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The potential of solar water disinfection as a household water treatment method in peri-urban Zimbabwe

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ABSTRACT

The potential for reducing diarrhoea morbidity and improving the health status of children in developing countries using solar water disinfection (SODIS) has been demonstrated in past research. A baseline survey was conducted to explore the feasibility and necessity of introducing SODIS in peri-urban communities of Zimbabwe. The survey sought to establish drinking water quality in these areas and to determine the health and hygiene beliefs as well as practices related to water handling in the household. Microbiological water quality tests and personal interviews were carried out in Epworth township and Hopley farm, two peri-urban areas near the capital of Zimbabwe, Harare. These two areas are among the poorest settlements around Harare with 80% of inhabitants being informal settlers. Community meetings were held to introduce solar water disinfection prior to the survey. This was followed by administration of questionnaires, which aimed to investigate whether the community had ever heard about SODIS, whether they were practicing it, other means that were being used to treat drinking water as well as health and hygiene beliefs and practices. It was found out that most households cannot afford basic water treatment like boiling as firewood is expensive. People generally reported that the water was not palatable due to objectionable odour and taste. Microbiological water quality tests proved that drinking water was contaminated in both areas, which makes the water unsafe for drinking and shows the necessity of treatment. Although the majority of people interviewed had not heard of SODIS prior to the interview, attitudes towards its introduction were very positive and the intention to do SODIS in the future was high. Amongst the ones who had heard about SODIS before the study, usage was high. Plastic PET bottles, which were used for the SODIS experiments are currently unavailable and this has been identified as a potential hindrance to the successful implementation of SODIS.

1. Introduction

At least one third of the population in developing countries and almost one fifth of the global population has no access to safe drinking water and drinking water related diseases continue to be one of the major health problems globally (WHO, 2002). The lack of adequate water supply and sanitation facilities causes a serious health hazard and exposes many to the risk of water borne diseases. There are about 4 billion cases of diarrhoea each year, out of which 2.5 million cases end in death (WHO, 2002). Every day about 6000 children die of dehydration due to diarrhoea (Ashbalt, 2004). Universal access to safe water and sanitation is an essential step in reducing this preventable disease burden. Moreover, some of the 83% of the world's population who use improved water sources nonetheless drink water that has been contaminated. The water quality of systems classified as improved water supply is often affected by unreliable operation and lack of maintenance, or is affected by secondary contamination during collection, transportation, and storage. For these segments of the world's population, decentralized point-of-use water treatment systems have direct beneficial effects in the form of reduced infectious diseases. The UN set the goals of halving the proportion of people without sustainable access to safe drinking water and of reducing under-five mortality by two thirds by 2015 under the Millennium Development Goals (MDG). To reach those goals, more than one approach to solving the existing problems has to be undertaken. WHO in its 2002 report recommended that increased emphasis should be placed on home water treatment and storage, and that more research should be conducted to assess the components of such interventions (WHO, 2002). Solar water disinfection (SODIS) is one possible solution to the problem of contaminated water (Conroy et al., 1999).

SODIS is a pro-poor point-of-use water treatment system that is effective and affordable to the peri-urban inhabitants and may reduce diarrhoeal diseases at household level. SODIS is a simple method: it uses solar radiation to destroy pathogenic microorganisms that cause water borne diseases. Contaminated water is

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filled into transparent plastic bottles and exposed to full sunlight for about 6 h (or two consecutive days if the weather is more than 50% cloudy). Sunlight treats the contaminated water through two synergetic mechanisms; radiation in the spectrum of UV-A (wavelength 320–400 nm) and increased water temperature. A combination of the two kills most of the bacteria, which are harmful to human health. SODIS is completely effective against the pathogens responsible for cholera, dysentery, typhoid, giardiasis, salmonella, gastroenteritis, and polio (Conroy et al., 2001).

In Kenya, a study among 206 people aged 5–16 years was conducted. During the four-month study-period, the number of new cases of diarrhoea in families using SODIS was 10% less than in families that were not using the method (Conroy et al., 1996). Another study among Kenyan children under 5 years showed a reduction of 16% of diarrhoeal illnesses among SODIS users compared to non-users of SODIS, over a one year observation period (Conroy et al., 1999). In Bangladesh, SODIS was introduced in 16 villages. The uptake of the method was promoted by local development committees. Child diarrhoea was significantly less frequent in villages with strong committees, high level of village organization and commitment for community development, which led to a better adoptation of SODIS by the villagers (Hobbins et al., 2000).

