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ASSESSMENT OF THE PARASITOLOGICAL QUALITY OF ROOF-COLLECTED RAINWATER STORED IN CISTERNS FOR DOMESTIC USE IN THE SUBURBS OF BENIN CITY, SOUTHERN NIGERIA

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ABSTRACT

One hundred and twenty (120) roof-collected rainwater samples in six domestic cistern sites in the suburbs of Benin City, southern Nigeria, were investigated in a cross-sectional survey to determine the parasitological quality. Seventeen (14.2%) rainwater samples analysed were contaminated with parasites and exceeded the acceptable limit of the WHO for safe drinking water. Site environment had a significant effect on the parasitological quality of rainwater samples. The degree of cleanliness of roof catchment surfaces, gutters and cisterns or storage tanks differed from one cistern site to another and the prevalence of positive samples for parasites' contamination varied from 5% to 25%. Rainwater samples from semi-urban cistern sites recorded 70.6% positivity of parasites' contamination while those from rural sites had 29.4%. The use of various unhygienic fetching containers to draw water from cisterns had a significant detrimental effect on the parasitological quality of stored rainwater. Higher parasites' contamination was observed from water samples obtained using fetching containers (64.7%) than that obtained directly from cisterns (35.3%). Eighteen species of parasites were isolated and identified during the study. These were: Entamoeba histolytica, E. coli, Iodamoeba buetschlii, Endolimax nana, Acanthamoeba spp., Naegleria fowleri, Giardia intestinalis, Pentatrichomonas hominis, Chilomastix mesnili, Cryptosporidium spp., Eimeria spp., Cyclospora spp. (Protozoa); Fasciola hepatica, Hymenolepis nana, H. diminuta (Helminths); Aedes aegypti, Anopheles gambiae and Culex quinquefasciatus (Arthropoda). Overall, the results from this study suggest that roof-collected rainwater stored in cisterns in the suburbs of Benin City, provided potable supplies of relatively poor parasitological quality. It is proffered that adequate post-cistern treatment devices such as filteration, disinfection, chlorination and boiling are necessary to eliminate or prevent parasites' contamination. Further research is advised to determine the health risks associated with the consumption of untreated stored rainwater in the study area.

KEYWORDS: *Parasitological quality, Roof-collected rainwater, Cistern, contamination, Treatment*

INTRODUCTION

The practice of capturing rain runoff from roofs and other surfaces and storing it for a later use, is common in many parts of the world (T.W.D.B., 2005). In cities, issues such as rapid urban growth, limited public water supplies, ageing storm water infrastructure and environmental sustainability have prompted renewed interest in rainwater harvesting (Despins *et al*., 2009). In rural communities, where surface water such as springs and streams are not available, most households depend on roof-collected rainwater for domestic purposes.

The increasing population and the development of unplanned suburbs in Benin City, the capital of Edo State, Nigeria, have made municipal pipe-borne water supplies to be inadequate. Most households in Egor and Ovia North East communities located far from the metropolis, resort to rain water harvesting for their domestic water supplies.

A typical local roof-collected rainwater system comprises of a catchment surface or roof-top, a conveyance network that includes a gutter and a down-pipe, and a concrete cistern or storage tank. Water in the storage tank is accessed by means of a hand-drawn fetching bucket or container.

To maintain good health, water should be safe to drink and meet local and international standards (Cheesbrough, 2006). One of the primary areas of concern regarding the use of roof-collected rainwater for potable application is its parasitological quality. Rainwater could be contaminated by parasites in several locations. Apart from atmospheric contaminants, the catchment surface or roof-top, where faecal droppings from birds, lizards, rats and other animals, are deposited, constitutes a major contamination source of concern. Also, the use of dirty fetching containers to abstract water could introduce faecal and soil dwelling parasites as contaminants into the storage tank.

The greatest public health risks are associated with the consumption of water that is contaminated with human or animal (including bird) faeces. Faeces could be important sources of pathogenic protozoan and helminth parasites (W.H.O. 2017). The human health effects caused by water borne transmission of pathogenic protozoan and helminth parasites could vary in severity from mild gastroenteritis to severe and sometimes fatal diarrhoea or dysentery, fascioliasis and dracunculiasis (W.H.O. 2017).

