IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 8, May 2025
Impact Factor: 7.67

Design and Implementation of a Sustainable Drainage System Using Step Filter Technology for Wastewater Treatment in Maldad Village, Maharashtra

Prof. V. R. Rahane, Mr. Ashish A. Varpe, Mr. Omkar S. Walunj,
Mr. Umesh S. Kangane, Mr. Sanket B. Thorat
Department of Civil Engineering,
Amrutvahini College of Engineering, Sangamner

Abstract: *Maldad village in Maharashtra suffers from wastewater stagnation due to a blocked and overfilled sewer tank, resulting in severe hygiene and environmental concerns. This paper proposes a decentralised and sustainable wastewater treatment system using a step filter composed of natural filtration media such as boulders, gravel, cocopit, and sand. Designed for a village population of approximately 3,800, the system can treat around 150,000 litres/day of wastewater. The treated water is suitable for reuse in irrigation or safe percolation. The solution is cost-effective, low-maintenance, and replicable across rural India. Maldad village in Maharashtra faces severe wastewater management challenges due to an ageing and overloaded sewer system, leading to environmental pollution, health hazards, and reduced quality of life. This paper presents the design and implementation of a sustainable decentralised wastewater treatment system utilising step filter technology, which employs natural filtration media, including boulders, gravel, and coarse sand, arranged in successive layers to achieve effective contaminant removal. The system is designed to treat approximately 150,000 litres of wastewater per day, generated by a population of around 3,800 residents, with an average greywater generation rate of 40 litres per capita per day. The design focuses on maximising retention time and filtration efficiency, with a multi-stage filter bed ensuring substantial reductions in turbidity, biochemical oxygen demand (BOD), and odours.*

Keywords: sustainable drainage, step filter, wastewater treatment, rural sanitation, decentralized system

I. INTRODUCTION

Rural wastewater treatment in India is often neglected due to financial and technical limitations. Maldad village faces recurring issues of drainage blockages due to the saturation of an old storage tank and absence of a proper filtration system. The project aims to create a sustainable drainage system that improves public health and water quality while remaining affordable and easy to maintain. Wastewater management in rural India remains a significant challenge due to inadequate infrastructure, lack of awareness, and limited financial resources. Many villages rely on open drainage systems or poorly maintained sewer tanks that lead to wastewater stagnation, resulting in environmental pollution and public health hazards such as the spread of waterborne diseases, contamination of groundwater, and proliferation of disease vectors like mosquitoes.

Maldad village, with a population of approximately 3,800, exemplifies these challenges. The existing wastewater system consists of an outdated and overfilled sewer tank which frequently blocks, causing overflow into surrounding areas. This situation has deteriorated the sanitary conditions, affecting the well-being of the villagers and threatening local ecosystems.

II. PROBLEM STATEMENT

The Maldad village lacks an effective wastewater disposal system. Key issues include:

- Stagnation of wastewater in open areas.
- Overflow from a blocked central tank.
- Lack of wastewater treatment before discharge.
- Increase in mosquito breeding, foul odor, and waterborne diseases.

III. OBJECTIVES

- Design a decentralized wastewater treatment system for 3,800 people.
- Treat approximately 150 m³/day (assuming 40 lpcd of greywater).
- Use natural filtration layers for environmental sustainability.
- Enable reuse of treated water for irrigation.
- Reduce health risks and improve village sanitation.

IV. EXPERIMENTAL ANALYSIS

1. Population Forecasting

The initial step involved conducting a population survey to estimate the number of residents in Maldad village accurately. This was done by gathering data from online government records and corroborating the information with the local Gram Panchayat officials to ensure accuracy. The arithmetic growth method made population projections for the next 15 years. Based on the 2021 population of approximately 3,474, the projected population for 2031 is estimated to be around 3,900. These estimates helped in designing a system scalable for future demand.