A cholera outbreak occurred in 1997/1998 in the Kenyan study by Conroy et al. (1996). The researchers were able to demonstrate the efficiency of solar water disinfection for cholera prevention in children below the age of 6. Among SODIS users, children below 6 years were eight times less likely to contract a cholera-diarrhoea. This could be attributed to the fact that mothers strictly controlled the type of drinking water consumed by their small children, while older people also drank water from contaminated water sources.

Children from Maasai village below the age of six were selected at random and were given water either left in plastic bottles and exposed to sunlight on the roof of the house or kept indoors as the control (McGuigan et al., 1998). Children drinking solar disinfected water had a significantly lower risk of severe diarrhoeal disease over two weekly follow up visits. This confirms solar disinfection as effective in vivo as a free, low technology point of use method of improving water quality. This study analysed the drinking water quality in Epworth and Hopley farm. Data from clinics on diarrhoea incidences were reviewed. Together with household interviews, the need for treating water (with SODIS) was examined. For that, SODIS was briefly introduced, so that health and hygiene beliefs, attitudes towards SODIS, practices related to water handling and their effects could be determined.

2. Materials and methods

2.1. Study area

The study was carried out in Epworth township and Hopley farm, two peri-urban settlements around Harare. About 350,000 people live in Epworth of which 80% are informal settlers (CSO, 2002). Epworth which has 90% of the residents unemployed (CSO, 2002) is situated on the south-eastern end of Harare. Water sources are either open unprotected or protected self-dug shallow wells. Most people in this area cannot afford to treat their water and report regular health problems related to the stomach and diarrhoea. Especially weak people (children, older people and the sick people) suffer from the water situation. The rainy season stretches from December to March.

Hopley farm is a government resettlement area located 25 km from the city centre of Harare. There are about 6000 households each with an average of 5 people (Ashuyari, 2007). People living in informal settlements from all over the country are usually relocated to this farm. More than 70% of the residents are poor (CSO, 2004). Climatic conditions are the same as for Epworth.

2.2. Sampling

Water samples were collected from different sources of water used by the communities in both Epworth and Hopley farm. The samples were collected from boreholes, open shallow wells (unprotected), shallow wells (protected), and water stored in different containers at homesteads, such as 5l plastic bottles, 20l metal or plastic containers. Water samples from these sources were sent for analysis at the Zimbabwe National Water Authority Water Quality Laboratory.

Five community meetings were held for the purpose of introducing SODIS. Epworth is divided into six wards with four wards having no potable water supply system, and as such meetings were conducted in these four wards. One meeting was conducted in Hopley farm with the health promoters, care givers and the home based care committee, who were requested to disseminate information about SODIS during their day to day work in the community.

A questionnaire aimed at obtaining information on attitudes and practices of the local people towards water treatment (including SODIS) was administered. The systematic sampling method was used to select households for administering the questionnaires.

3. Results and discussion

3.1. Water sources and treatment of water

A total of 878 inhabitants were interviewed of which 364 were at Hopley farm and 514 in Epworth. A household had on average five people. Of the respondents, 91% were women and 9% were men. Some 24% of the respondents were unemployed, 22% vendors, 27% informal traders, and 27% housewives. Water sources used by communities in Epworth and Hopley farm are presented in Table 1.

Unprotected wells are the most common source of water in Epworth, while most households in Hopley farm obtain their water from public taps. Most of the households in both locations did not carry out any treatment of their water (Table 2).

Although most residents of these settlements do not treat their water, diarrhoea was reported in interviews to have affected about 20% of the households at some stage. Interviews with staff at local clinics suggested high incidences of diarrhoea particularly among the under 5 year children. Bacteriological analysis of water samples collected during this study revealed the presence of coliforms in water, an indication that water used in these two communities was contaminated (Table 3).

Table 1
Proportion of households using different types of water sources at Hopley farm and in Epworth

Water source	Hopley farm (%)	Epworth (%)
Unprotected wells	14	69
Public tap	77	11
Boreholes	27	2
Protected well	0	19

Columns add to more than 100% as some households use multiple water sources.

Table 2
Proportion of households carrying out treatment of water for household use

Water treatment method	Hopley farm (%)	Epworth (%)
No treatment	76	73
Boiling	6	15
Use of chemicals	2	5
SODIS	6	15

Table 3
Total coliforms occurring in various water samples obtained from Epworth and Hopley farm

Sample type	Epworth	Sample type	Hopley farm
Protected well A	42	Borehole A	1
Protected well B	7	Borehole B	33
Protected well C	420	Stored tap water in the house	181
Unprotected well	27	Stored tap water in the house	183
Pond	60	Stored tap water in the house	17
Stored water in the house	400	Tap water	7

All units are in CFU/100 ml.