An uncovered household water cistern is a potential breeding habitat for mosquitoes which serve as vectors of diseases such as malaria, yellow fever, dengue and filariasis (WHO, 2017). Insects such as beetles, crickets, cockroaches, mantids etc. could fall into uncovered water storage tanks. Some of these insects potentially harbour parasites such as hair worms or nematomorphs. Worse still, there has been no record of any treatment of the stored rainwater before its consumption by households in the study area.

Many previous studies on roof-collected rainwater were on the physical and chemical quality (Shu and Hirner, 1998; Forster, 1998); microbiological quality (Ahmed, *et al*., 2014; Evans, *et al*., 2007; Abbott, *et al*., 2006; Coombes, *et al*., 2000; Yaziz, *et al*., 1989; Fujioka and Chinn, 1987) or a combination of physico-chemical and microbiological qualities (De Kwaadsteniet, *et al*., 2013; Despins, 2009; Sazakli, *et al*., 2007; Chan *et al*., 2007; Efe, 2006; Simmons, *et al*., 2001).

Limited data are available on the presence of parasites in stored roof-harvested rainwater (Yousefi, *et al*., 2009; Abo-Shehada, *et al*., 2004; Crabtree, *et al*., 1996). This study was undertaken to assess the parasitological quality of roof-collected rainwater stored in household cisterns for domestic use in the suburbs of Benin City, Edo State.

The potential health risks associated with pathogenic parasites contaminants identified in this study could be eliminated or mitigated by using appropriate treatment measures, thereby making stored rainwater fit for drinking.

MATERIALS AND METHODS

Study Area

Benin City is the capital of Edo State, Nigeria, and lies between longitudes 5° 35′ and 5° 41′ East and latitudes 6° 17′ and 6°26′ North. It lies in the tropical rain forest zone, with two seasons, rainy and dry. The rainy season occurs between April and September, while the dry season extends from October to March. Annual rainfall is between 1850 – 2455mm and temperature range between 30 – 37°C. Benin City, with a population of about 1.5million (Wikipedia, 2015), is an important commercial, educational and cultural centre.

The study sites comprise of six randomly chosen domestic storage tanks or cisterns in Egor and Ovia North East Local Government Areas in Benin City. Three cistern sites were selected from each of the two Local Government Areas.

Study Site Characteristics

All the six cistern sites shared common characteristics, namely: roof catchment surface material made of corrugated iron sheets; storage tank or cistern material made of concrete; absence of water delivery taps, and no treatment devices. The abstraction of water for domestic use is by means of local fetching containers. Stored rainwater applications include: drinking, cooking, bathing and washing (Table 1).

However, each cistern site had peculiar features. These include: the degree of cleanliness of roof-top catchment and storage tanks, relative distance from Benin metropolis, proximity to a road, a refuse dump, a bush or garden, tall trees etc. Three cistern sites, 1 – 3, were relatively near Benin metropolis and three, 4-6, were far from the city centre. The former were designated as semi-urban sites while the latter as rural sites.

Table 1: Some site characteristics of the six household cisterns

Cistern Site	Site Environment	Roof-top Surface Material	Cistern Material	Rainwater Application
1	Semi- Urban; near a busy road	C1	C	DCBW
2	Semi-Urban; near a garden	C1	C	DCBW
3	Semi-Urban; near a refuse dump	C1	C	DCBW
4	Rural; near tall trees	C1	C	DCBW
5	Rural; near a firewood depot	C1	C	DCBW
6	Rural; in an open space	C1	C	DCBW

C1= Corrugated Iron (Iron-sheets) C= Concrete DCBW = Drinking/Cooking/Bathing/Washing

Sample Collection

The study was carried out in the early part of the rainy season, April-June. A total of one hundred and twenty (120) stored rainwater samples were collected for analysis. Twenty water samples were drawn from each cistern in sterile 250ml glass bottles, two samples per week. On each day of sampling, two water samples were collected at each cistern site. The first sample, (A), was taken by lowering a sample bottle directly into the centre of the cistern. The second sample, (B), was obtained from the water drawn earlier from the cistern using a local fetching container (a typical hand-drawn device for accessing water from the cisterns by households for domestic use).

