

**DESIGN AND IMPLEMENTATION OF A MINI WATER TREATMENT
PLANT FOR THE DEPARTMENT OF MECHANICAL ENGINEERING,
UNIBEN**



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CERTIFICATION

This is to certify that this research and fabrication project titled: DESIGN AND IMPLEMENTATION OF A MINI WATER TREATMENT PLANT FOR THE DEPARTMENT OF MECHANICAL ENGINEERING, UNIBEN, was carried out under the supervision of ENGR. P. O. Olagbegi.

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Head of Department

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Date

DEDICATION

We dedicate this report to God Almighty, whose grace has given us the strength and perseverance to bring this project to fruition. To our families, whose unwavering support and encouragement have been the foundation of our academic journey. To the Department of Mechanical Engineering, whose guidance, mentorship, and dedication to our education have played a crucial role in shaping us. Finally, we extend our gratitude to all who have inspired and supported us along the way. Your belief in our potential has fueled our passion for learning and striving for excellence.

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ABSTRACT

Access to clean water is essential for human health and environmental sustainability. This project focuses on the design and implementation of a mini water treatment plant for the Department of Mechanical Engineering, University of Benin. The system is designed to treat raw water by removing impurities, ensuring it meets safe consumption and laboratory usage standards.

The project involves the integration of filtration, coagulation, sedimentation, and disinfection processes to achieve efficient purification. Key design parameters, including flow rate, treatment capacity, and material selection, were carefully considered to ensure optimal performance and cost-effectiveness. The implementation phase includes system fabrication, installation, and testing to evaluate efficiency and compliance with water quality standards.

The results demonstrate that the proposed water treatment system effectively reduces contaminants, providing a reliable and sustainable solution for the department. This project not only enhances water quality but also serves as a practical model for small-scale water treatment solutions in institutional settings.

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ABBREVIATIONS AND KEYWORD

Abbreviation	Definition
RO	Reverse Osmosis
MBRs	Membrane Bioreactors
UV	Ultraviolet

Abbreviation	Definition
IoT	Internet of Things
AI	Artificial Intelligence
AI-IoT	Artificial Intelligence & Internet of Things
NIS	National Irrigation System
pH	Potential of Hydrogen
NTU	Nephelometric Turbidity Unit
Ca ²⁺	Calcium Ion
Mg ²⁺	Magnesium Ion
flocs	Flocculants
WHO	World Health Organization
EPA	Environmental Protection Agency
PLCs	Programmable Logic Controllers
HRT	Hydraulic Retention Time
DOC	Dissolved Organic Carbon
BAC	Biological Activated Carbon
HP	Horsepower
GPM	Gallons Per Minute
PVC	Polyvinyl Chloride
LPM	Liters Per Minute
TCU	True Color Unit
TDS	Total Dissolved Solids
mg/L	Milligrams Per Liter
E. coli	Escherichia coli

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

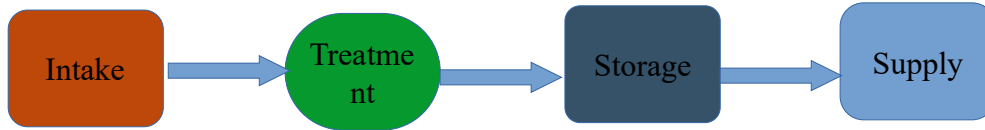
Water pollution is a global problem threatening the entire biosphere and affecting the life of many millions of people around the world. Not only is water pollution one of the foremost global risk factors for illness, diseases and death, but it also contributes to the continuous reduction of the available drinkable water worldwide. Clean water which is an essential resource for human survival, economic activities, and environmental sustainability is unfortunately not always available especially in developing countries and more rural regions of developed countries (Singh, Nagpal and Agrawal, 2018)

Over the years as human innovation has grown so have different methods for combating water pollution been developed and optimised from simple filtration and surface skimming techniques to boiling to distillation and reverse osmosis (Yang *et al.*, 2019). The two primary kinds of water purification techniques that are most frequently used in practice are physical techniques and chemical techniques. Physical techniques for purifying water include desalination, distillation, boiling, filtration, sedimentation, and reverse osmosis. The three most used chemical purification techniques for water are flocculation, chlorination, and coagulation (Jiang, 2015). Photocatalytic degradation of dissolved water contaminants under irradiation is another type of physicochemical process and a strategy for wastewater treatment that is being studied extensively.

