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Investigation of Rainwater Harvesting Quality with the Application of the First Flush System

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Abstract: *Rainwater harvesting is crucial for collecting and storing rainwater for various uses. However, improper management can have adverse environmental effects. Improper collection can lead to water clarity issues and mosquito breeding. A study was conducted at Surau Kampung Parit Karjo in Batu Pahat and the Faculty of Civil Engineering and Built Environment to investigate the quality of rainwater harvesting using the first flush system. The system uses a floating ball diverter to remove contaminants from rainwater before it is channelled into storage tanks. The results showed that the installation of a first flush system significantly improved rainwater quality by eliminating contaminants. The study also found that the physicochemical parameters align with class I standards, suggesting the potential use of rainwater as a drinking water supply. However, the study refrains from recommending it as drinking water due to the absence of bacteria-related parameters.*

Keywords: First Flush System, Rainwater Harvesting, Quality Rainwater

1. INTRODUCTION

Here By utilizing a first flush diverter, water-reaping applications can be made more viable and productive in giving perfect and safe water to different motivations. Rainwater harvesting is an important method for collecting and storing rainwater for various uses. This cycle can enhance water supply, diminish natural contamination, and assist with rationing water assets (Rahman, 2017a). The first flush diverter system is an essential component of rainwater harvesting. Using this system, only high-quality roof runoff can be collected and stored. Additionally, it reduces pump and other component wear caused by tank dirt accumulation, lowering maintenance costs.

As rainwater flows off the roof, it can pick up all kinds of contaminants, including dirt, debris, bird droppings, and even chemicals such as airborne dust, ash, and other particulates can get washed out of the atmosphere by rain, contributing ions like calcium ($Ca2+$) and ammonium ($NH4+$) (Unoki & Itoi, 2003). So, from the roofing material because the water that flows from the roof is not filtered first before entering the rainwater collection tank. Therefore, it will affect the quality of rainwater. To guarantee that the water-gathering framework works proficiently, a first flush diverter should be introduced to sift through any poisons and foreign substances in the rooftopspillover. This paper analyzes how implementing a first flush system can improve the quality of rainwater harvesting and its use.

Rainwater harvesting (RWH) is the world's most seasoned strategy for satisfying water supply needs. In ongoing many years, a few states have upheld the sending of such techniques because of working on mechanical capacities to deal with the expansion in water request needs connected with climatic, ecological, and social changes (Christian Amos et al., 2016). Water that is potable and non-potable can be obtained through rainwater collection. Even though the water in storage tanks is supposed to be used for non-potable activities like flushing the toilet, washing, landscaping, and irrigation outside, these activities use more than 80% of the water in a typical home (GhaffarianHoseini et al., 2015). Thus, introducing water gathering frameworks expands urban areas' water independence and assists with deferring the requirement for new unified water foundation. Water assortment can bring down storm water overflow volume by up to 20% in semiarid areas and less in wet locales in a drawn-out recreation (Steffen et al., 2013).Water is less contaminated than water from other stockpile sources, like underground or surface, and in light of the fact that it is gathered and kept away tanks, different areas use it for drinking after a basic cleaning process, as per (Palawat et al., 2023). Notwithstanding, the heft of devastated nations' water gathering framework plans need first-flush components. T. Thomas (2014) The capacity tank plan of a water collecting framework is basic for holding the nature of gathered water. A typical water gathering capacity tank design has just a single stockpiling tank. Soluble contaminants that enter a single storage tank pose a threat to the entire system and can quickly reach the outlet because there is no barrier in place. Moreover, as suspended particles enter the framework, they either arrive at the leave quick or collect quickly at the base. Indeed, even within the sight of a peaceful delta, the subsequent residue layer is quickly worked up by the section of water during a stormy occasion (Won et al.2018). The heft of current RWH frameworks in created nations incorporate energy-concentrated layer separating advances to work on the nature of collected water to drinking water.

First flush system is basic treatment method utilized in both created and non-industrial countries for water collecting frameworks. Redirecting the underlying flush from the primary stock can build the nature of put away water, yet it comes to the detriment of some water supply misfortune.