The water samples were appropriately labeled and kept in iced coolers at 4^{o}C. Thereafter, samples were transported to the laboratory and stored in refrigerators at 0 – 4^{o}C. Parasitological examination of the water samples was done within 6 hr. of sample collection.

Parasitological Examination and Identification of Parasites: Macroscopic Examination of Water Samples

Each water sample was examined carefully for the presence of larvae/adult helminths (cestodes, nematodes, nematomorphs) and arthropods (insects, ticks and mites) with naked eyes.

Microscopic Examination of Water Samples: Formol-ether Sedimentation Technique

The rainwater sample was poured into different centrifuge tubes. Formol water and diethyl ether were added. Each tube was centrifuged at low speed, 1,000 rpm for 1 min. A pipette was used to remove the supernatant. Formol water was added to the sediments to make the volume up to 15ml and centrifuged at 3,000 rpm for 5 min. After removing the supernatant, each sediment was transferred to a clean glass slide, a drop of iodine or Field's stain was added and examined for cysts and oocysts of protozoa, and eggs/ova of helminths, using the x10 and x40 objective of the microscope. The sediments were also stained by the modified Ziehl-Neelsen method to detect the oocysts of *Cryptosporidium* and *Cyclospora* species, if present.

Zinc Sulphate Floatation Technique

Test tube floatation method was used with zinc sulphate solution as the floatation solution. The rainwater sample was poured into different 15ml test tubes. Zinc sulphate solution was poured to fill the test tubes up to the brim. Cover slips were placed on top of the test tubes and left to stand undisturbed for 30 minutes to give time for the cysts, oocysts and eggs of parasites to float. The cover slips were carefully lifted from the tubes and placed downwards on clean glass slides for microscopic examination (Cheesbrough, 2006).

For both sedimentation and floatation methods, trophozoites, cysts, oocysts and eggs/ova of parasites isolated were photographed with a digital camera attached to the research microscope and identified with the aid of appropriate keys (Cheesbrough, 2006; Lee, 2000; Ash and Orihel, 1987; Soulsby, 1986).

RESULTS

From a total of 120 stored rainwater samples collected from six household cisterns during the study 17(14.2%) were contaminated with parasites (Tables 2). Site 3 and site 6 recorded the highest (25%) and lowest (5%) positive samples, respectively.

Table 2: Frequency of positive samples for parasites' contamination of stored rainwater from the cistern sites

Cistern Sites	Number of Water Samples Examined	Number of Positive Samples for parasites contamination (%)
1	20	4(20)
2	20	3(15)
3	20	5(25)
4	20	2(10)
5	20	2(10)
6	20	1(5)
Total	120	17(14.2)

The effect of an independent variable of site environment on the parasitological quality of stored rainwater is shown in Fig. 1. Sites in semi-urban location (Sites 1, 2 and 3) and that in rural location (sites 4, 5 and 6) recorded 70.6% vs 29.4%, positivity of parasites contaminated samples, respectively ($P < 0.05$).

