The Microbiological Quality of Harvested Rainwater System for Domestic Use in Gambang, Malaysia

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The use of roof-collected rainwater as a freely available and sustainable alternative to be used as drinking water that is produced by many drinking water companies around the world is increasing significantly. Malaysia is blessed with an ample supply of water and abundant rains. However, increasing usage by the industry, agriculture and by household users is straining the existing water supply infrastructure. The costs of adding to this infrastructure and that of replacing the ageing system are further burdening Malaysia's exchequer. At the present, Malaysia depend upon rainwater that falls over hills and countryside, which is collected then into large servitors inside ground as groundwater. Initially, rainwater is free of microbial contamination, but it may become contaminated by animals, surrounding environment that can help pathogens to grow in stored rainwater system and may result in a significant human health risk from infectious diseases. In this study rainwater samples were collected from rainwater Harvesting system tank that is located in a rural area in Gambang at University of Malaysia Pahang. The target microorganism were *E. coli* and total coliform which were measured by using colilert quanti tray 2000 at the University Environmental Lab. The experiments were performed for 6 months' period time with different time intervals or which is known as southeast monsoon in Malaysia to evaluate the seasonal change on the microbial parameters variation and their presence in harvested rainwater tank.

Keywords: Rainwater Harvesting System (RWH), Microbiological parameters, Monsoon season, Rural area, Malaysia

1. **Introduction**

Malaysia as a developing nation has experiencing a rapid urbanization, however in rural and remote areas where access to safe drinking water is limited so that rainwater harvesting is the most common practice to be used as a supplementary resource, and among of exiting solutions for conservation and sustainability development, rainwater recently has tackled the problem as an alternative source for domestic use (Li and Zhang, 2010). Despite that rainwater harvesting system is still considered as a new phenomenon in Malaysia (Othman *et al*., 2007).

In addition, water management should be improved appropriately through the years, as the water is a key resource for human and development. The United Nations World Water Assessment Program has shown the sustainability of water use propels consequences far beyond economic, social and environmental scopes (Cosgrove and W. J., 2012). Moreover, with increasing world's population and to meet the water demands, more interest is growing in the utilization of rainwater harvesting system (RWH) and typically is as good for landscape use (Kabir *et al.* 2014)

Roof-Collected rainwater is commonly accepted to be safe, free of pathogens and microorganisms and abundant source for potable domestic supply and the risk of diseases that rise from collected rainwater consumption could be low, however the most important issue that is related to untreated harvested rainwater is the potential public health risks that is associated with the pathogens (Ahmed et al. 2008). The contamination is impacted directly by the roof runoff through deposition of birds, small lizards, mammals, insects and the cumulative deterioration of the organic remains and deposition of micro-organism (Dehgahni *et al.* 2011). The direct monitoring routine of the microbiological quality of rainwater harvesting system (RWH) for all potential pathogens is not functional economically and technologically but the traditional fecal indicators, such as fecal coliform, Escherichia coli have been long used to determine the presence of pathogens and water contamination biologically and most of the studies evaluate the quality of roof-collected rainwater based on the numbers of these fecal indicators (Horman *et al*.2001). The microbiological quality of rainwater harvesting system (RWH) may depend on several factors such as the storage conditions, material of the cistern, intensity and the concertation of pollutants in atmosphere, vegetative and animals' contaminations inputs, the material type of the roofing and the location of the storage tank (Phillips et al.2005). To determine the rainwater harvesting system acceptability for drinking use purposes, it is a common practice to refer to guidelines to monitor the microbial quality of the water. Most of the guidelines involves the non-detection of the common indicators bacteria Such as E. coli and total coliforms and usually should be at numbers less than 1 colony forming unites[MPN/100mL] and their existence are used to indicate a potential fecal pollution of the water (NHMRC-NRMMC,2004; WHO, 2004).

The objectives of this study were to examine and evaluate the microbiological quality of the rainwater harvesting system in rural areas in Malaysia, Pahang state, Gambang to test the effect of monsoon seasonal changes on the variability of microbial water quality to produce a good quality of water for domestic use and to assess the potential risks of microbial contaminations so that the rainwater system was examined and monitored for fecal indicators (*E. coli* and total coliform) for six months' period of time during that the study was conducted in three-stages time period, through pre-monsoon season, monsoon and post monsoon to check the fecal variability in rainwater harvesting system.

