A study of the bacteriological quality of roof-harvested rainwater and an evaluation of SODIS as a suitable treatment technology in rural Sub-Saharan Africa

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SHORT TITLE – The use of SODIS to treat roof- harvested rainwater

Abstract

Harvested rainwater (HRW) is of great socio-economic importance particularly in areas where water sources are scarce or polluted. This case study was carried out in a rural area of Southern Uganda where the community has limited access to safe drinking water. The aims of the project were to investigate the quality of harvested rainwater over a year long period covering wet and dry seasons and to investigate the use of solar waterdisinfection (SODIS) as a water treatment technology. Fifty households using roof HRW were selected. The systems used included catchment ponds, metallic, concrete and plastic tanks. All households used the HRW for drinking. The raw HRW was analysed for temperature, pH and total dissolved solids (TDS) and for the presence of the bacterial indicators of faecal pollution - *Escherichia coli,* faecal enterococci and *Clostridium perfringens.* Results indicated that while the HRW met the required physiochemical drinking water standards, the majority of samples from all types of system showed levels of microbiological contamination indicating that the water was unsafe for drinking without treatment. The use of SODIS to treat the water was investigated using 2 liter PET bottles and was shown to be an effective treatment technology.

KEYWORDS: Drinking water; Harvested Rainwater; SODIS

ABBREVIATIONS:

ATCC American Type Culture Collection

DWD Directorate of Water Development

HRW Harvested rainwater

JMP Joint Monitoring Programme

MDG Millennium Development Goal

NGO Non-governmental organization

PET Polyethylene-terephthalate

SODIS Solar disinfection

TDS total dissolved solids

UNBS Uganda National Bureau of Standards

UNICEF United Nations Children's Fund

WHO World Health Organisation

1. INTRODUCTION:

As the deadline for the Millennium Development Goals (MDGs) is reached it is reassuring to know that Target 7.C, which aimed to halve by 2015 the proportion of the population without sustainable access to safe drinking water, has been achieved [1]. This global success is not shared by many Sub-Saharan countries and while Uganda has met the MDG target [2] as predicted by Salami *et al.* in 2014, poor communities in rural Uganda still do not have access to safe drinking water [3]. Safe drinking water is defined by the World Health Organisation (WHO) as drinking water which 'does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages' [4]. The World Health Organisation (WHO) and United Nations Children's Fund (UNICEF) Joint Monitoring Programme (JMP) for Water Supply and Sanitation considers access to safe drinking water as water collected from improved sources. Improved sources of drinking water include piped water, public taps or standpipes, boreholes, protected wells, protected springs and harvested rainwater [5].

The population of Uganda exceeds 36 million and over 80% of the population lives in rural areas. While 71% of the rural population has access to an improved water source, only 1% has access to piped drinking water while 70% use other improved sources [2]. In Uganda, access to an improved water source implies that the water source is within a walking distance of 1.5 kilometers.
The provision of safe drinking water is one of the major challenges facing African governments [3]. In developing countries about 80% of diseases are water originated [6] including diarrheal disease, a major cause of death among children [7].

Solar water disinfection (SODIS) is an effective point of use water treatment process. In using this method, transparent bottles are filled with microbially contaminated water and exposed to sunlight for a specific period of time thus inactivating the waterborne pathogens and ensuring the safety of the water for drinking [8]. Usually the bottles are polyethylene terephthalate (PET) plastic, but other plastic or glass containers can be used. SODIS is a simple, green and low-cost technology [9] which is suitable for availing of safe drinking water for rural communities in developing countries, most of whom are known to have high levels of solar radiation [10-13].

The technology uses easily accessible local materials and low cost tools [13]. Amin and co-workers [14] viewed the coupling of harvested rainwater and SODIS as an easy approach for poor communities living in the developing world in accessing potable water using efficient and cost effective point of use treatment methods. However, while SODIS and HRW technologies are suitable in a Ugandan setting, little has been done to evaluate their efficacy in Ugandan rural conditions. The aim of this study was to investigate the quality of HRW in the rural area of Makondo and the effectiveness of using SODIS with 2L PET bottles for treating roof HRW under field conditions over a twelve month period.

2. METHODS:

2.1 Study area: The study was carried out in the sub-parish of Makondo which is located west of Masaka in the recently established administrative District of Lwengo in South Eastern Uganda along the Western shores of Lake Victoria (Figure 1). The area lies at over 1,100 meters above sea level and just south of the equator. Fifty households took part in the year- long study. Each household had one harvested rainwater tank. The types of system varied and included 8 catchment ponds, 11 concrete tanks, 20 metallic tanks and 11 plastic tanks. The location of each household and the type of tank used are described in Figure 1. The harvested rainwater systems used included catchment ponds, concrete tanks, metallic tanks and plastic tanks.

