Effectiveness of Solar Disinfection (SODIS) as a low cost water purification technology

A case study of Kikandwa model village, Mukono District

APPROPRIATE TECHNOLOGY CENTRE
FOR WATER AND SANITATION

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Abstract

Water borne diseases such as cholera are such a menace affecting the poorest population segment in Uganda. This owes to high contamination of natural water sources and harvested rainwater. 90% of water borne diseases can be prevented through promotion of point-of-use interventions at household level. Solar disinfection is one of the low cost water purification technologies that can be used to improve the quality of water in rural areas however; there was need to investigate technology effectiveness for generation of evidence before promotion.

This experimental study investigated the quality of water in Kikandwa model village to ascertain the feasibility of SODIS application as a water purification technology. Samples from five selected water sources were subjected to SODIS. Bacteriological and physiochemical analysis was done at the Water Quality Department, Directorate of Water Resources Management, Ministry of Water and Environment.

The physiochemical analysis indicated that all samples taken meet the class 11 drinking water standards i.e. EC, PH, Turbidity, TSS(1050C), colour, Total hardness and Total Dissolved Solids were all in the acceptable range of the UNBS standards. All sources were free from E.coli at the time of collection but harvested rainwater in underground tanks had relatively high counts of total coliforms. It was also established that SODIS is effective if administered for a minimum of 6hours during sunny days. WADI indicator was as well effective at 6hours. SODIS can work as a low cost water purification technology if right procedures are followed. There is however need to repeat the experiment during rainy season and widen the scope to undertake larger study to so as to validate some uncertain findings.

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1. INTRODUCTION

Waterborne diseases such as Cholera, Typhoid and Hepatitis have become more frequent over time in Uganda due to poor water quality. Natural water sources are contaminated by human activities such as urbanization and the associated pollution, poor disposal of industrial effluent, unsafe storage/ handling of water and wastes (both garbage and faecal matter) at household level (MWE, 2012). Water can be contaminated at the source, in the home or during transportation (IFRCRCS, 2008). Similarly, harvested rainwater is contaminated by poor system operation and maintenance and dirt trapped at the catchments (ATC, 2013). Such practices if not controlled expose users to waterborne diseases and are threats to achievement of the Millennium Development Goals (MDGs) by 2015.

In effort to reduce the prevalence of waterborne diseases, government recommends promotion of household safe storage and water treatment among others (MWE, 2012). 90% of the water born diseases can be prevented through simple modification to the environment and increasing access to clean drinking water through promotion of appropriate point-of-use interventions within households (WHO/ UNICEF, Water for Life, 2005). Water can be treated at household level by either physical or chemical disinfection. The physical methods include boiling, heating (fuel and solar), settling, filtering, exposure to UV radiation in sunlight [SODIS] and UV disinfection with lamps. The chemical methods include coagulation-flocculation and precipitation, adsorption, ion exchange and chemical disinfection with germicidal agents (primarily chlorine).

1.1. Kikandwa model village

Kikandwa village is located in Kasawo sub-county, one of the six sub-counties of Nakifuma county, Mukono district. The village has about 231 households served by three point water sources and about 10% of the population uses seven unprotected which are shared with animals. Two households had improved rainwater harvesting systems (Bamutaze & Mutenyo, 2011). By the time of the ATC intervention about 14% of the households did not have toilets. There was also the challenge of collapsing toilets especially for people staying in high water table areas especially along Kayunga road (Ibid, 2011), this coupled with evidence of open defecation (ATC, 2013). All these practices are unhealthy because they suggest possible contamination of the water sources thereby putting the lives of the community members at risk of water borne diseases.

ATC established Kikandwa as a model village in 2011; representing a learning Centre for appropriate technologies in water and sanitation with intention of having the technologies appreciated and replicated by other communities. The model village idea was built on appreciation of the fact that; "though inaccessible, there are a number of appropriate technologies that can adequately address water, sanitation and hygiene challenges including rampant breakdown of preventable diseases such as malaria, diarrhoea, skin and respiratory infections" (Bamutaze & Mutenyo, 2011). As part of the interventions, ATC has so far constructed two underground EMAS tanks, one above the ground rainwater harvesting tank and seven low cost environmentally viable fossa alterna toilets Bamutaze, 2013).

