

Investigation of rainwater quality at different rooftop types: a case study at the large Islamic Boarding School in Madura

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ABSTRACT

Rainwater is an alternative water resource and it is relatively clean. In addition, it can be categorized as a free source and can be collected in a considerable quantity from roof catchments. The aim of this study was to investigate the rainwater quality collected in the Islamic Boarding School of Adduriyah Bangkes, Indonesia. Various water samples including rainfall and rainwater falling on different rooftop types such as clay tile roof, metal sheet tile roof, old metal sheet tile roof, and concrete tile roof were collected and analyzed. In this study, physical and chemical properties of all water samples were examined. In general, the study observed that the quality of rainwater was relatively clean and can be possible to be used for several non-potable purposes.

Keywords: Rainwater harvesting; Rainwater quality; Alternative water resources

1. Introduction

Rainwater is an alternative water source that can be utilized for daily needs [1]. It is relatively affordable since it is obtained directly from environment. Areas with high rainfall have the potential to utilize rainwater as a water source which is mainly found in tropical regions [2]. One of the countries having high rainfall is Indonesia and this is caused by the west monsoon [3]. So far, water supply in the country comes from surface water and groundwater.

Rainwater harvesting is a way to capture rainwater [4]. Rainwater can be collected from rooftop and can be stored in a tank before being used for non-potable and potable uses [5]. Analysis of rainwater quality is critical to make

sure that a proper treatment can be proposed as effective remediation. One of the established sampling techniques is the implementation of grab sampling because it is relatively easy to handle. Several studies have implemented the technique such as in the hybrid rainwater–greywater systems in Malaysia [6], the harvesting rainwater from green roofs under tropical climate [7], and monitoring harvested rainwater quality in agricultural system [8], and monitoring study of longitudinal harvested rainwater quality [9].

Currently, the implementation of rainwater harvesting has been more popular in several countries. For instance, the reliability of a rainwater harvesting system in Australia can be considerably high ranging from 80%–100% for toilet flushing and laundry use although its reliability becomes

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lower when it was implemented for combination of toilet flushing, laundry and irrigation [10]. Study carried out in Los Angeles County, California found that capturing water for outdoor use was cost-effective but including indoor use it became ineffective and this is partly because of installation and maintenance costs [11]. Moreover, study in Malaysia conducted for commercial buildings found that the percentages of reliability of the proposed system were up to 93% and 100% for the small and large commercial buildings, respectively [12]. It is noted that all the above-mentioned studies focus only on the analysis of rainwater availability and reliability. Therefore, intensive works need to be carried out particularly for the investigation of rainwater quality to encourage public acceptance.

It is noted that the quality of rainwater harvesting depends on environmental conditions and rooftop types. The quality of rainwater has been investigated in many countries, such as in Spain [13], in China [14], in Iran [15], in Ecuador [16], and in Malaysia [17] as well as in Indonesia [18]. Among these country, the rainwater quality had been broadly reported in Indonesia, for instance in Bekasi [19], Cimahi [20], Semarang [21], Bali [22], and Balikpapan [23]. In lining the research trend, the aim of this study was to investigate the rainwater quality collected in the Islamic Boarding School of Adduriyah Bangkes, Indonesia. In order to accommodate a comprehensive rainwater quality analysis, various rainwater samples including rainfall (RF) and rainwater falling on various rooftop types such as clay tile roof (CLR), metal sheet tile roof (MSR), old metal sheet tile roof (OMR), and concrete tile roof (COR) were analyzed. The novelty of this study is the analysis of rainwater collected from rooftop types and this knowledge is limited in literature.

2. Materials and method

2.1. Study area

The present study was conducted at in the Islamic Boarding School of Adduriyah Bangkes, Madura, Indonesia as shown in Fig. 1. It is noted that the Adduriyah Bangkes is one of the important Islamic Boarding School in Madura Island and it has a large roof area that has potential to implement rainwater harvesting.

2.2. Experimental design

Various rainwater samples including rainfall (RF) and rainwater falling on various rooftop types such as clay tile roof (CLR), metal sheet tile roof (MSR), old metal sheet tile roof (OMR), and concrete tile roof (COR) were analyzed. The assessment covers physical and chemical parameter. The rainwater from each roof were collected using grab sampling technique. Then, samples were instantly prepared for analysis. Turbidity was measured using turbidity meter WGZ-1B with a level accuracy of 0.1 NTU. Total dissolved solids (TDS), pH, temperature and dissolved oxygen (DO) were measured using water quality checker Lutron WAC-2019SD. Collected data were analyzed using excel software. Average values were expressed with the standard deviation. Correlation analysis were used to interpret the relation between types of roof tiles and water quality parameters.