All the tanks were sited above ground with a tap at the base through which the water samples were collected. The catchment ponds were ditches constructed behind a ground dam lined with a polythene sheeting to contain the water. A wall surrounding the entire ditch was built above the ground with an opening through which water was drawn using a small container tied on a rope or rod. All the systems were enclosed and the rainwater in the tanks was not exposed to natural sunlight. The water was sampled from each household once a month. The households were randomly allocated into three clusters of 15–17 households for sampling. Sampling was carried out during the first three weeks of each month. A different cluster was sampled each week.

2.2 Rainfall measurement: Daily total precipitation was recorded using three tipping bucket storage rain gauges (ONSET -HOBO Rain gauge data logger RG3- Version 2.7.3) with a fully self-contained,

battery-powered rainfall data collection and recording system. These were used at three locations within the project catchment area: the villages Kiyumbakimu, Kiteredde and Michunda (Figure 1). HOBOware graphing and analysis Pro software for Windows (Version 2.7.3 ONSET) and a water proof data shuttle were used for data processing, readouts and re-launch of the loggers. To obtain average rainfall for the study catchment area, precipitation computed at the three different rain gauge locations within the catchment area were averaged on a daily and monthly basis using the weighted averages (Thiessen) method [15].

2.3 Physico-chemical measurements: The temperature, pH and total dissolved solids (TDS) of HRW samples were measured on site using a calibrated field pH/TDS meter (model HI 9813-6N, Hanna Instruments, S.L. Eibar, Spain). The tap on the HRW systems was opened and water was allowed to flow for 5 seconds before sampling the water in a beaker. The probe was dipped into the water and the values for temperature, pH and TDS were recorded following the manufacturer's instructions. Temperature was recorded in degrees Celsius ($^{\circ}$C) and TDS in parts per million (ppm). The probe was then rinsed with distilled water.

2.4 SODIS treatment of water: Polyethylene-terephthalate (PET) bottles (2L), with caps were purchased locally. Each household was provided with four 2 liter PET bottles at the beginning of the study and these were replaced after 6 months. Participants in the study were initially informed and trained in the use of SODIS. They were instructed how to clean and prepare the PET bottles and how to sample the water. Bottles were washed with soapy water for disinfection and then rinsed with distilled water. The harvested rainwater was allowed to run from the tap for 5 seconds before sampling. The PET bottle was half filled with water, then shaken and filled to the top before tightening the cap. The bottles were exposed to the sun horizontally on a raised platform for a minimum of 6 hours if the day was bright and for two days if cloudy.

2.5 Microbiological analysis: For *Escherichia coli* and faecal enterococci, water for microbiological analysis was sampled aseptically from the harvested rainwater tanks and the PET bottles into sterile containers and transported on ice, within 6 hours, to the laboratory at Makerere University, Kampala. The presence of *E. coli* and faecal enterococci was determined using the membrane filtration technique [16]. Briefly, 100mL of water was filtered through 0.45-µm-pore-size and 47-mm-diameter

Whatman cellulose nitrate membrane filters (GN-6 Metricel Grid, Gelman Sciences Inc. USA). For the detection of *E. coli* the filters were placed onto ChromoCult Coliform agar (CCA-Merck Ltd) and incubated at 37°C for 24 hours. All deep blue colonies were counted as presumptive *E. coli* colonies. A random sample of 5 colonies from ChromoCult coliform agar was plated onto Les Endo agar (HiMedia Ltd) for confirmation. Red colonies with a golden yellow sheen were confirmed as *E. coli.* *Escherichia coli ATCC 25922* was used as a positive control. To detect faecal enterococci, filters were placed on membrane enterococcus agar (Slanetz and Bartley Agar, HiMedia Ltd) and the plates were pre-incubated at 35°C for 4 hours to aid bacterial resuscitation. The plates were then incubated at 44±0.5^{o}C for a further 44 hours. After incubation all red and maroon colonies were counted and recorded as presumptive faecal enterococci. For confirmation, a filter was aseptically lifted from Slanetz and Bartley Agar and transferred to Bile Esculin Azide Agar (HiMedia Ltd). Plates were then incubated at 44 ± 0.5°C for 2 hours and a brown black colour around colonies confirmed faecal enterococci. *Enterococcus faecalis* ATCC 2921 was used as a positive control. The detection limit of the method was one colony forming unit (CFU) of *E. coli* or faecal enterococcus per 100-mL of sample.

The presence of *Clostridium perfringens (C. perfringens)* was determined by heating a sample of water (100mL) at 80°C for 15 min in a water bath to kill all non-spore forming bacteria. The pasteurized water was then filtered through 0.45-µm-pore-size and 47-mm-diameter Whatman cellulose nitrate membrane filters (GN-6 Metricel Grid, Gelman Sciences Inc.) and the filter was transferred to tryptose sulfite-cycloserin (TSC) agar plates (Oxoid CM0587, London-UK) with the addition of TSC supplement (Oxoid-SR0088, London-UK) and egg yolk (Oxoid-SR004, London-UK). The plates were incubated in an anaerobic jar, containing an aerocultA anaerobic System (Merck, Germany), at 35°C for 24 hours. Black colonies were counted as *C. perfringens* colonies. *C. perfringens* (UG-MUKVET 1.04) isolated from soil and obtained from the School of Veterinary Medicine, Department of Biotechnology and Bio-safety Engineering, Makerere University, Uganda was used as a positive control in all tests.