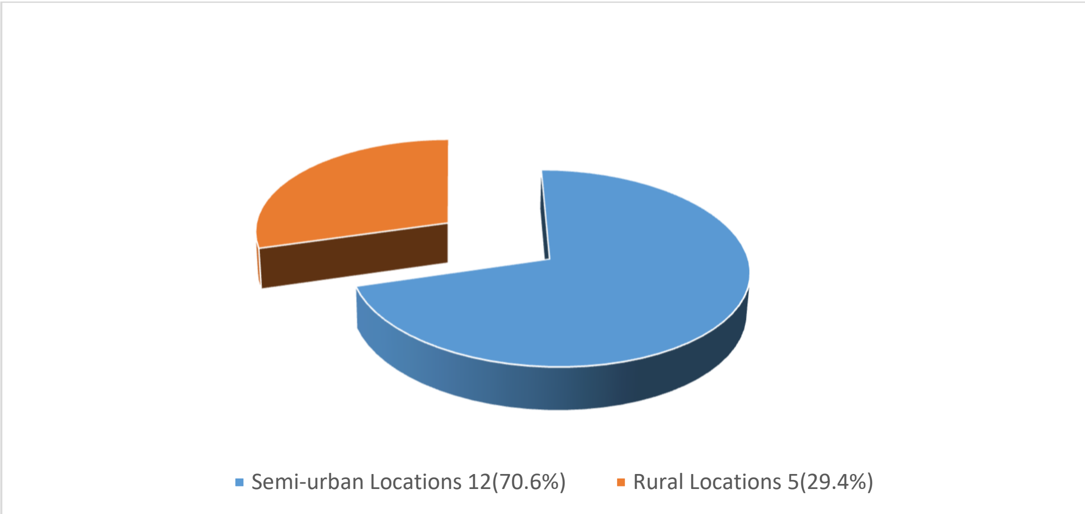

Fig. 1: Comparison of the frequency distribution of positive samples for parasites contamination of cistern stored rainwater in semi-urban and rural locations

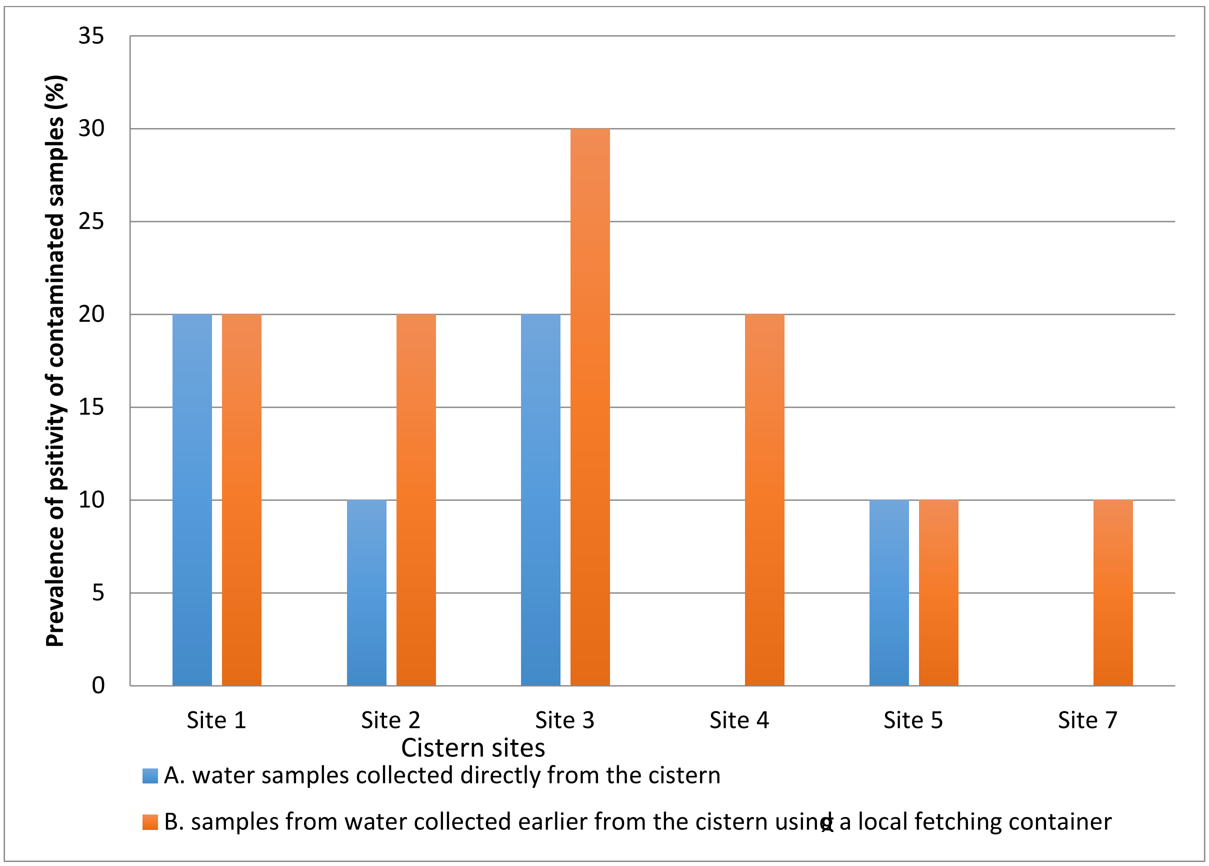

Fig. 2: Comparison of positive samples for parasites' contamination of stored rainwater in A and B from all the cistern sites.

