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Optimum Use of Rainwater Harvesting Case Study: An Indonesian Fivestar-Hotel

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ABSTRACT
The global problem faced in recent years is limited water resources due to increasing demand, seasonal rainfall, and depletion of groundwater reserves, leading to water scarcity. The purpose of this study focuses on the application of rainwater harvesting in a five-star hotel in East Jakarta, namely, to determine the characteristics of rainwater quality from the roof and walls, determine the water savings obtained, and the estimated benefits of implementing a rainwater harvesting system. Water savings obtained from the implementation of rainwater harvesting in this hotel reached 11.01% per year with the required investment and installation costs of Rp. 105.27 million.

Keywords: *Rainwater harvesting, hotels, water quality, clean water, sustainability.*

1) INTRODUCTION
Water scarcity is a growing global concern caused by limited freshwater availability [1], increasing demand, and the worsening effects of seasonal rainfall variability and groundwater depletion [2] which disrupt water supply systems [3] and alter rainfall patterns in both timing and intensity [4].

Indonesia experiences high rainfall, which often leads to waterlogging and flooding in urban areas [5], especially during the rainy season from October to March. However, the dry season from April to September brings a sharp decline in water availability [6], worsened by excessive groundwater extraction in densely populated cities. Despite abundant rainwater during the wet season, its potential remains underutilized to address water shortages in the dry months [7,8].

Jakarta, as Indonesia's capital and economic hub, often faces flooding during the rainy season due to poor land and water management [9]. With a population exceeding 10.6 million and a clean water demand of 1.2 billion m^3, only about 50% was met by the public water service in 2021 [10], with the hotel industry among the largest consumers [11]. To address this, the Indonesian government issued Regulation No. 11/PRT/M/2014, encouraging rainwater management in buildings to support urban water needs and restore the natural hydrological cycle by utilizing rainwater to meet the water needs of every building throughout Indonesia, primarily in urban areas.

Rainwater harvesting is a practical approach to address limited clean water sources by offering an alternative supply [10]. According to [12], implementing such systems in commercial buildings like hotels, schools, and offices is financially beneficial, while also reducing flooding and groundwater extraction [13,14]. Moreover, rainwater harvesting supports urban sustainability [15,12] and contributes to achieving Sustainable Development Goals, particularly SDGs 6 and 14 [16].

Rainwater harvesting has been widely studied globally, both at household and commercial scales, including in Denmark [17], Bangladesh [18], and Brazil [19]. This study aims to expand on previous research by exploring a scheme that combines roof and wall surfaces as rainwater collection areas in a hotel, one of the highest water-consuming sectors [11].

2) METHODS AND METHODOLOGY
This research was conducted at a five-star hotel in East Jakarta with 191 rooms. Rainwater was collected from the building's roof and wall drainage system and tested in an independent laboratory, then compared with clean water quality standards based on Ministry of Health Regulation No. 32 of 2017.

As the hotel relies entirely on public water services, the rainwater harvesting system is expected to help reduce dependency and support operational cost savings.

Table 1. Quality of Harvested Rainwater

No	Parameter	Unit	Quality of Rainwater Tested[a]	Regulation 32/2017
Physical Parameter				
1	Turbidity	[NTU]	<0.22	Appropriate
2	Colour	[TCU]	<1.09	Appropriate
3	Total Dissolved Solid	[mg/l]	15	Appropriate
4	Temperature	[C]	22.4	Appropriate
5	Flavour		No flavour	Appropriate
6	Odor		No odour	Appropriate
Biological Parameter				
1	*Total Coliform*	[CFU/100 ml]	50000	Not Appropriate
2	*E. coli*	[CFU/100 ml]	0	Appropriate
Chemical Parameter				
1	pH		6.5	Appropriate
2	Iron	[mg/l]	<0.02	Appropriate
3	Fluoride	[mg/l]	0.24	Appropriate
4	Hardness ($CaCO_3$)	[mg/l]	8.08	Appropriate
5	Manganese	[mg/l]	<0.01	Appropriate
6	Nitrate	[mg/l]	0.57	Appropriate
7	Nitrite	[mg/l]	<0.004	Appropriate
8	Cyanide	[mg/l]	<0.01	Appropriate
9	Anionic Surfactant	[mg/l]	<0.03	Appropriate
10	Total Pesticide	[mg/l]	<0.00004	Appropriate

[a] Laboratory test result

ANALYSIS OF HOTEL'S RAINWATER POTENTIAL

The calculation of rainwater harvesting potential in this study uses equation 1.

$$Q = I \times C \times A \quad (1)$$

Where Q is runoff (m3/Month), I is rainfall (mm/month), C is the runoff coefficient, and A is the catchment area (m2). The equation is a rational method developed by Kuichling (1889) that hydrologists and civil engineers often use to calculate peak flows from small catchments of less than 20 hectares [20]. With a total roof area of 1,898 m^2 and a runoff coefficient of 0.81 [21], rainfall data from BMKG for 2011, 2013, and 2018 were used to calculate monthly rainwater potential. Tables 2 and 3 present the estimated rainwater volume and potential water savings, based on a 62% room occupancy rate and hotel water demand provided by management.

