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Microbial quality variation within a rainwater storage tank and the effects of first flush in Rainwater Harvesting (RWH) System

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Abstract: Research has neglected to investigate many important facts of Rainwater Harvesting (RWH) with regard to water quality changes and treatment mechanisms within storage tank. To better understand these phenomenon and quality changes within RWH system, microbial quality of stored rainwater is examined in storage tanks of two buildings in Seoul National University, Seoul. The main objectives were to monitor the horizontal and vertical microbial quality variation within couple of storage tanks and the effects of first flush removal on microbial quality of rainwater. Pre- and post-treatment rainwater samples were collected from rainwater storage tank and within the RWH System and were analyzed for total and fecal coliforms, Escherichia coli, and Heterotrophic Plate Count. Additionally, some basics physicochemical parameters, including temperature, turbidity, pH, Electrical conductivity and dissolved oxygen were also examined for selected samples. Microbial quality improves within a rainwater tank from inlet to outlet points and it also varies vertically with better quality at supply point which is about 1m above the bottom of the tank as compared to the surface of the tank. First flush of rainwater was highly contaminated which was contributing towards microbial contamination of stored rainwater in tank. These results show rainwater collected from rooftop surfaces after removal of first shower of rainfall is suitable even for potable proposes with very little treatment. The findings in this study highlight the gaps in our understanding of design and specifications of rainwater storage tank and finally recommend the future research work to further support the conclusion drawn.

Key words: first flush, microbial quality, potability, rainwater harvesting

INTRODUCTION

Rainwater Harvesting (RWH), despite being an age-old practice in many parts of the world, has been used at the household level only on a limited scale. Many households in the tropics are exposed to abundant (but seasonal) rainfall yet do not have access to an adequate supply of potable water. RWH also has a range of possibilities in relation to its use ranging from an immediate and only source of water for daily use to storage of water for long periods to get through drought or address specific needs at times of emergencies. The application of an appropriate RWH technology can make possible the utilization of rainwater as a valuable and, in many cases, necessary water resource.

RWH is becoming essential owing to the temporal and spatial variability of rainfall and due to climate change effects. It's necessary in areas having significant rainfall but lacking any kind of conventional, centralized government supply system, and also in areas where there is no good quality fresh surface water or groundwater is lacking. The use of rainwater in domestic hot water systems can result in optimized environmental and economic benefits to urban water cycle management (Spinks *et al*., 2006). Rainwater is used as non-potable purposes for toilet flushing and clothes washing for saving drinking water resources in Denmark (Albrechtsen, 2002) as none of the investigated rainwater samples met the drinking water standards however the general microbiological quality in the toilets supplied with rainwater were approximately the same as in the reference toilets supplied with drinking water. The use of rainwater for water closet, flushing, laundry, irrigation, and car washing in Ringdansen, Sweden is analyzed and the quality of roof runoff is acceptable to supply low quality domestic uses (Villarreal and Dixon, 2005). Potable water savings by using rainwater ranges from 34% to 92%, with an average potential for potable water savings of 69% in Brazil (Ghisi *et al*., 2006; Ghisi and Ferreira, 2007)

Rainwater is also considered a safe and suitable source of potable water, especially in rural areas in developing countries of the world. Rainjars, for example, in Thailand, provided a purer and more convenient source than shallow wells and bacteriological analysis showed rainjar water to be much purer than drinking water from alternative sources (Pinfold *et al*., 1993) Similarly in Zambia, samples from a roof water system showed that the water can be used for drinking (Handia *et al*., 2003) Quality of rain water is monitored from

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different tank types in Sri Lanka and it is found that as compared to other available water sources in rural Sri Lanka, quality of rain water is much higher both biologically and chemically (Ariyananda, 2005)

Study carried out by Coombes *et al*., in Australia at Figtree Place showed that samples of rainwater from tanks and hot water systems was found compliant with chemical and metals parameters in the Australian Drinking Water Guidelines (ADWG, 1996) provided that they are operated at temperatures in the range 55°C and 65°C. The quality of rainwater is improved by storage in tanks and the combination of the rainwater tank and hot water system is an effective water treatment process that produces water quality results compliant with drinking water guidelines (Coombes *et al*., 1999). Similarly, he found rainwater at an old house in Maryville, Newcastle in New South Wales, Australia acceptable for hot water, toilet and outdoor uses (Coombes *et al*., 2003). The majority of parameters complied with the ADWG although the average values for Total Coliform (TC) in the water from the rainwater tank exceeded the recommended drinking water guideline. Rainwater used in the hot water service was compliant with Australian drinking water standards and water quality was found to improve in the rainwater tank and the hot water service.

