THERMAX MINIMIZE REJECT DURING WATER PURIFICATION

A project report

Submitted by :

Roll Number	**Student Names**
20211CAI0030	ASIF PASHA.B
20211CAI0059	MOHAMED AZEEM FARDEEN PASHA
20211CAI0106	ISMAIL AHMED KHAN
20211CAI0130	AFTAB HUSSAIN
20211CAI0176	BELDONA VISWESWARA

Under the guidance of
Mr. JOHN BENNET JOHNSON
Department of computer science and engineering
School of Engineering

In partial fulfilment for the award of the capstone of
BACHELOR OF TECHNOLOGY AT SCHOOL OF COMPUTER SCIENCE AND ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

PRESIDENCY UNVIERSITY
BENGALURU

NOVEMBER 2024

SCHOOL OF COMPUTER SCIENCE AND ENGINEERING
PRESIDENCY UNVIERSITY
BENGALURU

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

CERTIFICATE

This is to certify that the University project report titled "**Thermax Minimize reject during water purification**"being submitted by **"ASIF PASHA ,MOHAMED AZEEM FARDEEN PASHA,ISMAIL AHAMED KHAN,AFTAB HUSSAIN, BELDONA VISWESWARA"**bearing roll numbers**"20211CAI0030,20211CAI0059, 20211CAI0106,20211CAI0130,20211CAI0176"** in partial fulfilment of requirement for the award of degree of Bachelor of Technology is a bona-fide work carried out under supervision

Mr. JOHN BENNET
Assistant Professor
Department of CSE&IS
School of Engineering

Dr. ZAFAR ALI KHAN
HOD/ CAI
Department of CSE&IS
School of Engineering

Declaration

I ASIF PASHA ,MOHAMED AZEEM FARDEEN PASHA,ISMAI AHAMED KHAN,AFTAB HUSSAIN, BELDONA VISWESWARA", bearing roll number " 20211CAI0030,20211CAI0059,20211CAI0106,20211CAI0130,20211CAI0176", hereby declare that the project report titled "Thermax Minimize reject during water purification" is a result of my original work under the guidance of " Mr. JOHN BENNET , Assistant Professor, Department of CSE, School of Engineering".

I/We further declare that:

- All sources of information have been duly acknowledged and cited.
- No part of this work has been submitted for any other degree or diploma.
- The work presented in this report is original and has not been copied from any other source.
- Any external help received, if any, has been duly acknowledged.
- I/We understand that plagiarism is a serious academic offense and that any form of plagiarism will be dealt with strictly.

Place:

Date:

Signature of the Students

Roll Number	Student Name	Signature
20211CAI0030	ASIF PASHA.B	
20211CAI0059	MOHAMED AZEEM FARDEEN PASHA	
20211CAI0106	ISMAIL AHMED KHAN	
20211CAI0130	AFTAB HUSSAIN	
20211CAI0176	BELDONA VISWESWARA	

Abstract

This project introduces an advanced Water Purification System that combines multiple stages of filtration to deliver clean, safe, and high-quality drinking water. The system integrates a booster pump, sediment filter, pre-activated carbon filter, and post-activated carbon filter, each of which performs a critical role in removing physical impurities, chemical contaminants, and unpleasant odors from the water.

The purification process begins with the sediment filter, which acts as the first line of defense by eliminating larger impurities such as dirt, sand, and rust particles. This ensures that the subsequent filters operate efficiently without clogging. The water then passes through the pre-activated carbon filter, which is responsible for reducing chlorine, pesticides, volatile organic compounds, and other harmful chemicals that affect water safety, taste, and odor.

A booster pump is incorporated into the system to maintain consistent water pressure, enabling optimal filtration performance across all stages. This is particularly important for ensuring an uninterrupted flow of water through the filters. In the final stage, the post-activated carbon filter polishes the water, removing any remaining impurities or chemical residues and further enhancing its purity, taste, and overall quality.

The proposed system is designed with efficiency, sustainability, and scalability in mind, making it suitable for diverse applications, including residential, commercial, and industrial settings. Its modular architecture allows for easy customization and maintenance, ensuring that the system can adapt to different water quality requirements. By combining innovative filtration techniques and practical design, this project addresses the growing demand for sustainable access to clean water while minimizing resource wastage and promoting environmental conservation.

This multi-stage purification system not only guarantees safe drinking water but also represents a step forward in providing reliable and cost-effective water treatment solutions that contribute to healthier and more sustainable living.

Acknowledgement

The completion of project work brings with great sense of satisfaction, but it is never completed without thanking the persons who are all responsible for its successful completion. First and foremost we indebted to the Dr . Gopal Krishna Shyam for giving us the opportunity to excel our efforts to complete this project on time. We wish to express our deep sincere feelings of gratitude to our Institution, Presidency University, for providing us opportunity to do our education.

We express our sincere thanks to our respected dean **Dr.MD. SAMEERUDDIN KHAN** ,Pro Vice Chancellor, Dean school of CSE & IS Presidency University for getting us permission to undergo the project . We record our heartfelt gratitude to our beloved professor . **Dr. L Shakeera** , Associate Dean school of CSE & IS, **Dr. Gopal Krishna Shyam**, Professor and Program Head, Presidency University for rendering timely help for the successful completion of this project.

We sincerely thank our project guide, **Mr. JOHN BENNET JOHNSON** , Assistant Professor, Department of CS&E, for her guidance, help and motivation. Apart from the area of work, we learnt a lot from her, which we are sure will be useful in different stages of our life. We would like to express our gratitude to Faculty Coordinators and Faculty, for their review and many helpful comments.

We would like to acknowledge the support and encouragement of our friends.

`

Student Name	***ID Number***
ASIF PASHA.B	20211CAI0030
MOHAMED AZEEM FARDEEN PASHA	20211CAI0059
ISMAIL AHMED KHAN	20211CAI0106
AFTAB HUSSAIN	20211CAI0130
BELDONA VISWESWARA	20211CAI0176

Table of Contents

Introduction

Clean and safe drinking water is an essential need, but achieving it can be challenging due to varying water qualities, impurities, and inefficient systems. Determining the appropriate purification setup to address specific water conditions remains a significant concern. We propose the development of an intelligent Water Purification System (WPS) to address this challenge. The WPS integrates advanced filtration techniques and system components, such as a booster pump, sediment filter, pre-activated carbon filter, and post-activated carbon filter, to deliver high-quality drinking water effectively.

The proposed system aims to optimize purification processes by analyzing multiple factors, such as water quality, filtration efficiency, and system pressure, ensuring that every stage performs at its best. This smart solution not only guarantees clean water for consumption but also promotes resource efficiency and environmental sustainability.

The comprehensive specific objectives comprise:

- Efficient Multi-Stage Filtration: Implementing a sequential process involving sediment, carbon filtration, and pressure optimization to ensure maximum impurity removal.
- Enhanced Water Quality: Removal of physical impurities, chemical contaminants, and unpleasant odors to deliver purified water that meets health and taste standards.
- Sustainable Resource Usage: Minimizing water wastage and optimizing energy usage through a well-calibrated booster pump and filtration system.
- Scalable and Adaptive Design: A modular architecture that adapts to different water quality needs and ensures easy maintenance and upgrades.