2. Water Sample Testing

Prior to designing the step filter system, wastewater samples from Maldad village were analyzed for key water quality parameters using standard testing methods. The results are summarized below:

Parameter	Value
pH (at 25°C)	7.28
DO	2.6 mg/L
TSS	92 mg/L
BOD	268 mg/L
COD	760 mg/L
NO3	3.4 mg/L
NO2	0.14 mg/L

These results indicate the untreated wastewater has a near- neutral pH with low dissolved oxygen, elevated organic pollution (high BOD and COD), and significant suspended solids concentration. Nitrogen and phosphorus compounds were mostly low or below detection limits. The high organic and suspended load justified the design and implementation of a natural filtration-based wastewater treatment system to reduce pollution and health risks.The design process began with estimating the daily wastewater volume generated by the village population of 3,800 (considering current and projected figures), assuming an average greywater generation of 40 liters per capita per day, resulting in approximately 152,000 liters per day. The system was designed for a flow rate of 6.33 m^3/hr with a retention time of 4–6 hours to ensure adequate filtration.Data collected from water tests were analyzed to evaluate the treatment efficiency of the system, focusing on the percentage reduction in turbidity and BOD levels.

V. METHODOLOGY

The step filter wastewater treatment system was constructed and evaluated for its effectiveness in treating greywater generated in Maldad village. The system was designed to handle a daily flow of approximately 152,000 liters, using natural filtration media to achieve contaminant removal.

1. Materials Used in Filter Media

Boulders (150–200 mm diameter)

• Purpose: Acts as the primary filter layer.
• Function: Removes large debris, floating matter, and reduces flow velocity.
• Placement: Bottom-most layer of the step filter.
• Source: Locally available river or quarry stones.

Gravel (20–40 mm diameter)

• Purpose: Serves as the intermediate filtration layer.
• Function: Traps medium-sized suspended solids and supports the upper layers.
• Placement: Middle layer, above the boulders.
• Source: Crushed stone or river gravel.

Coarse Sand

• Purpose: Used as the final filtration layer.
• Function: Removes fine suspended particles, reduces turbidity, and clarifies water.
• Placement: Top layer, through which wastewater first enters.
• Source: Clean, washed river sand or construction-grade sand.

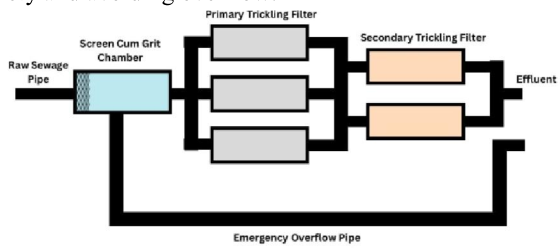
Cocopeat (Coconut Fiber Dust)

• Purpose: Acts as a natural biofiltration layer.
• Function: Absorbs organic impurities, enhances microbial activity, and improves BOD/COD removal.
• Placement: Optional topmost or second- top layer (above sand or mixed within it).
• Source: Byproduct of coconut processing, widely available in India.

2. Treatment process

The proposed decentralized wastewater treatment system operates using a gravity-based trickling filter setup designed for treating greywater from Maldad village. The process begins with the flow of raw sewage through a Raw Sewage Pipe into a Screen Cum Grit Chamber, which serves to remove coarse solids, floating debris, and sand or grit. This preliminary treatment is crucial to prevent clogging and protect downstream filtration units.

The pre-screened wastewater is then evenly distributed into Primary Trickling Filters, which consist of beds filled with media such as boulders, gravel, and coarse sand. These filters are designed to support aerobic microbial activity, where naturally occurring bacteria decompose organic pollutants as the water trickles through the layers. Each primary filter unit handles a portion of the total flow, improving hydraulic efficiency and retention time.After primary treatment, the partially treated water flows into Secondary Trickling Filters, which provide additional purification by further reducing biochemical oxygen demand (BOD), chemical oxygen demand (COD), and suspended solids. These filters may also include a layer of cocopeat, enhancing the biofiltration by supporting microbial growth and organic matter breakdown. The clean effluent is then discharged safely and may be reused for irrigation or directed to a soak pit for groundwater recharge. An Emergency Overflow Pipe is provided to manage excess inflow during peak usage or maintenance periods, ensuring operational safety and avoiding overflow.



