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Attitude, Perception, Knowledge and End-Use of Roof-Top Harvested Rainwater in Aduwawa Community, Edo State, Nigeria

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ABSTRACT

Several communities in water-limited area rely on harvested rainwater due to the perception that it is fit to drink without prior treatment. This study aims to assess user's perception and end-use of harvested rainwater as well as the microbiological quality of harvested rainwater in Aduwawa community, Benin City, Nigeria. A structured questionnaire was used to investigate users' perception and end-use of the harvested rainwater. Microbiological analysis was carried out using standard culture-based methods. About 28% of the rainwater harvesting system was situated in poor sanitary locations (close to a septic tank, refuse dump or pit latrine). The harvested rainwater was used for both potable and non-potable functions. Over 70% of respondents use the harvested rainwater for bathing and 40% for cooking. Also, 90% of the respondents use harvested rainwater as an alternative source of water. According to the respondents, about 82% attest that they do not notice any health-related illness as a result of using the harvested rainwater. Microbiological analysis of the rainwater revealed that the rainwater samples did not meet the WHO standard for drinking water. Harvested rainwater could serve as an alternate source of water for households for non-potable use. Rainwater should be treated before use for potable functions.

1. INTRODUCTION

Accessibility to safe potable water of acceptable quality is a major challenge faced by several communities around the globe. Impaired water quality in community systems has resulted in an annual estimation of 16.4 million cases of acute gastroenteritis in the United States (Messner *et al.*, 2006). Safe drinking water supply in communities is of significant consideration in the safety of human health and well-being. Epidemiological studies reveal that every phase of quality water supply service, hygiene behaviors and sanitation affect human health (WHO, 1997).

There is an increase in the demand for fresh water due to rapid growth of the world's population, contamination of available water sources, and the detrimental effect of climate change (MwengeKahinda *et al*., 2007; Dobrowsky *et al*., 2016). Communities in water-scarce areas have adapted rainwater harvesting due to the perception that rainwater is clean and safe to drink (Ahmed *et al*., 2017; Kaushik *et al*., 2012). Access and availability of water is of principal concern in addition to other factors including cost burden to the consumer and the dependability of the supply are vital to be put into consideration (WHO, 1997).

Roof-harvested rainwater (RHRW) has been used as a substitute of freshwater source in many countries, as RHRW systems could be exploited to supplement existing water supplies for domestic, recreation and agricultural uses (De Kwaadsteniet *et al*., 2013). However, during harvesting, rainwater could be contaminated (De Kwaadsteniet *et al*., 2013; Waso *et al*., 2019). During a rainfall event, airborne microorganisms and chemical contaminants could come in contact with rainwater (MwengeKahinda *et al*., 2007). Also, rainwater receives microbiological contaminants from the fecal materials of different animals and debris dropped on the rooftop and gutters (MwengeKahinda *et al*., 2007). Therefore, stored rainwater in the reservoir may harbour the potential pathogen of public health significance.

The use of untreated RHRW is associated with diseases such as diarrhoea with the causative agent being *Salmonella* and *Campylobacter*, bacterial pneumonia found to be associated with Legionella exposure, and botulism linked to *Clostridium* exposure (De Kwaadsteniet *et al*., 2013; Gwenzi *et al*., 2015; Waso *et al*., 2019). Waterborne diseases are spread through contaminated drinking water supply and inadequate sanitation and hygiene practices. Access to safe drinking water is critical to maintaining good health which is why the public and environmental health protection requires safe drinking water, one which must be free of pathogenic bacteria.