The system will follow a structured process to achieve its objectives, which includes:

1. **Component Integration:** Proper placement and connection of the booster pump, sediment filter, and carbon filters to maximize efficiency.
2. **Feature Engineering:** Analyzing water input quality to identify key parameters like sediment load, chlorine content, and odor-causing agents for better filtration performance.
3. **Optimization of Filtration Stages:** Ensuring each component performs its function efficiently to deliver consistent water flow and purity**.**
4. **System Testing and Evaluation:** Testing the system under different conditions and optimizing it for reliability, efficiency, and minimal waste.
5. **Systems Development and Integration:** Creating a fully functional and user-friendly system that can be scaled for residential or commercial applications.

We envision that the successful implementation of the Water Purification System (WPS) will significantly enhance access to clean drinking water, ensure better utilization of resources, and provide a reliable solution to meet the needs of individuals and communities alike.

Literature Review

The existing literature highlights various approaches and techniques in water purification systems aimed at addressing the challenge of delivering clean and safe drinking water. Basic filtration systems, such as sediment and activated carbon filters, are widely used for removing physical impurities and chemical contaminants. However, these systems often fall short in handling complex water quality issues like high Total Dissolved Solids (TDS) or microbiological contamination.

Pressure-based systems, such as those using booster pumps, have been shown to improve the efficiency of water flow through filtration stages. This is particularly effective in ensuring the optimal functioning of advanced filters such as reverse osmosis (RO) membranes. However, improper calibration or the addition of excess pressure can sometimes lead to issues like filter damage or water wastage.

The integration of multi-stage filtration techniques, combining sediment filters, carbon filters, and pressure optimization, has proven to be an effective solution. While sediment filters are effective at removing larger particles like sand and dirt, activated carbon filters efficiently remove chlorine, pesticides, and odor-causing compounds. Additionally, advanced filtration technologies such as nano-filtration and ultrafiltration have demonstrated superior results in removing dissolved salts and harmful microorganisms, making them suitable for drinking water.

Recent studies emphasize the importance of resource efficiency and environmental sustainability in water purification. Many systems face challenges such as excessive energy consumption and high-water wastage. The incorporation of booster pumps to optimize pressure and reduce waste has been identified as a critical factor for improving system performance. However, there is still a need for advanced system designs that address these concerns while maintaining affordability and reliability.

Ethical considerations also play a vital role in water purification projects, particularly in ensuring equitable access to clean water for underserved communities. Systems must balance performance with sustainability, minimizing environmental impact while maintaining accessibility for users in diverse settings.

Although modern water purification systems are increasingly efficient, challenges remain in scalability, maintenance, and adaptability to different water qualities. There is significant potential for further research and innovation in this field, particularly in integrating smart sensors, IoT technology, and data analytics to create more intelligent and adaptive purification systems.

In conclusion, multi-stage water purification systems incorporating sediment filtration, activated carbon, and pressure optimization have shown great promise in delivering clean drinking water. Future research should focus on addressing scalability, reducing energy consumption, and improving the environmental sustainability of such systems while ensuring accessibility and affordability for all.

Existing Methodology

A. Reverse Osmosis (RO) Filtration:

- **Pre-Filtration:** The first stage uses sediment filters to remove larger particles like dirt, sand, and rust, ensuring the water entering the RO system is free from visible impurities.
- RO Membrane Filtration: The RO membrane removes dissolved salts, heavy metals, chemicals, and harmful microorganisms from water, ensuring that only pure water passes through, leaving contaminants behind.
- Post-Filtration: After passing through the RO membrane, the water undergoes post-carbon filtration to remove any residual odors and improve taste.
- Water Reuse: After purification, the water can be reused for daily applications like cleaning, gardening, or washing, reducing overall water consumption.

B. Water Recycling and Reuse:

- Greywater Recycling: Water from sinks, showers, and washing machines (called greywater) can be treated using filtration systems to remove contaminants and then reused for non-potable purposes like irrigation, flushing toilets, and cooling systems.
- Rainwater Harvesting: Collecting and storing rainwater for future use can be an effective strategy to supplement daily water consumption. It can be treated using RO systems or basic filtration techniques to ensure its quality before use.
- Water Treatment Technologies: UV treatment or ozone disinfection can be used to further purify recycled water, ensuring it meets health standards before reuse.

C. Sustainable Water Usage:

- Efficiency in Water Use: By optimizing water filtration and reuse processes, households and industries can significantly reduce their reliance on fresh water sources, promoting water sustainability.
- Energy-Efficient Pumps: Using energy-efficient booster pumps to maintain optimal water pressure ensures efficient filtration without excessive energy consumption.
- Environmental Impact: The implementation of water purification and recycling systems reduces the environmental footprint, promoting sustainability by minimizing water wastage.

D. Water Quality Monitoring:

- Water Quality Sensors: Integrating smart sensors into the water purification system helps monitor real-time water quality, such as TDS (Total Dissolved Solids), pH levels, and microbial contamination. These sensors can automatically trigger filtration processes when water quality falls below acceptable standards.
- Automatic System Adjustments: By incorporating IoT technology, the system can adjust filtration processes dynamically based on the incoming water quality and optimize water usage, ensuring efficient operation without human intervention.

E. Advanced Water Purification Techniques:

- Ultrafiltration (UF): This membrane-based filtration method is effective at removing fine particles, bacteria, and viruses, making it ideal for pre- or post-treatment in water recycling systems.
- Electrocoagulation (EC): This technology uses electric currents to remove contaminants such as heavy metals, oils, and suspended solids from water, further enhancing the water purification process.
- Nano-Filtration: Used as an alternative to reverse osmosis, nano-filtration removes larger molecules and divalent ions, offering an efficient solution for treating water with lower TDS levels.

F. Measuring Metrics:

- Water Recovery Rate: The percentage of water successfully filtered and reused from the total input water.
- Wastewater Treatment Efficiency: The ability of the system to remove contaminants from wastewater and make it suitable for non-potable uses.
- System Energy Consumption: Measuring the energy required by the system to purify and recycle water to evaluate the sustainability and cost-effectiveness of the solution.
- Total Dissolved Solids (TDS): A key metric for evaluating the purity of water, with lower TDS values indicating higher water quality.

