

Original Research Article

Inverted umbrella type rainwater harvesting system for terrace gardening at Raichur campus

Abstract

The Inverted Umbrella-Type Rainwater Harvesting System is an innovative approach to collecting and storing rainwater efficiently. It is designed in the shape of an inverted umbrella, with a lightweight and durable frame that can be installed on rooftops, open fields, and urban landscapes. This unique design maximizes rainwater collection efficiency, even during light showers, while occupying minimal space. Key features of this system include high collection efficiency, a small footprint, environmental sustainability, ease of maintenance, and water quality assurance. It reduces reliance on traditional water sources, helping conserve water and mitigate environmental impacts. The system's adaptability to various geographic and climatic conditions makes it a versatile solution for addressing water scarcity. It has potential applications in residential, commercial, and industrial settings, contributing to more responsible water resource management. The Inverted Umbrella-Type Rainwater Harvesting System is a promising innovation that demonstrates the creative possibilities in addressing water scarcity and promoting sustainable water management. The Inverted Umbrella-Type Rainwater Harvesting System represents a promising step toward more responsible water resource management. It has the potential to benefit residential, commercial, and industrial applications, thereby contributing to a more sustainable and water-secure future. However, further research and development are essential to tailor the system to meet specific local needs and regulatory requirements. This innovative approach is a testament to the creativity and adaptability of rainwater harvesting techniques in addressing one of the world's most pressing challenges—access to clean and reliable water sources.

Keywords: Rainwater harvesting, Inverted Umbrella, Rainwater collection, Water scarcity, Efficient design

Introduction

The resource water is essential to human survival. It makes up roughly two-thirds of the earth's surface, but only 2.5 percent of it can be used by living things. Surface, ground, and atmospheric water can all be classified as types of water; atmospheric water includes moisture found in clouds which precipitates as snow and rain (Shittu, *et al.*, 2012). Rainfall is a type of precipitation where liquid water descends to the earth's surface (White, *et al.*, 2007). Snowmelt

and rainwater are commonly recognized as the planet's main sources of drinking water. Due to the high rate of enteric and water-borne disease transmission, inadequate and unsafe water supplies, as well as poor sanitation and hygiene practices, are linked to increased morbidity and mortality (Chabalala, and Mamo, 2001). Millions of people worldwide lack access to clean drinking water for home use, and in many developing nations, conventional piped water is nonexistent, unstable, or prohibitively expensive.

In 2004, the World Health Organization (WHO) and the United Nations International Children Education Fund (UNICEF) estimated that 80% of all illness in developing countries was linked to water and sanitation (Cudjoe, and Okonski, 2006). It was recently estimated that about 1.1 billion people globally did not have access to improved water supply sources whereas 2.4 billion people did not have access to any type of improved sanitation facility (WHO and UNICEF, 2010) (Hammed *et al.*, 2017).

Only 2.5 percent of the world is covered in freshwater, despite the fact that nearly 70 percent of it is. The remainder is marine and saltwater based. Even so, only 1% of our fresh water is readily available, with the majority of it being frozen in snowfields and glaciers. Earth's freshwater reserves remain unchanged, but due to population growth, the world's water supplies are facing an urgent crisis. Our lives now revolve around the reality of a water scarcity in both urban and rural areas. Even though the design of rain has changed due to environmental changes, sporadic rain does produce enough water for human use. However, the great majority of it is being wasted because there are no water storage facilities (Harshitha *et al.*, 2020).

The relationship between water scarcity and population is complex and interdependent. A growing population increases the demand for clean water, which can lead to competition for limited resources, over-extraction, pollution, and ecosystem disruptions. Addressing these challenges involves sustainable water management, conservation, efficient use, infrastructure development. Also, uncertainty in market for agricultural produce is demanding an Integrated Farming Systems (IFS) (integration of agriculture and allied business like aquaculture, dairy, poultry *etc.*) which assures additional income to the farmers. The hydraulic and hydrologic design of inverted umbrella rainwater harvesting (RWH) systems is crucial for their effectiveness and sustainability. Inverted umbrella RWH systems are designed to capture and store rainwater

underground, typically beneath impermeable surfaces such as roads and parking lots. Therefore the study was taken up as a step to conserve this precious natural resource called water.

MATERIALS AND METHODS

Inverted Umbrella Rain water Harvesting System:

The Inverted Umbrella Rainwater Harvesting System is a unique method for managing urban water resources. It uses a subterranean structure that resembles an umbrella to collect rainwater effectively beneath impermeable surfaces. A storage chamber, overflow and drainage mechanisms, a collection and conveyance system, inlets for water entry, filtration and treatment for water quality, and optional features like pumps and monitoring systems are among the essential parts. By collecting, holding, and encouraging the wise use of rainfall in cities, this creative system tackles three issues: sustainability, stormwater management, and water scarcity.