2.6 Data Analysis: All samples were analysed in triplicate. Mean and median values were calculated in MS Excel 2010 (Microsoft Excel 2010 32-Bit Edition) and Pearson Chi-square using SPSS PASW

Statistics for Windows, Version 18.0. Chicago: SPSS Inc. USA. Graphs were created using Sigmaplot version 11.0 from Systat Software, Inc., San Jose California USA .

3. RESULTS

3.1 Rainfall: The daily rainfall range and the total monthly rainfall values for each month of the study are presented in Table 1. The total monthly rainfall varied from month to month and ranged from 2.9mm to 135.9mm. The values reflected the bimodal rainfall pattern of two rainy seasons and two dry seasons in the year. October 2011 had the highest monthly total rainfall of 135.9mm followed by November 2011. January, February, June and July were typically dry months with very low amounts of rainfall.

3.2 Harvested rainwater systems studied: The total number of systems sampled varied depending on the availability of members of the household and the availability of rainwater in the tanks. The maximum number of systems sampled in any month was 48 in December 2011 and the minimum number of systems sampled was 19 in February 2012 (Figure 2).

There were noticeably fewer systems sampled during the dry season months of February, March and July 2012. This was because most systems especially catchment ponds had no water during the dry season mostly towards the end of dry seasons. This is clearly visible by the reduced number of samples in February and July, by which time many of the tanks had run dry.

The mean monthly temperature recorded for the HRW ranged from $22.5^{O}C$ – $27.5^{O}C$. The minimum temperature recorded was $19.5^{o}C$ and the maximum temperature was $33.6^{o}C$. There was no significant difference in temperature between the wet and dry months ($p=0.07$) and among the different systems ($p=0.09$). .The average pH of the water was 6.9±0.7 and did not show a significant association ($p=0.08$) with the different types of system. The levels of TDS in all the systems ranged from a minimum value of 0ppmin November 2011 to a maximum value of 287 ppm in March 2012. No correlation was found between levels of TDS and wet or dry season.

3.3 The bacteriological quality of the water before and after SODIS: The bacteriological quality of the harvested rainwater was evaluated by monitoring the presence of *E. coli,* faecal enterococci and *C. perfringens.* None of the water samples showed the presence of *C. perfringens*. The percentage of non-compliant systems that is systems that showed the presence of *E. coli* or faecal enterococci in 100mL of water is described in Fig. 3(a) for *E. coli* and in Fig. 4(a) for faecal enterococci. The results show that the water from the majority of the systems was not compliant. The average number of indicator organisms varied with system type and with time. The level of contamination was highest in the catchment ponds and faecal enterococci were more prevalent than *E. coli*. Following SODIS treatment, the percentage of non-compliant samples decreased significantly (Fig. 3(b) and 4(b)) and the majority of the water samples were found to be safe to drink. Average numbers of any indicator organisms remaining were generally less than 10org/100mL. When the SODIS treated water is compared for the two indicator organisms, the percentage of samples containing faecal enterocooci are generally lower than those containing *E. coli*, suggesting that these organisms were more sensitive to solar disinfection than the *E. coli* strains. No correlation was found between the levels of contamination and the type of system or the season.

3.4 Rainfall and microbiological parameters of raw HRW: The median numbers of each indicator organism (cfu/100mL) were correlated with total rainfall values for each month (Fig 5). There was a wide range in the numbers of each organism detected which in many cases exceeded 400cfu/100mL. The range varied from month to month and did not correlate with total rainfall values. When the median numbers of indicator organisms for a given month were correlated with the total levels of rainfall for the month there was no significant correlation for either *E. coli* (R^2 =0.15; p=0.86) or for faecal enterococci (R^2 =0.27; p=0.389).

4. DISCUSSION

The sub-parish of Makondo where the study took place is located in a remote region of South Eastern Uganda. There is no centralized water supply system. The four main types of water source used in rural areas were all represented in the study area and included traditional water sources (ponds, unimproved shallow wells and unprotected springs) and improved water sources (shallow wells and protected springs, boreholes and rainwater harvesting). Uganda is particularly suited to using

harvested rainwater as it has a plentiful supply of rain. The rainfall pattern in the region followed the bimodal pattern of rainfall previously reported by Ssegawa & Kasenene [17] and Kiwanuka *et al.* [18] where the peak rain periods were the months of March through May and October through November and the dry seasons occurred from December through February and June through July. The community in the Makondo area are poor and the majority of the households earn less than 50,000 Ugandan shillings in a month [19]. While the cost of installing tanks has been described as a challenge by Gould [20] two thirds of these households had incomes in the range 100,000 – 200,000 Ugandan shillings per month [21] which was above the average income of households in the region. Furthermore the type of tank most frequently used in this study, the metallic tanks, had been donated by a local NGO.