Among the pathogens disseminated in water sources, enteric pathogens are the most frequently encountered. As a consequence, sources of faecal pollution in waters caused by human activity must be strictly controlled (Annie *et al*., 2002). The surveillance of water quality is carried out by assessing the presence of faecal indicator bacteria (FIB) such as *Escherichia coli* (*E. coli*), *Enterococcus* spp., and total faecal coliforms. This has been attributed to the fact that FIB is dominant in faecal matter, non-pathogenic, and more convenient and safer to handle (Harwood *et al*., 2005; Waso *et al*., 2019). The incidence of *E. coli* in stored rainwater signifies the presence of faecal contamination and the occurrence of potential pathogens (Ahmed *et al*., 2011a,b; Ahmed *et al*., 2017). Therefore, this study aims to assess the user's perception, end-use of rooftop harvested rainwater by Aduwawa community dwellers and microbiological quality assessment of the rooftop harvested rainwater.

2. MATERIALS AND METHODS

2.1. Study Site

The study was conducted in Aduwawa community located in Ikpoba-Okha Local Government Area of Edo State, in the South-South geopolitical region of Nigeria. It is a large community which shares boundaries with other communities like Oregbeni, Evbomodu, Idunmwunowina, Uteh and Iwogban communities. The area is characterized by two distinct seasons, the wet season which lasts between March and November and the dry season which lasts between November and February.

2.2. Questionnaire Survey

Households in Aduwawa community with visible rainwater harvesting system were recruited into the study. A household with no visible rainwater harvesting system was not included in the study. Informed consent was given to an individual in a household with a rainwater harvesting system. A structured questionnaire was used for data collection. A questionnaire was given to the household head or representative member of a household above 18 years of age to participate in the study. Before the administration of the questionnaire, informed consent was received from each respondent. The structured questionnaire used for the survey was modified form in an earlier study (Mosley, 2005; Igbinosa and Osemwengie, 2016).

2.3. Sample Collection

Rainwater samples were collected from a storage reservoir of rainwater harvesting system into a sterilized sampling container. The sterile sampling container was first rinsed with the samples three times before sample collection. To limit unevenness with samples, samples were collected from all locations same day and transported to the laboratory for microbiologically analysis. Samples were collected within 3 months (August to October, 2018) from 50 households resulting in a total of 150 rainwater samples. The samples were labelled appropriately and immediately transported in a cooler box containing ice to the Applied Microbial Processes and Environmental Health Research Group at the Faculty of Life Sciences, University of Benin, Benin City, Nigeria for bacteriological analysis out using standard procedures (IOS, 2017).

2.4. Bacteriological Analysis

Water indicator organisms including *Enterococcus* species, *Escherichia coli* and *Salmonella* were enumerated to ascertain the water quality. Faecal coliforms were detected using m-Fc agar (Merck, Darmstadt, Germany), total coliforms were enumerated from m-Endo agar (Merck, Darmstadt, Germany), *Enterococcus* were enumerated from Bile Esculin Azide agar (Merck, Darmstadt, Germany), *Salmonella* species were detected using Hektoen enteric agar (Merck, Darmstadt, Germany), *Escherichia coli* were enumerated from Chromocult coliform agar (Merck, Darmstadt, Germany). All media were prepared according to the instruction given by the manufacturer. Each agar plate was inoculated with 100 µL of rainwater samples and evenly spread using the spread plate technique. Agar plates were incubated for 24 h. All agar plates (m-Endo agar, Bile Esculin Azide agar, Hektoen enteric agar, Chromocult coliform agar) were incubated at 37ºC except (M-FC agar) which was incubated at 44ºC (Igbinosa and Kadiri, 2018).

2.5. Statistical Analysis

The completed questionnaires were screened for completeness. Descriptive statistical analysis was employed for the data obtained in the questionnaire. Statistical analysis of differences between the different bacterial counts was carried out using the chi-square test. Statistical significance was set at $p < 0.05$ for all values of the chi-square test. All data were performed using Statistical Package for Social Sciences (SPSS) version 16.0 (SPSS Inc, Chicago IL 60606- 6412).

