Monitoring bacterial water quality in rainwater tanks using the H_2S method

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Abstract

The collection and storage of rainwater for household purposes is becoming increasingly essential in all parts of the world due to the shortage of good quality drinking water. Rainwater is usually of good quality but is prone to chemical and microbial contamination from the collection and storage systems. Chemical contamination is easier to control with good installation strategies, but microbial contamination is very unpredictable and occurs from any organic litter, faecal deposits of birds or from dead animals from roof tops. The intensity of contamination varies with temperature, season and cleaning strategies adopted. Therefore to ensure the safety of rainwater used for drinking, regular testing of the microbial quality is important. The standard methods and most of the onsite methods available are expensive, require technical expertise and /or laboratory facilities to conduct the test which is impossible for rainwater tank owners to conduct routinely. Therefore only a low cost and technically simple onsite method can meet the purpose of testing rainwater tanks. This paper suggest the use of H_2S method which is simple and easy enough for the householders to test their rainwater tanks regularly. The method has also been identified as a good screening method for testing microbial quality of drinking water.

Key words: microbial quality, onsite test, rain water

INTRODUCTION

The availability of good quality drinking water is of great concern in all parts of the world, either due to shortage of freshwater related to geographic situations, drought or due to pollution of available sources. Due to the problems of ground water contamination and arsenic contamination recently being reported from more parts of the world and severe contamination of surface waters in highly populated developing countries, intense action is taken in many countries such as India to harvest rainwater. In Australia rainwater is a source of drinking water for many households and South Australia, the driest state, has the highest rate of usage, with 51 per cent of households (ABS, 1994, 1999, 2001) having a rainwater tank and 36 per cent using them as the main source of drinking water. The general perception that rainwater is safe to drink is usually true, but can change with low maintenance of the collection and storage systems, in which case it poses health risks from chemical and organic contamination. Rainwater is a good source of drinking water if collected before it reaches the ground, stored and handled properly.

Contamination with chemical pollutants can happen from polluted air as well as from collecting and storage systems. The aesthetic quality in terms of colour, taste and smell of uncontaminated rainwater is usually good and any change observed would indicate potential contamination which has to be detected. The chemical quality issues arise from roof coatings (that decolourise water), lead, asbestos, fibrocement, paints and coatings flashings, flues containing hydrocarbons from wood burners as well as air borne contaminants from highly industrialised or urban areas. Chemical contamination is easier to control with careful selection of materials and installation. The monograph by Cuncliffe (2004) on the guidance for use of rainwater stored in tanks provides a checklist on improving the quality of the rainwater collecting system.

Organic contaminants often include settled dust, leaf litter and faeces from birds, lizards and dead animals. These contaminants are usually controlled by screens filters, leaf and debris diversion and first flush devices. However organic components contribute to algal and microbial contamination in rain water harvesting systems.

MICROBIAL CONTAMINATION

Microbial contamination is of main concern for health risk as it varies with location, season, surrounding environment, maintenance practices and therefore unpredictable. Yet another factor that increases the risk is the decentralised nature of the rainwater collecting systems being used more in rural areas where maintenance and monitoring from a service provider is usually uneconomical. The main impact of contaminated water on public health is the incidence of enteric diseases. However the incidence rate of enteric diseases is influenced by a wide range of factors including personal hygiene, food safety and water quality. The data on the incidence of enteric diseases from 2001-2002 (Department of Health Western Australia, 2003) indicate an increase in reported cases in 2001, although this increase could be because the data included notifications from laboratories and medical practitioners compared to previous years where only reports from practitioners were included.

Microbial contamination in the form of bacteria, viruses and protozoa can occur from different sources in rainwater harvesting system, although those from enteric sources pose higher health concerns. The most likely source of pathogenic micro-organisms is from faecal matter entering the tank via the catchment or from dead animals and insects. Rainwater collected in tanks has been found to contain varying levels of these bacteria indicating that rain water when collected in tanks are susceptible to microbial contamination (Nair *et al*., 2000, 2001, Pillai *et al.,* 1999, Simmons *et al.,* 2001; Thurman,1995). Though surveys and water testing of microbial pathogens showed the presence of indicator species in rainwater tanks, no significant health risk has been reported. This could be due to underreporting of gastrointestinal (GI) diseases where people resort to some home remedies for minor cases of GI, which could be especially true of rainwater users. Opportunistic pathogens such as *Aeromonas* spp. and *Pseudomonas aeruginosa* is a risk only for severely immuno-suppressed people (WHO, 2002).