3. Results and discussion

3.1. Turbidity

In Table 1, turbidities of RF and four rainwater in different type of roof tiles were presented. This study found that turbidity ranged from 0.27 to 3.50 NTU. According to turbidity data, COR has the lowest turbidity value with 0.27 ± 0.31 NTU. Meanwhile, OMR has the highest turbidity value with 3.50 ± 0.28 NTU. For other type of rainfalls showed the turbidity value of RF, CLR, and MSR with 0.77 ± 0.44 , 1.20 ± 0.37 , and 2.97 ± 0.36 NTU. The high turbidity value in OMR is possible due to the large number of rusty metal particles that run off in sample OMR. Meanwhile, the turbidity value of COR is lower than RF because particles carried by rainwater are likely to be stuck in the COR in case COR has a lower turbidity value than RF.

Similar study was found in different subdistrict of Kalimantan area [24]. Study resulted that the turbidity in Siantan Hulu, Siantan Tengah, Limbung village, and Kuala dua village was 22.26, 21.57, 17.68, and 18.50 NTU as well as the average of all subdistrict is 20.00 ± 3.33 NTU. It indicated that different location of taking samples have different result of turbidity value. However, regarding to the turbidity value, these results specified that water quality in present study site is better than water quality in Kalimantan area.

3.2. Total dissolved solid

The measurement of the TDS contents in the present site runoff is a major concern with respect to the use of rainwater as potable water. The amount of TDS has minor value in all roofs ($TDS < 6$ ppm) with details 1.20 ± 0.37 , 2.97 ± 0.36 , 3.50 ± 0.28 , and 5.62 ± 0.02 for CLR, MSR, OMR, and COR, respectively, whilst TDS value from RF sample is the higher among others as shown in Table 2. The TDS sample from rainwater fall has the highest value because the material contained in the rainwater fall does not run off as the sample from rainwater falling on the tile roofs.

Recent investigation described that TDS value ranged 49.72–130.69, 47.38–91.75, and 27.5–79.5 mg/L from the course of the rainy periods, industrial area, and residential area [25]. These results had higher value of TDS compared to present study. It is understandable since the sampling location in the previous study was in an area containing relatively high pollution, while the present study was taken in a location with lower pollution.

3.3. Dissolved oxygen

The amount of dissolved oxygen (DO) content in rainwater falls and rainwater after falling on the roof is presented in Table 3. In general, DO value ranged from 6.00 to 8.00 mg/L. The measurements exhibit that rainwater on OMR has the lowest DO content (5.17 ± 0.27 mg/L). This DO value was followed from the lower to higher by RF, CLR, MSR, and COR with 6.03 ± 0.53 , 7.30 ± 0.62 , 7.47 ± 0.88 , and 7.93 ± 1.02 mg/L.

DO content in present study has lower value compared to previous finding of harvesting rainwater system on the Werrington South campus of Western Sydney University (WSU) in New South Wales, Australia that prescribed

Table 1
Turbidity of the collected rainwater

Type of roof tiles	Turbidity (NTU)
RF	0.77 ± 0.44
CLR	1.20 ± 0.37
MSR	2.97 ± 0.36
OMR	3.50 ± 0.28
COR	0.27 ± 0.31

Table 2
TDS of the collected rainwater

RF	TDS (ppm)
CLR	1.20 ± 0.37
MSR	2.97 ± 0.36
OMR	3.50 ± 0.28
COR	5.62 ± 0.02
RF	34.30 ± 0.12

Table 3
DO of the collected rainwater

RF	DO (mg/L)
CLR	6.03 ± 0.53
MSR	7.30 ± 0.62
OMR	7.47 ± 0.88
COR	5.17 ± 0.27
RF	7.93 ± 1.02

9.50 ± 1.00 mg/L for rainwater before filtration treatment and 9.00 ± 1.00 mg/L for rainwater after filtration treatment [26]. According to DO content, it indicated that the water quality in present study site is better than in New South Wales, Australia. However, it can be explained for the reason that the site is far from the urban environment and limited pollution and has a well-maintained environment.