The main objective of this study was to investigate the microbiological quality of the harvested rainwater. All the households in the study used the water for drinking and indeed perceived the water to be of better quality than water from any other source. However the quality of the harvested rainwater had never been tested.Water quality in rural areas is monitored by the Ministry of Water and Environment - National Water and Sewerage Cooperation (MWE-NWSC) but HRW systems are normally privately owned and no proper structure is in place to monitor the water from these systems.The most significant issue in relation to water for drinking is the health risks associated with the presence of pathogens of faecal origin. To ensure that water is safe to drink, water is routinely tested for the presence of bacteria which are indicators of faecal pollution including *E. coli* and faecal enterococci. In Uganda, water for drinking should comply with UNBS [22] and WHO-UNICEF[4] standards which state *E. coli* and faecal enterococci should be absent from 100mL of water. However, the majority of the water samples tested showed that these bacteria were present in 100mL of water. The quality of roof harvested rainwater can be influenced by many factors including the location of the roof and its proximity to sources of pollution [23]. Many of the harvested rainwater tanks in the study were surrounded by vegetation, mostly banana plantations, trees and other types of vegetation which provided suitable environments for a variety of avian, mammal and reptile fauna. *E. coli* and faecal enterococci indicate faecal contamination from human or animal origin. As the numbers of faecal enterococci in the water samples were consistently higher than the numbers of *E. coli. T*his suggests that the source of faecal pollution was of animal origin [24].

E. coli is widely used as an indicator of water quality and while it has been described as the best microbial indicator available to date to inform public health risks associated with the consumption of contaminated drinking water [25-26], faecal enterococci are also useful indicators of the microbiological quality of drinking water. They are always present in the faeces of warm blooded animals. Their die-off rate is slower than that of coliforms in water as well as their persistence pattern being similar to that of potential waterborne bacterial pathogens [27-28].The dominance of faecal enterococci in the harvested rainwater was in agreement with the findings of Ahmed *et al*. [29] and others who suggested that enterococci species may be a better indicator for assessing faecal contamination in rainwater than *E. coli.* Indeed the value of *E. coli* as the most suitable indicator of water quality was also questioned by Sorlini *et al.* [30] who carried out a study of water quality on the border between Chad and Cameroon and concluded that the JMP water source classification and *E. coli* measurements are not sufficient to state how safe the water is.

The response of the two indicator organisms to SODIS was found to vary and the faecal enterococci were in general found to be more sensitive to solar disinfection. There have been differing reports on the response of these indicator organisms to sunlight. The greater resistance of *E. coli* to the bactericidal effects of sunlight compared to faecal enterococci has been reported by Evison and others [31-33] while Keogh *et al.* [34] noted that *Enterococcus* spp. had increased resistance to SODIS compared to *E. coli*. The difference in response of the organisms to sunlight could be attributed to strain differences among the organisms investigated including differences between laboratory strains and strains in the environment.

Nguyen *et al.,* [35] found that the presence of pigmented enterococci in non-disinfected secondary effluent increased the resistance of the total enterococci community to sunlight inactivation. The finding suggests that both organisms should be used as indicators when evaluating the safety of water following solar disinfection. In addition to microbiological guidelines, drinking water standards also recommend that certain physicochemical characteristics are within limits including the recommendation that the pH be in the range 6.5 – 8.5 and that the total dissolved solids (TDS) be less than 600mg/L. The pH of harvested rainwater can be influenced by a number of factors including

the material of the roof and the material of the harvested rainwater tank. All the catchment roofs in this study were made of iron sheets. The material in the tanks varied and included metal, plastic and concrete and while Handia [36] and others have shown that water sampled from ferro-cement tanks was significantly more likely to be alkaline, this was not the case in this study where there was no significant difference in the pH of the water collected from the different systems. All systems were covered and only had a small opening for the gutter. The majority (98%) of systems did not have filters to prevent debris from entering the tank and while flushing of systems after the first rains is recommended [37] this was not generally carried out. Nevertheless, the levels of solids in the water was found to be well within the 600mg/L value stipulated in drinking water regulations.

The lack of compliance with the microbiological guidelines for drinking water suggested that the water should be disinfected before drinking. A variety of methods have been recommended to treat rainwater for drinking [29]. Treatment methods recommended in the region included boiling and the use of chlorine tablets. However, households considered these methods too expensive to use, a finding also reported by Baguma *et al.* [38] who carried out a study in the Luwero District, north of the Ugandan capital Kampala. McGuigan *et al.* [39] have shown that solar water disinfection is a cheap, accessible and effective water treatment technology in particular for developing countries like Uganda where there is plenty of sunshine. The results obtained following treatment of the water using SODIS were very encouraging. The results obtained in the majority of the water samples tested following SODIS demonstrated the effectiveness of the method. Although the participants were trained at the beginning of the project in the use of SODIS, the lack of success in using SODIS in some instances is attributed to the need for ongoing training. Information leaflets describing best practice in using harvested rainwater tanks and in carrying out SODIS have now been distributed to the households to help improve their management of the roof harvested rainwater.

