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Water Quality of Rainwater Cisterns in the Grenadines

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Abstract: *In some of the Grenadines, rooftop collected rainwater stored in cisterns has been, for centuries, the main source of freshwater particularly in the rural areas. Currently, there are neither regulations nor set standards for domestic rainwater in the islands. In this paper, the quality of rainwater harvested and stored in cisterns in two Grenadian islands, Carriacou and Petite Martinique, is assessed using the H_2S strip test method. Over 20% of the samples in both islands were CLASS III, while less than 20% was of CLASS I. Detailed chemical and biological tests were also carried out on samples of rainwater and rainwater stored in cisterns. Of the samples collected directly from the rain, 90% met this drinking water standard. Total coliform was detected in 27% of concrete cistern samples compared to 67% in plastic tanks. The maintenance practices for rainwater harvesting systems are poor and may partly explain the high levels of contamination. In this regard, public education on appropriate practices can improve quality. Further, regulations and or guidelines need to be developed and instituted to protect the growing tourism industry.Ultimately, the best approach would be to implement a Water safety plan system (WSPS) as described by the guidelines of the World Health Organisation.*

Keywords: *Rainwater harvesting, H_2S strip test, cistern water quality*

1. Introduction

Freshwater, which is fundamental to life and health, is a diminishing natural resource. Its access in many parts of the world is limited. In Latin America and the Caribbean (LAC), over 75 million people have no access to safe drinking water (IADB, 2005). While in the Caribbean Community (CARICOM) access to freshwater is better than that for the rest of LAC, population growth, rural to urban migration, environmental issues such as climate change and sea level rise are expected to negatively affect water quality in the future. The sustainability of access to safe freshwater, therefore, will be a future challenge for planners and policy makers in their quest to promote sustainable development.

In a preparatory workshop entitled "Integrated management of water resources", delegates from the LAC region recommended that the region should upgrade and improve the instruments and mechanisms by which increased knowledge of, and access to information on the quality of water for human consumption (OAS, 2006). This requires the development, strengthening and integration of networks for monitoring quality of water and water resources according to standards and criteria common to the countries of the region are achieved (OAS, 2006).

In some of the smaller islands of the Organisation of Eastern Caribbean States (OECS), rooftop harvested rainwater has been collected and stored in cisterns for centuries, and is the main source of freshwater particularly in the rural areas. In the Grenadines (see Figure 1), surface water is non-existent and groundwater is limited to narrow strips along the coasts. Rainwater has been harvested from rooftop runoff and communal catchment surfaces for almost all uses. Rainwater ponds have been used for agriculture and primarily for livestock production.

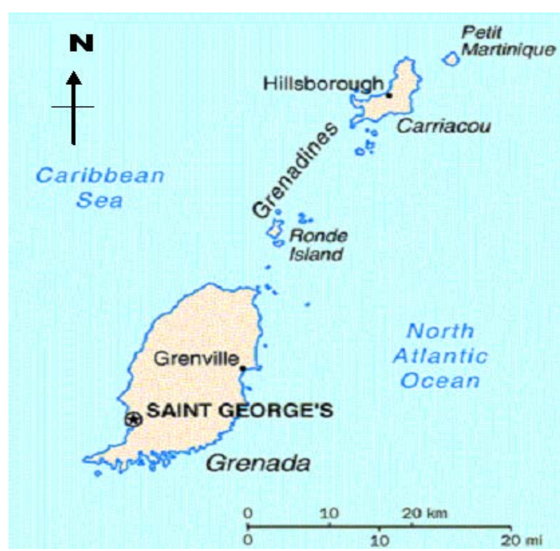

Figure 1. Map of the Grenadines

In the last two decades, as the Gross Domestic Product (GDP) of the Grenadines improved and the standard of living rose, islanders have constructed larger concrete underground cisterns (i.e., water storage tanks). As a result there is ample storage and the quantity of water for domestic use is no longer a serious concern. In these islands there is a public presumption that harvested rainwater is safe and that the risk of illness arising from its consumption is low. This presumption is possibly supported by the observation that there are few documented incidences of serious illnesses linked to the drinking rainwater stored in cisterns. It is noticed by the health authorities, however, that there is a higher level of diarrhea among visitors to the islands who drink un-boiled cistern water.