While roof surfaces are often viewed as a potential source of contamination for rainwater, storage tanks can be seen as a means of treatment, offering a series of beneficial processes. For example, as rainwater is often slightly acidic, the increase in pH is caused by contact with a concrete catchment and then in the concrete tank. Scott observed a rise in pH from 5.0 on the roof surface, to 9.4 in the tank and 10.3 from the tap, suggesting that a higher pH can inhibit coliform growth. During sampling over a two year period, coliform bacteria were only detected during periods of low pH (Scott and Waller, 1987) Sedimentation inside storage tank also plays a primary role in reducing the contaminant load of stored rainwater. Spinks et al. observed sludge accumulation rates up to 7.8 mm/yr and contaminant magnification rates up to 1349 for biological parameters (Spinks *et al*., 2005)

This study aims at encouraging RWH in terms of microbial quality for potable purposes, and rainwater quality assessment program was initiated with the objectives to:(i) assess the microbial quality variation of rainwater samples within couple of storage tanks located inside Seoul National University at Seoul in South Korea, and (ii) determine the effects of FF behavior on microbial quality changes within RWH system. Samples were collected within storage tanks and from the RWH systems located in the urban locations. The use of rainwater was limited to toilet flushing in investigated RWH systems.

Materials and methods:

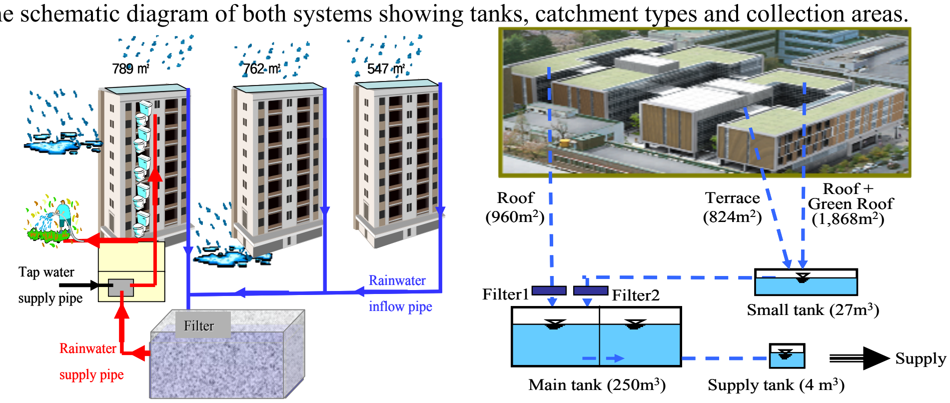
Experimental Sites and Sampling sketches:

This study was carried out at Seoul National University in Seoul, Korea. The choice of sites for sample collection was made mainly with regard to the availability of the rainwater facility. Two sites were selected namely the RWH System 1 and RWH System 2 as described in Table 1.

Table 1: Description of both RWH Systems.

Description	Catchment Type (Area)	Tank Size, Ton	Auxiliary Tank	Filter Type	Remarks
RWH System 1	Roof ($2098m^2$)	200	X	VF6	Dormitory Building
RWH System 2	Roof ($2828m^2$) Terrace ($824m^2$)	250	27 Ton	WFF 100 AFS 200	Engineering Building-39

In case of RWH System 1, there is only one main component and that is the underground concrete storage tank with size about 200 Ton and roof catchment area comprised of 2098 m2 of concrete surface. Figure 1 shows the schematic diagram of both systems showing tanks, catchment types and collection areas.



(a) (b)

Fig. 1: Schematic diagrams of; a) RWH System 1, b) RWH System 2.

RWH System 2 has several components including couple of storage tanks and rainwater is collected from roof catchment (both concrete and green roofing) along with terrace catchment. The main underground concrete storage tank size is about 250 ton with total roof catchment area of 3652 m^2 and auxiliary tank volume is about 27 Ton which is collecting water from concrete and green roof and from terrace catchment. The water from auxiliary tank then flows into main tank and finally to supply tank where it is pumped to toilets in the building.

In addition to these sampling points in storage tanks, rainwater samples were also collected from filters representing the roof-intercepted samples to find out the effects of FF. Figure 2 shows the plans and cross sectional views of all three tanks in both RWH systems for highlighting the sampling points.