The major components of inverted umbrella rainwater harvesting (RWH) system typically include:

1. **Umbrella Structure:** This is the most distinctive feature of the system. It is usually a curved or dome-shaped structure made of concrete or other suitable materials. The umbrella is installed beneath an impermeable surface such as a road, parking lot, or plaza.
2. **Inlets:** These are openings or collection points strategically placed on the umbrella surface to allow rainwater to flow into the system. Inlets can be designed to capture rainwater efficiently and distribute it to the storage area.
3. **Collection and Conveyance System:** This component consists of pipes, gutters, and other conveyance mechanisms that connect the inlets to the storage area. It ensures that rainwater is transported from the collection points to the storage chamber.
4. **Filtration and Treatment:** To improve water quality, many RWH systems include filtration and treatment components. These may include screens, sedimentation chambers, and water treatment systems to remove debris and contaminants from the harvested rainwater.

5. Storage Chamber: Rainwater is stored underground in a storage chamber, typically constructed of concrete, plastic, or other durable materials. The size of the chamber is determined by the required storage capacity and intended usage of the harvested water.

These components work together to capture, store, and manage rainwater efficiently while ensuring water quality and system functionality in inverted umbrella rainwater harvesting systems. The specific design and components may vary depending on the system's size, purpose, and local conditions.

Discharge Calculations

The discharge value is used to estimate the amount of rainwater that can be harvested from a given catchment area under specific rainfall conditions. Calculation of the discharge 'Q' is given by (Harshitha *et al.*, 2020)

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

Where,

Q= Discharge from roofs due to rainfall in ($\text{m}^3 \text{h}^{-1}$)

C= Coefficient of runoff by rational method taken as 0.7 for this case

I= Intensity of rainfall (m h^{-1})

A= Area of catchment (m^2)

Annual rainwater harvesting potential

The estimation of annual rainwater harvesting potential involves factors such as the catchment area, catchment efficiency, and the local climate, specifically the annual or monthly rainfall patterns. It provides valuable information for planning and designing rainwater harvesting systems, determining the capacity of storage tanks, and assessing the potential benefits of using harvested rainwater for various purposes, such as irrigation, non-potable water supply, or groundwater recharge.

Annual rainwater harvesting potential is given by (Harshitha *et al.*, 2020) (Villaret *et al.*, 2020)

$$V=K \times I_a \times A \quad \dots (2)$$

Where,

V=Volume of water that can be harvested annually (m³).

K = Runoff coefficient

I_a = Avg. annual rainfall (m)

A = Catchment area (m²)

Results and discussion:

Inverted umbrella of 3m×3m was designed and developed with an aim of harvesting high quality rainwater to be used for various purposes like irrigation, domestic, industrial etc.

Historical rainfall data was collected from meteorological station at Raichur and rainfall analysis was carried out prior to designing an Inverted Umbrella Rainwater Harvesting System (Table 1)

1. Discharge is given by:

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

Where,

Q= Discharge from roofs due to rainfall in (m³ /h)

C= Coefficient of runoff by rational method taken as 0.7

I= Intensity of rainfall (m/h)

A= Area of catchment (m²)

$$\begin{aligned} Q &= C \times I \times A = 0.7 \times 0.05188 \times 9 = 0.3268 \text{ m}^3/\text{h} \\ &= 0.33 \text{ m}^3/\text{h} \end{aligned}$$

2. Annual rainwater harvesting potential

$$V=K \times I \times A \quad \dots (2)$$

Where,

V=Volume of water that can be harvested annually (m³).

K = Runoff coefficient or harvesting efficiency (Assuming it as 100%)

I_a = Avg. Annual rainfall (m)

A = Catchment area (m²)

$$V = K \times I_a \times A = 1 \times 0.675 \times 9 = 6.08 \text{ m}^3$$

Dimensional details of developed inverted umbrella system is given in Fig 1:

Recent decade rainfall data was collected and analyzed. Average annual rainfall of recent decade (2012-2021) was obtained as 636.53 mm.

Annual Water Harvesting Potential of the study area was obtained as 6.08 m³ which suggests that annually by using the harvesting umbrella one can harvest upto 6100 Litres of water from a single unit.