From Fig. 2, rainwater samples, B, were contaminated with parasites' in the six cistern sites, while rainwater samples, A, recorded no parasites contamination in sites 4 and 5. Overall, out of the 17 stored rainwater samples that were positive for parasites' contamination, from all the cistern sites, B samples, recorded 11 (64.7%) positivity, while A samples, had 6 (35.3%) positivity (Fig. 3).

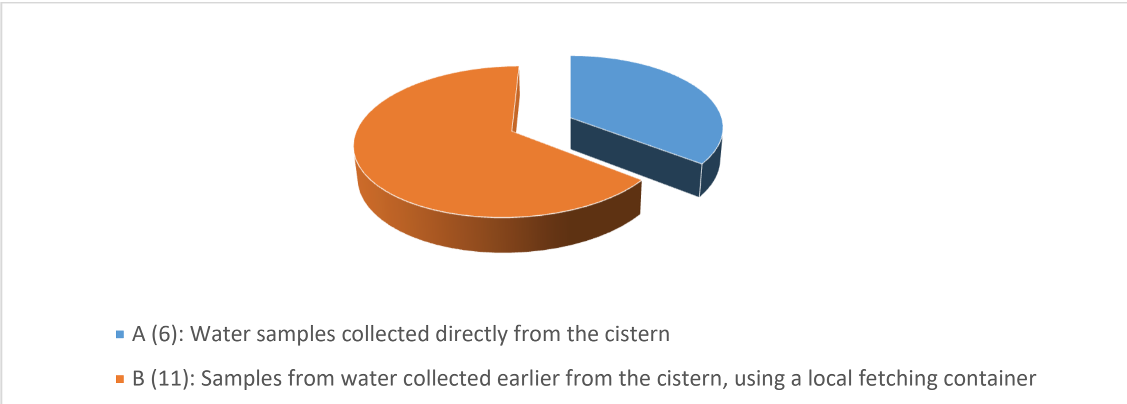

Fig. 3: Frequency of occurrence of positive samples for parasites' contamination of stored rainwater in A and B from all the cistern sites.

The eighteen (18) parasite species that were isolated and identified from stored rainwater in cisterns are presented in Table 3. Also, unidentified nematode eggs from the faeces of lizards were recovered.

Table 3: Parasite species isolated and identified from samples (N = 120) of roof harvested rainwater stored in household cisterns

Parasites	Form of parasite isolated	Number of Positive Samples (%)
Macroscopic Examination		
Aedes aegypti	Larvae	2(1.7)
Anopheles gambiae	Larvae	3(2.5)
Culex quinquefasciatus	Larvae	6(5)
Microscopic Examination		
Pathogenic amoebae		
Entamoeba histolytica	Cysts	4(3.3)
Non-Pathogenic amoebae		
Entamoeba coli	Cysts	6(5)
Iodamoeba buetschlii	Cysts	4(3.3)
Endolimax nana	Cysts	3(2.5)
Facultative amoebae		
Acanthamoeba spp.	Cysts/trophozoites	7(5.8)
Naegleria fowleri	Cysts/trophozoites	5(4.2)
Pathogenic flagellates		
Giardia intestinalis	Cysts/trophooites	4(3.3)
Non-pathogenic flagellates		
Pentatrichomonas hominis	Trophozoites	3(2.5)
Chilomastix mesnili	Cysts/Trophozoites	2(1.7)
Coccidia		
Cryptosporidium spp.	Oocysts	1(0.8)
Eimeria spp.	Oocysts	2(1.7)
Cyclospora spp.	Oocysts	1(0.8)
Digenia		
Fasciola hepatica	Eggs	2(1.7)
Cestoda		
Hymenolepis diminuta	Eggs	2(1.7)
H. nana	Eggs	3(2.5)