The difference in the level of risk for residents and visitors may be explained by an acquired immunity by locals to common pathogens from long-term use and exposure to untreated cistern water. This resilience of residents in the use of rainwater is supported elsewhere. In South Australia, about 42% of residents use rainwater in preference to mains water without any apparent effect on the incidences of gastrointestinal illnesses (Heyworth, 2001). Other studies also showed that among small children there was no greater risk for gastroenteritis in drinking rainwater instead of treated mains water (Heyworth, 2004; Wirojanagud et al., 1989). Notwithstanding the confidence in the quality, concerns have been raised elsewhere about the safety of harvested rainwater for drinking (Fujioka and Chinn, 1987, Krishna, 1989) that should not be ignored.

The Grenadines have been experiencing a rapid growth of the tourism industry, which depends on rainwater used as the main source of water supply by family operated guesthouses and small hotels. Many visitors come from Europe, where the European Directive (98/83EC) relating to the quality of water intended for human consumption went into force in 2000 (European Commission, 2000) and generally feel safe when drinking water at home. However, visitors can be exposed to water from private supplies when engaged in everyday activities such as going to a restaurant or buying food from the market. Reports of outbreaks from such exposure would be bad for tourism in the Grenadines.

The concerns of water safety in the islands, particularly, as it relates to visitors require that more scrutiny be placed on the drinking water quality to ensure that World Health Organisation (WHO) guidelines are met. The Ministry of Health uses the WHO guidelines to monitor water produced by the National Water and Sewerage Authority. In 2010, the Ministry of Health and the Grenada Board of Tourism initiated a programme to monitor the water quality of a selected number of hotels on the Grenada Mainland. However, there are neither regulations nor set guidelines or standards for domestic rainwater in the islands.

Moreover, there has never been any water quality testing of cisterns in the islands. This is not uncommon in places where there are substantial private water supplies or where rainwater harvesting is prominent. For example, private water supplies to a single dwelling that is not open to the public are exempt from some requirements of the 1991 regulations and the draft 2008 regulations in England and Wales. In Australia, where the use of rooftop rainwater harvesting systems has grown recently, there are no federal legislations for drinking rainwater quality (Water Quality Research Australia, 2011).

However, a detailed guidance booklet is available where rainwater is supplied to members of the public for drinking or used in settings such as hospitals and schools. Individual states and territories have specific safe drinking water legislations that usually exempt rainwater. For example, in Southern Australia, the Safe Drinking Water Act includes an exemption for rainwater tank supplies providing that members of the public are made aware of the use of this source for drinking (Government of South Australia, 2011).

Nonetheless, there is a need for information on the water quality of the rainwater-supplied systems in the islands. The lack of access to laboratories and the unavailability of field analysis kits are obstacles to the provision of island-wide, microbiologically safe, drinking water. In the absence of information on the water quality, residents and tourism operators are encouraged to boil all drinking water. This practice, although recommended by the local Department of Health, is not widespread or routine.

This paper is a first step to evaluating the quality of cistern water and reports on the water-quality of rainwater harvested and stored in cisterns for domestic use in two Grenadine islands, Carriacou and Petite Martinique. The microbial quality is assessed using the H_2S strip test method. Further, detailed analyses for physical and chemical properties are carried out on raw rainwater and stored drinking. It also reports on some of the basic household practices in rainwater harvesting systems. It is intended that this work can provide support for regional efforts promoting rainwater harvesting and allowing the region to reach the Millennium Development Goals (UNEP, 2011) related to water, sanitation and environmental health by providing baseline information on cistern water quality. Finally, the paper offers suggestions on making the use of cistern water sustainable.

2. Rooftop rainwater quality

Reasonably pure rainwater can be collected from roofs constructed with galvanized corrugated iron, aluminium, cement sheets, tiles and slates which are found in many countries including most Caribbean islands. In some underdeveloped countries, indigenous type roofs like thatched roofs tied with bamboo gutters and laid in proper slopes, can produce almost the same amount of runoff less expensively (Gould, 1992). The location of the rainwater harvesting points and cultural practices can strongly influence the physico-chemical and microbiological quality of the water. Meera and Ahammed (2006) reviewed rooftop rainwater harvesting systems, and concluded that the purity of rainwater harvested from rooftops should not be taken for granted, and analysis of the harvested water, especially for microbiological contamination, should be undertaken. Water having less than one bacterial faecal indicator per 100 ml, can contain sufficient pathogenic enteric viruses and protozoan to cause disease outbreak (Berry and Noton, 1976; Craun and Gunn, 1978; McKenzie et al., 1994).