A preliminary study of water quality in tanks in the Collie region of Western Australia (Nair *et al*., 2001) detected total coliforms in 25 of 100 tanks and thermotolerant coliforms in 3 tanks. This low number could be because the testing was conducted in winter, when there were heavy rains and the tanks were overflowing/ flushed. Analysis of water samples from the tanks around the city of Perth has shown that approximately half were contaminated with microorganisms of public health concern (Nair *et al*., 2000). The common bacteria observed were *Enterobacter* sp., *Proteus, Citrobacter* and phytopathogens such as *Erwinia* sp and *Chromobacterium* . The source of these bacteria could be leaves that were carried into the tanks. Most of the tanks were never cleaned nor the water quality tested. Other studies have also shown that the microbial quality of rainwater stored in tanks can be very poor (Coombes *et al.,* 2000; Fujioka *et al*., 1995; Simmons *et al.,* 2001; Thomas and Greene, 1993, Yaziz *et al*., 1989). The presence of some *Salmonella* sp. has also been reported in rainwater tanks (Fujioka *et al.,* 1991, Nair *et al.,* 2001). The quality of water collected could change significantly with the season with worse conditions expected in dry summer months.

Although few health problems linked to drinking rainwater have been reported, Brodribb *et al.* (1995) observed recurrent infection by *Campylobacter fetus* in an immuno-compromised patient. The source of the infection was rainwater as the infection stopped on using boiled rainwater for drinking. The research by Simmons *et al.* (2001) in New Zealand recommended that further research is required on *Aeromonas* spp. as potential indicators of both microbiological quality and health risk together with design and maintenance strategies to minimise contamination of potable roof-collected rainwater supplies. The intensity of contamination in rainwater tanks was linked to the tank maintenance strategies adopted by householder (Pillai *et al.,* 1999).

Heyworth *et al*. (1998) after an extensive survey of rainwater tanks in South Australia suggested that there was little understanding about the quality of rainwater stored in tanks in terms of potential health risks. The unavailability of data on health issues related to the drinking of rainwater may also be due to the patients not being aware of the source of infection, not keeping a record of infections or rather not linking those infections to drinking water. Although it has been proven that personal hygiene and maintenance practices can reduce microbial contamination in rainwater tanks, to promote personal and environmental hygiene, householders should be able to understand the results of the quality tests conducted on their drinking water samples.

The main reasons for the quality of rainwater being rarely tested are

1. Lack of proper awareness of the possibilities of contamination
2. Lack of proper direction for the periodical maintenance of the tanks
3. Remoteness of the place from the laboratories to test the water
4. Non-availability of a cheap on-site microbial testing procedure

WATER QUALITY TESTING

To understand the quality of the drinking water a very regular testing of the microbial quality of water at the main source and at the point of use is essential. Microbial quality of drinking water is usually ascertained by testing for thermotolerant coliforms or *Escherichia coli*. According to the World Health Organisation (WHO, 1993) water intended for drinking should be routinely monitored for total coliforms and *E. coli* and a 100 mL drinking water sample should not contain any total coliforms and *E. coli*. WHO (1993) recognises that it is often impossible to have water free of microbial contamination especially in remote communities and in many developing countries. Therefore it is recommended that samples with no more than 10 coliforms per 100 mL are acceptable, as long as the sample is free of faecal coliforms. In Australia routine testing of publicaly supplied water therefore is a requirement and it is recommended that water be tested for its microbial constituents as least once a month, preferably fortnightly as recommended by the National Health and Medical Research Council.

The standard methods used for testing coliform bacteria are expensive and require technical skills to conduct the test. Therefore relying on standard laboratory methods for assessing the quality of water in rainwater tanks is inappropriate, in which case there is a need for simple, inexpensive, on-site tests that can be used by the householder's onsite. On-site testing of water in remote areas offers the householders a quick, accurate and low cost option of testing their water for contamination at any time. On-site methods also allow people to access information, which affects their livelihood and quality of life.

The on-site methods currently available include the Colilert and Colisure, which test for total coliforms and thermotolerant coliforms. These tests require an incubator for constant temperature incubation as well as refrigeration facilities to store the biochemicals (which can be purchased from suppliers). Also the incubators need to be checked often for their performance, all of which make regular testing not practical if not possible for householders. Therefore there is a need for a more simple method for routine water testing by householders.

The H_2S method developed by Manja *et al.* (1982) based on the detection of sulphate reducing bacteria (SRB) in the water sample is a simple method. SRB like coliform bacteria are associated with faecal contamination. The H_2S method is a very user friendly method as the media can be prepared in any laboratory with minimum facilities at low cost and the chemicals, stored in bottles, can be stored in any household at room temperature for an indefinite period of time. The positive result (contamination) is indicated by a change in sample colour to black which can be identified by a layman. The major advantages are that it is inexpensive and does not require technical expertise or strict laboratory conditions to test the water.