2. Materials and Methods

2.1 Study Area description and location

The study monitoring was conducted at one harvesting system that is located in Gambang, Pahang state in Malaysia. The rainwater harvesting system was located in Universiti Malaysia Pahang, Gambang which is a small district of Kuantan that is a big city of state which is located to the south-east cost of Malaysia, ($3^{o}45'$N 102^{o} $30'$E) R. The average perception through month is around 438 mm and the temperature range is usually from 22C to 32^{o}C as maximum whereas the relative humidity varies from 62%, mild humidity to 96% very humid which is known as a monsoon season that is initiated from China and north Pacific start between November and February in Malaysia (Kang *et al*., 2012). The rain water was collected from the cistern that is located inside the university and known as WASRA system, a small project for collecting and harvesting rainwater for domestic purposes use. Rainwater was collected from the top roof which is made of Galvanized through the side gutter to a collecting pipe down to the cistern inlet and there is a mesh prior entering the tank that rainwater is passed through. While there is a drainage pipe for overflow rainwater that is fed into nearby channel. The capacity of the rainwater harvesting tank is 1m³and it is placed on a concrete base as shown in Fig 1.

Fig. 1- Photograph of WASRA rainwater harvesting system

2.1 Water Sample collection

Rainwater samples were collected weekly for six months' time period, during the pre-monsoon, monsoon and post monsoon season which is also known as the northeast monsoon season in Malaysia. Samples were collected directly from the top part and the bottom of the tank, and placed in glass sterilized bottles for microbiological analysis and put into ice-box container that is transported immediately to the laboratory of the university. A total of 40 samples were collected for microbiological assessment.

3. Analytical Methods

3.1 Microbiological Parameters analysis

All Samples were examined for the two widely used bacterial indicators total coliform and Escherichia coli (E. coli), by using the Colilert-Technology IDEXX- Quaniti- tray- Quanti Try 2000 technique, 57 wells, range 1-200 MPN/mLs at 35 C^{o}, method number SM9223B (APHA, 1998). All samples were collected directly into separately sterilized bottles of 400 mL size and transported directly to the Environmental laboratory of the university in a chilled-cold box. The samples were analyzed on the same day they were collected from the project site if that was not possible to achieve then within 24 hours as maximum as all samples were reserved in a chiller inside the laboratory.

3.2 Statistics Analysis

In this Study, to obtain the descriptive statistical analysis, (ANOVA) analysis of variance techniques test was performed by using the commercial software Minitab 17 as the data were divided into three groups and this statistical test is one of the most applied approach in the environmental studies of data structure (Minitab Inc, 2014). It is aimed at finding the significance differences between the results of the bacteria groups during the time period observation of the seasons variation and the differences were considered significant at $P<0.05$ as determined by the appropriate comparative test.

4 Discussion and Results

4.1 Descriptive statistics

Preceding to ANOVA analysis, descriptive statics were performed to compare the measured values of fecal bacteria with World Health Organization water guidelines and Malaysian drinking water quality (Maliyekkal, *et al.*200 ; Engineering division, Ministry of health, Malaysia). Statistics data for water samples of fecal bacteria of mean, maximum, minimum, median, and standard deviation were used to describe it in (Table1). Obviously, from the obtained results, the microbiological composition of the water tank varied over the time as shown in (Figures 1,2,3,4,5,6,7) and *E. coli* bacteria range was from 3.7 to 5.8

organisms per 100 mL at range of temperature (25-32 ^{o}C), while total coliform fecal range was from 113 to 314.9 organisms per 100 mL, and both types of bacteria exceeded the zero organism per 100 mL of water. All samples were tested positive for total coliform and *E. coli* as an indicator of fecal contamination and as shown in (Figure 8) and (Figure 5). These two widely used bacteria were detected in all rainwater samples and in accord with previous studies (Evans et al.2006), (Lye, 2009), (Mendez et al. 2011), (Ahmed et al. 2011), (Abbasi, and Abbasi, S. A, 2011) and according to our results show that the roof harvested rainwater of WASRA system is not suitable for human consumption due to the high and unacceptable levels of microbiological contamination within it and the fecal bacteria was above the acceptable guidelines limits for drinking water. So that as a result, it is highly and a must be recommended to use water disinfection methods. Moreover, it should be highlighted that no first-flush was used in this study.