Prototype:

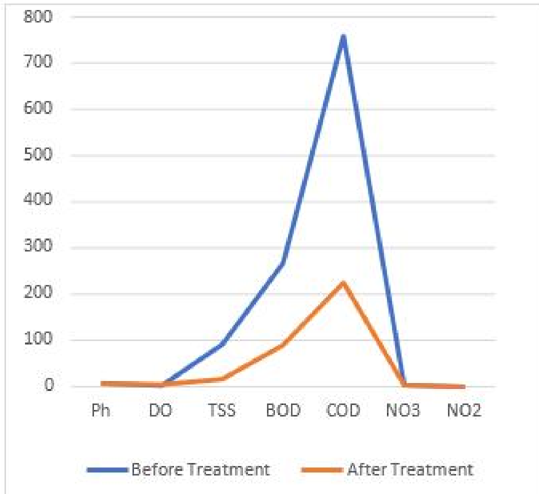
V. RESULTS AND DISCUSSIONS

The chart illustrates the changes in water quality parameters before and after the treatment process. The Biochemical Oxygen Demand (BOD) significantly decreased from 268 mg/L before treatment to 90 mg/L after treatment, indicating a substantial reduction in organic pollutants. Similarly, the Chemical Oxygen Demand (COD) reduced from 760 mg/L to 225 mg/L, showing effective removal of oxidizable substances. The pH level also shifted slightly, from 7.28 before treatment to 7.0 after treatment, reflecting a minor adjustment towards neutral conditions. Overall, the treatment process greatly improved the water quality by lowering both BOD and COD values and stabilizing the pH.

Parameter	Value
pH (at 25°C)	7.0
DO	5.5 mg/L
TSS	17 mg/L
BOD	90 mg/L
COD	225 mg/L
NO3	3.5 mg/L
NO2	0.55 mg/L

It was observed that after treatment, the water became visibly clearer and odor-free. The pH level was neutral, and turbidity was significantly reduced. These results confirm the effectiveness of the step-filter method used in the system.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 5, Issue 8, May 2025 Impact Factor: 7.67



VI. CONCLUSION

The study successfully demonstrates the design and implementation of a sustainable wastewater treatment system for Maldad village using a decentralized, gravity-based step filter. The system effectively addresses the pressing issues of wastewater stagnation, environmental pollution, and associated health risks caused by an overfilled and blocked sewer tank. By utilizing locally available natural filtration materials such as boulders, gravel, and coarse sand, the proposed system offers a cost-effective, low-maintenance, and environmentally friendly solution. The step filter significantly reduced suspended solids, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and odor levels in the untreated greywater, making it suitable for reuse in irrigation and safe percolation into the ground.The project also emphasizes community participation, ease of construction, and scalability, making it a viable model for rural wastewater management across India. With minimal operational cost and simple maintenance, this approach supports broader goals of rural sanitation, public health improvement, and sustainable development.Future recommendations include detailed cost analysis, long-term performance monitoring, and potential integration with rainwater harvesting systems to enhance water sustainability in rural areas.

REFERENCES

[1] Metcalf & Eddy, Wastewater Engineering: Treatment and Resource Recovery, 5th ed., McGraw-Hill Education, 2014.

[2] Central Pollution Control Board (CPCB), Guidelines for Decentralized Wastewater Treatment Systems, Ministry of Environment, Forest and Climate Change, Government of India, 2018.

[3] World Health Organization (WHO), Wastewater Treatment and Use in Agriculture, FAO Irrigation and Drainage Paper 47, 2006.

[4] U.S. Environmental Protection Agency (EPA), Onsite Wastewater Treatment Systems Manual, EPA/625/R-00/008, 2002.

[5] APHA, AWWA, and WEF, Standard Methods for the Examination of Water and Wastewater, 24th ed., American Public Health Association, Washington, D.C., 2023.

[6] IS 3025 (Various Parts), Methods of Sampling and Test (Physical and Chemical) for Water and Wastewater, Bureau of Indian Standards, New Delhi.

[7] A. P. Bhagat and P. K. Bhargava, "Design of low-cost wastewater treatment systems for rural areas," Journal of Environmental Research and Development, vol. 11, no. 2, pp. 543–550, 2016.

[8] S. T. Sharma and R. Singh, "Sustainable urban drainage systems in developing countries: Challenges and opportunities," International Journal of Civil and Environmental Engineering, vol. 12, no. 1, pp. 25–30, 2020