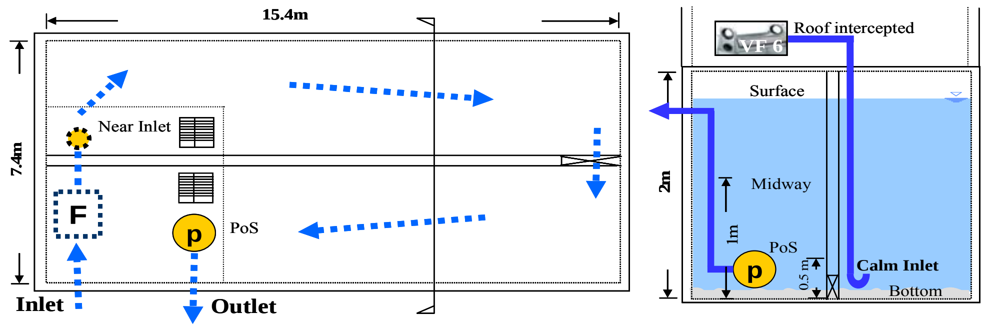
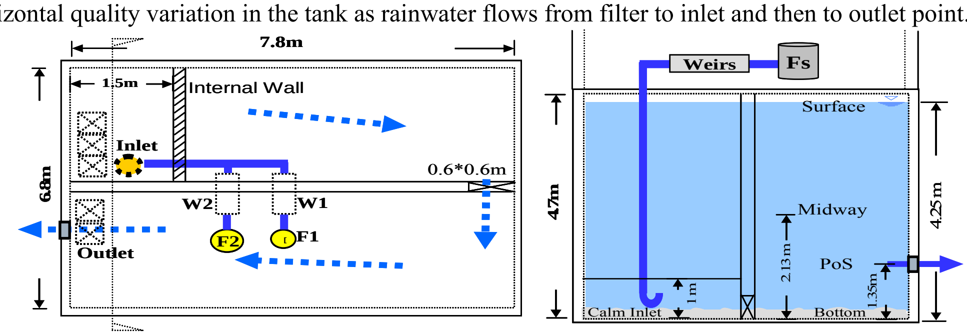


Fig. 2: a Storage Tank (Plan and Section) in RWH System 1.

In figure 2a, which is the plan and sectional view of the only tank in RWH system 1, three vertical sampling points are shown at outlet point. These samples are taken to represent the vertical water quality variation in the tank. One sample is taken near supply pumps representing the outlet sample. The rainwater from rooftop flows into Filter (VF6 type with mesh size of 0.65mm and capacity of 70.5L/sec) at first and then enters into main tank through calm inlet (Plan view of Figure 2a). One sample is taken in the filter assembly representing the roof-intercepted sample and then another sample is taken near inlet point. These samples were taken to find out the horizontal quality variation in the tank as rainwater flows from filter to inlet and then to outlet point.



Fig, 2: b Main tank (Plan and Section) in RWH System2.

Figure 2b, represents the plan and sectional view of main tank in RWH System 2. Vertical samples are taken both at inlet and outlet points for evaluating the vertical quality variations at two points in main tank and also horizontal quality variations as water flows from inlet to outlet point as is clear in the plan view of tank.

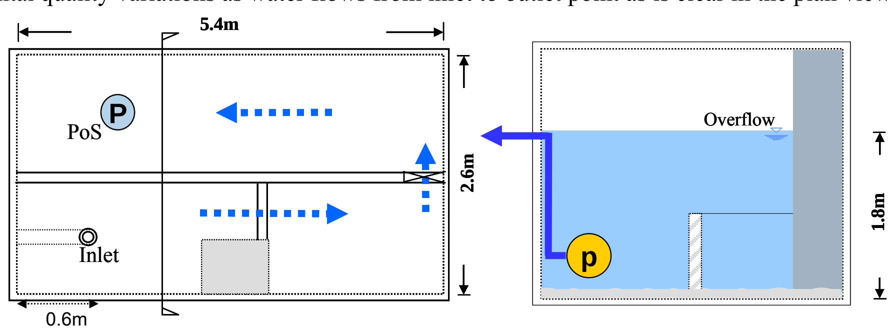


Fig. 2: c Auxiliary tank (Plan and Section) in RWH System 2.

In case of Auxiliary Tank, the samples were taken only at inlet and outlet points to find out the horizontal quality variation as water flows from inlet to supply point in the tank.

Bacteriological water quality parameters:

Total and fecal coliform bacteria tests are used to assess bacteriological water quality. These tests are used to index hygienic quality because total and fecal coliform are usually associated with fecal contamination and thus their numbers reflect the degree of pathogenic risk. Also, the tests are relatively easy to perform in comparison with analysis for specific pathogens. Fecal Coliform (FC) is the most widely used indicator to determine the possible presence of pathogenic organisms. Coliform bacteria originate from the feces of humans and warm-blooded animals in addition to be found in soils and other natural sources. The numbers of FC is often used as an indicator to judge water quality. Heterotrophs use organic chemicals as a principal carbon source. Heterotrophic Plate Counts (HPC) can be used to determine the presence of organic matter in water and as an indicator of general water quality.