Table 1. Descriptive Statistics for the Data

Variables	Units	Observation	Min.	Max.	Mean	Median	Standard deviation	WHO Drinking Water Guidelines	Malaysian Drinking Water Guidelines
Total coliform	MPN per 100 mL							0	0
Pre-Mons.		40	301.5	616.4	456.8	445.1	83.5	0	0
Monson		40	188.2	301.2	249.87	244.58	24.2	0	0
Post-Monson		40	35.8	151	81.71	79.6	27.42	0	0
E. coli	MPN per 100 mL								
Pre-Monson		40	10.5	16.3	12.807	12.650	1.503	0	0
Monson		40	7.2	10.9	9.030	9.250	0.960	0	0
Post-Monson		40	0	7.4	5.012	5.100	1.479	0	0

Figures 2,3 and 4, show the variation of *E. coli* over the time period of sampling (pre-monsoon, monsoon and post-monsoon season).

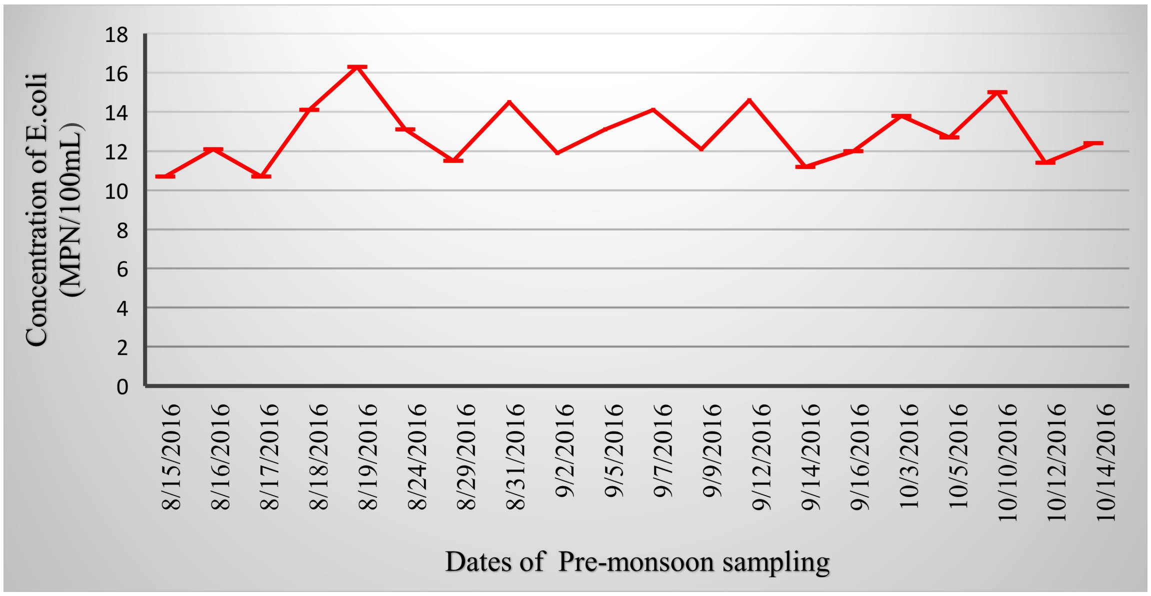

Figure 2. The variation of concertation of *E. coli* during the Pre-monsoon sampling