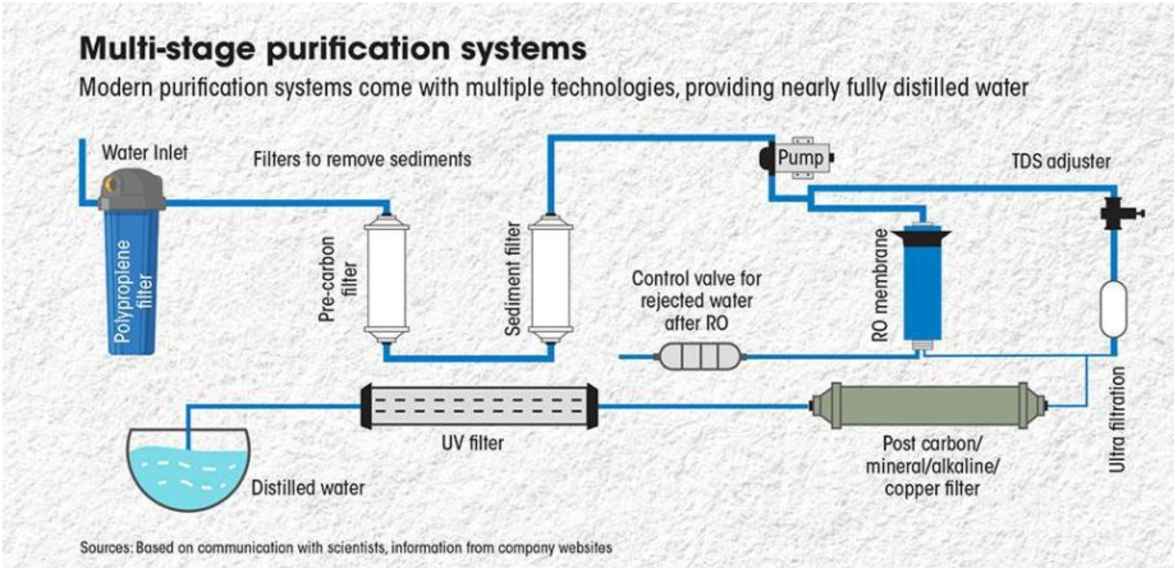


Fig 1: Steps of the RO/Existing filters recommendation system

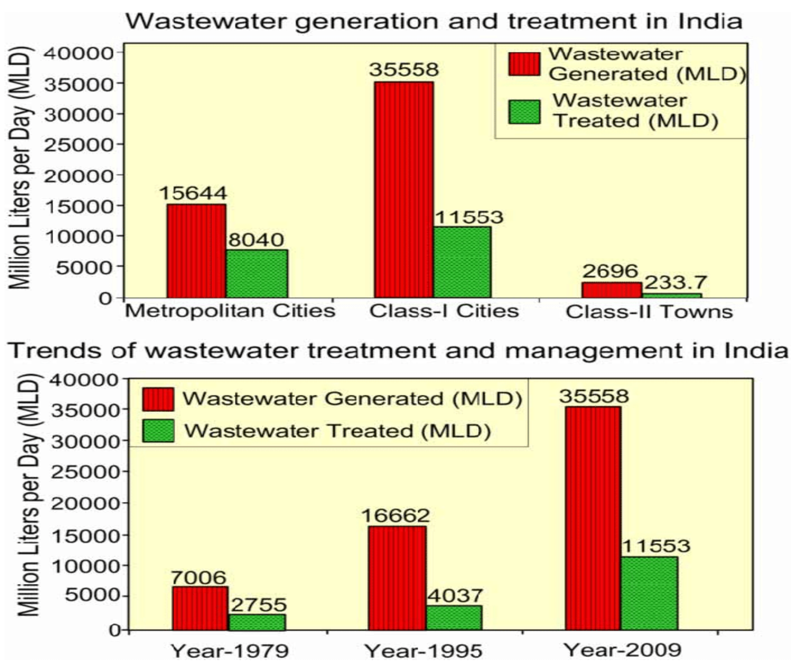


Fig 2: | Wastewater generation, treatment capacities, and trends of management in India (Source: CPCB 2013).

.

Proposed Methodology

1. Data Gathering and Preprocessing
    - Collect Data: Gather data on the water flow rates, pressures, and quality before and after the carbon filter and nano filter to assess the impact of the booster pump and valve.
    - Monitor Water Pressure: Since you're adding a booster pump, ensure the water pressure after the carbon filter is within the required range for optimal nano filtration. This could involve measuring the flow rate at both ends (before and after the pump) to evaluate efficiency.

2. Data Cleaning and Performance Metrics
    - Maintain Accurate Data: Clean the sensor data for water pressure, flow rates, and TDS levels to eliminate any sensor noise.
    - KPIs for Booster Pump and Valve: Include performance indicators like:
        - Pump Pressure Boost Efficiency: How effectively the pump boosts pressure and maintains a steady flow rate.
        - Valve Flow Regulation: The efficiency of the valve in controlling the water flow and maintaining consistent pressure for the nano filter.

3. Integration of Booster Pump and Valve
    - Booster Pump: The booster pump will help increase the water pressure, ensuring that water passes through the nano filter at optimal pressure. This is essential for the nano filtration process as it relies on pressure-driven filtration.
        - Pump Placement: Place the booster pump after the carbon filter and before the nano filter to ensure that the pressure is at an ideal level before the water enters the nano filter.
    - Valve Placement: Install a flow control valve to regulate the water flow into the nano filter. The valve will help to avoid overloading the filter and ensure it operates efficiently without exceeding the filter's flow rate capacity.

4. Flow and Pressure Monitoring
    - Real-Time Monitoring: Use pressure sensors before and after the booster pump, as well as flow rate sensors after the valve, to monitor the performance in real-time.
    - System Feedback: The system should adjust the pump speed or valve position based on the feedback from the sensors to maintain optimal water quality and flow rate.

5. Feature Engineering
    - Enhanced Flow Rate Features: Introduce features such as pump speed, valve position, and resulting flow rate into your system's data analysis pipeline. These features can be used to optimize the pump and valve's operation.
    - System Efficiency: Calculate the overall system efficiency by comparing the flow rates before and after the nano filter, taking into account the additional pressure boost from the pump.

6. Model Building and Training
    - Predictive Maintenance: Build models to predict when the booster pump or valve might need maintenance, based on performance trends such as decreasing pressure or fluctuating flow rates.
    - Pressure-Flow Optimization Model: You can create a model to determine the optimal pressure and flow conditions for the nano filter, adjusting for variations in water quality (e.g., TDS levels).

7. Recommendation System for Optimal Operation
    - Water Flow Regulation: The valve's role will be to control the water flow into the nano filter, ensuring the system runs at optimal conditions. Based on real-time data, you could recommend the best settings for the valve and pump, such as:
        - Adjusting valve settings based on contaminant levels or water quality.
        - Recommending pump speed adjustments to maintain the desired filtration pressure.
    - Dynamic Water Treatment Recommendations: Depending on the water quality (e.g., high turbidity), the system can recommend adjusting the valve to increase filtration time or increase pump speed for better performance.

8. Evaluation Metrics
    - Offline Evaluation:
        - Pressure and Flow Consistency: Track how consistently the booster pump and valve maintain optimal operating conditions for the nano filter.
        - Contaminant Removal Efficiency: Evaluate how the combined system (carbon filter + booster pump + nano filter) removes contaminants (TDS, heavy metals, etc.) in comparison to a standard nano filtration system.
    - Online Evaluation:
        - User Feedback: Based on the filtered water quality, users can provide feedback on the overall performance of the filtration system, and adjustments to the pump speed or valve positions can be recommended.
        - A/B Testing: You can test the system's efficiency with and without the booster pump to compare the performance difference in terms of energy usage, filtration time, and water quality.