Table 4
pH value of the collected rainwater

RF	pH
CLR	6.98 ± 0.01
MSR	6.87 ± 0.09
OMR	7.50 ± 0.07
COR	7.05 ± 0.20
RF	6.21 ± 0.08

3.4. pH

Table 4 presents the pH value on different tile roofs and rainwater falls (RF). RF reach up to 6.98 ± 0.01 of pH value. Meanwhile, the pH value of CLR, MSR, OMR, and COR are 6.87 ± 0.09, 7.50 ± 0.07, 7.05 ± 0.20, and 6.21 ± 0.08. It is noted that generally the pH values are insignificant different. The pH value mostly near 7.00.

Generally, the pH value of rainwater reach 3.8–6.3 and adjust slightly after dropping on the roof and storage [27]. Previous finding showed that rainwater in COR was approximately 6.70 [28]. In other tile roofs, the pH value is approximately 6.5 for ceramic tile roof and galvanized steel sheet whilst for epoxide-coated material tile roof, the pH value ranged from 6.0 to 7.0. These results indicated that different tile roof has different pH value since the material of tile roof contributes the alkalinity and acidity of rainwater.

Quality analyses designated that rainwater runoff samples are in the low range for turbidity (0.27–3.50 NTU), TDS (TDS < 6 ppm) and DO (6.00–8.00 mg/L) as well as their pH (6.21–7.50). According to WHO regulation, all samples met the standard as potable water with 5 NTU, 1000 ppm and 6.5–8.5 for turbidity, TDS and pH standard value.

4. Conclusion

In this study, rainwater as an alternative water resources was collected using grab sampling technique. The area of collected rainwater was at the Islamic Boarding School of Adduriyah Bangkes, in Pamekasan, Madura Island. According water quality analysis, all rainwater samples have a low range for turbidity (0.27–3.50 NTU), TDS

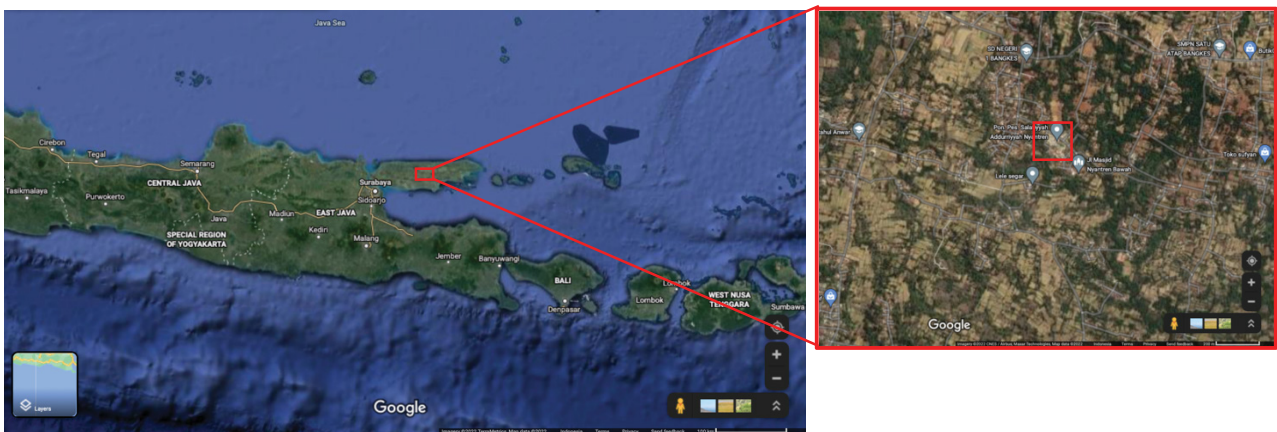


Fig. 1. The selected study location, the Islamic Boarding School of Adduriyah Bangkes, Indonesia.

(TDS < 6 ppm), DO (6.00–8.00 mg/L) and pH (6.21–7.50). It is interesting to note that all samples met the standard as potable water according to WHO regulation, with 5 NTU, 1,000 ppm and 6.5–8.5 for turbidity, TDS, and pH standard value, respectively. It is interesting for future study to do more comprehensive water quality analysis to make sure it is safe to be used for non-potable uses.

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Conflicts of interest

The authors declare no conflict of interest.

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