The reception of a "1 mm redirection following 3 days" rule will prompt a decline in dependability of somewhere in the range of 1 and 2%, bringing about 4 to 8 extra days of the year when request isn't met. However, RWH systems should not be used as the only source of water for a community because they are never 100% reliable. Eliminating the principal millimeter of overflow following three days with little downpour can significantly work on the nature of put away water. (Doyle and Shanahan, 2010)

First flush redirection is a fundamental treatment technique utilized in both created and emerging countries for water gathering frameworks. Redirecting the underlying flush from the primary inventory can build the nature of put away water, yet it comes to the detriment of some water supply misfortune. While first flush redirection is a clear procedure to upgrade water quality, it, similar to any remaining innovations, should be overseen and kept up with fittingly. There are a few "automatic" diverters on the market, but for long-term use, the best option is a basic system with parts that can be found locally.

In this paper, we will investigate the quality of rainwater harvestedusing a first-flush diverter system. Need to analyse seven (7) physio-chemical parameters before and after the first flush system. The physio-chemical includes test ICPMS to detect elements Zn, Pb, Cd and Fe other test is pH, turbidity, and total suspended solid. In this study, we will be looking the effect of this system on roof runoff quality and its potential applications in different contexts. The first flush system is one of the most commonly used techniques to improve the quality of roof runoff. This system involves diverting the initial flow of rainwater away from the storage tank,thereby reducing pollutants from entering it.

2. MATERIAL AND METHOD

The first flush system in rainwater harvesting is critical to improving the quality of collected rainwater. The system eliminates pollutants, contaminants, and debris by redirecting and disposing of the roof's first discharge. This ensures that the stored rainwater is pure and free of sediments, resulting in improved water quality for various applications (Rahman, 2017b). The first flush system also improves system efficiency, decreases maintenance requirements, and helps fulfil health and safety regulations.

2.1 First Flush System Design

In this study, two types of flush water system were proposed which are (i) Flush system with ball floating. The dimension of first flush system as shown in Fig. 1. Based on the design, the operation mechanism of this device is solely depend on the floating ball and the depth of the flushing zone. The floating ball floats up and shuts the first flush after rainfall passes through the pipe, enabling the remaining rainwater to flow into the storage (Fig. 1). After rain, the initial flush may be moved gradually to a little drill hole towards the bottom. Water ispermitted to enter the tank first once the area beneath the intake is full. The pipe may release fresh water into the tank after it has filled the area. The particulate matter thenfalls down and settles beneath the floating balls rather than being permitted to flow straight into the tank system. So, the ball sealed chamber and blocked the debris. Cleaning of blockages and any debris that has made its way into the first flush is made possibleby the detachable lid. Empty the flush first to ensure that any fines are fully eliminated from the system and cleaned. The PVC pipe is 110mm in diameter. The high of first flush system is 1500 mm so the first flush volume is 14 liters.

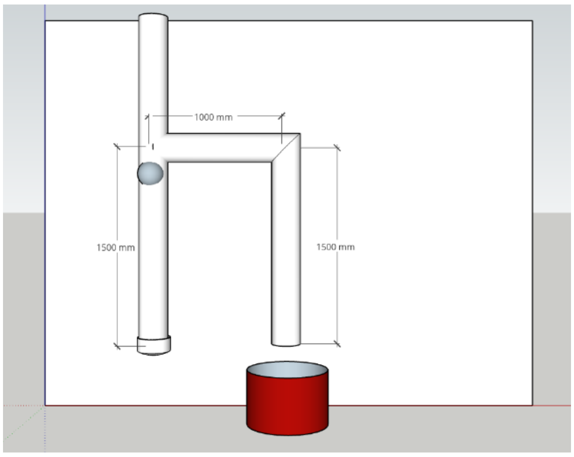

Fig. 1. Application of First Flush System on building

2.2 Application of First Flush System

Installation First Flush System as shown in Figure 1 the floating ball floats up and shuts the first flush after rainfall passes through the pipe, enabling the remaining rainwater to flow into the storage. After rain, the initial flush may be moved gradually to a little drill hole towards the bottom. Water ispermitted to enter the tank first once the area beneath the intake is full. The pipe may release fresh water into the tank after it has filled the area. The particulate matter then falls and settles beneath the floating balls rather than being permitted to flow straight into the tank system. So, the ball sealed the chamber and blocked the debris. Cleaningof blockages and any debris that has made its way into the first flush is made possible by the detachable lid. Empty the flush first to make certain that any fines are fully eliminated from the system and that it is cleaned.