Laboratory analyses of samples:

Microbiological samples were collected directly into individual sterile 1L bottles and transported to the laboratory. Samples were received and analysis usually commenced on the day they were taken or if that were not possible, within 24 h of sampling. The investigated water-quality parameters include TC, FC, Escherichia Coli (*E. coli*) and HPC. The other parameters were temperature, pH, turbidity, Electrical Conductivity (EC), and Dissolved Oxygen (DO). All bacteriological parameters including TC, FC and *E. coli* were conducted using the multiple tube fermentation technique (MPN method) using Lauryl tryptose broth for the Presumptive Phase of total and fecal coliforms and Brilliant green lactose bile broth and EC Medium for the Confirmation Phases of TC and FC respectively and EC medium with Mug for *E. coli*. The water quality analysis was carried out in accordance with the Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1995)

HPC was determined by the Pour Plate Method using Standard Plate Count agar. One milliliter of each water sample was serially diluted in a set of test tubes each containing 9ml of sterile distilled water. Then, 1ml of each dilution was plated out respectively in duplicates employing the use of nutrients agar medium kept in molten form at 45◦C. Having allowed the agar medium to set, the culture plates were incubated aerobically at 35◦C for 48 h. The plates were observed for growth and selected for counts. The culture plates in which the number of colonies was in the range of 30–300 and their respective duplicates were selected. The average count was multiplied by the reciprocal of the dilution and expressed as the number of colony-forming units (CFU) per milliliter of original sample.

RESULTS AND DISCUSSIONS

In both RWH systems, basic physicochemical parameters are analyzed along with bacteriological parameters but these values are used only as references while the discussion is focused mainly on microorganisms during analysis. Table 2 shows the simple physicochemical parameters measured in all three tanks of both RWH systems in two buildings. These are the average values of five to six samples each taken at different times during one year of analysis mostly on bi-monthly basis. So, most of the values of temperature were measured in winter and hence the average value is 17^{O}C. These values are significant since temperature has considerable effects on the microorganism's concentration and there is less activity of microorganisms reported during winter season than in summer period when the temperature lies between 20 and 30^{O}C in the tank.

Table 2: Physiochemical parameters in storage tanks of both RWH systems.

Parameters	Main Tank-RWH System 1			Main Tank- RWH System 2			Auxiliary Tank- RWH System 2		
	Min.	*Max.*	*Avg.*	*Min.*	*Max.*	*Avg.*	*Min.*	*Max.*	*Avg.*
Temp. ^{o}C	10	28	17.0	11	27	18	10	25	14.0
pH	6.84	8.2	7.04	7.7	9.85	8.71	6.68	9.7	8.56
EC, mS/cm	42	56	45.0	75	109	88	152	428	286
DO, mg/l	5.3	6.9	6.78	4.35	7.2	5.66	3.52	5.89	4.53
Turbidity, NTU	1.4	10.8	3.4	0.41	8.56	5.7	1.31	11	4.90

The average values of pH in storage tanks water were observed to be above the lower guideline value of 6.5 and the lowest value was 6.84 in storage tank of RWH system 1. There is no health-based guideline for pH and Annual Report of the National Health and Medical Research Council in 1996 (NHMRC, 1996) indicates that the consumption of food or beverages with low (2.5) or high pH (11) does not result in adverse health effects.

Contact with water with pH values below 4 can cause eye irritation and pH values above 10 can cause skin irritation. Water with pH values greater than 11 and less than 6.5 can, under some conditions, may corrode plumbing fittings or pipes which were not the case with the measured pH values in this study. The pH values were above the neutral value of 7.0, and especially in case of RWH System 2, due to reason that it was relatively new construction and both concrete roof catchment and tank material of concrete are the main sources for higher pH values.

Horizontal and Vertical quality variation in Storage Tank of RWH System 1:

In case of RWH System 1, most of the samples were taken from the storage tank for the horizontal and vertical microbial quality variations within tank. Bulk sample is collected at rooftop, which represents the direct precipitation. One sample is taken from the filter assembly before rainwater being enters into the tank. This sample was taken short after the rainfall begins and hence represents the FF of rainfall and so the average values of roof-intercepted sample for all bacteriological parameters are higher than tank samples. In this dormitory system there was no facility to separate FF of rainfall and it was also introduced into tank. Once again, average values in the table are the representative values of about six samples taken at different time intervals during one year of analysis mostly on bi-monthly basis.

Figures 3 and 4 represent the vertical and horizontal microbial quality variation at outlet point and from inlet point to outlet point in the tank, respectively. Samples are taken at outlet point vertically from Point of Supply (PoS) to the surface of water level in tank. These samples are taken every time when the water level in tank was full. Better vertical quality at PoS is observed than near surface of tank or at midway of tank height. The PoS is situated about half meter above the base of the tank. Microbial quality results from six samples drawn from the PoS in storage tank revealed that the average values for parameters of all bacteriological parameters like TC, FC, *E. coli*, HPC exceeded well the guideline values but were significantly less than the corresponding average values obtained from samples at the water surface in the tanks. All the rainwater samples contained heterotrophs which are common in natural aqueous environments.