DISCUSSION

Safe drinking water does not represent any significant risk to health over a lifetime of consumption (WHO, 2017). Access to safe drinking water is critical to maintaining good health. In this study, the overall prevalence of positive samples for parasites' contamination of stored rainwater was 14.2% (Table 2). Parasites' contamination exceeded the WHO acceptable limit for safe drinking water, which stipulates that pathogens: *E. coli* or thermo tolerant coliform bacteria, protozoa and helminths must not be detectable in any 100ml sample. The infective stages of many helminths such as parasitic roundworms and flatworms can be transmitted to humans through drinking water. As a single mature larva or fertilized egg can cause infection, these should be absent from drinking water (WHO 2017).

Yousefi *et al*. (2009) reported that 19.9% of the water samples examined in Iran were positive for parasites. Simmons, *et al*., (2001) reported the presence of *Cryptosporidium* sp. in 4% of tank-water samples in Auckland, New Zealand. Crabtree, *et al*., (1996) also found that 45% and 23% of the 44 private and public tank water samples in U.S. Virgin Islands were positive for *Giardia* sp. cysts and *Cryptosporidium* sp. oocysts respectively. The prevalence of 14.2% of positive samples for parasites' contamination of stored rainwater in this study was not unexpected. Households recorded no post cistern treatment such as disinfection or boiling, of stored roof-harvested rainwater before its consumption.

Evidence of the effect of site environment on the parasitological quality of stored rainwater was provided by comparing the frequency of positive samples for parasite contamination between sites. The highest (25%) level of positivity of samples was observed in cistern site 3, followed by site 1 (20%) and the least was site 6 (5%) (Table 2). The proximity of site 3 to a refuse dump (Table 1) could have had a detrimental effect on the rainwater quality. The poor sanitary condition within the environment could facilitate the breeding and transmission of protozoan, helminth and arthropod parasites. Site 1, located near a busy road with attendant extra exposure to air-borne dust containing eggs, cysts, oocysts etc. of soil dwelling parasites' could have contributed to its high positivity of parasites' contamination of rainwater samples. However, it could be argued that the degree of cleanliness of roof catchment surfaces, gutters and cisterns which differed from one cistern site to another, primarily accounted for the variation in the prevalence of positivity of parasites' contamination of stored rainwater samples.

Cistern site conditions have been identified as a source of potential contamination of stored rainwater by several other studies (Yousefi *et al*., 2009; Despins, 2009; Forster, 1998). In this study, all the pathogenic parasites detected were site specific and occurred at low level of contamination. For example, species of *Cryptosporidium* and *Cyclospora* were detected in a sample from site 3 only. *Giardia intestinalis* was isolated in samples from sites 1, 2 and 3 only.

A statistically significant effect of site environment on the parasitologically quality of stored rainwater was also observed when the prevalence of parasite contaminated samples from semi-urban locations (Sites, 1, 2 and 3), 70.6%, was compared with that from rural sites (Sites, 4, 5 and 6), 29.4% (Fig. 1 and Table 2). A possible explanation of this finding could be that increased human activities in semi-urban locations contributed adversely to the parasitological quality of stored rainwater compared with those from the rural cistern sites. The result from this study is largely consistent with the report of Despins (2009) who observed that the quality of stored rainwater in rural locations was better than those harvested in urban locations.

The use of contaminated fetching containers by households to draw stored rainwater from cisterns had a significant detrimental effect on the parasitological quality of samples. Rainwater samples obtained using fetching containers from the six cistern sites were all contaminated while samples taken directly from the cisterns were not contaminated in two sites (Sites 4 and 6) (Fig. 2). Besides, the overall frequency of positive samples in the former and the latter was 64.7% vs. 35.3%, respectively (Fig. 3).