(a) **(b)**

Fig. 2. Installation First Flush (a) Surau Parit Karjo; (b) Faculty Civil Engineering and Built Environment

2.3 Data Collection

A rigorous data collection process was imperative to gauge the proposed first flush system's effectiveness. The system, designed by drawing insights from a previous study, underwent targeted upgrades to align with the specific characteristics of the local climate. This study focused on evaluating seven (7) key parameters, involving the collection of water samples immediately after rainfall events. Each sampling activity meticulously acquired five (5) water samples, including: (i) a control sample, (ii) two samples before the first flush, and (iii) two samples after the first flush. The sample collected 10 minutes after rainfall stops is noteworthy. It is important that water samples were procures on 13th and 15th December 2023. Next for do data analysis on 18th December 2023 at Environmental Analysis Laboratory to get data ICP-MS. Meanwhile data pH, Total Suspended Solid, and Turbidity at Environmental Engineering Laboratory on 19th December 2023.

2.4 Data Analysis

To determine the quality of rainwater harvesting, to analyses are carried out, including those of physio-chemical parameter. By executing test correctly, the physio-chemical parameters will then test the water quality by measuring the pH, turbidity and total suspended solids. So, to determine the value of pH each sample this study use pH meter such figure 3.5. Turbidity is analyzed through the extent to which light passes through the liquid while total suspended solid can analyze the quantitative expression of suspended particles. So based on figure 3.5 using UV-VIS Spectrophometer for analyse the total suspended solid. Figure 3.6 show the turbidity meter for to assess the effectiveness of rainwater quality by measuring the turbidity level of harvested rainwater. The determination of metal in rainwater harvestingincluding Fe (iron), Zn (Zinc), Pb(Lead) and Cd (Cadmium) will be determined through ICMPS test.

3. RESULT AND DISCUSSION

The research focuses on the efficacy of the First Flush System in rainwater harvesting to enhance water quality by minimizing surface pollutants. The study aims to analyze five rainwater catchment samples, evaluating parameters such as turbidity, pH, and Total Suspended Solids. Additionally, an ICP-MS test will identify elements like Zn, Cd, Pb, and Fe. The findings will inform the optimal utilization of rainwater harvesting, aligning with Malaysia's Interim National Water Quality Standards (INWQS). The research anticipates contributing valuable data to guide development strategies, enhancing the reliability and safety of harvested rainwater for various applications.

3.1 WATER QUALITY OF RAINWATER HARVESTING

Installation The first flush system is one of the systems designed to divert initial runoff from rain events that may contain contaminants. Therefore, through this study evaluate the water quality of rainwater harvesting with first flush to ensure the effect of pollutant reduction in the initial run. Thus, table 1 refers to the data taken as water quality parameters.

Table 1 Data Sampling rainwater

SAMPLE PARAMETER	Raw RW 1	Raw RW 2	W/ FS RH F 1	W/ FS RH F 2	W/O FS RH F 1	W/O FS RH F 2	W/ FS RH F 1	W/ FS RH S 2	W/O FS RH S 1	W/O FS RH S 2
Zn (mg/l)	0.0524	0.119	1.03	3.64	2.61	2.27	0.237	0.189	0.379	0.37
Cd (mg/l)	0.000521	0.000256	0.0000916	0.000139	0.000471	0.00044	0.000465	0.000853	0.00068	0.00056
Pb (mg/l)	0.00777	0.00165	0.00297	0.0184	0.202	0.0793	0.0194	0.0152	0.0212	0.0261
Fe (mg/l)	0.517	0.899	0.156	0.215	0.787	0.38	0.431	0.704	0.405	0.298
pH	7.77	7.74	7.73	7.58	7.72	7.7	7.56	7.5	7.58	7.53
Turbidity (Ntu)	0.51	0.21	0.08	0.78	0.48	0.9	0.05	0.03	0.11	0.16
TSS (mg/l)	2	2	3	10	15	15	10	11	11	12

Notes

Raw RW : Raw Rainwater
W/ FS RH F : With First Flush System Rainwater Harvesting Faculty
W/O FS RH F : Without First Flush System Rainwater Harvesting Faculty
W/ FS RH S : With First Flush System Rainwater Harvesting Surau
W/O FS RH F : Without First Flush System Rainwater Harvesting Faculty

3.2 Water Quality Rainwater Harvesting

Based on the Interim National Water Quality Standards for Malaysia (INWQS) the element values under class II there is only one element which is Zn class IV. Therefore, by observing the results, it was found that the Zn value was high due to the rainwater catchment surface of the zinc roof type. Because of that, the Zn element is high in the data found. Figure 3 refers to the comparison of element values of each sample taken.