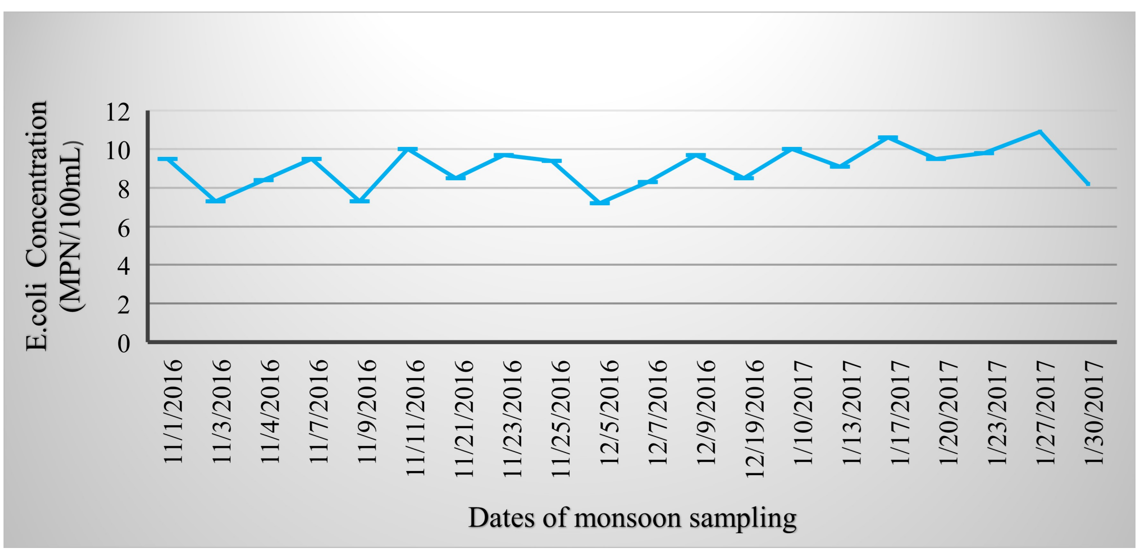

Figure 3. The variation concertation of *E. coli* during the monsoon sampling

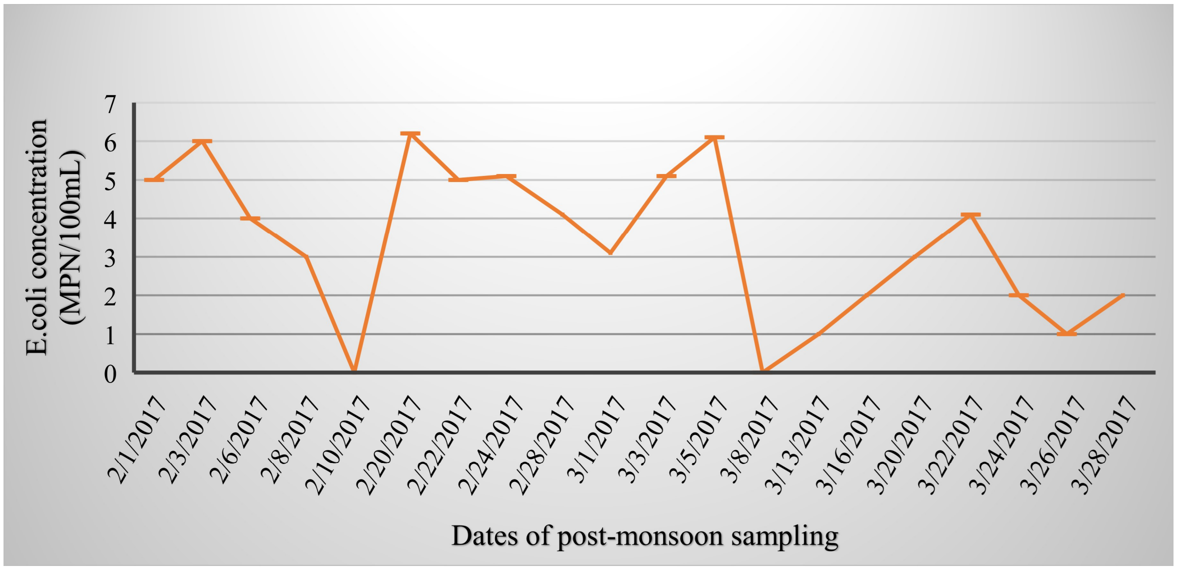

Figure 4. The variation concertation of *E. coli* during the Post-monsoon sampling

While Figure 5, 6 and Figure **7**, show the variation of concentration of total coliform over the time of sampling during the (pre-monsoon, monsoon and post-monsoon season).