1.2. Solar Disinfection (SODIS)

SODIS is a simple technology that relies on the use of the sun's energy to inactivate and photo-oxidative destruction of disease causing organisms in water such that it is safe for drinking. SODIS breaks down the most dangerous pathogens and greatly enhance the quality of drinking water (Conroy R.M et al, 2001). This is possible with oxidative effect of radials formed by UV radiation. In simple terms, solar disinfection kills pathogens by the combined action of UV radiation and heat.

Source: McGuigan, et al. (2012:pg3)


SODIS experiment at the ATC

1.3. Procedures of using SODIS

The technology works by exposing plastic bottles filled with contaminated water under sun for a specified period of about 6hours. The following must be observed when using SODIS (Dübendorf, 2002);

i) Fill the bottles with water, close and shake for about 20seconds for oxygenation
ii) Place the bottles filled with water on a corrugated iron sheet, rack or underground which reflects sun light.
iii) Bottles should be placed horizontally in a flat angle towards the sun instead of upright.
iv) The bottled should be left in sunlight usually on the roof of your home for one day or two days if the sky is cloudy.
v) Ensure that no shadow falls on the bottles.
vi) Aluminum bucket can be used to construct solar collector.
vii) In the rainy season, paint one side of the bottle black. This will increase the water temperature. The painted side should be placed underneath.

The effectiveness of SODIS depends on the amount of sunlight available. It is also important to note that SODIS does not disinfect residual and may be less effective for bacteria spores and cysts stage of some parasites. It does not improve water turbidity and needs constant supply of bottles. It therefore works well for water with turbidity of 30NTU or less (ibid, 2002).

1.4. WADI indicator

WADI indicator is a new technology developed to eliminate the uncertainty of using SODIS by visualizing the progress of solar water disinfection. The indicator is a measurement device which visualises the progress of SODIS by recording the UV-A irradiation (Helioz Research and Development, 2013). If for example 10 bottles filled with water are administered to SODIS, WADI is fitted on one bottle and will work for all the 10 bottles as long as they are subjected to the same conditions. The reduction of microbial contamination in water is indicated by a progress bar and the smiley face indicates that water is disinfected and safe for drinking. WADI is however a new technology brought in Uganda from Austria and thus the need for country based evidence on its efficacy in enhancing SODIS technology before promotion in the rural communities.

1.5. Problem statement

Pathogenic enteric bacteria present in water are a major cause of waterborne illnesses and the associated mortality that affects Uganda's poor population segment. SODIS is a simple priceless household water treatment technique that can help control preventable diseases outbreak, by improving the quality of drinking water among the rural poor communities. However, information about the effectiveness of SODIS technology in Uganda is very scanty. The technology is currently being applied at the Water School in Kisoro District but there is no documented evidence of . Besides, knowledge and information about the technology has remained unknown in most parts of the country where the prevalence of preventable diseases is fairly high. If well administered, SODIS could provide a remedy for enhancing the safety of drinking water without reliance on wood fuel, expensive electricity and gas.

The technology has gained popularity in Haiti, Indonesia, Sri Lanka, India, Indonesia, Cameroon, Vietnam and Kenya because of its potential to reduce diarrheal diseases incidence (Tamas & Mosler, 2009). However, there is need for a situation based study because the findings of available studies from outside Uganda are double fold. For example, studies in Kenya indicated potential for SODIS to reduce prevalence of water related diseases (Graf et al, 2008 & Conroy et al, 2001) but the health impact study carried out on 7 treatment communities and 4 control communities for a period of one year indicated that in Bolivia illness such as diarrhea did not drop despite the wide adoption of SODIS (Maüsezahl et al, 2009).