Although the current study did not investigate the presence or absence of specific pathogens, several studies have reported the presence of pathogens in HRW Simmons *et al.* (2008) [40] reported detecting *Legionella pneumophila in* rainwater storage systems in suburbs of Auckland, New Zeland using molecular-based techniques. In Victoria, Australia, Franklin *et al.* (2009) [41] reported detecting *Salmonella typhimurium* phage type 9 (DT9) in rainwater samples using binary PCR and quantitative

PCR (qPCR). Ahmed *et al*., (2010) [42] reported the presence of genes from a number of pathogens including *Salmonella* invA (10.7%), *Giardia lamblia* β-giardin (9.8%), *Legionella pneumophila* mip (5.6%), and *Campylobacter jejuni* mapA (0.4%) in 214 samples of HRW from urban Southeast Queensland (SEQ) in Australia. Dobrowsky *et al* (2014) [43] carried out a study on HRW used in households in Kleinmond, South Africa and a diversity of pathogens was detected using PCR assays including *Aeromonas* spp., *Klebsiella* spp, *Legionella* spp, *Pseudomonas* spp., *Salmonella* spp., *Shigell*a spp., *Yersinia* spp. and *Giardia* spp. The findings suggest that future studies on HRW should include the study of specific pathogens

Previous studies have examined risks associated with the photodegradation of the plastic container material after prolonged use [39, 44]. These studies reported no genotoxic risks associated with SODIS bottle use over periods of up to 6 months. In the absence of data extending beyond this period, it is recommended that SODIS containers are replaced after 6 months.

5. CONCLUSIONS

Roof harvested rainwater used for drinking by a rural community in South Eastern Uganda did not comply with national and international microbiological drinking water standards. The presence of *E. coli* and faecal enterococci in the majority of the water samples tested indicated the presence of faecal pollution. Numbers of enterococci were consistently higher than numbers of *E. coli* which suggested that the contamination was of animal origin. The presence of faecal contamination in the harvested rainwater indicated that the water should be treated before drinking. Communities should be made aware of the need to treat the water for drinking and in the proper use of treatment technologies including SODIS, which was shown to significantly improve the water quality in the majority of harvested rainwater samples studied.

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TABLE CAPTION

Table 1 : Daily range and total monthly rainfall values for Makondo, Masaka-Uganda during the study period (August 2011 to August 2012)

FIGURE CAPTIONS

Figure 1: Map showing Makondo sub-parish (study area) and the distribution of HRW systems studied.

Figure 2: Number and type of HRW system sampled during the 12 month study.

Figure 3: *E. coli* in harvested rainwater systems: (a) raw HRW and (b) SODIS treated HRW(note: no data collected in May).

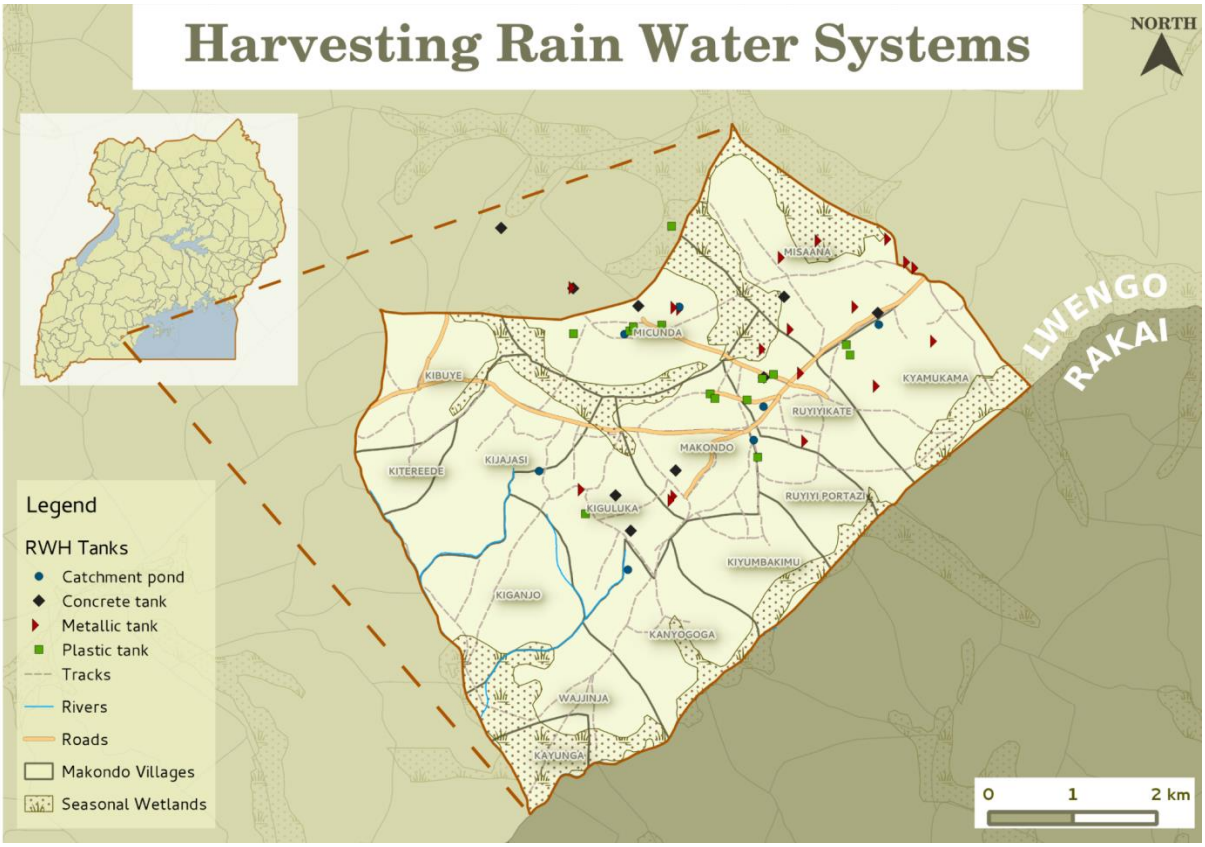
Figure 4. Faecal enterococci in harvested rainwater systems: (a) raw HRW and (b) SODIS treated HRW (note: no data collected in May).