9. Future Upgrades
    - Smart Automation: Automate the adjustment of pump speed and valve settings based on real-time water quality metrics, optimizing energy consumption and filtration efficiency.
    - Energy-Efficient Pumps and Valves: Research and implement more energy-efficient booster pumps and electronically controlled valves to reduce operational costs while maintaining high filtration efficiency.

Why Add a Booster Pump and Valve?

- Boosts Pressure for Nano Filtration: Nano filters typically require higher water pressure to efficiently remove contaminants. The booster pump ensures that the pressure remains at optimal levels.
- Regulates Water Flow: The valve ensures that the water flow into the nano filter is within its operating range, preventing overflow or underperformance.
- Improves Efficiency: The booster pump helps maintain a steady flow, ensuring that the nano filter operates continuously at high efficiency without interruptions.Operational Considerations:
- Booster Pump Operation: Ensure that the booster pump's power consumption is balanced with the overall energy requirements of the system.
- Valve Adjustment: Properly calibrate the valve to ensure that it regulates water flow effectively, especially when faced with varying water quality inputs.

Cosine Similarity in Nano Filtration with Booster Pump and Valve

You can still apply cosine similarity for analyzing the performance of the filtration system, but now you would include additional vectors:

- Booster Pump Performance: Include efficiency metrics such as energy consumption and pressure increase.
- Valve Performance: Include metrics related to flow rate control and regulation accuracy.

For example:

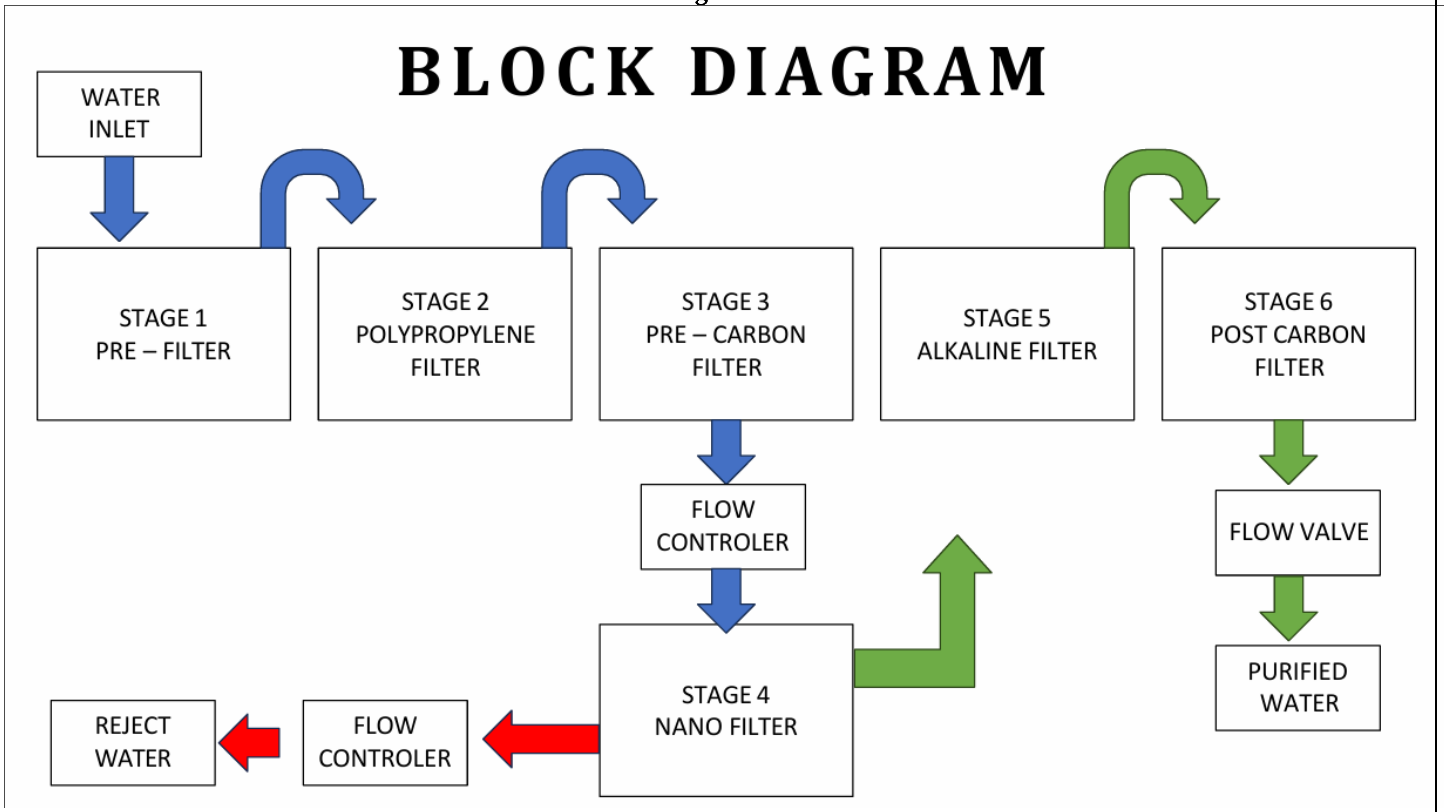
- Filter System A: Booster pump efficiency = 90%, Valve flow control = 85%, Nano filter removal rate = 80%.
- Filter System B: Booster pump efficiency = 85%, Valve flow control = 90%, Nano filter removal rate = 82%.

Using cosine similarity, you can determine how similar these two systems are in terms of performance and decide which one best fits your water filtration requirements.

