WATER FILTRATION PROTOTYPING LARGER SCALE FOR UNIVERSITY USE

By **Manjaka Fitia Frédéricka RANDRIATSIHOARANA**

"The value of this fellowship to me is immense, it would greatly accelerate both my technical and soft skills development in service of promoting water sustainability in Madagascar."

Editorial Notes:

Ms. Manjaka Fitia Frédéricka Randriatsihoarana, a dedicated and passionate master's degree student in Hydraulic and Infrastructure Engineering from the "Ecole Supérieure Polytechnique d'Antananarivo," has undertaken a crucial research project under the auspices of the Jacquelyn Sanders Foundation. Her work focuses on planning biological water filtration at the university level, specifically targeting the pressing need for sustainable water management solutions in Madagascar.

As a young engineer with a strong technical foundation and a commitment to addressing water resource challenges, Ms. Randriatsihoarana has brought both enthusiasm and expertise to this project. Her background in hydraulic engineering and her desire to implement innovative, context-appropriate solutions make her an ideal candidate for this fellowship. In her own words, she is "fully committed to applying [her] engineering knowledge to push forward progress in sustainable water resource development in Madagascar and other countries."

Initially, there was consideration for Ms. Randriatsihoarana to use Canva for her project planning, potentially incorporating graphics as part of the design process. However, she ultimately chose to deliver her work in PDF format. This decision highlights the importance of flexibility in the tools and methods employed by our fellows. Moving forward, the Jacquelyn Sanders Foundation recognizes that training in unified design software for our team may lead to more consistent and visually impactful results across our projects.

Ms. Randriatsihoarana's report represents a significant contribution to the ongoing efforts to optimize water filtration systems in off-grid settings and university environments in Madagascar. Her work is not only technically sound but also reflects a deep understanding of the local context and a commitment to making a tangible difference in her community. As we continue to support projects like hers, we emphasize the importance of early-stage planning and design that align with our Foundation's values and mission.

JACQUELYN JESTINE SANDERS FOUNDATION
BUILDING VISION, REALIZING CHANGE

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JJSF – Jacquelyn Jestine Sanders Foundation

A STUDY PROJECTS

By **Manjaka Fitia Frédéricka RANDRIATSIHOARANA**

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INTRODUCTION

The scarcity of clean drinking water is a pressing issue worldwide, affecting both developing and developed regions. Universities, as microcosms of larger communities, face similar challenges in providing safe, potable water to their inhabitants. This dissertation explores the prototyping of a large-scale water filtration system, specifically designed for use on a university campus. By utilizing four 10,000-liter water tanks, this system aims to collect and filter rainwater, ensuring a sustainable and reliable source of clean water for university students and staff.

The problem of water scarcity and contamination highlights the critical need for effective water management and filtration solutions in educational institutions. Universities, often housing thousands of individuals, require substantial amounts of water for various needs, including drinking, cooking, and sanitation. The proposed water filtration system not only addresses the immediate need for clean water but also promotes environmental sustainability by leveraging rainwater harvesting.

The primary objectives of this research are to design a comprehensive water filtration system, analyze its effectiveness in providing potable water, and ensure its maintainability over the long term.

1. Literature Review

The design and implementation of water filtration systems are rooted in various theories and models, which provide the necessary framework for developing effective and efficient solutions. This section reviews the relevant literature, focusing on the key theories, models, and previous research findings that inform the design of a large-scale water filtration system for university use.

1.1. Theories and Models

One of the foundational theories in water filtration is the hydrological cycle, which describes the continuous movement of water on, above, and below the surface of the Earth. Understanding this cycle is crucial for designing systems that effectively capture and filter rainwater. Additionally, the theory of adsorption and filtration is essential, as it explains the mechanisms by which contaminants are removed from water. Adsorption involves the adhesion of particles onto a surface, while filtration physically separates impurities based on size.

1.2. Previous Research and Findings

Numerous studies have explored the effectiveness of various water filtration technologies. For instance, research on slow sand filtration has demonstrated its ability to remove pathogens and suspended solids from water. Similarly, activated carbon filters are widely recognized for their capacity to adsorb organic compounds and chlorine, improving water taste and odor.

1.3. Gaps in the Existing Literature

While there is a wealth of research on individual filtration methods, there is limited literature on the integration of multiple filtration technologies into a single system designed for large-scale applications, such as a university campus. Furthermore, existing studies often focus on small-scale or household filtration systems, leaving a gap in the understanding of how these technologies can be scaled up effectively. Additionally, the long-term maintenance and sustainability of large-scale filtration systems remain underexplored, highlighting the need for comprehensive maintenance plans that ensure continuous operation and water quality.