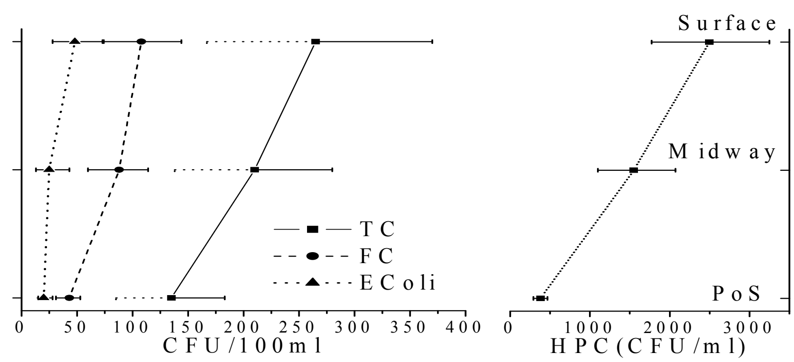


Fig. 3: Vertical quality variation at outlet point in storage tank of RWH System 1.

TC and others were detected in all rainwater samples collected throughout the analysis period. Figure 3 shows that all samples had total and fecal coliforms, much greater values (maximum values) in the summer months than in the winter months (minimum values). These values experience a considerable drop in the fall (lowest values on error bars), with a much larger drop in the presence of total and fecal coliforms throughout the winter and spring months. This decline in microbiological activity throughout the winter months could be attributed to a number of factors. One possibility is that the colder air temperatures between October and February (ranging from -15°C to 15°C) inhibited the growth of bacteria within the storage tank itself, thereby reducing the number of coliforms present. Another potential contributor to the fewer number of samples with coliforms in the winter and spring months is the decreased activity of rodents and birds. The decreased fecal contamination of the catchment surface by birds and rodents during these months would reduce the influx of fecally-contaminated rainwater into the cistern. Samples taken at the bottom of the tanks show very high concentrations of microorganisms supporting the assumption that contaminants settle to the bottom of tanks (Table 3). The maximum concentration of microorganisms is at the base of tank due to sedimentation but decreases abruptly upwards and becoming minimum somewhere very near to the base of tank.

Table 3: – Sludge characteristics.

Parameter	Value
Particle Size (□)	38.78 ~ 64
Water Contents (%)	75.4 ± 5.06
Specific Gravity	1.01 ~ 2.33
Percentage of organic matter (%)	15 ~ 34.25
Ph	6 ~ 8
Chemical oxygen demand (□/L)	20 ~ 100
Total coliforms (CFU/100ml)	1200-1600
HPC (CFU/ml)	>10000

Quality is improved horizontally in the system from filter assembly (roof-intercepted sample) to inlet point and to the PoS as is shown in Figure 4. Better quality is observed at near-inlet point than the roof-intercepted sample collected from filter assembly in terms of TC, FC and others. First Flush (FF), which is collected from filter assembly, is obviously more contaminated than stored rainwater in tank. The main reason for horizontal quality improvement from inlet to outlet in the tank is due to sedimentation process as the water flows from inlet to outlet points inside storage tank. Roof-intercepted sample, which was the FF in this case and was collected within the filter assembly, is more contaminated than stored rainwater in tank due to the dirty catchment surface in the beginning. Rainwater in storage tank is cleaner than FF because of the dilution effects since relatively clean water is entering into tank after FF entry.

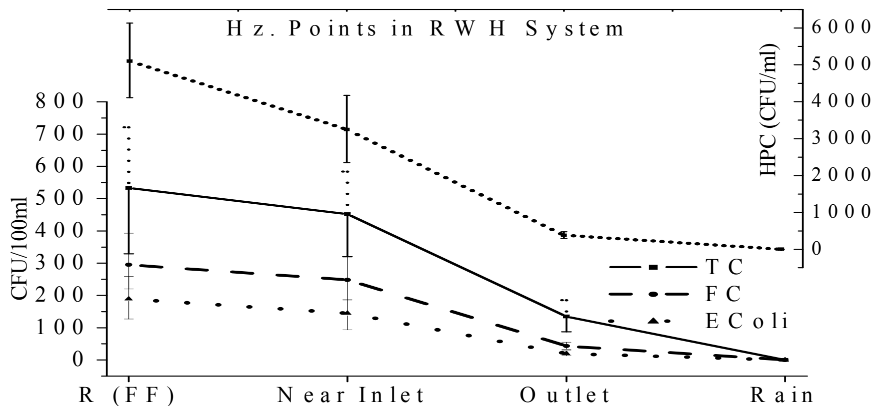


Fig. 4: Horizontal quality variation in RWH System 1.