In areas with high avian population, contamination of rooftop rainwater may take place. For example, Birks et al. (2004) reported that rainwater off the roof of the Millennium Dome contained relatively high levels of fecal bacteria, probably of avian origin, from the high bird population in that area. They also detected Giardia in rainwater samples, confirming the potential for this water source to contain pathogens. Simmons et al. (2001) found that 56% of rainwater supplies exceeded the microbiological criteria of less than 1 FC/100 mL.

Some other studies, however, have been less concerned about harvested rainwater quality. Coombes et al. (2006) concluded that there is a sparsity of knowledge about the microbial processes in rainwater tanks and that the use of some approved tests can potentially result in a misleading view that rainwater supplies are unsafe. Investigations on seven Danish rainwater facilities indicated that while the general microbiological quality (total numbers of bacteria) by the acridine orange direct counting (AODC) and heterotrophic plate counts on Reasoner’s 2A (R2A) medium and plate count agar of rainwater were approximately the same as drinking water supplied from the public supply (Albrechtsen, 2002).

In urban and industrialised areas, there are increased risks of airborne contamination from heavy traffic and industries. Industry and traffic conditions may provide a source for lead, cadmium, zinc and arsenic (Gould, 1999). Consequently, collecting rainwater for drinking and cooking is not recommended in areas affected by airborne pollution resulting from very heavy traffic and industrial activities.

Rainwater stored in cisterns can also be chemically contaminated from roof sources (Simmons et al., 2001; Lye, 2002). Roof-source contamination depends on material types and the age and state of the roof. Good practice requires a first flushing system to reduce contamination (Cunliffe, 1998). In Texas where roof materials (mainly galvanized sheets and tiles) are similar to those found the Grenadines, Chang et al. (2004) reported that collected rainwater exceeded the Environmental Protection Agency (EPA) freshwater quality in pH, Cu and Zn. In urban Paris, Gromaire et al. (2002) showed high Zn and Cd contamination from zinc roofing. This high level of contamination is associated with zinc roofing in the presence of SO_2 in urban areas. In unindustrialised islands like the Caribbean, such contamination is not expected. In New Zealand, Simmons et al. (2001) suggested that the level of lead contamination observed was likely to be due to rooftop materials and paint, rather than atmospheric lead pollution, as these areas had low traffic density.

In rural areas, stored rainwater may be of low quality from poor harvesting practices. For example, in some rural areas in China, the total number of bacteria and coliforms in cistern water was higher than the standard set for drinking water (Ling et al., 2001). Cisterns made from concrete or ferrous-cement can become contaminated if they are located in close proximity to cesspits or other household solid waste points. Al-Khatib and Orabi (2004) found that 87% of cisterns in Palestine were contaminated at levels that exceeded the WHO guidelines for drinking and that the main cause of drinking-water contamination was the presence of cesspits, wastewater and solid waste dumping sites near the cisterns.

3. H_2S test for household water quality

An essential goal in the provision of safe drinking water is that it should be free from disease-causing microorganisms. For more than a century, a criterion for guidelines and standards for acceptable drinking water has been the detection of indicator faecal bacteria in the water. Now, many authorities, such as the Australian Government (2004) water authorities provide guidelines for drinking water which support the use of thermo-tolerant coliforms as the preferred indicator for assessing the microbiological quality and safety of drinking water for routine monitoring.

In isolated situations such as the Grenadines, where households have private water supplies, a possible solution to promote widespread safe drinking water quality would be tests that are cheap and simple to apply, understand and interpret. The H_2S strip test first proposed by Manja et al (1982) is ideal for this situation. Since then, there have been many versions of the tests available (Ratto et al., 1989; Venkobachar et al., 1994; Pillai et al., 1999).