These results suggest that the fetching containers used by various households to draw water from cisterns were unclean and unhygienic. The findings obtained in this study largely agree with reports from related previous studies (Okiki and Ivbijaro, 2013; Adekunle *et al*., 2011; Barnes, 2009). These authors in their separate reports observed higher contamination of water samples that were hand-drawn using various fetching containers than water samples collected directly from wells using mechanical/electric pumps.

In this study, eighteen (18) species of parasites were isolated and identified from stored rainwater in cisterns (Table 3). They comprise of 8(44.4%) pathogenic, 8(44.4%) non-pthogenic and 2(11.1%) facultative parasites. The likely main sources of these parasites contamination were wind-borne dust and faecal materials deposited by birds, lizards, rodents, insects etc. either on the roof catchment surface or in the cisterns.

The human health effects of some of the parasites isolated from cistern stored rainwater are briefly highlighted. *Entamoeba histolytica* causes amoebic dysentery with symptoms which include: diarrhoea with cramping, lower abdominal pain, fever and the presence of blood and mucus in stools. *E. histolytica* may invade other parts of the body, such as the liver, lungs and brain, sometimes with fatal outcomes. *Giardia intestinalis* causes giardiasis with symptoms which include diarrhoea and abdominal cramps, malabsorpton deficiencies in the small intestine. The genus *Cryptosporidium* has about eight species, of which *C. parvum* is responsible for most human infections. *Cryptosporidium* spp. causes diarrhoea, sometimes including nausea, vomiting and fever. Severity of cryptosporidiosis varies according to age and immune status.

Cyclospora spp. causes cyclosporiasis. The clinical symptoms include watery diarrhoea, abdominal cramping, weight loss, anorexia and occasionally vomiting and /or fever. *Acanthamoeba* spp. are free-living amoebae common in soil and aquatic environments. The genus contains many species, of which *A. castellani, A. polyphaga* and *A. culbertsoni* are human pathogens *A. castellani* and *A. polyphaga* are associated with acanthamoebic keratitis, a painful infection of the cornea. *A. culbertsoni* causes granulomatous amoebic encephalitis (GAE). *Naegleria fowleri* are free-living amoebae distributed widely in the environment. *N. fowleri* causes primary amoebic meningocephalitis (PAM) or Naegleriamoebiasis. It is a facultative parasite of humans.

Fasciola hepatica causes fascioliasis. The acute phase is characterized by symptoms such as nausea and vomiting, abdominal pain and high fever. The chronic phase may be characterized by painful liver enlargement and in some cases obstructive jaundice, chest pains and loss of weight. Migrating juveniles of *H. hepatica* frequently produce ulcers in ectopic locations such as eyes, brain, skin and lungs. *Hymenolepis nana* causes hymenolepiasis. The clinical symptoms are restlessness, irritability and diarrhoea. *H. diminuta* and *Eimeria* spp. are primarily parasites of rats and birds, respectively.

The larvae of *Aedes aegypti, Anopheles gambiae* and *Culex quinquefasciatus,* though non-infective, are potential vectors of yellow fever, malaria and filariasis, respectively. The proximity of mosquito breeding sites in cisterns near the house could represent potential health risks to households. However, the prevalence of these larvae in very low densities probably was at a level in which potential disease transmission was unlikely to occur.

The detection of pathogenic parasites in this study, is of course, not evidence of the occurrence of waterborne parasitic diseases. However, it is important for consumers to be aware that these pathogens compromise the purity of harvested rainwater and thus cannot be lightly disregarded. It is therefore proffered that households should ensure safe collection, storage and adequate treatment of stored rainwater. These measures could eliminate all forms of pathogenic parasites present and thus produce safe drinking water.

CONCLUSION

This study has shown that supplies of roof-collected rainwater stored in household cisterns are of relatively poor parasitological quality. The quality of rainwater was most affected by contaminated roof catchment surfaces, unhygienic quality of storage and fetching containers and cistern site environment. Such challenges bolster support for post cistern treatment devices like filtration, disinfection, chlorination, boiling etc. of stored rainwater as the mainstay of improving its parasitological quality and ensuring its safety for drinking. Further research is advised to determine the health risks associated with the consumption of untreated rainwater in the study area.

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