This literature review provides the theoretical and empirical foundation for the design and implementation of a large-scale water filtration system for university use. The subsequent sections will build on these insights, detailing the methodology, technical design, water flow projections, and maintenance plan necessary to develop a robust and efficient system.

2. Methodology

The methodology section outlines the research methods used to design, develop, and evaluate the large-scale water filtration system for university use. It provides a rationale for the chosen approaches and details the data sources and collection techniques employed in the study.

2.1. Description of Research Methods

This research employs a combination of design-based research (DBR) and experimental methods. DBR is utilized to iteratively design, test, and refine the water filtration system, ensuring it meets the specific needs of the university setting. The experimental methods involve laboratory testing and field trials to assess the system's performance in real-world conditions.

2.2. Justification of Methodology Choice

The choice of DBR is justified by its emphasis on developing practical solutions through continuous refinement based on feedback and testing. This approach is particularly suitable for prototyping the water filtration system, as it allows for adjustments and improvements in response to observed challenges and performance data. Experimental methods complement DBR by providing empirical evidence of the system's effectiveness, ensuring that the design is grounded in robust scientific principles.

3. Technical Design of the Water Filtration System

This section details the technical design of the water filtration system, including the design techniques, a comprehensive list of required parts and components, and a detailed technical conception of the system.

3.1. Design Techniques

The design of the water filtration system incorporates multiple stages to ensure the effective removal of contaminants and the provision of clean, potable water. The key design techniques include:

Pre-filtration: This initial stage involves removing large debris and sediments from the rainwater using mesh screens and sedimentation tanks.

Filtration: The system uses a combination of sand filters, and activated carbon filters

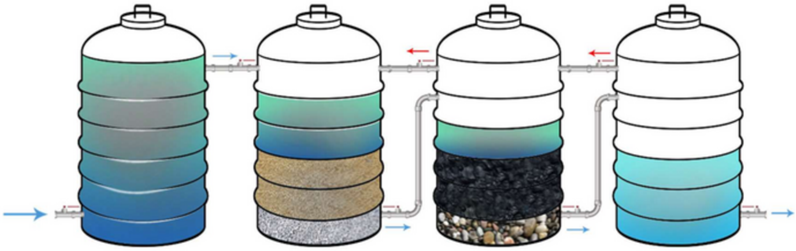

Figure 1: Design Techniques

3.2. Parts and Components List

The construction of the water filtration system requires the following key components:

Water Tanks	Mesh Screens	Sand filters	Activated carbon filters
			
10.000 Liters Ø 2,16 m x 3,10 m	50 µm	70 µm	Ø ≈ 30 mm

T-Joint	Pipe PVC	Shut-off Valve	PVC Elbow 90°	PVC Threaded Coupling
				
Ø40 mm	Ø40 mm x 4	PPR Ø40 mm	Ø40 mm	Ø40 x 1.1/4M
2 600 Ar	41 600 Ar	31 500 Ar	1 900 Ar	1 700 Ar

3.3. Detailed Technical Design

The technical design involves the integration of the components into a cohesive system that ensures efficient water filtration. The following steps outline the detailed design process:

Rainwater Collection: Rainwater is collected from the rooftops and funneled into the first 10,000-liter tank. Mesh screens are placed at the inlets to remove large debris.

Sedimentation: Water from the first tank flows into sedimentation tanks where heavy particles settle at the bottom.

Sand Filtration: Water passes through sand filters to remove flocs and suspended particles.

Activated Carbon Filtration: The water then flows through activated carbon filters, removing organic compounds and chlorine.

4. System Diagram

The following diagram illustrates the flow of water through the filtration system.

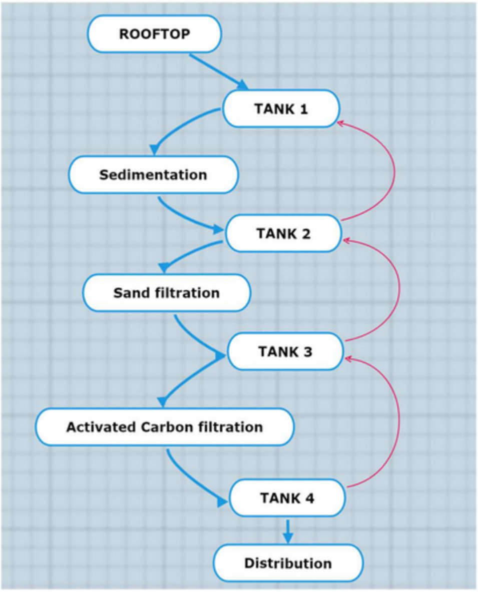

Figure 2: System diagram

This technical design ensures that the rainwater collected is thoroughly treated and safe for consumption, meeting the needs of the university campus. When tank became full they return to the previews tank.