The H_2S strip test is based on the readily observable formation of an iron sulphide precipitate on a paper strip or in the water in a bottle or test tube resulting from the reaction of H_2S with iron. The intention of the test is to detect bacteria associated with faecal contamination. This is evidenced by the activity of these microorganisms in reducing organic sulphur to an oxidation state, as H_2S gas, which ultimately reacts with iron to form a black iron sulphide precipitate (Allen and Geldreich, 1975). Sobsey and Pfaender (2002) reviewed the scientific basis, validity, available data and other evidence for and against the H_2S test. Some studies showed that the method is sometimes superior and gives results comparable to the tests for traditional bacterial indicators of faecal contamination (Sobsey and Pfaender, 2002).

Hence, some shortcomings were pointed, for example, there is a concern that the test may detect bacteria not associated with faecal contamination and its attendant pathogens. However, the importance of such tests where others are not available or practical is recognised (Sobsey and Pfaender, 2002). Another noted weakness of the test is the possibility of false positive results (Desmarchelier et al., 1992). The implication of a false positive test result is rejection of the water for drinking or water treatment which can be expensive. Notwithstanding some of the limitations pointed out by some, the test has been recommended as a screening test for water quality at the household level and in developing countries where resources are limited (Bukenya, 1990; Anwar et al., 1999).

4. Procedure

The Grenadine islands are isolated and have no routine water quality testing facilities. On-site testing methods are useful alternatives. The H_2S test medium was prepared by incorporating the modified (improved) method described by Venkobachar et al. (1994) of the original method by Manja et al (1982). Strips of folded paper towel of approximately 50 cm^2 were impregnated using 1 mL aliquots. The folded strips of paper containing the solution were heat sterilised and placed in pre-sterilised 40 ml glass sample bottles. The test bottles, once prepared, have a long enough shelf-life to allow valid tests within 3 months of test bottle preparation.

Prepared sample bottles were filled with the water sample being analysed to a pre-measured 20 mL mark. Samples were then incubated at room temperature (22-25^{0}C) and examined for H_2S production after 18 hours (overnight) followed by 12-hour intervals over a period of 72 hours. Two hundred storage facilities were tested on the island of Carriacou (about 10% of all households) and 80 on Petite Martinique (that is about 25% of all households). These storage facilities were either concrete cisterns or PVC storage tanks. In addition tests were carried out on rainwater samples collected directly from precipitation.

A contaminated sample not meeting WHO guidelines (i.e., less than 10 faecal coliforms per 100 mL) would turn black after 17 to 24 hours and was indicative of faecal contamination (Venkobachar et al., 1994). The test was used for classifying the water into three qualities (Class I: 0 faecal coliforms per 100 mL; CLASS II: 1-10 faecal coliforms per 100 mL and CLASS III- greater than 10 faecal coliforms per 100 mL) as proposed by Krishna (1993). Samples which tested negative after 72 hours incubation period are considered CLASS I. These are considered to be safe, while samples that tested positive (indicated by a change in colour (black) of the medium) within the period were considered CLASS III and unsafe. Samples in which there was a visible colour change after an extended period were considered to be CLASS II.

In addition to the H_2S test more detailed physiochemical and biological tests were carried out on rainwater stored at 50 homes. Two sets of samples were taken from 50 random homes in Carriacou. One was taken during the end of the dry season (May-June) when the water in the tank is at its lowest level and the other during the middle of the rainy season (September). In addition, 25 samples were taken from residences in Petite Martinique at the end of the dry season.

Finally, a simple household survey was carried out to determine the practices carried out by households to protect or improve the quality of the harvested rainwater. The survey instrument was a short questionnaire.

5. Results and discussions

5.1 The H_2S test

The results of the field sampling using H_2S test (Table 1) showed that on the two islands between 10% and 20% of the cistern water was of good quality (CLASS I) that is showing an absence of faecal coliforms. This high quality water is consistent with households that use basic chlorination to treat the water stored in the cisterns. More than 70% of the samples in both islands had faecal coliform count of less than 10 CFU/ml (CLASS I and II). This suggests that in the majority of cases the water in storage is safe. Overall over 20% of the samples in both islands were highly contaminated, that is CLASS III. This contamination may be due to poor household practice in collecting and storing the rainwater, since 100% of the samples of raw rainwater were of CLASS I type using the H_2S test.