Figure 5 (a): Relationship between the numbers of indicator organisms in each month and the total rainfall mm/month (a*) E. coli* and (b) faecal enterococci.

Table 1

Month/Year	Daily Range [mm]	Total monthly rainfall [mm]
Aug. 2011	0.0-27.8	43.3
Sept. 2011	0.0-12.4	64.7
Oct. 2011	0.0-36.5	135.9
Nov. 2011	0.0-29.4	81.6
Dec. 2011	0.0-8.2	32.1
Jan. 2012	0.0-1.9	5.3
Feb. 2012	0.0-2.3	12.9
Mar. 2012	0.0-10.9	44.2
April. 2012	0.0-13.3	64.4
Jun. 2012	0.0-0.8	2.9
July. 2012	0.0-3.0	4.2
Aug. 2012	0.0-7.8	24.2

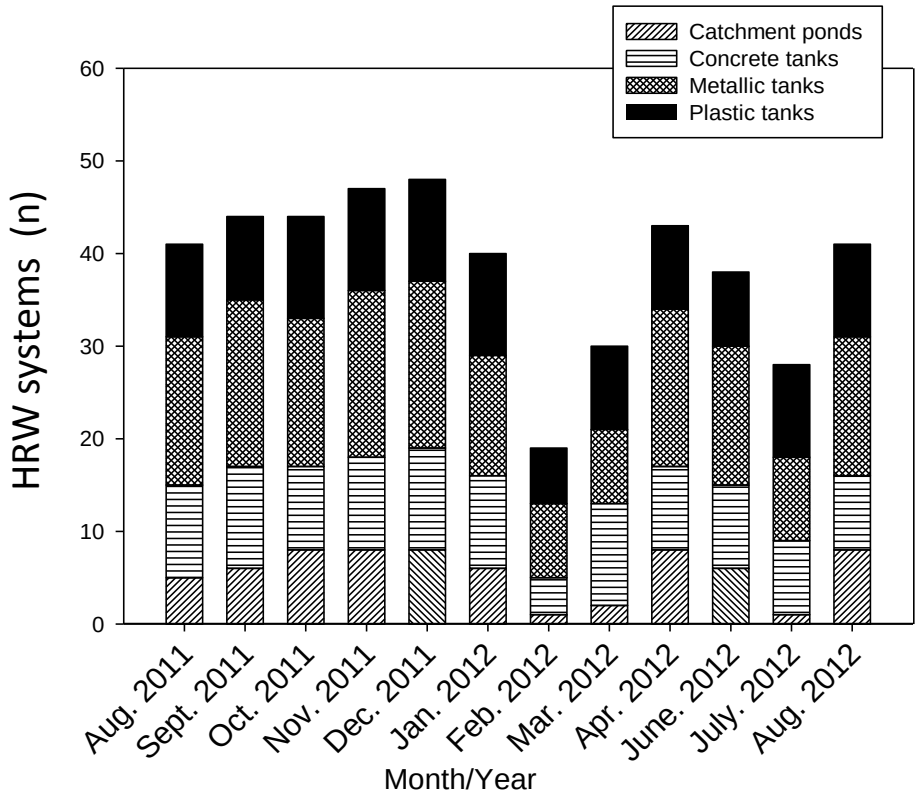
1 Figure 1.