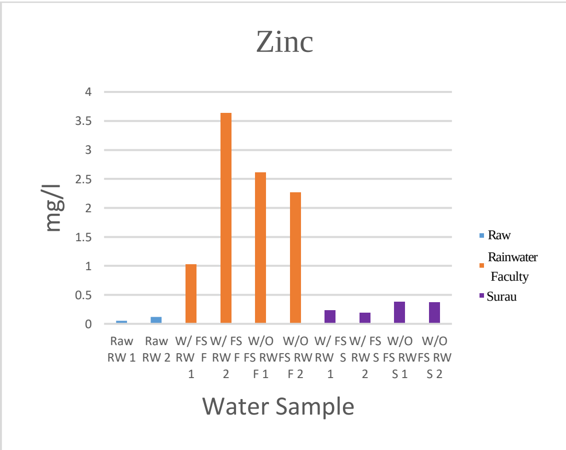

Fig. 3.1. The zinc result for all sample

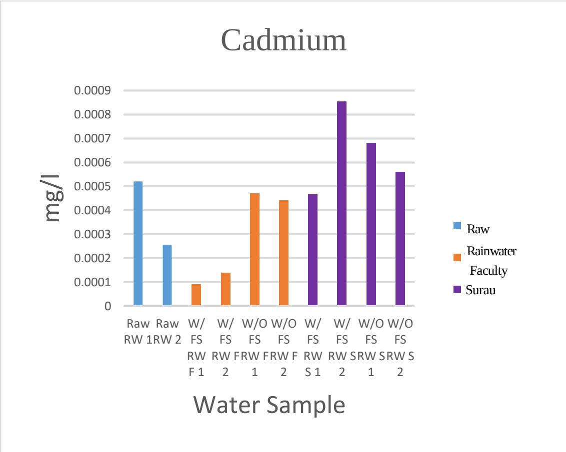

Fig. 3.2. The cadmium result for all sample

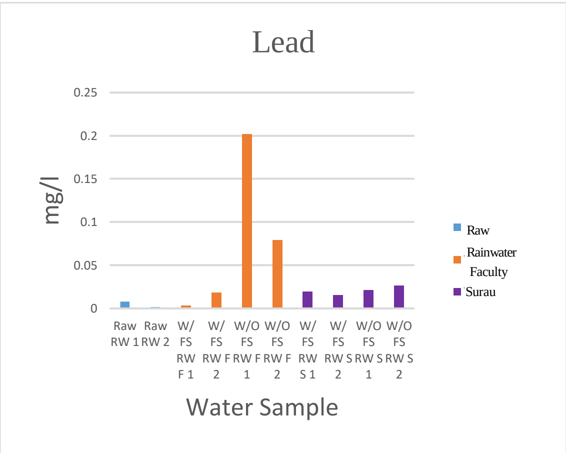

Fig. 3.3. The lead result for all sample

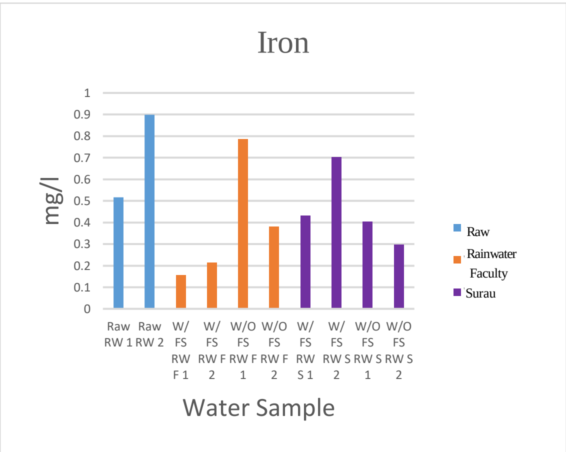

Fig. 3.4. The iron result for all sample

3.3 pH

The pH level in rainwater harvested using the first flush system can be analysed. By comparing the Interim National Water Quality Standards for Malaysia (INWQS), all samples are between class 1. Therefore, the pH value of the entire sample is in the neutral range. Fig. 4 refers to the comparison of the pH value of each sample taken.