Water purification plants are not limited in size or scale depending on their intended purpose, ranging in size from small units intended for use by a single person, a few people or one family to huge industrial plants meant to supply enter towns and cities and all operating on different principles as dictated by the state of the water to be purified. The standard modus operandi of a water purification plant is simply:

1. Intake or water supply.
2. Water treatment.

3. Storage.
4. Supply for external use.



1.1.1 Water Purification and Treatment Through the Ages

Throughout human civilization water has always been a requirement for the continued existence, growth and propagation of any society so at different times in human history different methods have existed to provide clean water for use, looking back on these techniques and methods we see the foundation of water purification technology now, and grouping them according to time period we get three distinct groups which are:

1. Ancient Water Treatment:

These techniques were limited mostly to filtration and boiling and used primarily by civilization such as the Egyptians, Greeks, and, Indians these techniques comprised of methods some of which are still used today like:

- Sand and gravel filtering which remains one of the most widely used methods of water filtration. (Verma, Daverey and Sharma, 2017)
- Boiling which is still one of the easiest and most straight forward ways of water purification.
- The storage of water in copper and silver vessels used by ancient Egyptians and Romans who stored water in copper or silver containers, which had antimicrobial properties.(Vincent, Hartemann and Engels-Deutsch, 2016) And finally **Solar Purification** used by some cultures , it involves the use of sunlight to purify water, a practice known today as Solar Disinfection (SODIS).(Khan *et al.*, 2015)

2. Middle Ages and Early Modern Periods Water Treatment

- **Distillation:** This process required quite a bit of equipment unavailable to earlier civilizations and involved boiling water and condensing and then collecting the condensed steam in a clean container, leaving impurities behind in the container used for boiling. While not commonly used for drinking water, it was used to purify water used in alchemy and medicine in the Middle Ages. This process is also used in the petroleum industry for the separation of crude oil into its components.
- **Coagulation and Sedimentation:** Some early civilizations, including the Egyptians, utilised a form of coagulation by adding the crushed seeds of certain plants (like Moringa seeds) to water stored in containers (Jiang, 2015). This helped suspended particles to clump together and settle, making filtration of the clear water at the top of the container by far easier.

3. 18th and 19th Centuries: Early Scientific Approaches To Water Treatment

- **Sand Filters:** The first slow sand filters were invented during the 18th century by Joseph Amy in Scotland. These were in use in London during the early parts of the 19th century and lowered considerably the toll of waterborne diseases. (Verma, Daverey and Sharma, 2017)
- **Chlorination:** Chlorine's prowess as a disinfectant for water supplies was well recognized by the scientists of the late 19th century since chlorine occasions significant injury to bacterial cells, cell permeability dislocation and nucleic acids and enzymes injury. Hypochlorous acid oxidizes sulfhydryl groups, harms iron-sulfur centers, deactivates nutrient transport, hinders cell respiration, and deteriorates the capacity of cells to keep a sufficient adenylate energy charge to stay viable. Its application onto municipal water supplies began in Jersey City, New Jersey, USA, in 1908, marking an important milestone in water treatment. (Ghernaout, 2017)

4. 20th Century: Chemical and Mechanical Purification

- **Ozone Treatment:** Ozone treatment, because of its strong oxidant characteristic, was used for the first time to treat water in France in the early 20th century. This helped get rid of the bacteria and viruses from water, and quite a number of water treatment plants have continued using the treatment up to present times(Wei *et al.*, 2017)
- **Activated Carbon Filtration:** Before long, activated carbon filters were developed to take out organic chemicals and contaminants that improved the taste and odor of water. They are in wide use in both industrial and household water purification up to the present time(Jjagwe *et al.*, 2021)
- **RO works by using a semipermeable membrane in order to take out the ions, molecules, and larger particles. Invented in the 1950s, RO soon became popular for seawater desalination but today is used in most home water filters.**
UV Treatment: UV light can kill microorganisms when UV light breaks down DNA molecules. That also became widely used in the latter half of the 20th century because it was so effective for chemical-free disinfection.

5. 21st Century: Modern Innovations and Advanced Purification

- **Nanotechnology:** Nanomaterials consisting of carbon nanotubes and graphene oxide are utilized in advanced filtration systems to clean water at molecular levels through the removal of viruses, bacteria, and even heavy metals.
- **Electrochemical Methods:** Several methods-which include electrocoagulation-use electric currents for the purification of water. These systems are actually quite efficient in heavy metal removal and have been tested in wastewater treatment applications (Alkhadra *et al.*, 2022)
- **MBRs:** Biological treatment in combination with membrane filtration gives some of the best systems for organic matter and pathogen removal from wastewater. **Portable Water Purification Devices:** Personal water purification devices, including UV pen purifiers and portable RO filters, have become popular for outdoor activities and emergency preparedness.

- IoT and AI in water management include the immense integration of most water treatment optimization processes with AI-IoT. These are the technologies that further assist in real-time monitoring, predict and manage water quality.