Table 1. Summary of H_2S test results

CLASS	Corresponding Number of faecal coliform/ 100mL	Portion of Sample (%)	
		Carriacou	Petite Martinique
I	Zero	11	20
II	<10	65	60
III	> 10	24	20

5.2 Detailed tests

Samples collected from rainfall and from the storage tanks were tested for a range of parameters indicated in Tables 2, 3 and 4. There was no iron, magnesium, phosphates or nitrates detected in the stored samples. There were less than 2 mg/L sulphates which is much lower than the maximum acceptable level of 500 mg/L and 250 mg/L set by WHO and the European Union, respectively.

5.2.1 Physical characteristics

The water stored in tanks in Carriacou and Petite

Martinique was found to be free from odour and colour. The highest quantity of total suspended solids (TSS) was found to be less than 3 mg/L at the end of the dry season, when the water level is at its lowest and a churning up of the water in the tank is more likely. During the rainy season when the tank is almost full, TSS was not detected. While standards for TSS are not set for drinking water, TSS of 300 mgLl can affect the colour and smell of drinking water and may provide a medium through which some metals may have entered the storage facility. The low level of TSS in stored rainwater in the islands helps to give a perception of high purity, which may reduce the care taken by users to ensure that the water is safe for drinking.

Table 2. Summary of mean test results for two seasons in Carriacou

Parameter tested	**Source Carriacou**	
	End of the dry season	Middle of rainy season
pH	7.3	9.98
Odour	Non-offensive	Non-offensive
Colour (Hazen Units- HU)	0	0
Calcium (mg/L)	17	27
Chlorides (mg/L)	15	9
Alkalinity (mg/L)	27	21
Total suspended solids (mg/L)	<3	Not detected
Total dissolved solids- TDS mg/L	37	21
Sulphates	2.1	12.1

Table 3. Summary of mean water quality parameter values for stored rainwater at the end of the dry season for Carriacou and Petite Martinique

Parameter tested	**Source**	
	Carriacou	**Petite Martinique**
	Mean (*STD*)	Mean (*STD*)
pH	7.76 (*0.98*)	6.57 (*0.8*)
Total dissolved solids- TDS mg/L	17.5 (*12.3*)	33 (*14*)
Colour (Hazen Units- HU)	0.46 (*5.2*)	0.38 (*5.4*)
Calcium (mg/L)	26.4 (*11.0*)	24.0 (*11.1*)
Chlorides (mg/L)	13 (*5.45*)	21 (*5.8*)
Alkalinity (mg/L)	28 (*10.0*)	29 (*10.0*)
Sulphates (mg/L)	0.65 (0.87)	1.1 (1.2)
	Portion of cisterns	**Portion of cisterns**
Faecal coliform (detected in % of sample)	0%	75%
Total coliform (detected in % of sample)	30%	100%
Heterotrophic plate count (greater than 10 CFU/ml)	50%	100%
Odour (non-offensive)	100%	100%

Table 4. Quality of rainwater and water in two types of storage facilities

Parameter tested		**Storage type**	
	Rain	**Concrete cistern**	**Plastic tanks**
No. of samples	*10*	*25*	*20*
pH	6.24	7.25	6.33
Odour	Non-offensive	Non-offensive	Non-offensive
Colour (Hazen Units- HU)	0	0	0
Calcium (mg/L)	21	27	21.1
Chlorides (mg/L)	10	13.8	20.7
Alkalinity (mg/L)	12	20.55	27.3
Total dissolved solids (TDS) mg/L	9	19	33
Total suspended solids (TSS) (mg/L)	<3	<3	<3
Sulphates (mg/L)	0.3	0.75	1.5
Heterotrophic plate count (less than 25 CFU/ml)	0%	60%	25%
Faecal coliform (detected in % of sample)	0%	0%	10%
Faecal coliform (in 100mL) detected	0%	0%	10%
Total coliform (detected)	10%	27%	67%

Dissolved solids usually are composed of major ions; calcium, magnesium, sodium, sulfate and alkalinity originating from the decomposition of soils and rocks can be used as a general indicator of water quality. High concentrations of dissolved solids can make water cloudy and give it a bitter taste. Stored rainwater in the islands has low levels of dissolved solids. The overall physical quality of stored rainwater in the islands is good.