The observed failures of SODIS technology in other countries cannot be taken binding for Uganda.
The causes of failure are not explicitly indicated and this gives room for speculations. There is a need for experiment and generation of laboratory based evidence of the potential of this home-based water treatment method to purify water for drinking.

1.6. Objective of the study

To investigate the effectiveness of SODIS as low cost household water purification technology for possible promotion in Kikandwa model village.

1.6.1. Specific objectives

i) Examine the quality of water in Kikandwa model village.
ii) Examine the efficiency of using SODIS to purify drinking water.
iii) Investigate the effectiveness of WADI indicator as an enhancer for SODIS technology.

2. METHODOLOGY

2.1. Baseline samples

Water samples were collected from the model village from four water sources; two rainwater harvesting tanks (1 underground and 1 above the ground) and two boreholes (DWD22418 and DWD 8328). Water samples were also taken from the underground rainwater harvesting tank at the ATC office. These samples were taken for testing to guide selection of water sources for administering SODIS experiment. Samples were administered to the physiochemical and bacteriological analysis. Test results are presented in tables 1 and 2 below.

Table 1: Test results: Bacteriological analysis (Quantity Tray Method)

Parameters (Bacteriological)				
Source			Total Coliform	E.Coli
Name	Location	Type	(No/100mls	No/mls
Tank 1	Kikandwa	Rainwater	2000	<1
Tank2	Kikandwa	Rainwater	19	<1
DWD 8328	Kikandwa	Groundwater	7	<1
DWD22418	Kikandwa	Groundwater	28	<1
Tank3	ATC Office	Rainwater	291	<1
Drinking Water Standard			0	0

The bacteriological analysis (Table 1 above) indicated that all water sources sampled had no E.Coli but the underground rainwater harvesting tanks had high counts of Total Coliforms. Among the boreholes, DWD22418 had the highest count of Total Coliforms.

Table 2: Test results: Physiochemical analysis

Source		EC	PH	Turbidity	TSS (1050C)	Colour	Total Hardness as CaC03	Total Dissolved Solids
Name	Location	ɥs/cm	Unit	NTU	mg/l	Hz Units	mg/l	mg/l
Tank 1	Kikandwa	63	7.4		<1	5	16	44.1
Tank 2	Kikandwa	36	8.4	0.6	1	10	16	25.2
DWD 8328	Kikandwa	369	8.5	0.7	<1	5	98	258.3
DWD22418	Kikandwa	290	8.2	0.5	1	10	99	203
Tank 3	ATC Office	39	8.2	0.4	3	15	22	27.3
UNBS Drinking water standards		**2500**	**6.5-8.5**	**10**	**0**	**15**	**800**	**1500**

The physiochemical analysis indicated that all parameters analyzed were within the acceptable national standards. All water sources had clear with relatively good turbidity, factors that are key to using SODIS (Table 2 above).

Water source selection

The selection of water sources for experimenting SODIS was based on baseline results of bacteriological analysis (table 1). Sources with high Total Coliform count i.e. Tank 1, borehole No. DWD22418 and Tank 3 were selected for administering SODIS.

2.2. Experimental set up

Water samples were collected from the selected sources in labeled Rwenzori mineral water bottles which were very clean. All the bottles were kept in a supervised room from where bunches were picked for subsequent experiment.

The first trial was to administer the water under SODIS for four (4) hours, the second trial was done for six (6) hours and the third trial was done by administering the water bottles under SODIS with WADI indicator. All samples were immediately taken to the Directorate of Water Resources Management, Water Quality Department for analysis.

3. Experimental results

3.1. Bacteriological analysis

Table 3 below presents the bacteriological analysis results for all SODIS experiement conducted.