3. RESULTS AND DISCUSSION

Fifty households that consent to the study were surveyed. Water samples were collected for three months resulting in a total of 150 samples. The demographic characteristics of the respondent in the study are as shown in Table 1. The frequency of respondent who were employed was 52%, and female respondent was 74%. The demographic characteristics of the respondent reveal that over half were educated at the tertiary level, sixty-eight per cent (68%) were married, and thirty-two per cent (32%) of respondent were between the ages of 36-50 years, and seventy-four per cent (74%) of respondent were female. The high frequency of female observed in the study may be associated with the fact that females are more involved in the providence of water supply in homes as part of their role in the management of their household. The proximity of harvested rainwater no doubt plays a role in assisting household water use and management. The report on the Myanmar community initiative to support rural dwellers and adaptation to climate change has shown to be helpful to women (Htun *et al.*, 2017). The women used to fetch water for drinking and other home use from the pond. The women were usually tired and have a challenge in carrying out other household chores. However, with the community rainwater harvesting system installed, it takes less than 25 min to fetch water, thus enabling them to dedicate more time to childcare, household chores and farm work.

Table 1: Demographic characteristics of respondents from households that practice rainwater harvesting in Aduwawa community

Sex	Frequency (%)	Employment status	Frequency (%)
Male	26	Employed	52
Female	74	Unemployed	28
		Students	20
Age	Frequency (%)	Educational status	Frequency (%)
18-25	20	Tertiary	60
26-35	18	Secondary	12
36-50	32	Primary	10
51-70	22	None	18
70 and above	8		
Religion	Frequency (%)	Marital status	Frequency (%)
Christians	94	Single	32
Muslims	2	Married	68
Others	4		

Site assessment of rainwater harvesting system was carried out to ascertain the nature and condition of the reservoir, the type of roof materials they are made up of among others as shown in Table 2. Corrugated iron-sheet has a higher incidence in most rainwater harvesting system, and most of the roofing sheet was in 'fair' appearance. The storage reservoir were mainly concrete wells (50%) followed by open containers (26%) which encompasses bowls, buckets for harvesting rainwater. Only 18% of the reservoirs were in 'good' condition and 8% in a very 'poor' condition. About 70% of the reservoir had lid while 40% of the lid was tight fitted. Sanitary location of the harvested rainwater reveals that twenty-eight percent (28%) were situated close to a septic tank, refuse dump or pit latrine. About 21% of the gutter/funnels were in "Good" condition and 56% has never washed their gutters/ funnels.

Corrugated iron sheet and long span aluminum were the roof types used in rainwater harvesting system in the studied community. In a study carried out at Ugbihioko community, (Igbinosa and Osemwengie, 2016), corrugated iron sheet was the predominant roofing sheet found in the harvested rainwater system. This study differs with another rural community previously studied (Igbinosa and Aighewi, 2017) which had asbestos and open space as additional means of rainwater harvesting. However, corrugated iron sheet span at highest frequency in all studied locations. Also, in Aduwawa community studied, storage reservoirs were predominantly concrete wells, followed by open containers, whereas in Oluku community drums (30%) had the highest prevalence of storage reservoir followed by concrete wells and bucket (25%). Most of the storage reservoir was over ten years of age (Igbinosa and Aighewi, 2017).

About 70% of the rainwater storage reservoir had a lid (Table 2). The lid is vital in storage reservoir as covering of the water help in preventing debris and contamination in the water. The need for cleanliness and management of water storage reservoirs cannot be overemphasized. Debris and insect may fall into the reservoir, sludge and sediments can accumulate which can lead to water contamination and microbial growth, thereby having an impact on the user's health. In the Aduwawa community studied, about 82% do clean their reservoir which encompass 36% that cleaned their reservoir annually. This observation is higher than a previous study in South Australia (Rodrigo *et al.*, 2010) and a study in Nigeria (Igbinosa and Osemwengie, 2016). According to Canadian Standards Association (CSA), annual cleaning of water reservoirs is recommended and subsequent periods of maintenance, repair and construction, of a reservoir, during times of non-use and indication of bacterial contamination. Furthermore, reservoirs should be installed in areas that will ease accessibility to cleaning and maintenance. Filter screen and First flush diverters were absent in most of the rainwater harvesting system in households surveyed. The presence of first flush diverters and filter screens improves the water quality in reservoirs by preventing dirt and debris from entering the rainwater storage reservoirs and minimizes contamination. (Singwane and Kunene, 2010; Igbinosa and Osemwengie, 2016). Adequate installation and maintenance of the filters impacts on the quality of rooftop runoff.