Harvesting Rain Water Systems
NORTH
LWENGO
RAKAI
MISAANA
MICUNDA
KIBUYE
KYAMUKAMA
RUYIYIKATE
MAKONDO
KIJAJASI
KITEREEDE
KIGULUKA
RUYIYI PORTAZI
KIYUMBAKIMU
KIGANJO
KANYOGOGA
WAJJINJA
KAYUNGA
Legend
RWH Tanks
Catchment pond
Concrete tank
Metallic tank
Plastic tank
Tracks
Rivers
Roads
Makondo Villages
Seasonal Wetlands
0
1
2 km

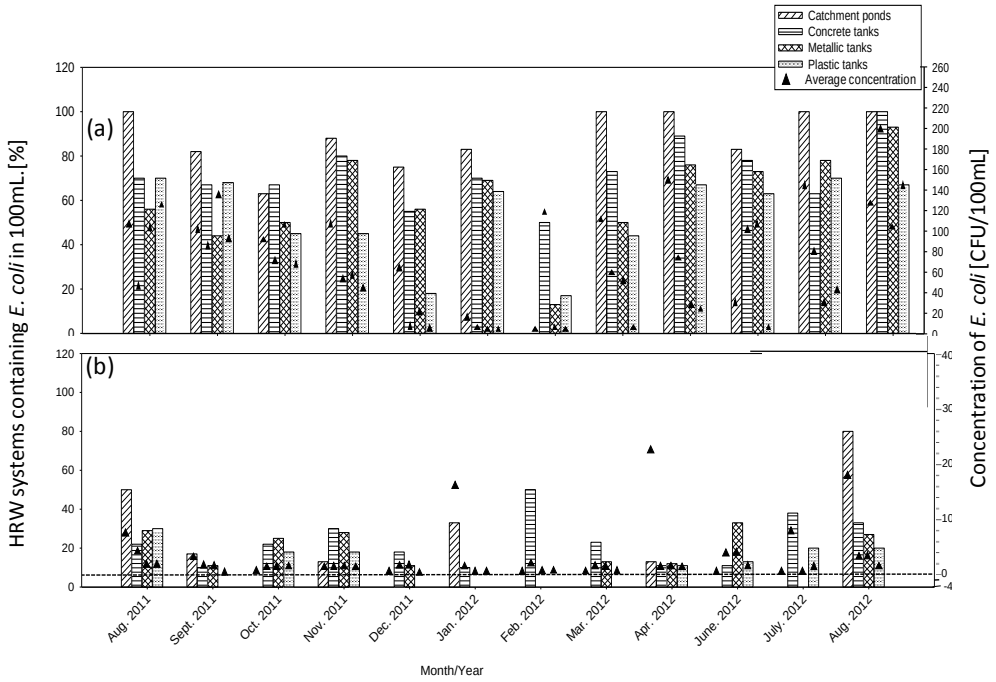
2

3

Figure 2.


Catchment ponds
Concrete tanks
Metallic tanks
Plastic tanks
HRW systems (n)
0
10
20
30
40
50
60
Aug. 2011
Sept. 2011
Oct. 2011
Nov. 2011
Dec. 2011
Jan. 2012
Feb. 2012
Mar. 2012
Apr. 2012
June. 2012
July. 2012
Aug. 2012
Month/Year

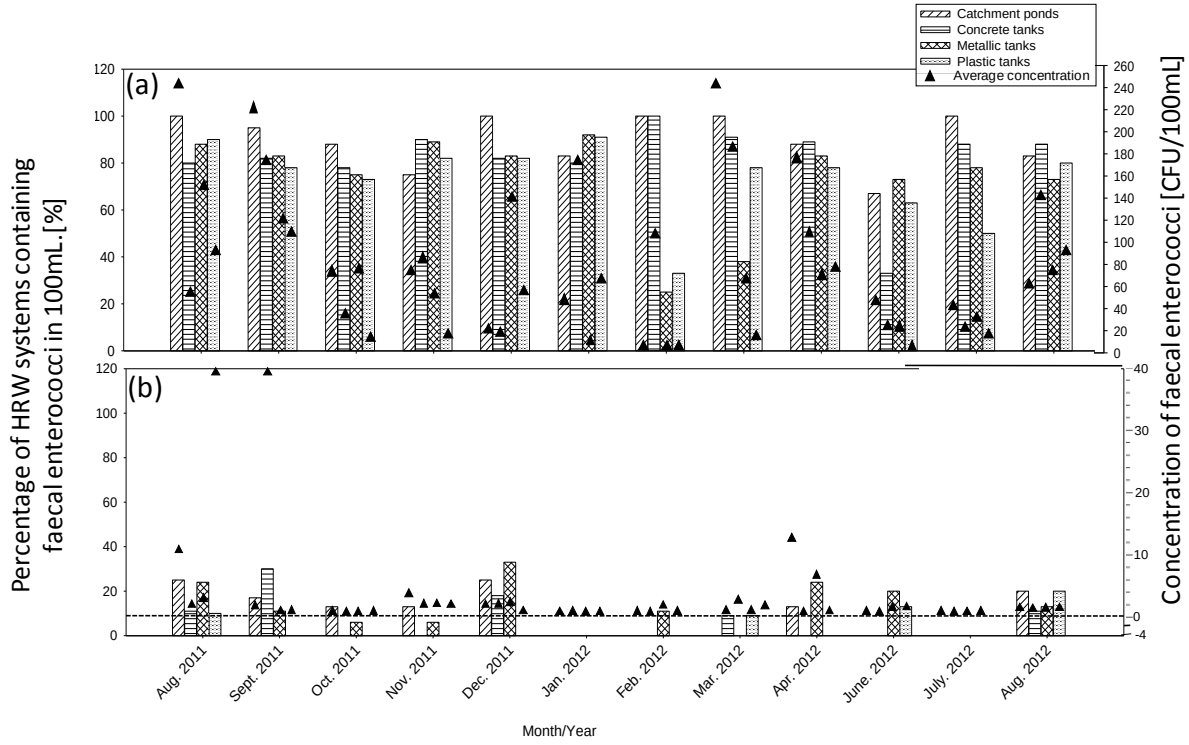
1 Figure 3.