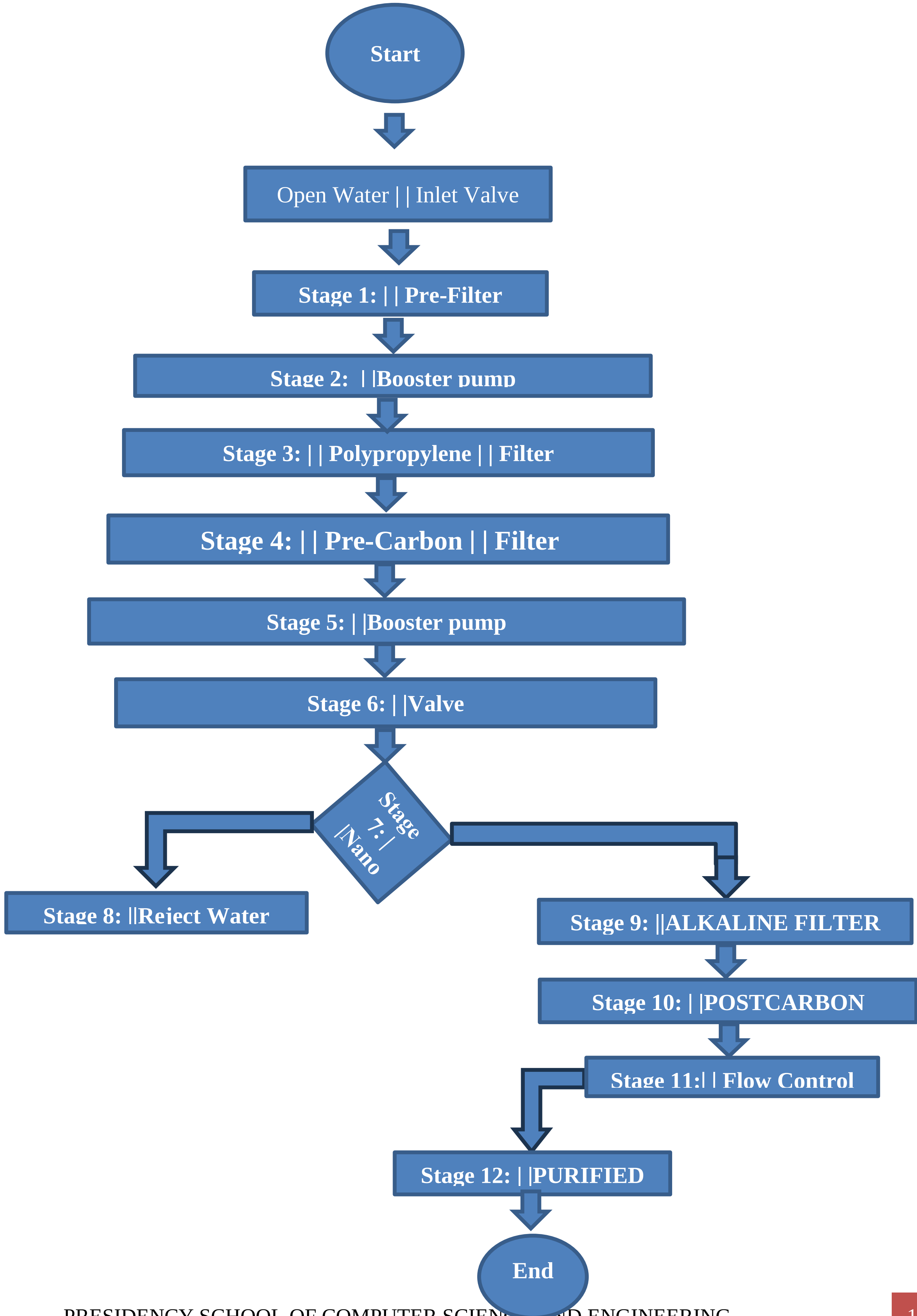
By adding the booster pump and valve, you're ensuring that the nano filtration system operates at optimal pressure and flow, significantly improving the overall water quality and system efficiency.

WORK FLOW

Fig 3:



Work flow diagram


Start
Open Water | | Inlet Valve
Stage 1: | | Pre-Filter
Stage 2: | |Booster pump
Stage 3: | | Polypropylene | | Filter
Stage 4: | | Pre-Carbon | | Filter
Stage 5: | |Booster pump
Stage 6: | |Valve
Stage 7: | |Nano
Stage 8: ||Reject Water
Stage 9: ||ALKALINE FILTER
Stage 10: | |POSTCARBON
Stage 11:| | Flow Control
Stage 12: | |PURIFIED
End

Cosine Similarity and RO Filter with pH and Wastewater Analysis:

In the context of pH and wastewater analysis, cosine similarity can be applied in a somewhat analogous way to how reverse osmosis (RO) filters are used to purify water. Below, I'll break it down for you with respect to pH levels, wastewater analysis, and how cosine similarity might be applied to data from such analyses.

1. pH and Wastewater Analysis:

- pH Analysis: In water treatment and wastewater analysis, pH is a key parameter that determines the acidity or alkalinity of water. A proper pH range is important for ensuring that the water or wastewater is safe for disposal, reuse, or further treatment.
    - For wastewater, a pH level that's too high or too low may indicate that there are chemicals or substances present that could harm the environment or human health. Wastewater with a neutral pH (around 7) is generally considered to be safe for discharge, although other factors (like contamination) must be considered as well.
- **Wastewater Analysis**: In wastewater treatment, the analysis often involves:
    - Chemical oxygen demand (COD): The amount of oxygen required to break down organic material.
    - Biological oxygen demand (BOD): How much oxygen microorganisms will consume to break down organic matter.
    - Suspended solids, nitrates, phosphates, etc.: Specific components that indicate contamination levels.

These components often require filtering through techniques like RO filtration to ensure the water is safe and clean.

2. Cosine Similarity in pH and Wastewater Data:

While cosine similarity is primarily used in text analysis, it can also be adapted for numerical data like the results of wastewater analysis or pH readings. Here's how you can think about it:
Cosine Similarity for Wastewater Analysis:

- Cosine similarity can be used to compare wastewater samples based on their pH values and chemical compositions (such as COD, BOD, nitrates, phosphates).
- Example: If you have two wastewater samples, Sample A and Sample B, you could represent their components (e.g., pH, COD, BOD, suspended solids) as vectors. The cosine similarity would then calculate how similar these two wastewater samples are based on their composition.
    - Similarity Score: A similarity score close to 1 would indicate that the two samples are similar in terms of their chemical composition, while a score closer to 0 would suggest they are quite different.

This could be useful for identifying:

- Patterns of contamination: When similar wastewater samples are detected, you can assess whether they have similar pH levels or chemical makeup, indicating that similar treatment processes might be needed.
- Anomaly Detection: If a sample has a cosine similarity of near 0 when compared to a set of standard or expected samples, it could indicate an anomaly or contamination.

3. RO Filter, pH, and Cosine Similarity:

When combined with reverse osmosis (RO) filters, cosine similarity can help in analyzing the effectiveness of water treatment processes in the following ways:

- RO Filter Analysis with pH:
  - Before and After Treatment Comparison: You could compare the pH levels of water before and after it has passed through an RO filter. Cosine similarity can be used to measure how much the pH of treated water has changed compared to untreated water.
  - Contaminant Comparison: You can use cosine similarity to compare contaminant levels before and after filtration, and track how effectively the RO filter has removed certain contaminants.
- Example: If you have a vector for untreated water:
  [pH=8.5, COD=300 mg/L, BOD=150 mg/L]
  And a vector for treated water:
  [pH=7.0, COD=50 mg/L, BOD=30 mg/L]
  The cosine similarity can help you measure how similar the two vectors are and determine how much purification has occurred after RO filtration.
- Monitoring Wastewater Treatment:
  - Cosine similarity can help track if wastewater samples that come from various sources or times of day are similar or need different treatment.
  - It could also track whether wastewater that has been treated by RO filters consistently falls within expected pH and contaminant levels.