Table 3: Test results: Bacteriological analysis (Quantity Tray Method)

Source			Parameters (Bacteriological)							
			Day 2 (No intervention)		SODIS (4hours)		SODIS (6hours)		SODIS + WADI	
			Total Colifom	E.Coli	Total Colifom	E.Coli	Total Colifom	E.Coli	Total Colifom	E.Coli
Name	Location	Type	(No/100 mls)	(No/100 mls)	(No/100 mls)	(No/100 mls)	(No/100 mls)	(No/100 mls)	(No/100 mls)	(No/100mls)
Tank1	Mubiru, Kikandwa	Rainwater	2420	<1	201	<1	<1	<1	<1	<1
DWD 8328	Kikandwa	Ground water-Borehole	7	<1	<1	<1	<1	<1	<1	<1
Tank3	ATC Office	Rainwater	249	32	<1	<1	<1	<1	<1	<1
Drinking Water Standards			0	0	0	0	0	0	0	0

3.2. Bacteriological growth

Bacteriological growth relates with the microorganism growth i.e. as a thumb rule, in a closed system, under favorable circumstances (medium, temperature, pH, etc.) the multiplication of microorganisms is analogous to the autocatalytic processes (Willey et al, 2009). For water drawn and kept at room temperature there are two likely effects; either a reduction or an increase in the bacterial count (http://www.univet.hu/sc1/feltoltott/425_1272276477.pdf). For this experiment, water stored registered bacteriological growth as illustrated in table 4 below.

Table 4: Change in bacteriological count

Source Name	DAY 1	DAY 2
	Total Coliform (No/mls)	Total Coliform (No/mls)
Tank1	2000	2420
DWD 8328	28	7
Tank3	291	249

Water was taken from the respective sources and kept for 2days at room temperature. By day two, the sample exhibited both bacterial growth and reduction (table 4 above). The physiochemical analysis in table 2 above indicated that all parameters studied i.e. EC, PH, Turbidity, TSS, color, total hardness and total dissolved solids are within the range of acceptable national standards. There is therefore need for further study to investigate what exactly caused a reduction of bacteria in some samples and a recognized growth in other samples subjected under the same conditions.

3.3. Disinfection time

The bacteria could not be eliminated completely just in four hours. For example, tests done after subjecting water to direct sun's heating for 4hours indicated that water was not yet safe for drinking. Particular for tank1, the Total Coliform count just reduced from 2420mls to 201mls in 4 hours. Effectiveness of SODIS was registered after administering the bottles to direct sun heating for 6 hours i.e., tests done indicated that Total Coliforms significantly to less than one in all samples. Even with the use of WADI indicator, it took 6hours for the indicator to smile, an indication that water has been purified and is safe for drinking.

3.4. Total Coliforms in underground tanks

Underground rainwater harvesting tanks had the highest count of Total Coliforms (Table 1). Though this is suggestive of a challenge that needs further investigations to establish causes of contamination, the sample was too small to reach a sound conclusion. There is thus need for a large scale study.

3.5. E.Coli

Originally E.Coli count was less than one in all samples; however, tank 3 exhibited an exponential growth in E.coli by day two. This growth could also be attributed to other factors i.e., samplings procedures. However, by administering SODIS for 6hours, the bacteria were wiped out to less than one.

4. CONCLUSION AND RECOMMENDATIONS

The quality of water in Kikandwa model village did not exhibit presence of E.Coli. Though the Total Coliform count was relatively high, the physiochemical parameters i.e., turbidity, PH and Total Hardness were within acceptable standards for drinking water. Therefore, SODIS can work perfectly well if administered at 6hours minimum on sunny days, following the right procedures. It is deemed important to filter the water before administering SODIS and this can be done by using a clean piece of cloth. SODIS is a priceless technology that can be used by the rural poor to purify drinking water. It can be applied by any local person once they understand the procedures.

However, there is need to repeat the experiment during rainy season. As earlier pointed out, there is also need for a study with larger sample to be able to validate some uncertain findings i.e., water from underground rainwater harvesting tanks being more contaminated compared to above the ground tanks and also establish the certainty of E.Coli growth in water samples that presented no threat at earlier analysis.

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