Results from about 20 samples taken from the filter assembly representing roof-intercepted and at the PoS in the tank water showed that the average values for parameters TC, FC and others exceeded the guidelines. The bacterial contamination in the tanks appears to result mainly from the FF entry into the storage tank. The minimization of bacterial contamination in the rainwater tanks can be attributed to the filtering and effective seals in the rainwater tank that minimize entry of debris, soils and leaves to stored water. Normal maintenance of roof gutter systems may have also reduced the amount of contamination entering rainwater tanks. Natural cleaning processes in the storage tank like settlement, sorption and bioreaction may also remove contamination that enters the tank.

Horizontal and Vertical quality variation in Storage Tank of RWH system 2:

Samples are collected from both main and auxiliary tanks in the RWH System 2 for the horizontal and vertical microbial quality variations within tanks. In case of auxiliary tank only few samples are taken for horizontal quality variation, while in main tank, samples are taken both at inlet and outlet points for horizontal and vertical quality variations. The average values shown in Figures 5 and 6 are the representative values of seven samples each taken at approximately monthly time intervals of one year study period. Figures 5 and 6 represent the vertical and horizontal microbial quality variation at outlet point and from inlet point to outlet point in the main storage tank, respectively.

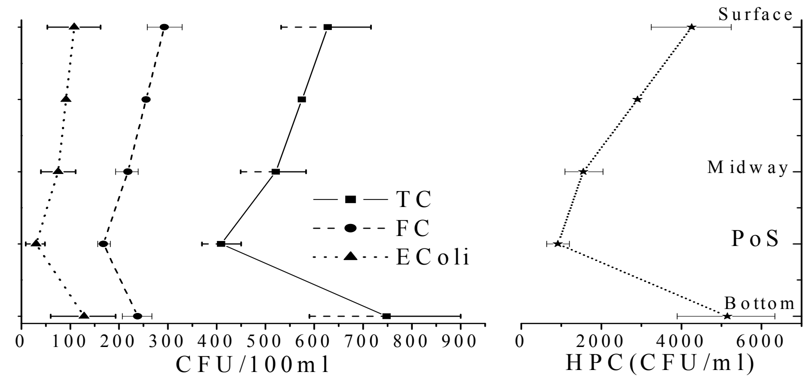


Fig. 5: Vertical quality variation at outlet point in main storage tank of RWH System 2.

Samples were taken both at inlet and outlet points vertically from the base of the tank to the surface of water level in tank. The height of water level in main storage tank of RWH System 2 is 4.25 m (Figure 2b) as compared to the storage tank of RWH System 1 where it was only 2m. These vertical samples are taken every time when the tank was full. The PoS is situated 1.35 meter above the base of the tank. The horizontal error bars in Figure 5 at each point represent the maximum and minimum values at each point since these values are measured at different times and the effects of different weather conditions and detention time are incorporated. The maximum values in each case represent the values usually taken in summer season and right after the rainfall event. The average values are the representative values of rainwater samples taken after a detention period of about two weeks in mild weather (during September and October). The minimum values are the observed concentrations of bacteriological parameters in winter season usually after a detention period of about one month. So, concentration decreases from average values to minimum mainly due to low temperatures in the tank and due to the detention time of rainwater in storage tank.

As is shown in Figure 5, better vertical quality is observed at PoS than near surface of tank or at bottom of the tank. It suggests that settlement was a key process in the operation of RWH system. This observation led to the hypothesis that a naturally occurring set of treatment processes were operating within the storage tank which might include processes of flocculation and settlement and the action of biofilms at the water surface interfaces that has improved the water quality at the PoS. This is also supported by the earlier researches establishing the fact that many bacteria conglomerate in a macro-layer on the water surface, whereas other contaminants precipitate out of the water column and settle at the bottom of the tank (Coombes et al., 2000; Spinks et al., 2005, Han and Mun, 2008, Kim and Han, 2011). Furthermore, this suggests that tank water quality also improves because of the sedimentation at the bottom of the tank where they sorb to sludge.

A similar trend is also observed for vertical microbial quality variation at inlet point of main storage tank with slightly higher values at respective points than at outlet point (results not shown). Microbial water quality varies considerably from the water surface to the inlet point near the base of the tank. Possible reason could be that many bacteria conglomerate in a macro-layer on the water surface, whereas other contaminants precipitate out the water column, and settle at the bottom of the tank. Figure 6 represents the horizontal microbial quality variation form inlet to outlet point in main storage tank of RWH System 2.

