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Performance Analysis of a Filter System Using Sustainable Treated Coconut Coir and Activated Charcoal

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***Abstract*:** As much as the issue of water scarcity, availability of right quality of water is also a growing concern. In the current scenario of water stress, it is essential for efficient use of available water. Rainwater harvesting offers one such solution for better water resources management. An essential part of rainwater harvesting is the filter system adapted. The current research focuses on developing a sustainable filter system using natural and abundantly locally available Coconut coir along with Charcoal to filter rainwater for domestic use. Charcoal was activated with $CaCl_2$ solution and crushed to different size gradations. Coconut coir was treated with Aqueous solution of Sodium Hydroxide pellets.

Filter system was developed with a layer of Coir and two layers of Activated Charcoal as per the grain size requirement. Physio-Chemical analysis including tests for Total Solids, Alkalinity and Acidity was carried out on the untreated and treated water sample. Results have suggested a promising, sustainable treatment process with easily available filter material.

***Keywords*:** Rainwater harvesting, Water Filter System, Coconut Coir, Activated Charcoal

1. Introduction

Water scarcity has emerged as a critical global concern, particularly in regions with high water demand and limited natural resources. Sports facilities, which require significant water for turf maintenance and irrigation, contribute heavily to groundwater depletion. Rainwater Harvesting (RWH) systems offer a sustainable solution to reduce reliance on groundwater by utilizing rainwater efficiently.

The RIT sports ground currently lacks a rainwater conservation system, relying solely on groundwater for irrigation. This study aims to develop and implement an RWH system using cost-effective, locally available filtration materials, ensuring sustainable water management for the ground.

The objectives include:

- Designing a rainwater collection and storage system for the sports ground.
- Analyzing the efficiency of activated charcoal and alkali-treated coconut coir as filtration media.
- Evaluating the system's economic and environmental benefits.

2. Literature Review

Several global studies highlight the benefits of RWH systems in reducing water stress. In Germany, Frankfurt Airport collects rainwater from its expansive rooftops for reuse, while Singapore maximizes its high annual rainfall through integrated RWH systems.

In India, the Center for Science and Environment (CSE) has implemented RWH systems in urban areas like Delhi and Bangalore. The use of **activated charcoal** and **coconut coir** as filtration media has been widely studied for their adsorption capacity, cost-effectiveness, and availability.

Research findings show that:

- Activated charcoal significantly reduces water contaminants by adsorption.
- Alkali-treated coconut coir improves water quality by reducing turbidity and suspended solids.

These materials are ideal for low-cost filtration systems, making them suitable for RWH projects in developing regions.

3. Methodology

The study follows a comprehensive experimental approach to design, develop, and evaluate a **Rainwater Harvesting (RWH) system** for the self-sustained irrigation of the RIT sports ground. The methodology is divided into five key stages to ensure thorough analysis and successful implementation.

3.1 Site Selection and Assessment

The RIT sports ground was selected as the study area due to the following factors:

1. **Large Catchment Area**: The sports ground covers an area of approximately **2000 m²**, which provides significant potential for rainwater collection.
2. **Current Groundwater Dependency**: At present, groundwater is the sole source of irrigation for maintaining the turf, resulting in high water costs and resource strain.
3. **Topographical Suitability**: A preliminary **topographical survey** using a **Total Station** identified low-lying areas where rainwater naturally accumulates, making it feasible for storage.

- **Rainfall Data Collection**: Rainfall data for the study area was obtained from the regional meteorological department for the past **10 years**. The average annual rainfall was determined to be **900 mm**.
- **Soil Infiltration Capacity**: Infiltration tests were conducted at different sections of the sports ground using a double-ring infiltrometer to understand the soil's permeability for potential groundwater recharge.

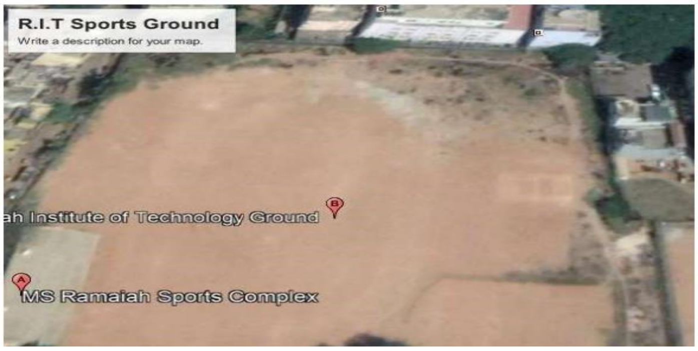

Fig 3.1: RIT sports Ground

Fig:3.2 Undulation on ground

Fig:3.3 Improper drainage system

Fig:3.4 Lack of turf

3.2 System Design

The RWH system was designed to include the following components:

1. **Rainwater Collection**:

o Surface runoff was collected from the sports ground using **natural slope grading**.

o Roof surfaces of adjacent buildings (covering an additional 400 m²) were equipped with **PVC pipelines** to direct rainwater to the filtration unit.