5. Water Flow Projection

This section presents the projected potable water flow rate for the water filtration system, including the methods and assumptions used in the calculations and data analysis.

5.1. Projected Potable Water Flow Rate

To ensure the system meets the water demand of the university campus, it is crucial to accurately project the flow rate of potable water. The calculation considers the average rainfall, catchment area, filtration efficiency, and daily water consumption needs of the campus population.

5.2. Calculation Methods and Assumptions

a) Assumptions:

Average Rainfall: The university receives an average annual rainfall of 1000 mm.

Catchment Area: The rooftops used for rainwater collection have a combined area of 2000 square meters.

Collection Efficiency: The efficiency of rainwater collection is assumed to be 80%, accounting for losses due to evaporation and spillage.

Filtration Efficiency: The filtration system is assumed to have an overall efficiency of **90%.**

Daily Water Consumption: The campus population (students and staff) is estimated at 5000 people, with an average daily water consumption of 50 liters per person.

b) Calculations:

Annual Rainwater Harvesting Potential:

$$Annual\ Rainwater\ (liters) = Average\ Rainfall\ (mm) \times\ Catchment\ Area\ (m^2) \times Collection\ Efficiency = 1000 \times\ 2000 \times\ 0.8 = 1.600.000\ liters/year$$

Daily Rainwater Harvesting Potential:

$$Daily\ Rainwater\ (liters) = \frac{Annual\ Rainwater}{365}$$

$$= \frac{1.600.000}{365} \approx 4384\ liters/day$$

Filtered Water Output:

$$Filtered\ Water\ \left(\frac{liters}{day}\right) = Daily\ Rainwater \times Filtration\ Efficiency\ = 4384 \times\ 0.9$$
$$\approx\ 3946\ liters/day$$

Total Daily Water Demand:

$$Total\ Daily\ Demand\ (liters) = Campus\ Population \times Daily\ Consumption$$
$$= 5000 \times 50 = 250{,}000\ liters/day$$

Given these calculations, the projected water flow from the filtration system is significantly lower than the total daily demand of the campus. This highlights the need for supplementary water sources or additional water conservation measures.

5.3. Data Analysis

The calculated filtered water output of approximately 3946 liters per day provides a substantial but insufficient contribution to the university's water needs. This shortfall underscores the importance of integrating the filtration system with existing water supply infrastructure and implementing water-saving practices across the campus.

5.4. Recommendations

To maximize the effectiveness of the water filtration system:

- Expand Catchment Area: Increase the rooftop collection area to capture more rainwater.
- Improve Collection Efficiency: Enhance the collection system to reduce losses.
- Supplementary Sources: Integrate the system with municipal water supplies or additional rainwater harvesting systems.

Water Conservation: Implement water-saving measures to reduce overall consumption.

6. Maintenance Plan

Ensuring the longevity and reliability of the water filtration system requires a comprehensive maintenance plan. This section outlines regular maintenance procedures, a preventive maintenance schedule, and guidelines for troubleshooting and repairs.

Solutions: Clean or replace clogged filters, inspect and repair or replace the pump, and check piping for blockages.

f) Poor Water Quality:

Possible Causes: Ineffective filtration, exhausted filter media, or malfunctioning disinfection unit.

Solutions: Inspect and clean filters, replace filter media, and check the UV disinfection unit for proper operation.

g) System Leaks:

Possible Causes: Damaged piping, loose connections, or faulty valves.

Solutions: Repair or replace damaged piping, tighten connections, and replace faulty valves.

h) Pump Failure:

Possible Causes: Electrical issues, mechanical failure, or wear and tear.

Solutions: Check electrical connections and power supply, inspect for mechanical faults, and replace worn components.

By adhering to this maintenance plan, the water filtration system will operate efficiently and reliably, ensuring a continuous supply of clean water for the university campus.

CONCLUSION

The proposed water filtration system appears to be a comprehensive solution to the potable water needs of the university campus. The systematic design, supported by calculations and projections, suggests a robust framework capable of addressing water scarcity and contamination challenges effectively.

While the theoretical framework suggests a promising solution, it's important to note that practical implementation may introduce unforeseen challenges. Variations in environmental conditions, regulatory requirements, and operational factors could impact the system's performance.

Nevertheless, the comprehensive maintenance plan and adherence to industry standards provide a strong foundation for practical implementation. It's recommended to conduct pilot tests or simulations to validate the system's performance before full-scale deployment, allowing for adjustments and optimizations as needed.

In conclusion, while the theoretical model appears sound, practical implementation may require adaptation and fine-tuning. With careful planning, monitoring, and adjustment, the water filtration system has the potential to provide a sustainable and reliable source of potable water for the university campus, contributing to the well-being and resilience of the community it serves.

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