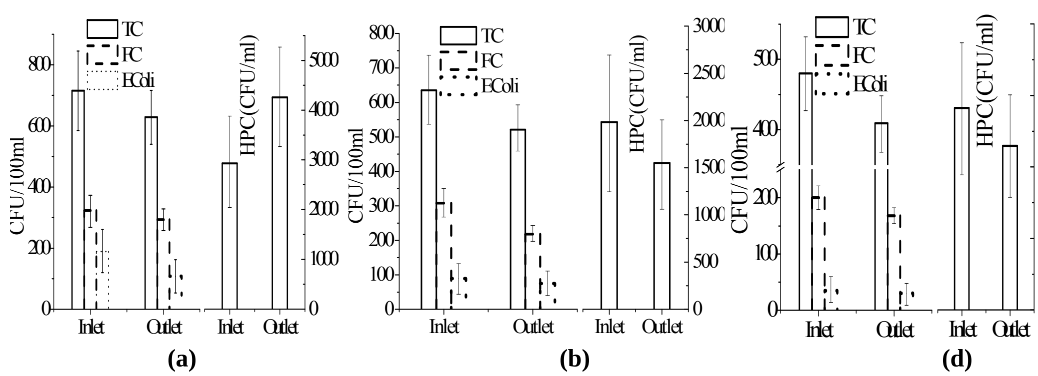


Fig. 6: Horizontal quality variations from inlet to outlet point in main tank of RWH System 2 at; (a) Surface point, (b) Midway Height, and (c) Near Bottom.

Quality is improved horizontally in the main storage tank from inlet point to outlet point at respective heights although this difference is not significant. The HPC concentration is somewhat higher at the outlet point than at the inlet point which is contrary to the conclusion drawn of quality improvement from inlet to outlet point in the tank. The reason is now known exactly and it might be due to the irregular pattern on tank cleaning or may be thicker biofilm on the wall of the tank near inlet point that entrapped more heterotrophs. Another reason could be the small effects of sedimentation or flow path length from inlet to outlet.

In fact, the tank is divided into two halves by a central wall and water flows from inlet to outlet point through a baffle which is at the farthest end of wall from the inlet point (Figure 2b). So, water flows across the length and width of tank to PoS and this quality improvement is thus due to the tank design parameters including the height and length/width of tank. So, the tank specification and design parameters are crucial in terms of quality management and length/height ratio should be selected carefully. The provisions of baffles can further improve the quality from inlet to outlet point due to the formation of biofilms on walls and more sedimentation at the bottom of tank. The similar trend of horizontal quality variation from inlet to outlet is observed in auxiliary tank where water flows from inlet to outlet through baffles provided in the auxiliary tank as shown in Figure 2c. The horizontal microbial quality improvement (results now shown) is less in auxiliary tank as compared to the main tank despite of the fact of the presence of baffles in auxiliary tank, however, this might be due to the short length/width of tank and hence shorter water flow path in auxiliary tank than in main tank and also may be due the worse water quality in auxiliary tank where the water is also introduced from terrace catchment.

First Flush Effects on Microbial Quality in RWH System 2:

Roof-intercepted sample is taken from the Filter 1 (WFF 100 type with mesh size of 0.28mm and capacity of 1.5L/sec) before rainwater being enters into the tank (Figure 1). This sample is collected short after the rainfall begins which represent the FF of rainfall and one more was collected after 1mm of rainfall which when compared with previous sample represents the effects of FF. Also, the similar two samples are taken from the Screen (T-101 type with mesh size of 0.6mm) attached to auxiliary tank (Figure 1) which represents the roof and terrace-intercepted samples since catchment surface of auxiliary tank comprise of concrete and greed roofs and terrace surfaces as compared to the sample collected in Filter 1 where it was only concrete roof catchment. Two samples in each case which are taken short after rainfall and after about 0.05mm of rainfall, when compared with each other, represent the effects of FF.

The FF of runoff water that occurs at the beginning of a storm event contains a high proportion of the pollutant load. The main cause of this phenomenon is the deposition and accumulation of pollutant material to the roof during dry periods. The FF from green-roof-terrace catchment, collected from Screen assembly entering into auxiliary tank, is highly contaminated and TCs concentrations are as high as about 2000 CFU/1000ml while in case of roof-intercepted FF, collected from Filter 1 entering into main tank, this value is slightly less but still in the range of 1500 CFU/100ml as shown in Figures 7a and 7b.