Table 2. Rainwater Potential from Hotel Roof Side

Month	Rainfall [mm]	Catchment coefficient	Roof Area [m^2]	Rainwater Potential [m^3/month]
Jan	206.73	0.81	1,898	317.99
Feb	261.77			402.63
Mar	175.73			270.30
Apr	153.87			236.67
May	98.10			150.89

June	49.97			76.86
July	17.87			27.48
August	11.43			17.59
Sept	45.63			70.19
Okt	86.63			133.25
Nov	170.47			262.20
Dec	151.13			232.46

Table 3. Hotel Water Retrenchment for the Entire Year Using Rainwater Harvesting

Month	Rainwater Potential [m^3/month]	Hotel's Water Consumption [m^3/month]	Retrenchment [%]
Jan	317.99	1642.06	19.36
Feb	402.63	1592.63	25.28
Mar	270.30	1635.23	16.53
Apr	236.67	1605.24	14.74
May	150.89	1661.74	9.08
June	76.86	1420.12	5.41
July	27.48	1949.58	1.41
August	17.59	1851.54	0.95
Sept	70.19	1727.31	4.06
Okt	133.25	1759.40	7.57
Nov	262.20	1853.08	14.15
Dec	232.46	1719.41	13.52
Average	**183.20**	**1701.445**	**11.01**

RAINWATER HARVESTING BENEFITS ESTIMATION

With an average rainwater harvesting potential of 183.20 m^3 per month (approximately 6 m^3/day), a durable storage tank is recommended due to its strength and ease of installation [22]. However, water quality tests revealed coliform levels of 50,000 CFU/100 ml, which exceed Indonesian clean water standards. To meet usage requirements, rainwater must undergo treatment processes such as sedimentation, filtration (60–90% removal), or advanced membrane and disinfection systems (up to 90% removal) depending on the intended water quality [23,24]. The next step involves estimating the investment cost for installing a rainwater harvesting system in the hotel. Cost assumptions include operator wages based on Jakarta Governor Regulation No. 1153 of 2022, electricity usage (5 kW/day), coagulant materials, and maintenance components such as silica sand, carbon, and membranes. Tables 4, 5, and 6 detail the system's investment, operational, and maintenance costs, respectively.

Table 4. Investment and Installation Cost

Investment and Installation Cost				
Item	**Type**	**Capacity**	**Unit**	**Cost**
Storage Tank	Fiber Tank	6	[m^3]	Rp 37,500,000
Sediment Tank	Horizontal concrete	6	[m^3/days]	Rp 1,171,810
Filtration	Sand	2	[m^3/hour]	Rp 14,800,000
	Carbon	2	[m^3/hour]	Rp 24,800,000
Membrane	RO Package + Booster Pump	0,6	[m^3/hour]	Rp 27,000,000
Total Cost			Rp 105,271,810	

Table 5. Operational Cost

Operational Cost				
Item	**Description**	**Price**	**Unit**	**Cost/day**
Operator Fees	Two workforces	Rp 163,000	[/days]	Rp 326,000
Electricity	5 kW	Rp 1,115	[/kWh]	Rp 5,575
Chemicals	Al_2SO_4	Rp 3,500	[/kg]	Rp 21,000
Total Cost			Rp 352,575	

Table 6. Maintenance Cost

Maintenance Cost				
Item	**Description**	**Price**	**Unit**	**Cost/day**
Sand	Silica	Rp 5,500	[/kg]	Rp 3,056
Carbon	*Activated Carbon*	Rp 28,900	[/kg]	Rp 16,056
Membrane	Cartridge	Rp 25,000,000	[/ea]	Rp 138,888
Total Cost			Rp 158,000	

3) RESULT AND DISCUSSION

Rainwater collected in this study contained 50,000 CFU/100 ml of coliform bacteria, a common finding in both freshly fallen and stored rainwater [25,26], which may also harbour Escherichia coli [27] and Salmonella [28]. While the physical and chemical properties of rainwater often meet WHO drinking water standards [29], certain heavy metal concentrations may still exceed safe limits. Therefore, treatment methods such as chlorination are recommended to deactivate microorganisms after storage [30].

The study found that the hotel's rainwater harvesting system can reduce annual water use by 11.01%, assuming a 62% room occupancy rate. While rainwater use in many studies is limited to non-drinking purposes such as irrigation and washing [32,33], commercial-scale systems are considered more financially feasible than household ones [34]. To harvest 6 m^3 of rainwater daily, the system requires an investment of approximately Rp 105.27 million, with operational and maintenance costs of Rp 352.25 thousand and Rp 158 thousand per day, respectively. As storage tanks represent up to 70% of the total system cost [35], careful tank sizing is essential—oversized tanks reduce water quality and efficiency, while undersized tanks fail to meet demand [26,37].

4) CONCLUSION

The hotel achieved 11.01% water savings, with estimated investment and installation costs of Rp 105.27 million, and daily operational and maintenance costs of Rp 352.25 thousand and Rp 158 thousand, respectively. While the system is effective in high-rainfall areas, further research is needed to explore its applicability in low-rainfall regions. Rainwater harvesting can be one of the right strategies for obtaining alternative water resources if appropriately planned when water conditions are an essential global issue.

5) FUNDING STATEMENT

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6) DATA AVAILABILITY

No new data were created or analyzed in this study. Data sharing is not applicable to this article.

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