5.2.2 Microbiological Quality

The heterotrophic plate count (HPC) is one method of monitoring the overall bacteriological quality of drinking water and is a good indicator of the distribution system's integrity and cleanliness (WHO, 2004). HPC results of the samples show that, in Carriacou, 50% of the stored water in the cisterns has a HPC concentration of less than 10 CFU/ mL. While HPC in drinking water is not a health concern to the general public (WHO, 2002) and there is no maximum acceptable concentration specified for HPC (Health Canada, 2006) the sample results compare well with the quality that is expected from water utilities which generally achieve HPC concentrations of 10 counts per mL or less in finished drinking water (Fox and Reasoner, 1999). HPC results are not an indication of water safety and as such should not be used as an indicator of water safety (Health Canada, 2006).

The level of concentration of HPC can be influenced by residence time (stagnation) and construction material among others (Payment et al., 1994), hence it should be expected that in cisterns where stored water has a long residence time, HPC counts would be high. Indeed in 50% of the samples HPC concentrations were more than 6,500+ colonies/ml. In the case of plastic tanks where there are smaller residence times than the larger concrete cisterns, there was no significant difference in the concentrations of HPC.

The level of faecal contamination in the drinking water from rainwater storage was measured by total coliforms and faecal coliform. In the past, the maximum acceptable concentration of total coliforms was zero per 100 ml in developed countries for public, semi-public and private water supply systems (WHO, 2002; Health Canada, 2006). Of the samples collected directly from the rain, 90% met this drinking water standard. The contaminated rainwater was most likely due to contaminated equipment. Total coliform was detected in 27% of concrete cistern samples compared to 67% in plastic tanks. Plastic tanks (capacity of between 1.8 m3 and 3.7 m3) were found in the lower-income households, where general sanitary conditions may be at a lower level than found in households with concrete cisterns. Unlike concrete tanks which are partly underground, plastic tanks are not exposed to ground contamination through seepage of water through the concrete walls from the soil.

Hence, a possible explanation for higher levels of contamination in plastic tanks is the greater contact of people and animals with the harvesting system. In lower-income households, for example, there is greater contact with the roof surface by humans and animals, which may account for the means of contamination. In these low-income households there is a tendency to have large numbers of poultry which may use parts of the roof for sleeping. In other cases, the roofs are used by residents for drying grains, fruits or even washed clothes. In higher-income households where, larger concrete cisterns are used, the longer residence time associated with the larger volumes enhances bacterial die-back resulting in higher quality. It was also found that in the case of the larger concrete cisterns, the quality improved with size.

All of the samples taken on Petite Martinique were contaminated with total coliform, compared to 30% of the samples obtained in Carriacou. The difference in the level of contamination between the two islands may be due to the greater aridity of the smaller island, which has large areas bare of vegetation that provides a source of windblown sediments.

5.3 Practices used in improving water quality

In the Grenadines, accounts of serious illness linked to rainwater supplies are few; this suggests that the unsophisticated rainwater harvesting technologies available in the islands are effective sources of water supply. About one third of the households use chlorine tablets or liquid bleach without specified dosage (see Table 5). The other forms of protection were for mosquito control and the prevention of wild life entering the storage facilities. In addition regular cistern cleaning is not practiced.

Table 5. Types of quality improvement activities undertaken by households

Type of activity	Quantity of Households
Use of commercial purifications systems	6%
Biological control for mosquitoes	24%
Use of chlorine tablets	33%
Protection from wild life	25%
Cistern cleaning (every 2 years of less	5%
Cistern cleaning (more than 5 years)	65%
Cleaning gutters (every year)	10%
Cleaning gutters (more than 4 years)	50%
First flush system	15%

6. Conclusions

In the Grenadines more than 98% of the water is produced privately. Drinking water from rainwater harvesting systems may contain many contaminants that can present a health risk if present in sufficient concentrations. It would be costly, and in most cases unnecessary, to test private water supplies in the same way as public water supplies. While Total Coliform is generally not an acceptable indicator of the sanitary quality of water supply (Cunliffe, 2004), the use of H_2S test for indicating faecal coliform provides a good first step in assessing the quality of the rainwater cistern supply in isolated islands where more sophisticated applications are unavailable. The results from the H_2S test showed that in some cases cistern water is totally safe, while in other cases there is evidence of contamination.