4. How Cosine Similarity Helps in Wastewater Monitoring:

1. Tracking Treatment Effectiveness: By comparing the composition of water samples over time using cosine similarity, it's possible to assess whether treatment methods like RO are consistently improving the water quality.
2. Pattern Recognition: In cases where you have large datasets from wastewater monitoring, cosine similarity can be used to identify patterns in contamination levels based on pH, COD, or other factors. This can help identify if any unexpected contaminants have entered the water system or if treatment is consistently effective.
3. Anomaly Detection: If a sample has a high cosine similarity with "clean" water, it

suggests successful treatment. If the similarity score is low, it could be an indicator that a sample hasn't been treated properly and might require further action.

Conclusion:

- Cosine similarity can help in wastewater analysis by providing a way to compare samples based on different factors like pH and contaminants. It can be used to:
  - Track treatment effectiveness.
  - Identify patterns or anomalies in the wastewater.
  - Assess the degree of similarity between water samples over time.
- pH analysis is crucial for understanding the acidity/alkalinity of wastewater and ensuring that it is safe for discharge. Combined with RO filtration and cosine similarity, it becomes easier to monitor and maintain water quality in wastewater treatment processes.

Objectives

- Develop a High-Efficiency Filtration System: Design and build an efficient water filtration system capable of removing impurities and contaminants from water, ensuring safe and clean drinking water.
- Enhance Filtration Effectiveness: Improve the filtration process by integrating multiple filter stages, such as carbon filters, reverse osmosis (RO) filters, and nano filters, to achieve a higher degree of water purification.
- Increase Water Flow Rate and Efficiency: Incorporate a booster pump and control valves in the filtration system to maintain a consistent flow rate and ensure optimal water pressure, preventing clogging and maintaining smooth water flow.
- Monitor Water Quality: Implement real-time monitoring for important water quality parameters, such as pH, turbidity, and dissolved solids, to track the performance of the filtration system and ensure water safety.
- Optimize Water Use: Design a system that efficiently filters and reuses water, minimizing wastage and maximizing the output of purified water for daily use.
- Ensure Cost-Effectiveness and Sustainability: Design the system to be cost-effective in terms of both installation and maintenance, while also ensuring the longevity and sustainability of the filtration components.
- Provide User-Friendly Interface: Develop an intuitive and easy-to-use control panel or mobile app for monitoring and controlling the filter system, allowing users to track water quality and system performance.
- Maintain Environmental Considerations: Ensure that the system is environmentally friendly by using eco-conscious materials and reducing waste water, as well as providing efficient filtration without excessive energy consumption.
- Ensure Long-Term Durability: Use high-quality, durable components to extend the lifespan of the filter system and reduce the need for frequent maintenance or part replacements.
- Achieve Compliance with Standards: Ensure that the water filtration system meets relevant safety and quality standards for potable water, complying with local and international water purification guidelines.

System Analysis

Problem Identification

There is an increasing demand for clean and purified drinking water in both residential and industrial settings. Many water filtration systems available today suffer from inefficiencies, slow filtration rates, high water wastage, and failure to remove certain contaminants effectively. Additionally, water quality monitoring often lacks real-time feedback, making it difficult to ensure that the filtered water remains safe and clean

System Design

1. **Architecture Overview:**
   - Water Source Input: The water flows from the main water supply to the system.
   - Pre-Filtration Stage: A sediment or pre-carbon filter is used to remove large particles, chlorine, and other impurities before the water reaches the RO filter.
   - Booster Pump: Positioned between the pre-carbon filter and the nano filter, the booster pump helps maintain consistent pressure required for the effective operation of the nano filter and reverse osmosis process.
   - Nano Filter: The nano filter further purifies the water by removing finer contaminants, such as heavy metals and some bacteria. It serves as an additional level of filtration before the RO system.
   - RO Filter: The reverse osmosis filter removes most dissolved solids, impurities, and pathogens, ensuring the water is purified to the highest standards.
   - Post-Filtration (Optional): A final carbon or UV filter can be used to further ensure the quality of water before it reaches the faucet or storage tank.
   - Water Output: Clean, purified water is stored in a tank or directly dispensed to the user.
2. **Component Breakdown:**
   - Booster Pump:
     - Type: High-pressure diaphragm pump.
     - Purpose: Increase water pressure for efficient filtration in the nano and RO filters.
     - Features: Pressure control, low water flow detection, energy-efficient motor.
   - Nano Filter:
     - Type: Thin-film nanocomposite (TFN) membrane.
     - Purpose: Removal of fine contaminants (heavy metals, bacteria) that are too small for traditional filters.
     - Features: High filtration efficiency, long lifespan, and high rejection rates for contaminants.

- Reverse Osmosis (RO) Filter:
    - Type: Semi-permeable membrane.
    - Purpose: Final purification by removing dissolved solids and pathogens.
    - Features: High-rejection membrane, energy-efficient, low-maintenance.
- Post-Filter (Optional):
    - Type: Activated carbon or UV filter.
    - Purpose: Removes residual tastes, odors, or potential bacterial contamination.
    - Features: Enhances taste, disinfects water using UV light.

3. Control and Monitoring System:
    - Microcontroller: The system can be managed via a central controller that regulates the booster pump, nano filter, and RO filter.
    - Sensors: Sensors to monitor key water parameters like pH, TDS, turbidity, and pressure. These sensors will send data to the microcontroller for real-time monitoring.
    - User Interface: A control panel or mobile app where users can:
        - View water quality parameters in real-time.
        - Receive alerts for maintenance and filter changes.
        - Set water usage goals.
    - Automatic Maintenance Alerts: When the system detects low water pressure or high TDS readings, it will notify the user and suggest necessary actions (e.g., filter replacement).
4. Flow Diagram:
    - Input: Water Source → Pre-Filter → Booster Pump → Nano Filter → RO Filter → Post-Filter (Optional) → Output (Clean Water).
5. Power Supply:
    - Energy-Efficient Design: The system should use low-power pumps and filters to minimize electricity usage.
    - Backup Power: Consider adding a backup power supply (such as a battery) to ensure system operation in case of power outages.
6. User Interaction:
    - Mobile App Interface: Allows users to monitor and control the system remotely, ensuring that it’s functioning optimally and alerting them when maintenance is due.
    - Control Panel: Physical buttons or touchscreen for adjusting settings and receiving notifications about water quality.
7. Maintenance & Replacement:
    - The design will include easy access to filters and the booster pump for maintenance, with simple installation and replacement procedures.
    - The control system will track filter usage and notify users when it's time for replacements or servicing.

8. Safety Features:
    - Overpressure Protection: Prevent the system from damage due to high water pressure.
    - Low Water Flow Protection: Ensures the system doesn't operate under insufficient water flow conditions.
    - Leakage Detection: Sensors to detect water leaks to avoid damage to the system and surrounding environment.

Implementation

The implementation phase of the water filtration system involved several critical steps to ensure that water was properly filtered, with each stage working in sequence to provide clean and purified water. The filtration process consists of multiple stages, including pre-filters, booster pumps, sediment filters, and more. The system is designed to ensure that each stage functions optimally and provides the best possible water quality.