Table 2: Site assessment of rainwater harvesting systems in Aduwawa community

Type of roofing sheet	Frequency (%)	Type of reservoir	Frequency (%)
Corrugated iron sheet	76	Concrete wells	50
Long span aluminium	24	PVC tanks	14
Others	0	Open containers	26
Condition of roofing sheet	Frequency (%)	Condition of reservoir	Frequency (%)
Good	28	Good	18
Fair	62	Fair	74
Poor	10	Poor	8
Overhead vegetation	Frequency (%)	Lid	Frequency (%)
Present	38	Present with tight Fitting	40
Absent	62	Present without tight fitting	30
		Absent	30
Age of roof	Frequency (%)	Washing of reservoir	Frequency (%)
Less than 10 years	24	Once a year	36
Above 10 years	76	Twice a year	30
		Once in 2-5 years	26
		Never	8
Gutters and Funnels	Frequency (%)	Duration of storage	Frequency (%)
Present	56	Less than 3 months	36
Absent	44	6 months	20
		1 year	10
		Above 1 year	14
Condition of gutters/funnels	Frequency (%)	Condition of fetcher	Frequency (%)
Good	21	Good	18
Fair	68	Fair	76
Poor	11	Poor	6
Ever washed gutters/funnels	Frequency (%)	Type of fetcher	Frequency (%)
Yes	44	Plastic	94
No	56	Metal	6
Downpipes	Frequency (%)	Sanitary location	Frequency (%)
Present	50	Septic tank	20
Absent	50	Refuse dump	6
		Pit latrine	2
		None	72
Filter screens/leave control device	Frequency (%)	First flush diverters	Frequency (%)
Present	40	Present	26
Absent	60	Absent	74

The result of the questionnaire survey revealed that the harvested rainwater was used for both portable and non-potable functions. The uses of rainwater in Aduwawa community as well as treatment options are shown in Table 3. Over 70% of respondent use the harvested rainwater for bathing and 40% for cooking. Also, over 90% of the respondent use rainwater as an alternative source of water. About 4%, 8% and 6% attest that the harvested rainwater has odour, colour and taste respectively; however, a larger percentage (82%) attest that harvested rainwater does not show any aesthetic characteristics. According to the respondents, about 82% attest that they do not notice any health-related illness as a result of using the harvested rainwater. However, 18% indicate that they do experience body itching as a result of using the harvested rainwater.

Table 3: Rainwater usage and treatment types

Source	Frequency (%)	Uses	Frequency (%)
Only source	8	Drinking, cooking, bathing, washing and flushing	6
Alternative source	92	Cooking, bathing, washing and flushing	34
		Bathing, washing, and flushing	18
		Bathing and washing	24
		Washing and flushing	18
Means of fetching	**Frequency (%)**	**Aesthetic condition**	**Frequency (%)**
Bucket	86	Odour	4
Tap collection	14	Colour	8
		Taste	6
		None	82
Treatment before use	**Frequency (%)**	**Method of treatment**	**Frequency (%)**
Yes	16	Boiling	37
No	84	Chlorination	26
		Alum	37

The use of harvested rainwater was surveyed, only 18% use it solely for a non-potable role. The harvested rainwater in the study area was used for several purposes including drinking. The use of rainwater for potable function has been described in Ethiopia and Sri Lanka (Devi *et al*., 2012), and a higher prevalence reported than the one observed in this study. Rainwater has been a source of drinking water to communities in remote and rural Australia, and increased use in the urban areas. Yet health authorities are disinclined to recommend rainwater as a source of drinking water (Leder *et al*., 2002; Chubaka *et al*., 2018).) Rainwater has proved to be a valuable substitute for community water use. The Royal Australian Air Force (RAAF) supplied water tanks with harvested rainwater to communities in Katherine, Northern Territory of Australia in 2017 (Chubaka *et al*., 2018). About three decades ago, rainwater harvesting was not a welcome practice in urban areas with available municipal water; nevertheless, as time goes by, rainwater harvesting and its use became an established practice in urban areas (Sinclair, 2007).