3.2. Bacteriological water quality

The results of the bacteriological water quality assessment are presented in Table 3.

Bacteriological analysis of water samples shows that secondary contamination of stored water is high in both Epworth and Hopley farm. The quality of water from protected wells in Epworth is highly variable (Table 3). Stored water obtained from taps at Hopley farm indicated possible secondary contamination as a maximum of 183 CFU/100 ml were found in stored water while in samples taken directly from the tap, 7 CFU were found. In Epworth, the protected wells are safer (7 CFU/100 ml for total coliforms) than unprotected wells (27 CFU/100 ml), the other water (from open water source, stored water) was not safe (42–420 CFU/100 ml).

The recommended limit for total coliforms in drinking water in Zimbabwe is zero CFU per 100 ml (ZINWA, 2003) and the results show that coliform values for all the samples were above the recommended limit thus the water was (highly) contaminated. The presence of coliforms is an indication that the water has been contaminated biologically and that it has a risk of containing pathogens. Potential health effects of biological contamination of water include assorted gastro enteric infections and diseases (Feachem, 1981). Total coliforms come from the air, handling water with dirty hands, dead animals or insects which fall into the water sources. Symptoms such as nausea, vomiting, diarrhoea, and stomach cramps are typically associated with drinking water that is contaminated biologically. People with weakened immune systems are especially susceptible to illnesses. *E. coli* is a normal inhabitant of the intestine and most strains are non-pathogenic. Pathogenic *E. coli* strains cause intestinal disease by a variety of mechanisms. Infections may resemble cholera, dysentery or gastroenteritis (WHO, 2002). The presence of *E. coli* in water always indicates potentially dangerous contamination, requiring immediate attention (Feachem, 1981).

3.3. SODIS application

Data collected during the questionnaire survey revealed that 21% of the respondents had some information about SODIS derived from meetings conducted or information passed by friends. More than half of those who heard about SODIS are practicing it.

Respondents practising SODIS do not find it time-consuming and find it easy to remember to regularly use SODIS for the treatment of their water. Reasons cited for the use of SODIS included the prevention of diseases (19%), safety of the raw water (21%), routine practice (54%), need for clean water (17%), reminder by others (7%) and the empty SODIS bottles, which imply that more SODIS treated water is now required (20%). Those interviewed think SODIS is worth a lot more than it costs. Perceived safeness of drinking water was mixed although people were aware that drinking untreated water has health risks and feel that it is very important for them that their drinking water is safe. Generally, respondents knew that there were some quality problems with their drinking water, but were not aware of bacterial contamination of the water. For all those interviewed, the intention to use SODIS in the near future was high.

When asked whether they see other advantages about SODIS, 61% said that it is easy (less laborious, no firewood requirements, understandable), 36% felt that it prevents diseases (kills the germs, promotes good health) and 4% find water treated by SODIS to have a better taste compared to that which has not been treated by SODIS. When asked for the disadvantages, 28% named bottle unavailability, 5% felt there was a problem in SODIS needing sunlight (wet season) and 1% was doubtful about leaving the bottles in the sun unattended. Others were of the opinion that the water might still be hot or warm at the time of consumption and that the treatable amount is too small and therefore making the exercise time-consuming. Overally, the attitudes towards and convictions about SODIS were very positive, like it has been recognized in other studies (Altherr et al., 2008). Apart from being viewed as expensive (due to low bottle availability), the benefits were viewed as very high. Although the knowledge about bacterial contamination of drinking water is low, there is doubt about the safeness and healthiness of the untreated water. Knowledge on bacterial contamination should be enhanced to raise awareness on the need for water treatment. Bottle availability and the negative perception about costs of SODIS should be addressed if an implementation of SODIS in the study areas is to be successful.

4. Conclusions

Based on the results of this study the following conclusions were made:

(1) Most of the water sources were contaminated biologically, a condition not favourable for drinking water according to standards.
(2) SODIS is a potential household water treatment system that can be implemented in Epworth township and Hopley farm to reduce the incidence of water borne diseases. SODIS is being practised by a fairly large proportion of those who heard about it and most of those interviewed are willing to practise SODIS in the near future.
(3) There is a low knowledge about bacterial contamination of water and consequently the appreciation for the need to treat water is low. This is a major challenge for the implementation of SODIS, and should be addressed.
(4) The unavailability of PET bottles (used in SODIS) and their cost are factors to consider in the implementation of SODIS.

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