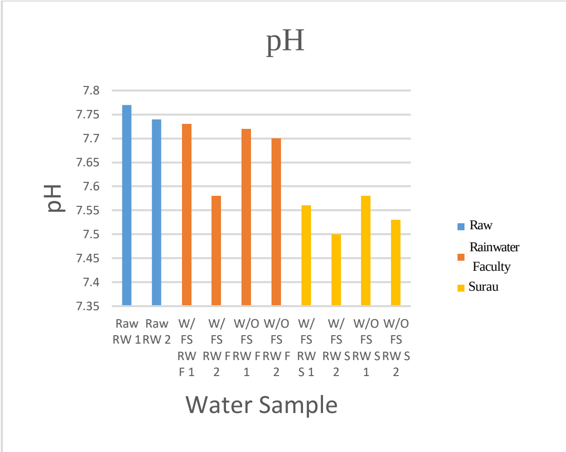

Fig. 4. the pH result for all sample

3.4 Turbidity

The turbidity values of first flush system were range 0.05 – 0.78 (Ntu). The range of first flush system is lower than without first flush which is 0.11 - 0.9 (Ntu). So, the quality water first flush system in range in class 1 compared with Interim National Water Quality Standards for Malaysia (INWQS). Fig.5 refers to the comparison of the turbidity value of each sample taken.

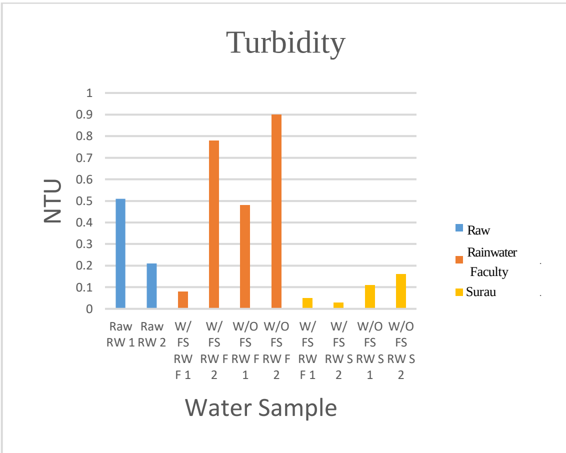

Fig.5. the turbidity result for all sample

3.5 Total Suspended Solid

The desired limit of TSS recommended of drinking water by WHO is 500 mg/l. The range for class 1 in Interim National Water Quality Standards for Malaysia (INWQS).is below 25. Based on result the TSS is below 25 mg/l. Fig. 6 refers to the comparison of the total suspended solid value of each sample taken.

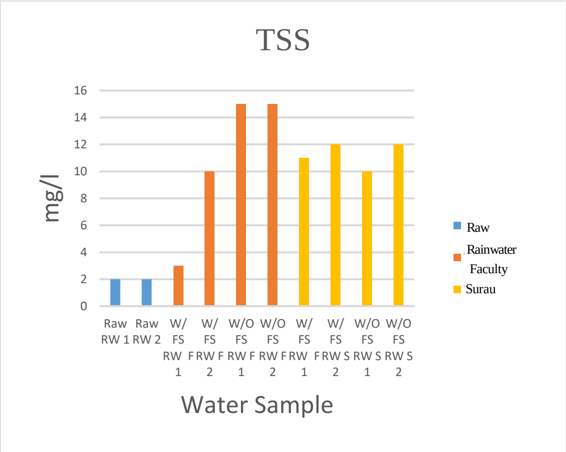

Fig. 6 the total suspended solid result for all sample

3.6 Interim National Water Quality Standards for Malaysia

Table 2 show that the class sampling based on Malaysia's Interim National Water Quality Standards (INWQS).