The duration of use and storage of the harvested rainwater was assessed. The respondent ascribed the duration of storage of the harvested rainwater to the frequency of usage. Majority of respondent store their water for less than 3 months; this may be ascribed to the fact that the respondents relied upon the harvested rainwater for most domestic use and as the main source of water supply. Nevertheless, about 14% store their rainwater for over a year. Factors that could result in longer storage include, water being used as an alternative water supply, no of individual per household, the size of the storage reservoir. However, for long storage of rainwater, it is recommended that there should be periodic addition of chlorine to maintain chlorine residual and reduce slimy growth of bacteria in the reservoir. The site location of the harvested rainwater to a septic tank, pit latrine or refuse dump is of public health concern. Generally, water storage reservoir is expected to be situated upslope away from sewage disposal amenities, at least 10 feet away from impermeable sewer lines and drains, minimum 50 feet away from non-impervious sewer lines and drains septic tanks, sewage, and animal stables. The frequency of presence of first flush diverters observed in this study is similar to a previous study where there were 30.8% of household with first flush diverters and 57.2% with leaf control screens. The use of first-flush diverters was found with most of the rainwater harvesting (RWH) system users. The presence of first flush diverters in the rainwater harvesting system improves water quality stored in reservoirs and subsequently, reduction in treatment need (Singwane and Kunene, 2010).

The microbiological characteristics of the harvested rainwater was carried out. The result reveals the presence of *Enterococcus* species in 80/150 samples (53.3%), total coliforms were detected in 126/150 samples (84%), *Salmonella* species was present in 71/150 (47.3%) samples, *Escherichia coli* was detected in 38/150 (25.3%) samples, fecal coliform was detected in 67/150 (44.7%) samples. The mean of the respective bacterial count expressed from the harvested rainwater is as shown in Table 4.

Table 4: Mean bacteria counts from the roof-top harvested rainwater

Bacteria	Mean ± SD (CFU/mL)	WHO standard
Enterococcus species	8.32 ± 0.14	<1
Total coliforms	56.62 ± 0.43	<10
Salmonella species	21.72 ± 0.22	<1
Escherichia coli	7.64 ± 0.013	<1
Faecal coliform	10.80 ± 0.27	<1

Some respondent in the study attests that the harvested rainwater has some aesthetic condition. The direct impact of their claim on the health of the consumer could not be ascertained. However, it is interesting to note that Adelaide residents in Australia preferred drinking harvested rainwater even with available and accessible municipal water, a survey of their attitude reveals that their preference for rainwater was based on the taste as per quality (Chubaka *et al*., 2017). A study on quality assessment of harvested rainwater in Ugbihioko community in Benin city, Nigeria, about 10% of respondent affirm that they drink the harvested rainwater (Igbinosa and Osemwengie, 2016). It has also been documented that harvested rainwater is used for potable functions including drinking in Sri lanka and Ethiopa (Devi *et al*., 2012), Although, most of respondent attest that they do not notice any health-related disease associated with the use of harvested rainwater, this observation is contrary to the microbiological quality of the rainwater recorded in the study, as the result reveal microbial contamination and none of the rainwater samples assessed meet with WHO standard of drinking water (WHO, 1997; 2004). The limited or lack of reported illness may be explained with evidence from earlier studies which suggest the low intensity of human health impact associated with the use of rainwater (Evans *et al*., 2006; WHO, 2011). The design and maintenance of rainwater harvesting system play a vital role in limiting health consequence associated with harvested rainwater. Also, there is the possibility of the development of immunity to pathogens in rainwater, or they may experience asymptomatic illness or mild infection that is self-resolving without being noticed (Macomber, 2001; Chubaka *et al*., 2018). Reports by Himalica women on the community rainwater harvesting project reveal that the providence of rainwater to community plays a significant role in reducing the incidences of waterborne disease experiences by inhabitants of Himalica community (Htun *et al*, 2017).