2. **Conveyance System**:

o High-density **PVC pipelines** of diameter **150 mm** were installed for rainwater transport to the filtration system. Proper slope (1:100) was maintained to ensure gravitational flow.

3. **Filtration System**:
To ensure water quality suitable for irrigation, a dual-media filtration unit was developed using:

o **Activated Charcoal**: Derived from coconut shells and chemically activated with **calcium chloride ($CaCl_2$)** to enhance its adsorption capacity for removing impurities, including dissolved solids.

o **Coconut Coir**: Treated with a **2% sodium hydroxide (NaOH) solution** to improve its durability, porosity, and ability to reduce turbidity.

Fig:3.5: Coconut Coir

Fig:3.6 Sundried Coco

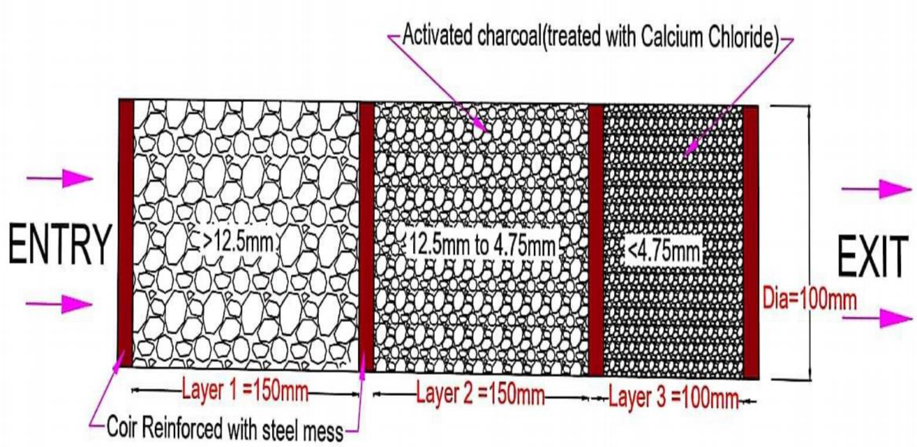

Fig:3.7 Filter model

Filtration Unit Dimensions:

- o Diameter: **0.75 m**
- o Height: **1.2 m**
- o Media thickness: 0.5 m (activated charcoal layer) and 0.3 m (coir layer).

4. **Storage** **Tank**:
A **25,000-liter RCC underground tank** was constructed in a designated low-lying area. It includes an **overflow mechanism** and connections to an irrigation pump for supplying filtered rainwater to the turf.

3.3 Experimental Setup

Fig:5.1 Treated and Untreated Sample of water

Table:3.1 Solid content in sample

soil content	initial weight(gm)	finalweight(gm)	total solids(mg/lt)	initial weight(gm)	finalweight(gm)	dissolved solids(mg/lt)	suspended solids(mg/lt
50 gm/lt	Before filtration			Before filtration			
	76.4450	76.4650	800.0000	68.6818	68.6985	668.0000	132.0000
	After filtration			After filtration			
	70.7900	70.7951	204.0000	42.1425	42.1468	172.0000	32.0000
25 gm/lt	Before filtration			Before filtration			
	73.6747	73.6926	716.0000	73.7865	73.8011	584.0000	132.0000
	After filtration			After filtration			
	42.1330	42.1379	196.0000	70.7850	70.7890	160.0000	36.0000
12.5 gm/lt	Before filtration			Before filtration			
	73.8170	73.8323	612.0000	76.4450	76.4565	460.0000	152.0000
	After filtration			After filtration			
	68.6501	68.6547	184.0000	73.6670	73.6708	152.0000	32.0000

Table:3.2 Acidity in sample

Trial no.	initial reading	final reading	NaOH consumed(ml)
1	7.800	9.800	2.000
2	12.200	14.100	1.900
3	14.100	16.000	1.900
		average consumption=	1.933
		Normality of NaOH=	0.020
		Total Acidity=	38.667
		(mg/lt as $CaCO_3$)	