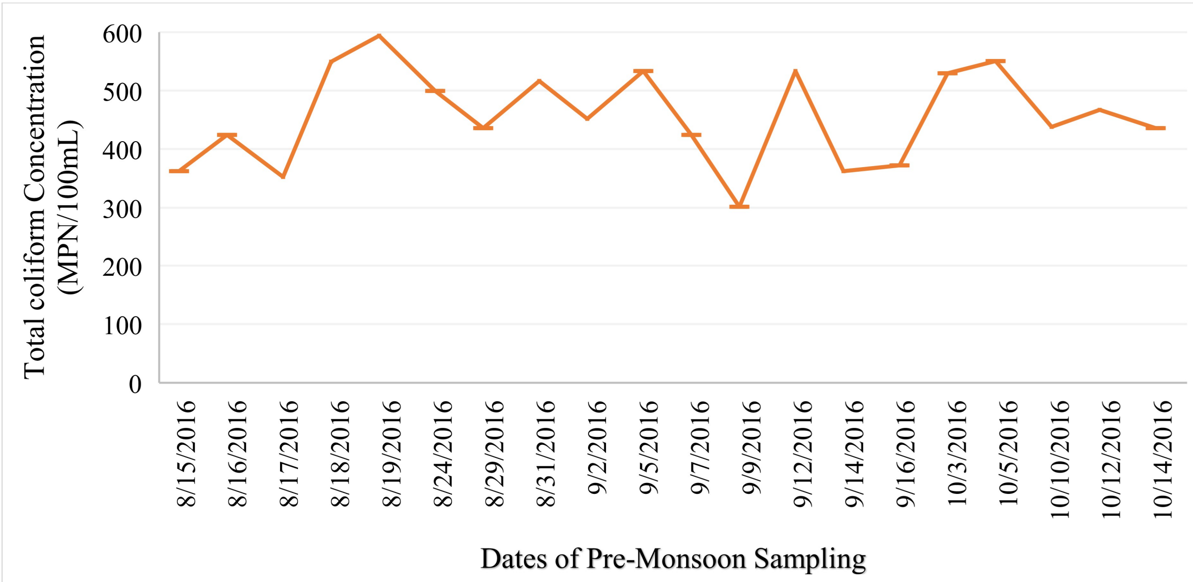

Figure 5. The variation concertation of total coliform during the Pre-monsoon sampling

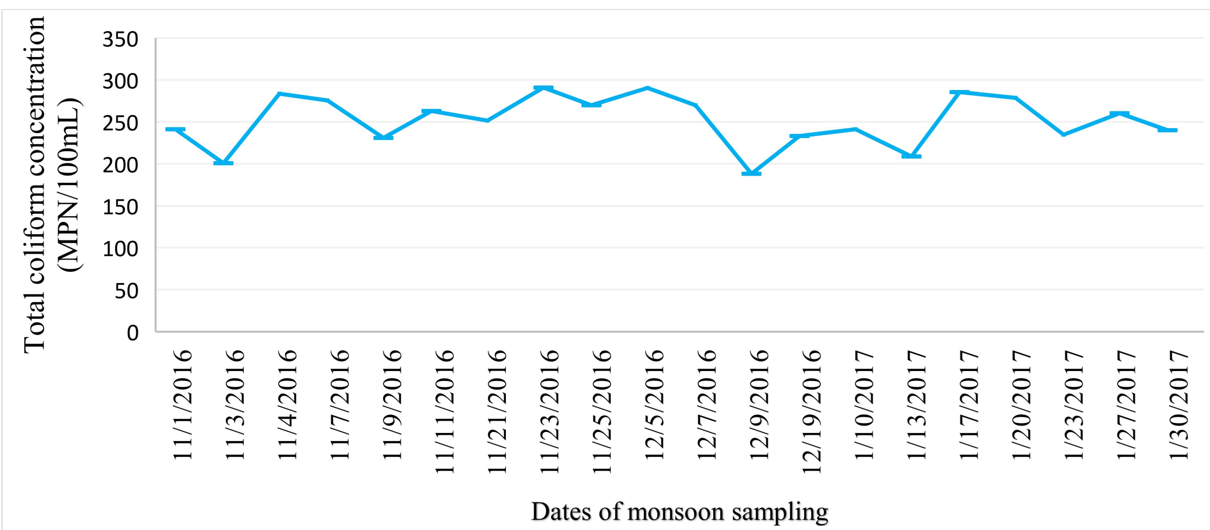

Figure 6. The variation concertation of total coliform during the monsoon sampling