The H_2S method was tested for its sensitivity compared to the standard laboratory methods for testing for thermotolerant coliforms in rainwater samples by Pillai *et al.* (1999) and Nair *et al.* (2001). Out of the 121 household tanks tested, every household was unaware of the quality of the rainwater and the majority of tanks were poorly maintained. The H_2S method was found to indicate better sensitivity after 48 hours of incubation. Agreement between the H_2S method and the standard coliform method is excellent. Some false negative results observed (7.4 %) after 48 hours of incubation were in the presence of very low levels of coliform bacteria at a concentration of <5 CFU/100 mL of total coliform, but no *E.coli* was found in those samples. The percentage of false positive results was higher after 48 hours of incubation, whereas false negative results were more after 24 hours of incubation with both media. Some false positive results (5.7 and 17.3%

respectively) observed after 24 and 48 hours of incubation respectively indicated the possible contamination with SRB from other sources and in these cases the test can be considered a more conservative measure than the coliform method. The H_2S method was found to be an effective test to detect contamination for samples with counts higher than 10 coliforms per 100 mL. This would be suitable for remote communities and countries where coliform counts lesser than 10 CFU/100 mL are considered as standard guideline for potable water. Nair *et al*. (2001) suggested that the H_2S method could be used as an ideal screening method for testing the quality of rainwater.

MAINTENANCE AND MONITORING STRATEGIES

The regular monitoring of the quality of harvested rainwater should be coupled with good maintenance strategies. Proper cover, litter screening devices and first flush systems can prevent most contamination. Treatment methods such as filtration, disinfection or boiling before consumption should be employed if the water is used for drinking. Water filters at the point of use and disinfection using common methods such as ozone, ultraviolet (UV) light and chlorine as used in public water supply would provide additional safety for rainwater users. Nevertheless together with those precautions, regular water quality testing is recommended to ensure the good functioning of those devices and for tanks without disinfection facilities to confirm the quality of the drinking water. For regular testing by householders the H_2S method is considered to be beneficial. If contamination is detected the common recommended method is boiling of water until the tanks are cleaned and found to be safe to drink.

REFERENCES

ABS (1994, 1999 & 2001). *Environmental issues, people's views and practices*, Australian Bureau of Statistics, cat. no. 4602.0, Canberra.

Brodribb, R., Webster, P and Farrell, D (1995). Recurrent *Campylobacter fetus* subspecies fetus bacteraemia in a febrile neutropaenic patient linked to tank water. *Communicable Diseases Intelligence*. Vol. 19, 312- 313.

Coombes, P., Kuczera, G, and Kalma, J (2000). Rainwater quality from roofs, tanks and hot water systems at Fig Tree Place. *Int. Hydrol. and Water Resources Symposium,* Perth, November 2000, 1042-1047.

Cuncliffe,D.A. (2004). *Guidance on the use of rainwater tanks,* enHealth Council, Australian Government Department of Health and Ageing, Canberra (ISBN N 642 82443 6)

Department of Health (2003) Annual report for the year 2001-2. Department of Health, Perth, Western Australia

Fujioka, R.S, Inserra, S.G and Chinn R.D (1991). The bacterial content of cistern waters in Tantlus area of Honolulu, Proc 5th Inter Conf on RWHS, Keelung, Taiwan, 4-10 Aug.

Fujioka, R., Rijal, G. and Ling, B. (1995). A solar powered UV system to disinfect cistern water. *Proceedings: Rainwater utilization for the world's people, Volume 2.The International Rainwater Catchment Systems Conference* June 21-25, Beijing, China.

Heyworth, J.S. Maynard, E.J. and Cuncliffe, D. (1998). Who drinks what? Potable water use in South Australia. *Water*, 25(1): 9-14.

Manja, K.S., Maurya, M.S. and Rao, K.M. (1982). A simple field test for the detection of faecal pollution in drinking water. *Bulletin of the World Health Organisation*. 60: 797-801.

Nair, J., J.Forrest, K.Mathew, R.Gibbs, and G.E.Ho (2001). Testing rainwater collected in tanks using the H_2S method, Water and Wastewater for developing countries, 6-8 November 2001, Kuala Lumpur, Malaysia.

Nair, J., R Gibbs, K Mathew, and G E Ho (2000), Suitability of the H_2S Method for testing untreated and chlorinated water supplies. *Wat.Sci.Tech*. 44(6): 119-126

Pillai, J, R. Gibbs, K.Mathew and G.E. Ho (1999). Suitability of the H_2S paper strip method for testing rainwater. In. Proceedings of the International Regional Conference on Environmental Technologies for Wastewater Management, *IETC Report No7*. p 251-256.

Simmons G, Hope V, Lewis G, Whitmore J & Gao W (2001). 'Contamination of potable roof-collected rainwater in Auckland, New Zealand', *Water Research*, vol. 35, pp. 1518–24.

Thomas, P.R. and Greene, G.R. (1993). Rainwater quality from different roof catchments. *Water Science and Technology,* vol. 28 (3-5): pp. 291-299.

Thurman R (1995).'Evaluation of rainwater stored in collection tanks', *Australian Microbiologist*, March, pp. 20–22. March, pp. 20–22.

WHO (2002). *Heterotrophic plate count measurement in water safety management*, *management* World Health Organization, Geneva.

WHO (1993). Drinking water quality control in small-community supplies, In: *Guidelines for Drinking Water Quality*. Volume 3. World Health Organization, Geneva.

Yaziz, M i., Gunting, H., Sapari, N and A.W. Ghazali (1989), Variations in rainwater quality from roof catchments, *Water Research,* 23 (6): 761-765