Catchment ponds
Concrete tanks
Metallic tanks
Plastic tanks
Average concentration
(a)
(b)
HRW systems containing E. coli in 100mL [%]
Concentration of E. coli [CFU/100mL]
Aug. 2011
Sept. 2011
Oct. 2011
Nov. 2011
Dec. 2011
Jan. 2012
Feb. 2012
Mar. 2012
Apr. 2012
June. 2012
July. 2012
Aug. 2012
Month/Year

2

3

1 Figure 4.



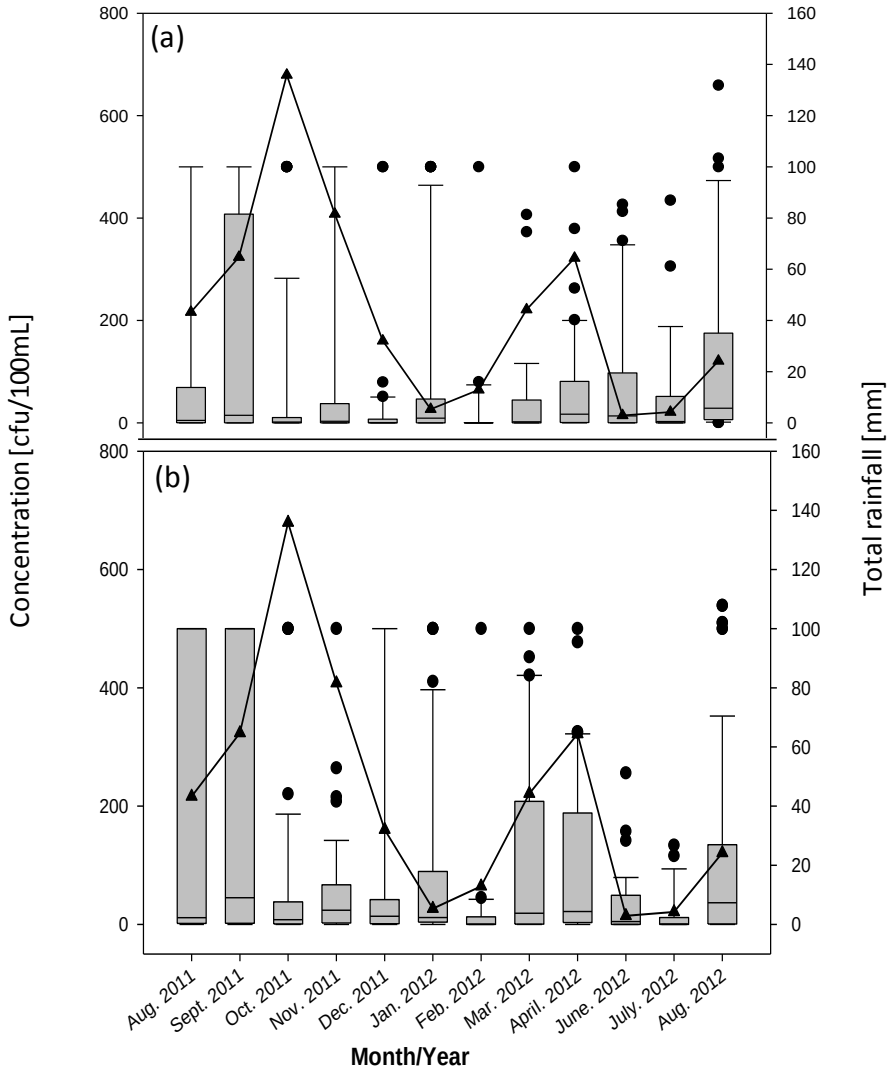
2

3

4 .

1 Figure 5.

2


(a)
(b)
Concentration [cfu/100mL]
Total rainfall [mm]
Month/Year
Aug. 2011
Sept. 2011
Oct. 2011
Nov. 2011
Dec. 2011
Jan. 2012
Feb. 2012
Mar. 2012
April. 2012
June. 2012
July. 2012
Aug. 2012

3