quality of the harvested rainwater. This may have been due to the fact that the majority of households earn low incomes (Rutakingirwa *et al.* 1999; UBOS 2002), which are not sufficient to influence the model. This is similar to the findings of Zaidi (1988) and Galea *et al.* (2005), who show that low-income populations are vulnerable to health-related conditions. Indeed, in areas with lower income levels, the other characteristics of the neighbourhoods can either exacerbate or reduce the economic vulnerability and thus lead to more or less healthy conditions.

Chemical measures to ensure that the harvested rainwater can be used as drinking water are not popular in Luwero District. This is most likely due to the limited access to financial, technical and medical knowledge that is crucial to improving health and living standards. Indeed, chemicals for treating harvested rainwater are expensive, and the rural people and the elderly, who are mainly rainwater harvesters, are often poor and illiterate (UBOS 2002). As the respondents reported a low rate on knowledge of chemical water treatment, this factor did not significantly affect the model, though chemicals improve water quality (Lantagne *et al.* 2008). The main method to treat water was boiling, which is practised by 87% of the interviewees. This finding correlates with a trend observed in other studies (Auslander & Langlois 1993; McLennan 2000). Hot water systems, however, should operate at a minimum of 60°C for water to be safe for drinking (Spinks *et al.* 2006).

The response rate was 85.6%. Non-participation may be related to respondent fatigue, given the numerous visits by the researcher and administrators within donor-funded projects, as well as the long distance between households and poor roads. The use of some closed items in the questionnaire may have created leading answers and caused bias. Nevertheless, the result of the survey provides valuable information about knowledge of measures to safeguard harvested rainwater for researchers, donors, tank builders, NGOs and policy-makers.

This survey included a range of variables that could potentially be linked to knowledge of measures to safeguard the quality of rainwater. However, other variables, such as the household utensils used to collect the water from the tank, and how safe water does not equate to consumption of safe water due to possible recontamination, were beyond the scope of this study, but may need to be investigated further.

CONCLUSION

The most important contribution of this study is the observed lack of awareness on the need to care for gutters in rural homes that harvest rainwater for domestic use. The influence of adequate gutter construction and management on the quality of rainwater, the need (or not) to treat water and the need to differentiate between the uses of water cannot be overemphasized. Water passing through gutters in which a variety of debris has accumulated is much more likely to transmit waterborne diseases. The water thus requires additional treatment before it can be used in the household.

This study therefore highlights the need to find innovative ways to communicate information on adequate gutter construction and care and to educate the public on ways to prevent health hazards and social implications arising from harvesting rainwater. If rural households have access to adequate information about physical and non-physical features to safeguard the quality of the rainwater, they are more likely to implement one or several of the precautions.

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