In the islands, water stored in concrete cisterns and plastic tanks which is harvested from rooftops is often presumed to be safe as it has not flowed on the ground and come into contact with any liquid or solid materials which can alter its quality. This presumption is considered reasonable as the detailed tests results showed low levels of contamination of raw rainfall water samples and the excellent physical quality (negligible suspended solids and absence of colour and odour) of stored drinking water in the islands.

The results showed that few households exercised good rainwater harvesting practices, like using first flush or employing simple treatments. When rainwater falls on the roof, it passes through the gutters and finally reaches the storage tank. In this process, water comes into contact with the dust, debris and leaf litter as well as faecal materials from birds and lizards collected on the roof and the gutters in addition to the chemicals used to coat the roofing material (note tests for these chemicals were carried out). Poor harvesting practice appears to be partly responsible for the level of faecal coliform contamination observed in some cistern water.

Tests for viruses and protozoan were not considered because there were no facilities readily available. Secondly, since the water supplies are household based, the large number of supplies would make the exercise financially prohibitive for this study. Thirdly, pipe network for household rainwater supply rarely passes through the ground hence cistern water reaching the household taps has little or no contact with soil.

Consequently, the likelihood of the presence of viruses and protozoan associated with contact with the soil and human activities would be small. The main possible source of contamination is from the roof catchment area which is accessible to native birds, lizards and wind-blown soil particles. However, as this is not widespread and viruses linked to these animals are not generally found in the islands, the concern in this study was not considered critical.

Finally, it was observed that the microbial quality of the water improved with increased tank size. While the cistern-size factor may be important in influencing water quality, potentially lower levels of hygiene practiced by lower income households could also be influential.

7. Recommendations

In these islands, in practice, most rooftop catchments and cisterns are poorly maintained. The cistern is deslugged every few years and the guttering is cleaned to improve more efficient water collection whenever problems of water over-spilling are encountered. It is recommended that the local Ministry of Health should implement a public education programme to address the current poor maintenance practices. In addition the local government should develop a programme that can utilise improved low-cost technologies and solutions or appropriate designs and maintenance strategies to minimise recontamination of cistern water.

It is recommended that some regulations to promote rainwater quality monitoring and encourage timely implementation of remedial action be undertaken. This should include proper assessments of the risks of contamination, followed up with action to mitigate any unacceptable risks. This should either be done by a trained person or the owner, with clear guidance from the local authority. The regulations may follow for example, the model used in New Zealand (NZ Ministry of Health, 2005), where individual supplies serving more than 1,500 person-days (e.g. more than 25 persons for 60 days) must have some form of continuous monitoring. This would capture those small bed and breakfast type establishments in the Grenadines.

Individual supplies serving households would be exempt from continuous monitoring but would be encouraged, where possible, to maintain the system in such a way that the risks for contamination is minimised. Ultimately, the best approach would be to implement a Water safety plan system (WSPS) as described by WHO guidelines (WHO, 2004). The long-term strategy for the water authorities and the Ministry of Health, Grenada for ensuring water safety is to be guided by this WSPS.

It is recognised that there is need for further microbial research to confirm the H_2S strip results for households and to identify the organisms involved. Moreover, while the quality of household stored rainwater is of concern, greater concern must be on public places such as schools, medical centres, hospitals and government buildings where more persons can be exposed to unsafe water. Although public buildings did not form part of this study, it strongly recommended that further research be undertaken in analysing the quality of stored water in these public places.

While there has not been any history of water related illness on any scale from the consumption of water from these public places, the growth of the tourism industry and the increasing number of tourists visiting the islands require greater vigilance in establishing and maintaining a high quality of stored rainwater. In this regard, advice to owners of tourism-based facilities should be given to help obtaining and operating equipment for testing and treating water at a reasonable cost should be available from the local authority.

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