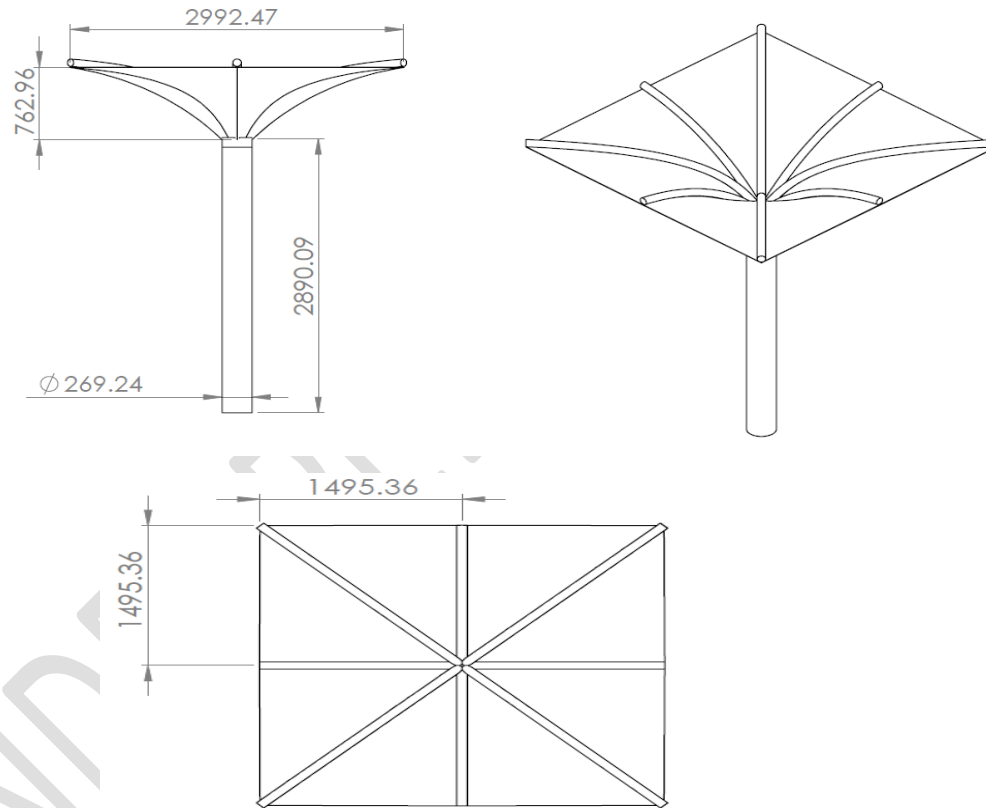


Fig. 1: Dimensional details of Inverted Umbrella Type Rainwater Harvesting System.

Months	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Mean
January	0	0	0	0	2.5	0	0	9.2	0	1.4	3.8
February	0	12.5	0	0	0	0	0	0	0	0.2	1.06
March	0	0	59.0	0	0	0	0	0	0.2	0	5.18
April	39.0	42.5	32.0	38.5	0	10.4	0	28.2	30.8	13.0	22.83
May	1.0	66.5	71.0	51.0	22.0	14.0	0	7.8	126.2	82.2	48.02
June	32.0	81.5	43.5	47.0	178.5	199.0	13.8	61.4	128.4	125.6	94.14
July	133.0	114.5	84.5	28.0	124.0	0	38.8	66.0	248.2	128.0	101.58
August	37.0	50.0	303.0	71.0	82.5	207.8	68.6	82.2	170.8	73.2	113.47
September	42.0	219.0	98.0	109.5	182.5	388.0	126.2	210.8	298.0	130.0	161.63
October	0	55.5	60.0	58.5	25.0	136.6	24.6	131.4	105.6	99.0	65.48
November	0	1	16.0	26.0	0	0	0	0.4	14.4	5.0	8.23
December	0	0	4.0	2.0	12.0	0.2	0	1	0	0.2	1.62
Total	284.0	643.0	771.0	431.5	629.0	956.0	272.0	598.4	1122.6	657.8	636.53

Table 1. Month and year wise variation of umbrella rainwater harvesting system

Conclusion

The hydraulic and hydrologic design of inverted umbrella rainwater harvesting (RWH) systems plays a pivotal role in their effectiveness and sustainability. It optimizes water collection efficiency by considering factors like the size and slope of the umbrella and the positioning of inlets to channel rainwater effectively into storage. Additionally, it addresses water quality concerns through filtration and treatment processes, making the harvested water suitable for various uses. The design determines the storage capacity based on local climate and intended

use, ensuring the system can capture and store sufficient water. It also incorporates overflow mechanisms to prevent flooding and erosion during heavy rain events. Maintenance and accessibility are facilitated to ensure the system's longevity, while sustainability is promoted through water conservation and urban flood mitigation. Annually 6100 litres of water can be harvested from a single unit of inverted umbrella type rainwater harvesting system. Compliance with local regulations is essential, and data collection mechanisms may be included for monitoring and making necessary adjustments. In summary, hydraulic and hydrologic design is vital to the success of inverted umbrella RWH systems, ensuring their efficiency, durability, and compliance with regulatory standards.

The Inverted Umbrella Rainwater Harvesting System offers an innovative solution to address urban water scarcity and stormwater management. It efficiently captures and stores rainwater, contributing to water conservation, flood prevention, and sustainable water resource management in urban areas.

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