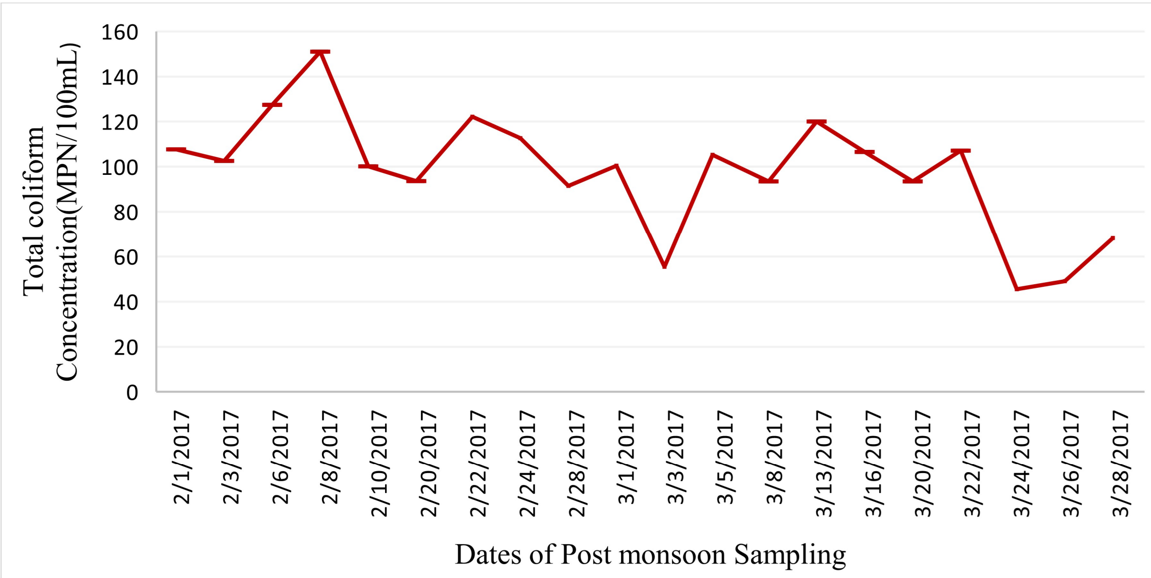

Figure 7. The variation concertation of total coliform during the Post-monsoon sampling

Figures 8 and Figure 9 showing the presence and observation of *E. coli* and total coliform during the sampling time period of three time intervals (Pre-monsoon season, monsoon season post-monsoon season) and both figures show the concentrations of fecal contamination in all water tank samples and as shown below:

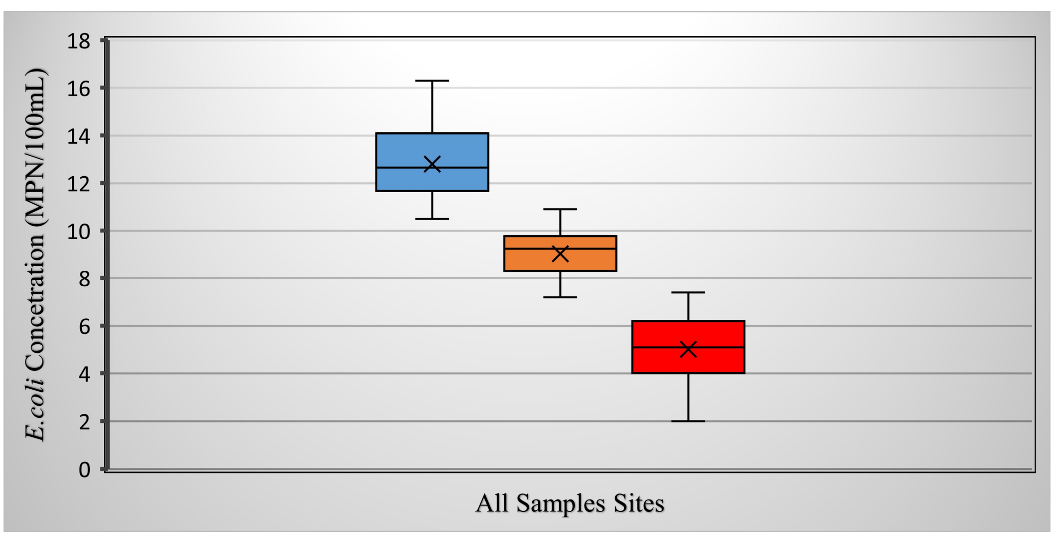

Figure 8. The presence and concertation of *E. coli* in all water samples

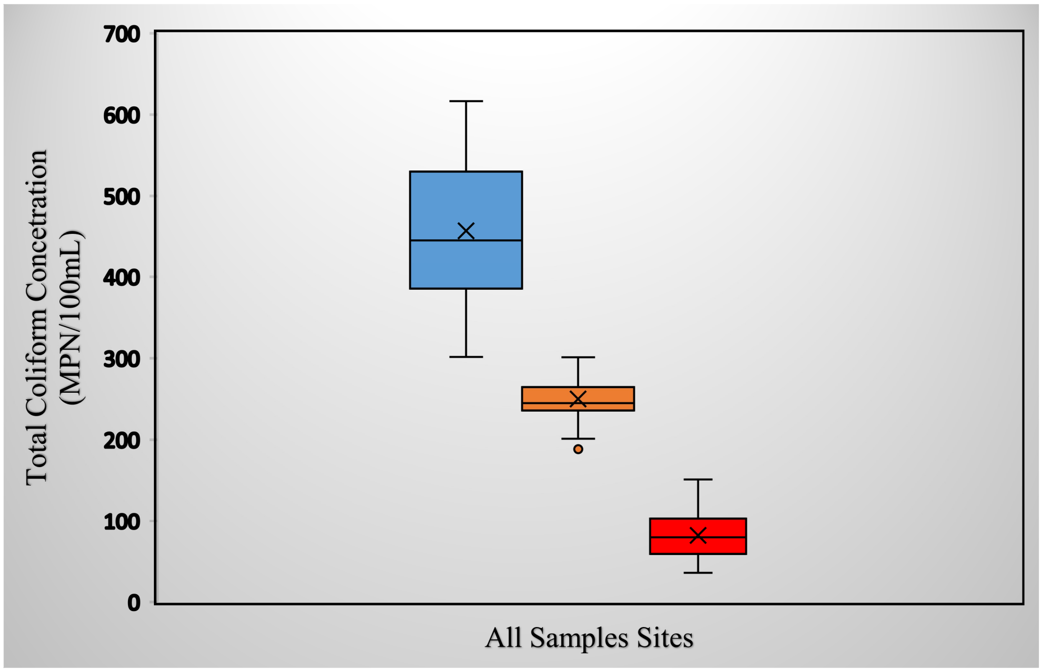

Figure 9. The presence and concentration of total coliform in all water samples

4.2 Analysis of variance (ANOVA) methods

Statistical analyses were carried out by using Mini tab 17 commercial software and ANOVA stat analyses were performed to analyze the data of two types of fecal contamination, *E. coli* and total coliform during three different time interval of the year which is also known as (Pre-monsoon, monsoon and post monsoon season) here in Malaysia to compare the differences and the variability of bacteria presence within these two main group of fecal contamination thus the data were divided into three main groups according to monsoon season changes and were analyzed by using one way analysis of variance (ANOVA) and by comparing the differences between the means of the three groups. A significant difference was indicated by ANOVA, and the individual groups were compared by the least significant difference methods. The data were compared by using Tukey and Fisher Pairwise Comparisons LSD percentages of 95% confidence level and Fisher individual differences of means. Statistical assumed as *P* value less than 0.05.

The data analysis for the total coliform by analysis of variance show that the *P* value was 0.025 and the maximum mean was 616.1 and the minimum mean was 301.5.The statistical analyses of *E. coli* by using ANOVA, show a significant differences and the P value is less than 0.02 while DF and F values equal to 14 and 3.84 respectively. Table **3** shows the Tukey Pairwise comparison of means

Table **2.** Tukey Pairwise comparison of means

Concentration of *E. coli*	N	Mean
7.1	1	10.10
1.0	1	9.800
2.0	1	9.700
3.0	1	9.500
4.1	4	9.350
7.4	1	9.300
3.1	1	9.300
5.0	2	9.250
6.2	4	9.050
7.3	3	8.976
6.1	3	8.900
6.0	2	8.65
4.0	1	8.4500
5.2	1	8.400
6.3	4	8.300
5.1		6.85

Obviously and from statistical data analyses by variance and from the results of table 3, it is clear that there is a significant differences of *E. coli* means values and concertation during the time interval period of Pre-monsoon, monsoon and Post monsoon and there is a variability in concertation of bacteria over the time.

Figures 10 and 11 show the distribution of data of *E. coli* and total coliform by using ANOVA analyses during the time interval of the study.