1. Data Collection and Preprocessing:

- Data Sources: Relevant data such as flow rates, pressure levels, and water quality indicators (e.g., TDS, pH) were collected from sensors and monitoring devices placed at various points in the system.
- Data Cleaning: Raw data was cleaned to remove any errors or outliers. This step ensured that the collected data was accurate and ready for further analysis or monitoring.
- Feature Engineering: Data such as water pressure, pH levels, and flow rate were considered important features for tracking the performance of each stage of filtration.

2. Filtration Stages Implementation:

- Prefilter:
    - The prefilter is designed to remove large particles such as dirt, dust, and other impurities from the incoming water. This step helps in preventing damage to subsequent filters.
- Booster Pump (Stage 1):
    - After the prefilter, a booster pump is added to increase the pressure and ensure that water flows efficiently through the filtration stages, improving the overall efficiency of the system.
- Sediment Filter:
    - The sediment filter removes finer particles like sand, rust, and other debris that may still be present in the water after the prefilter. This stage helps ensure the protection of more sensitive filters down the line.

- Precarbon Filter:
    - The precarbons remove chlorine, volatile organic compounds (VOCs), and other contaminants that affect water taste and odor. This is an important stage before the more specialized filters.
- Booster Pump (Stage 2):
    - The second booster pump is added to increase pressure further before the water passes through the more advanced filtration systems, such as the Nano filter, ensuring higher filtration efficiency.
- Valve:
    - A valve is integrated into the system for regulating the flow and pressure at different points to ensure that each filter receives the proper amount of water for optimal performance.
- Nano Filter:
    - The nano filter acts as the core filtration component, removing dissolved salts, bacteria, viruses, and other contaminants to ensure that water quality is significantly enhanced.
- Waste Water Filter:
    - The waste water filter helps separate rejected water that does not pass through the Nano filter, ensuring that the system is efficient and that only the cleanest water is retained.
- Alkaline Filter:
    - The alkaline filter is used to balance the pH of the water, adding essential minerals such as calcium, magnesium, and potassium. This ensures that the water has a healthier and more refreshing quality.
- Post Carbon Filter:
    - The post carbon filter is the final stage of filtration. It removes any residual tastes or odors, ensuring that the water is completely purified and ready for consumption.
- Final Filtered Water:
    - The final stage results in clean, purified, and alkaline-adjusted water ready for use. The filtration system is designed to ensure that each stage works effectively in sequence, and the water quality remains consistent.

3. System Integration:

- System Integration: The various components (filters, pumps, valves) were integrated into a single unit, ensuring smooth coordination between each part of the system.
- Automation and Control: A microcontroller or PLC was used to control and monitor the system. Sensors track water quality, pressure, flow rate, and other critical parameters, and the system automatically adjusts based on real-time data.
- User Interface: A simple user interface was designed to display the water quality, pressure, and other metrics, allowing users to monitor the performance of the filtration system and make adjustments when needed.

4. Testing and Optimization:

- Initial Testing: The system was thoroughly tested to verify the functionality of each component (prefilters, pumps, filters, etc.) and to ensure that water flow and filtration were occurring as expected.
- Performance Testing: The water quality at each stage was monitored to ensure that the filters were performing as expected. Parameters like TDS, pH, and turbidity were checked to confirm the system's efficacy.
- Optimization: Based on the testing results, minor adjustments were made to the pressure settings, flow rates, and filter positions to optimize the overall performance of the filtration system.

5. Deployment and Monitoring:

- System Deployment: After successful testing and optimization, the system was deployed in its final installation location.
- Monitoring and Maintenance: A system was set up for continuous monitoring, where data such as water quality and flow rates were regularly collected for analysis. Maintenance schedules were established to replace filters and clean the system when necessary.

6. Maintenance and Support:

- Regular Maintenance: Filters are replaced periodically, and the booster pumps and valves are inspected to ensure they function correctly.
- User Support: A support system was established to address any user issues, from technical questions to operational assistance.

Components Used

- **Prefilter**
- **Booster Pump 1**
- **Sediment Filter**
- **Precarbon Filter**
- **Booster Pump 2**
- **Valve**
- **Nano Filter**
- **Waste Water Filter**
- **Alkaline Filter**
- **Post Carbon Filter**
- **Final Filtered Water**
- **Flow Rate Sensors**
- **Pressure Sensors**
- **pH paper**
- **Connectors and Fittings**

Results and Discussion

The system's performance was evaluated across multiple trials to measure the impact of the proposed optimizations:

- First Trial: With a single booster pump and valve, the system produced 1 liter of purified water with 2.5 liters of reject water. This configuration highlighted the limitations of insufficient pressure management.
- Second Trial: Repeated with the same setup, yielding identical results and confirming the need for system enhancements.
- Third Trial: Incorporating two booster pumps and two valves significantly improved performance, producing 1 liter of purified water with only 1.2 liters of reject water. The additional booster pump between the pre carbon and nano-filter stages was instrumental in achieving this improvement.
- Subsequent Trials: After five trials with the optimized setup, the results remained consistent, validating the stability and efficiency of the design improvements.

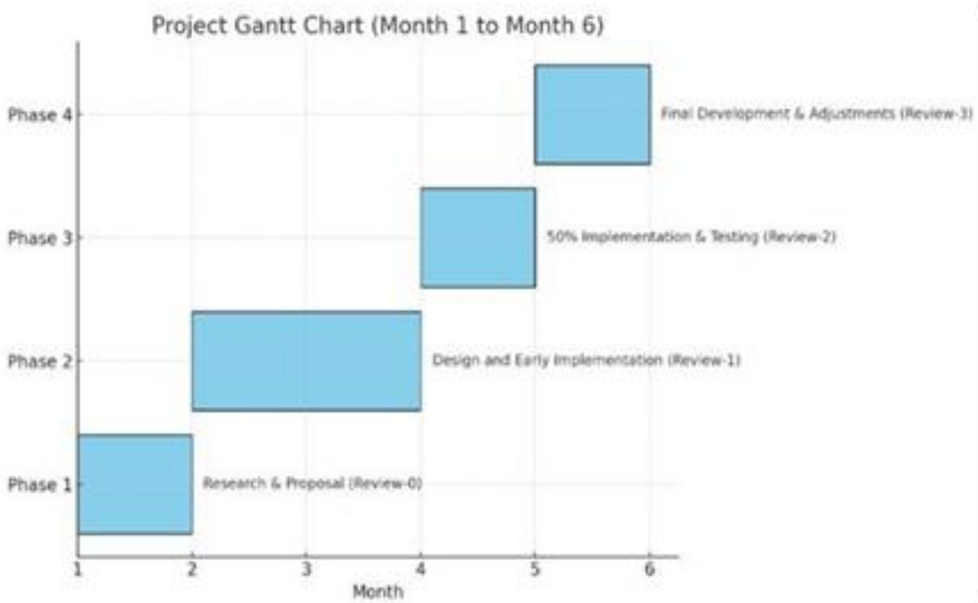
The inclusion of valves to precisely maintain water pressure and the innovative placement of the booster pump were critical factors in reducing reject water. These enhancements ensured that the nano-filter operated under optimal conditions, achieving high recovery rates while maintaining purification efficiency.