Table 2 INWQ class sample rainwater with first flush

Parameter	Surau	Faculty
Zn (mg/l)	IV	IV
Cd (mg/l)	II	II
Pb (mg/l)	II	II
Fe (mg/l)	II	II
pH	I	I
Turbidity (Ntu)	I	I
TSS (mg/l)	I	I

3.7 Discussion

The study utilizes ICP-MS data to identify elevated Zinc levels in rainwater collected from zinc roof surfaces. According to Malaysia's Interim National Water Quality Standards (INWQS), this places the water in the class IV category. pH analysis reveals a neutral range, meeting class I standards, and highlights the first flush system's role in controlling rainwater acidity or alkalinity. Turbidity evaluations, influenced by weather patterns, remain in class I. Total Dissolved Solid analysis demonstrates the first flush system's effectiveness in reducing suspended solids, maintaining a class I rating. Despite similarities with a prior study, the current rainwater is categorized as class I, suitable for various uses excluding drinking due to bacterial parameters. Recommendations include modifying catchment surfaces to increase the water quality rainwater.

The results found in this study indicate that the pH value has a neutral range. Therefore, based on the Interim National Water Quality Standards for Malaysia (INWQS), under class I. Next, the turbidity value that evaluates water clarity. Based on a study of the impact of different weather patterns on water turbidity. Like the rainwater sample at the faculty has different turbidity due to the rain weather pattern factor. Turbidity is still in class I based on the Interim National Water Quality Standards for Malaysia (INWQS). Finally, Total Dissolved Solid is done to ensure the value of debris, dust and other pollutants when they interact with the atmosphere. Based on the study, it was found that with the first flush system, it gives a satisfactory effect in which it reduces the value of suspended solids. With that, the data found is still in the class I range. In comparison with study (Janet Yip Cheng Leong, 2016) can categorised the sample rainwater harvesting class IIB but still need more treatment because have heavy metal in sample.

Table 3 Percentage data rainwater with first flush, %

Parameter	Faculty1	Faculty2	Surau1	Surau 2
Zn (mg/l)	86.81	46.36	46.10	64.76
Cd (mg/l)	134.87	103.98	37.55	41.47
Pb (mg/l)	194.20	124.67	8.87	52.78
Fe (mg/l)	33.83	55.46	6.22	81.04
pH	-0.13	1.57	0.26	0.40
Turbidity (NTU)	142.86	14.29	75	136.84
TSS (mg/l)	133.33	40.0	9.52	0.00

Based on, table 3 the percentage difference using first and without first flush at Faculty is 79.96 %. Meanwhile at Surau 20.31%. Overall, the quality water results in the class IV curve on the impact of rainwater catchment surface. To reduce the value element, the surface of the rainwater catchment can be modified. In addition, the water quality in class I bends based on the Interim National Water Quality Standards for Malaysia (INWQS). Class I provides excellent rainwater quality effects. Based on this class, it can be used as a drinking water supply, but through this study, it is not used as drinking water because it does not perform parameters indicator bacteria.

4. CONCLUSION

In conclusion, the implementation of the First Flush System has proven to be instrumental in enhancing the efficiency of rainwater harvesting, as evidenced by a battery of comprehensive tests. The analysis encompassed key parameters, including Zn, Pb, Cd, Fe, pH, turbidity, and total suspended solids (TSS). The findings derived from these tests provide valuable insights into the system's effectiveness in mitigating the influx of contaminants and improving the overall quality of collected rainwater. Based on this study how well the first flush system helps make rainwater better for use. pH regulation, turbidity reduction, and total suspended solids management collectively demonstrate the positive impact of this system on harvested rainwater. help control the level of acidity, make the water not too dirty, and regulate the amounts of solids in the water. While water quality is less satisfactory where the effect of the rainwater catchment surface has a high impact.

Moreover, the observed improvements in pH levels, turbidity, and TSS further underscore the positive impact of the First Flush System. The system's ability to maintain optimal pH levels, reduce turbidity, and minimize total dissolved solids contributes to the enhancement of water quality, aligning with the goals of sustainable rainwater harvesting practices.

In summary, the comprehensive testing conducted on the First Flush System has demonstrated its efficiency in safeguarding harvested rainwater from potential pollutants. These promising results not only validate the system's role in improving water quality but also emphasize its significance in promoting sustainable and reliable rainwater harvesting practices. The insights gained from this study can inform future developments and optimizations in rainwater harvesting systems, ensuring their continued efficacy in diverse settings. This finding informs us that it is important to have a good first flushing system in the rainwater system to ensure clean water and the system works well. As more and more people use rainwater, this study helps make good choices about how to manage water responsibly.

5. ACKNOWLEDGEMENT

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