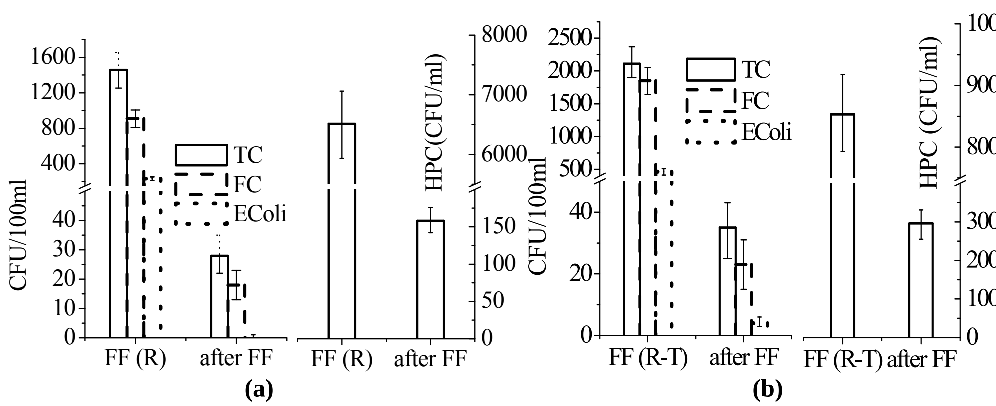


Fig. 7: Quality improvements after FF, RWH System 2; **a)** Filter 1 samples, and **b)** Screen samples.

Rainwater samples during FF are highly contaminated in case of roof-intercepted, for green-roof and terrace intercepted samples. The quality is improved considerably after FF of rainfall in case of roof catchment sample but still not good for roof-terrace surface although improved to greater extent. The roof-intercepted sample is almost free of contamination in terms of *E. coli* after FF of rainwater (about 0.05mm of rainfall) and has acceptable turbidity with neutral pH. The numbers of HPC were very high in FF of rainfall and presence of both *E. coli* and HPC in the FF of rainwater samples representing the contamination of catchment surfaces by human activities. The longer the dry period, the greater the probability of higher pollutant loads in the FF.

Yaziz *et al*., 1989.) also investigated the effects of FF signifying that concentration of various pollutants were high in the first liter of rainfall but decreased in subsequent samples with few exceptions without any total and fecal coliforms detection in the fourth and fifth liter samples from both roofs, and hence recommended "foul flush" volume of 5L as safeguard against microbiological contamination.

One specific feature and potentially a source of higher biological loading in this study could be the lack of a FF device to storage in the rainwater tank although there was filtering device. Excluding this first shower of rainfall, and with it, the dirt and debris deposited on the roof surface between rainfall events, may have attributed to the lower number of total and fecal coliforms detected in the tank. The FF is heavily polluted and should be treated in an appropriate way by diverting the first 0.05 to 0.1 mm of rainfall depending upon the maintenance of catchment surface .So, pre-treatment (Filtering) alone can not be the enough factors for reducing the number of total and fecal coliforms. Best practices are filters that have a separate outlet for dirt and reject the FF as a side effect. Regular cleaning of the storage tank may prove to be unnecessary if fine filters are used in the inlet to the storage cistern.

Conclusions:

It needs to recognize at present that suitably harvested rainwater can represent an acceptable new water source and in some areas of extreme water shortage may even serve as the only source of potable water. There is little understanding about the quality of rainwater stored in tanks in terms of potential health risks due to microorganisms present are stored rainwater. The presence of total and fecal coliforms in RWH systems are more influenced by temperature, and thus microbial growth inside the tank, than the presence of external sources active in warmer temperatures. Main reason for high pH is newly constructed concrete catchment surfaces in case of RWH System 2 and also the concrete storage tanks. High turbidity values are due to Pine Pollen, yellow sand, dust etc. The catchment area should be maintained properly and debris should be cleaned up.

The quality is improved horizontally form inlet to outlet in the storage tank. The quality at outlet point is best as compared to surface of tank which is little better than the quality at bottom of tank. The reason for worst quality at bottom of the tank are the sediments at tank where microbes are attached but not scattered to the water layer above as in the case of water surface where microbes are scattered throughout some depth of water. Also, it can be concluded both from horizontal and vertical quality variations inside tank that wider the tanks better the quality is from inlet to outlet points but quality varies significantly in vertical direction than horizontally from inlet to outlet. Hence, the deeper tank designs more effective than wider ones and supply point should be situated at about 1m from the base of the tank. Finally, the baffles or internal walls inside the storage tank are not very much significance in terms of microbial quality improvement.

The effect of FF is very obvious on the quality of water. The quality is improved after FF of rainfall. The quality deterioration in storage tanks may be due to the fact that FF is also introduced in storage tank that carries microbes from the roof catchment. Most of organic substances in water are biodegraded to varying extents. A part of organic compounds adsorbed on the suspended solids slowly falls to the bottom of the cistern, forming sediments to be removed from water body. Finally, the FF of rainfall can be diverted for improved microbial quality of stored rainwater.

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