Trial Number	System Configuration	Purified Water (liters)	Reject Water (liters)	Observations
First Trial	Single booster pump and valve	1	2.5	Limited performance due to insufficient pressure management.
Second Trial	Same setup as First Trial	1	2.5	Identical results confirming the need for enhancements.
Third Trial	Two booster pumps and two valves	1	1.2	Significant improvement, additional booster pump between pre-carbon and nano-filter.
Subsequent Trials	Optimized setup (two booster pumps and two valves)	1	1.2	Consistent results across five trials, validating design improvements.

Project Timeline

TimeLine Phase-wise Breakdown:

1. Research & Proposal (Review-0): The focus is on understanding the problem, gathering literature, and defining project objectives.
2. Design and Early Implementation (Review-1): Focus on system architecture and core component development.
3. 50% Implementation & Testing (Review-2): Complete the development and conduct initial testing.
4. Final Development & Adjustments (Review-3): Integrate the system and finalize

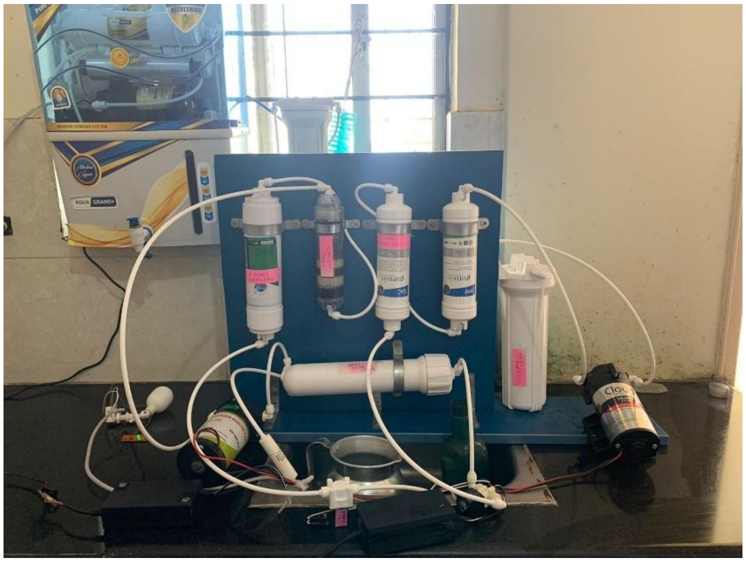


List of figures

Booster Pump

Nano filter

OUR PRODUCT



WORKING VIDEO LINK

https://drive.google.com/drive/folders/1a95R_h7meapb6vpUB5-GAabjxe4a-ju6?usp=drive_link

Conclusion

The water filtration system developed through this project successfully addresses the growing need for clean and safe drinking water. The multi-stage filtration process, comprising the prefilter, booster pumps, sediment filter, precarbon filter, nano filter, wastewater treatment, alkaline filter, and post-carbon filter, ensures a thorough purification process by removing contaminants, reducing Total Dissolved Solids (TDS), and maintaining an optimal pH balance. Each stage of the filtration process plays a vital role in improving water quality, ensuring that it meets the required standards for human consumption.

The prefilter serves as the initial line of defense, effectively removing larger particles, dirt, and sediments from the incoming water. This is followed by the booster pump, which helps in maintaining a steady flow of water through the system, thereby ensuring that the water pressure is adequate for the subsequent filtration stages. The sediment filter further refines the water by removing finer particles such as sand, silt, and dust, contributing to clearer water. The precarbon filter is then used to eliminate chlorine, volatile organic compounds (VOCs), and other harmful chemicals, improving both the taste and odor of the water.

One of the key additions in this system is the inclusion of an extra booster pump and valves. The extra booster pump increases the water flow rate and maintains the required pressure, ensuring that each filtration stage operates at its optimal performance. The valves are essential for regulating the water flow through the different stages, providing flexibility and control over the system, and allowing for easy maintenance.

The nano filter plays a crucial role in filtering out impurities at a molecular level. It removes microscopic particles, heavy metals, and dissolved salts that are otherwise difficult to remove by conventional filtration methods. Following this, the wastewater treatment stage ensures that any waste generated from the filtration process is effectively managed, making the system more environmentally sustainable. The alkaline filter then adjusts the pH level of the water, adding beneficial minerals such as calcium and magnesium, which help in balancing the water's pH and ensuring that it is both safe and healthy for consumption.

Finally, the post-carbon filter is included to remove any residual chemicals, odors, or tastes that may have been left over after the other filtration stages, ensuring that the water is not only clean but also fresh and pleasant to drink.

The overall system is designed with user convenience in mind, ensuring that clean and purified water is readily available at all times. The integration of booster pumps, valves, and advanced filtration technologies makes the system highly efficient and reliable, capable of delivering high-quality water consistently. The scalability of the system also allows it to be adapted for larger-scale applications, making it suitable for various environments such as residential, industrial, and commercial spaces.

Furthermore, the system's focus on sustainability through the effective management of wastewater and energy-efficient components ensures that it remains eco-friendly and cost-effective over time. Continuous monitoring and maintenance procedures, along with the use of advanced technologies, guarantee that the system operates at peak performance and delivers clean water for an extended period.

The combination of cutting-edge filtration techniques and thoughtful design makes this water filtration system an optimal solution for providing purified water. With its emphasis on health, sustainability, and efficiency, it is well-equipped to meet the increasing demand for high-quality drinking water while minimizing waste and environmental impact. This system not only provides immediate access to clean water but also contributes to long-term health benefits by ensuring that the water is free from harmful contaminants and enriched with essential minerals.

This water filtration system provides an effective, reliable, and comprehensive solution to the water purification problem. It is a model of modern water treatment technology that offers both quality and sustainability, setting a high standard for water filtration systems in the future. The implementation of the system presents an exciting opportunity for improving the quality of life by ensuring access to safe drinking water and promoting healthier living environments for communities.

Reference

- https://www.carbotecnia.info/learning-center/filtration-methods/what-is-nanofiltration/?lang=en
- https://www.peore.in/products/fine-sediment-filter
- https://www.desertcart.in/products/513953707-reverse-osmosis-system-under-sink-water-filter-booster-pump-8000-k-drinking-water-system-pressure-increase-spare
- https://www.amazon.in/Konvio-Carbon-Filter-Sediment-Purifier/dp/B09C4JLZVM
- https://greatwaterfilters.com.au/articles/diet-wellbeing/what-are-alkaline-water-filters/
- https://www.pureitwater.com/blog/post/what-is-a-carbon-filter-and-what-role-does-it-play-in-water-purification1#:~:text=Pre%2Dcarbon%20filters%20in%20Pureit,bad%20taste%20in%20the%20water
- https://www.kent.co.in/blog/how-reverse-osmosis-works/