4. CONCLUSION

With the ever-increasing demand for water supply, harvested rainwater could serve as an alternate source of water for households for nonpotable use. Rainwater should be treated before use for potable functions. There is a need for public health education for the appropriate design for rainwater harvesting system and use to eliminate possible health impact that may result from poor water quality.

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Ahmed, W., Hodgers, L., Masters, N., Sidhu, J. P., Katouli, M. and Toze, S. (2011a). Occurrence of intestinal and extra intestinal virulence genes in *Escherichia coli* isolates from rainwater tanks in Southeast Queensland, Australia. *Applied Environmental Microbiology*, 77: pp. 7394–7400.

Ahmed, W., Gardner, T., and Toze, S. (2011b). Microbiological quality of roof harvested rainwater and health risks: a review. *Journal of Environmental Quality*, 40(1), pp. 13–21.

Ahmed, W., Staley, C., Hamilton, K, A., Beale, D. J., Sadowsky, M, J., Toze, S. and Haas, C, N. (2017). Amplicon-based taxonomic characterization of bacteria in urban and periurban roof-harvested rainwater stored in tanks. *Science of the Total Environment*, 576, pp. 326-334.

Annie, R., Pierre, S., Julia, B., Marie-Rene´e, D. and Patrick, L. (2002). Detection and enumeration of coliforms in drinking water: current methods and emerging approaches. *Journal of Microbiological Methods*, 49, pp. 31–54.

Chubaka, C. E., Whiley, H., Edwards, J. W., Kirstin, E. and Ross, K. E. (2018). A Review of Roof Harvested Rainwater in Australia. *Journal of Environmental and Public Health*, 6471324, p. 14.

Chubaka, C. E., Ross, K. E. and Edwards, J. W. (2017). Rainwater for drinking water: A study of household attitudes. *WIT Transactions on Ecology and the Environment*, 216, pp. 299-311.

De Kwaadsteniet, M., Dobrowsky, P. H., Van Deventer, A., Khan, W. and Cloete, T. E. (2013). Domestic rainwater harvesting: microbial and chemical water quality and point-of-use treatment systems. *Water Air Soil Pollution*, 224, pp. 1-19.

Devi, R., Diboch, B. and Singh, V. (2012). Rainwater harvesting practices: key concept of energy-water linkage for sustainable development. *Scientific Research and Essays*, 7, pp. 538-543.

Dobrowsky, P. H., Khan, S., Cloete, T. E. and Khan, W. (2016). Molecular detection of Acanthamoeba spp., Naegleria fowleri and Vermamoeba (Hartmannella) vermiformis as vectors for *Legionella* spp. in untreated and solar pasteurized harvested rainwater. *Parasites and Vectors,* 9, p. 539.

Evans, C. A., Coombes, P. J. and Dunstan, R. H. (2006). Wind, rain and bacteria: The effect of weather on the microbial composition of roof-harvested rainwater. *Water Research,* 40(1), pp. 37- 44.

Gwenzi, W., Dunjana, N., Pisa, C., Tauro, T. and Nyamadzawo, G. (2015). Water quality and public health risks associated with roof rainwater harvesting systems for potable supply: review and perspectives. *Sustainable Water Quality and Ecology*, 6, pp. 107-118.

Harwood, V. J., Levine, A. D., Scott, T. M., Chivukula, V., Lukasik, J., Farrah, S. R. and Rose, J, B. (2005). Validity of the indicator organism paradigm for pathogen reduction in reclaimed water and public health protection. *Applied Environmental Microbiology*, 71(6), pp. 3163–3170.