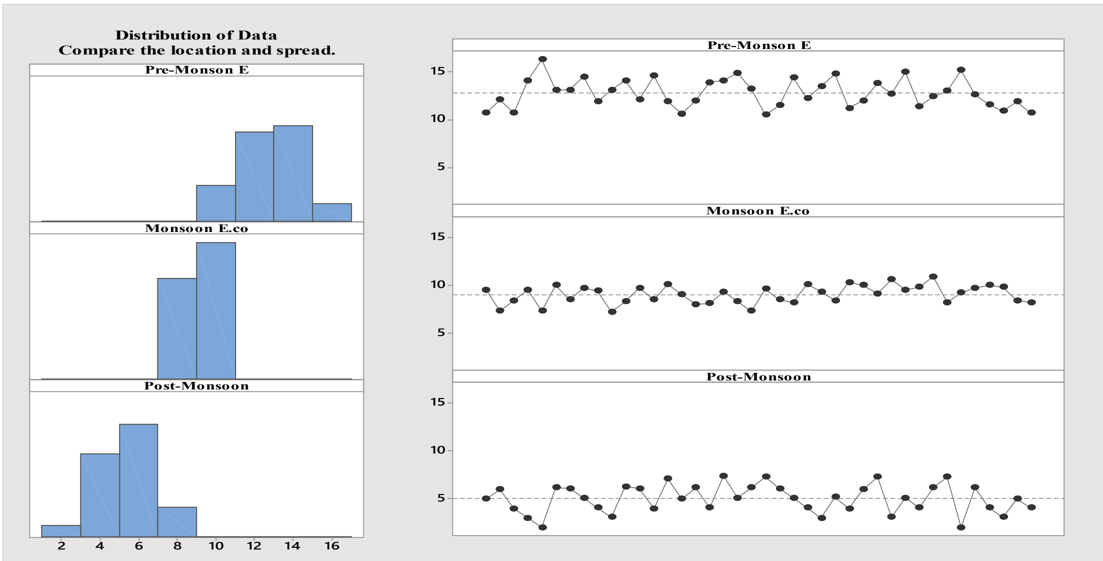

Figure 10 Data distribution of *E. coli* by ANOVA analyses

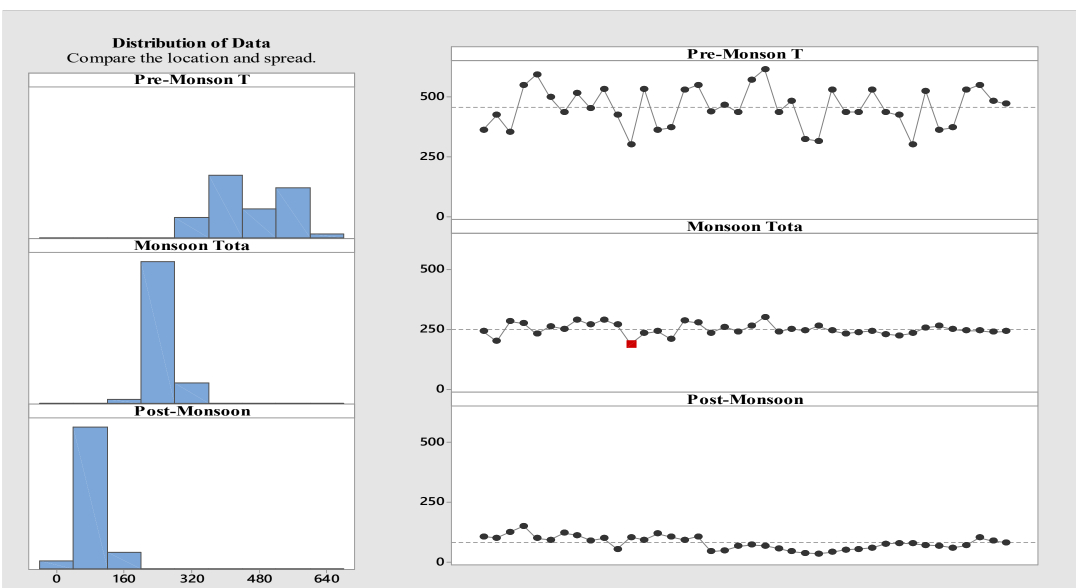

Figure 11 Data distribution of Total coliform by ANOVA analyses

5 Conclusion

The present work presents the results of microbiological rainwater quality of harvested rainwater system (HRW) in a rural area in Malaysia. For each sample, we tested *E. coli* and total coliform fecal at 35 ^{o}C. Descriptive and variance statistics analyses were performed for the observed variables for each sampling event. Several conclusions can be drawn from this study but in the same time it is based on a limited set of data. The performance of rainwater harvesting system was monitored for two months' interval cumulated time period through Pre-monsoon, monsoon and post-monsoon season. The rainwater harvesting system did not meet drinking water guidelines standards and it is contaminated with fecal bacteria. These findings are corresponding with a number of other studies that is indicating that collected rainwater makes poor quality drinking water due to the high levels of bacterial contaminations. There was a great variability of fecal quality over the course of the study and was demonstrated with plots and variance statistical analyses. We also found that microbial quality of harvester rainwater system was also varying through season changes, and this great variability is coherent with recommendation of a system disinfection. As a result, a first-flush and applying disinfectant to rainwater harvesting system could improve the quality of harvested rainwater and could be used for drinking purposes after a proper treatment.

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