Table: 3.3 Alkalinity in sample

Sl. No.	Indicator used	initial reading	final reading	HCl consumed(ml)	average HCl (ml)
1	phenolphthalein	18.500	18.500	0.0000	0.0000
2		18.500	18.500	0.0000	
3		18.500	18.500	0.0000	
1	methyl orange	33.000	44.700	11.7000	11.7667
2		44.700	56.500	11.800	
3		56.500	68.300	11.800	
		Phenolphthalein alkalinity=		0.000	(mg/lt as $CaCO_3$)
		Total alkalinity=		235.333	(mg/lt as $CaCO_3$)
		Hydroxide Alkalinity=		0.000	(mg/lt as $CaCO_3$)
		Carbonate alkalinity=		0.000	(mg/lt as $CaCO_3$)
		Bi-Carbonate alkalinity=		235.3333	(mg/lt as $CaCO_3$)

Table: 3.4 Permeability of Filter

Sl. No.	Volume of water filtered(Lt)	Time taken(sec)	
1	1.35	32.5	
2	1.35	32.4	
3	1.35	32.2	
	Average time taken,t=	32.4	sec
	Avg. volume of water filtered		
	during this time period,V=	1.35	lt
	Diameter of the filter,d=	100.0	mm
	Area of cross section,A =	0.0079	m^2
	Discharge through filter,Q=	0.0417	lit/s
	Length of the filter,L=	0.44	m
	Constant head provided,H_f=	0.86	m
	Hydraulic gradient,i=	1.9545	
	Constant head permeability,k=	2.72	lit/sec/m^2

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The experimental process was conducted in controlled laboratory and field conditions:

1. **Filtration Media Analysis**:
    - **Activated Charcoal**: Adsorption capacity was tested using a batch adsorption experiment with varying concentrations of contaminants (TSS, COD).
    - **Coconut Coir**: Water turbidity reduction and flow rate improvement were analyzed.
2. **Water Quality Testing**:
    - Rainwater samples collected by pre- and post-filtration were analyzed for:
        - **Turbidity** (NTU)
        - **Total Suspended Solids (TSS)**
        - **pH levels**
        - **Chemical Oxygen Demand (COD)**
3. **Rainwater Storage Efficiency**: The volume of water collected during rainfall events was monitored over the study period to determine the efficiency of the collection system.
4. **Economic Analysis**: A cost-benefit analysis was performed to compare system installation costs, operational expenses, and long-term savings from reduced groundwater usage.

4. Results and Discussion

4.1 Topographical and Rainfall Analysis

The **topographical survey** revealed a **20 cm elevation difference** across the ground, enabling efficient water flow toward the designated collection zones. Historical rainfall data indicated an annual average of **900 mm**, with peak rainfall occurring during the monsoon season (June–September).

4.2 Filtration System Performance

1. **Activated Charcoal Efficiency**:
    - Adsorption tests showed **85% reduction** in Total Suspended Solids (TSS).
    - COD levels decreased by **72%**, indicating significant removal of organic contaminants.
2. **Coconut Coir Efficiency**:
    - Untreated rainwater had an average turbidity of **52 NTU**. Post-filtration, turbidity reduced to **9 NTU**.
    - The permeability test showed a steady flow rate of **3.5 liters/min**, making it ideal for irrigation purposes.

4.3 Water Collection and Storage Analysis

The RWH system successfully collected approximately **1.35 million liters/year** of rainwater from the sports ground and adjoining rooftops, achieving an efficiency of **75%** of the total rainfall.

- **Water Storage**: The 25,000-liter RCC tank provided sufficient capacity for irrigation during dry periods.
- **Reduction in Groundwater Usage**: Groundwater dependency for irrigation decreased by **60%**, significantly conserving water resources.

4.4 Economic and Environmental Benefits

1. **Economic Analysis**:
   - Total installation cost: **₹3.5 lakhs**
   - Annual savings on groundwater pumping: **₹50,000**
   - Payback period: **7 years**
2. **Environmental Impact**:
   - Prevented surface water runoff, reducing erosion.
   - Improved soil moisture retention.
   - Promoted sustainable water resource management for the sports ground.

4.5 Discussion

The results demonstrate that the proposed **dual-media filtration system** using activated charcoal and alkali-treated coconut coir is highly effective in improving rainwater quality for irrigation. The significant reduction in TSS, COD, and turbidity ensures safe and efficient water use, contributing to groundwater conservation.

The system's design provides a **scalable and cost-effective model** for other sports grounds, educational institutions, and open areas, emphasizing sustainability.

5. Conclusion

This study successfully implemented and analyzed a Rain Water Harvesting system for the RIT sports ground using locally available filtration materials. Key findings include:

1. Filtration Performance: The combination of activated charcoal and alkali-treated coconut coir achieved high contaminant removal efficiency (85% TSS reduction and 72% COD reduction).
2. Water Collection: The system collected approximately 1.35 million liters of rainwater annually, reducing groundwater dependency by 60%.
3. Economic Viability: The system demonstrated a payback period of 7 years, making it a cost-effective solution for sustainable water management.

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