Htun, W. W., Burgess, C. and Dhakal, M. P. (2017). Women benefit most from rainwater harvesting systems at community level in Himalica pilot villages in Myanmar 2017 https://www.icimod.org/women-benefit-most-from-rainwater-harvesting-systems-at-community-level-in-himalica-pilot-villages-in-myanmar accessed 22-02-2020

Igbinosa, I. H. and Aighewi, I. T. (2017). Quality assessment and public health status of harvested rainwater in a peri-urban community in Edo State of Nigeria. *Environmental Monitoring and Assessment*, 189, p. 405.

Igbinosa, I. H. and Osemwengie, O. V. (2016). On-site Assessment of Environmental and Sanitary Qualities of Rainwater Harvesting System (RWH) in a Rural Community in Benin City, Nigeria. *Journal of Applied Science and Environmental Management*, 20 (2), pp. 320- 324.

Igbinosa, I.H. and Kadiri, R.A. (2018). Quality assessment of abattoir effluents from the discharged point into a receiving watershed in Ikpoba river community: a potential source of microbial contaminant. Nigerian Research Journal of Engineering and Environmental Sciences 3(1), pp. 140-147.

International Organization for Standardization. (IOS) (2017). Microbiology of the food chain – Preparation of test samples, initial suspension and decimal dilutions for microbiological examination – Part 1: General rules for the preparation of the initial suspension and decimal dilutions, 2017, 2nd Edition. ISO, p. 26.

Kaushik, R., Balasubramanian, R. and de La Cruz, A. (2012). Influence of air quality on the composition of microbial pathogens in fresh rainwater. *Applied and Environmental Microbiology* 78(8), pp. 2813-2818.

Leder, K., Sinclair, M.I. and McNeil, J.J. (2002). Water and the environment: a natural resource or a limited luxury? *Medical Journal of Australia*, 177 (11/12), pp. 609–613

Macomber, P. S. (2001). Guidelines on rainwater catchment systems for Hawaii, College of Tropical Agriculture and Human Resources. University of Hawaii at Manoa, 2001.

Messner, M., Shaw, S., Regli, S., Rotert, K., Blank, V. and Soller, J. (2006). An approach for developing a national estimate of waterborne disease due to drinking water and a national estimate model application. *Journal of Water and Health*, 4 (2): pp. 201-240.

Mosley, L. (2005). *Quality of rain water harvesting system*. SOPAC. Miscellaneous report, 579.

MwengeKahinda, J., Taigbenu, A. E. and Boroto, J. R. (2007). Domestic rainwater harvesting to improve water supply in rural South Africa. *Physics and Chemistry of the Earth*, 32(15-18), pp. 1050-1057.

Rodrigo, S., Sinclair, M. and Leder, K. (2010). A survey of the characteristics and maintenance of rain water tanks in urban areas of South Australia. *Water Science Technology*, 61, p. 1569.

Sinclair, M. I. (2007). How safe is rainwater consumption? *Public Health Bulletin South Australia,* 4(2), pp. 11 - 13.

Singwane, S. S. and Kunene, S. G. (2010). Viability of rainwater harvesting in supplying domestic water in rural areas of Swaziland; a case of Mpaka community. *Journal of Sustainable Development Africa*, 12, pp. 90-109.

Waso, M., Dobrowsky, P. H., Hamilton, K. A., Puzon, G., Miller, H., Khan, W. and Ahmed, W. (2018). Abundance of Naegleria fowleri in roof-harvested rainwater tank samples from two continents. *Environmental Science and Pollution Research*, 25, pp. 5700-5710.

World Health Organization (WHO) (1997). World health organization, Guidelines for Drinking Water Quality Volume 3 Surveillance and control of community supplies, World Health Organization, Geneva 1997.

World Health Organization. (2004). *Guidelines for drinking-water quality volume 1: Recommendations* (3rd Ed.).

World Health Organization (WHO) (2011). World Health Organization, Adverse Health Effects of Heavy metals in Children, Children’s Health and the Environment, Geneva, Switzerland