1.2 STATEMENT OF THE PROBLEM

It will be expected that UNIBEN's Department of Mechanical Engineering would have a reliable source of clean, treated water; on the contrary, this is not the case. As a matter of fact, water supply within the department is often filled with contaminants and deterrence to experimentation and demonstration activities in the effort toward quality engineering education coupled with the safety of the laboratory environment. The quality and conventional availability of municipal water sources grossly fall short of meeting the required standards in the different engineering applications and tests. Inconsistency in this evidences a critical gap in infrastructure within the department for both laboratory and project-based studies reliant on a stable supply of appropriately treated water.

Because appropriate and inexpensive small-scale treatment systems are not available, this significantly limits the students and researchers in getting hands-on experience with diversified purification technologies. The absence of a localized facility for treatment implies that there is higher reliance on sources outside the facility, in the end limiting exposure for the students in the salient areas of the engineering processes involved in water treatment. A reasonably priced, compact, and efficient water treatment system is, therefore hugely needed to address the special needs of the department and in furnishing the students with practical skills in water purification.

The project, therefore, attempts to fill these gaps by designing and constructing a mini-water treatment plant for the Department of Mechanical Engineering, UNIBEN. It is envisioned that the plant would be designed to be equipped with all various treatment processes, which include filtration, sedimentation, and chemical treatment. These would improve water quality to acceptable standards. The initiative contributes to building further capacity within the Department for practical work in a sustainable and safe manner; it also serves as an educational tool for students in practical learning about water treatment technologies and sustainable engineering practices.

1.3 AIMS AND OBJECTIVES

The aim of this project is to design and implement a mini water treatment plant that will provide a reliable source of clean and safe drinking water for the Department of Mechanical Engineering at the University of Benin (UNIBEN).

Objectives:

1. To design a comprehensive water treatment system that includes raw water intake, pre-treatment, filtration, disinfection, and distribution components.
2. To procure and install all necessary materials and equipment for the mini water treatment plant.
3. To ensure the treated water meets the NIS standards for drinking water quality.
4. To test and commission the mini water treatment plant to ensure its functionality and efficiency.

1.4 SCOPE OF THE STUDY

This project encapsulates the design, construction, and commissioning of a mini-water treatment plant, best suited for the needs of the Department of Mechanical Engineering at the University of Benin. The scope of work will therefore cover the development of an efficient and reliable system for adequate drinking water-safe and clean-for the students, staff, and visitors to meet their day-to-day needs. The following will form the components of the scope:

1. **System Design:** The project will include the design of a complete water treatment system that will be involved in the series of treatments from raw water intake through pre-treatment, filtration, disinfection to the distribution network. The design shall ensure that the water meets the Nigerian Industrial Standards for drinking water quality.
2. **Procurement and Installation:** All materials necessary for the mini water treatment plant will be identified and sourced out for installation. This would cover

component packaging of raw water intake systems, sedimentation units, sand and activated carbon filters, disinfection units, storage tanks, and piping.

3. Operational Testing and Commissioning: The series of tests to be conducted in ensuring the plant operates according to intended design, and all stages of treatment will guarantee the production of clean, potable water. Commission the plant for service, proving efficiency and reliability beforehand for handover for normal use.
4. Documentation: This process and workflow of the entire project will be documented in the design, construction, and testing processes to allow for periodic maintenance and performance checks. This is due to the fact that proper documentation of the process would be of value during upgrading or replication of similar water treatment technology for other departments/institutions.

The present research will attempt to work out a sustainable treatment solution in such areas with low maintenance that can then serve as a model for similar educational institutions to help improve health, safety, and sustainability within the university community.

1.5 SIGNIFICANCE OF THE STUDY

The impact of the study will allow research to improve the water supply and quality of water supplied to the Department of Mechanical Engineering, University of Benin (UNIBEN). In other terms, the design of the mini water treatment plant in this project will be able to create a reliable and continuous source of clean and safe drinking water for students, staff, and visitors with great concern about water contamination within the department.

In addition to that, it will contribute to good health and well-being within the university community due to the provision of potable water, as most daily activities, practical learning, and research would rely on it. Secondly, a water treatment plant will lessen dependence on insecure sources of external water supply. It guarantees a cost-effective and perpetual solution to the challenges associated with the supply of water.

This is of particular importance from an educational perspective in that participants in the research will be directly exposed to water treatment technologies and engineering processes to develop practical understandings of water purification. The project will also raise awareness about sustainable water management within the university principles of environmental stewardship.

This will help serve, in the long run, as a model study for other departments or institutions of higher learning that are in dire need of improvement in their water treatment and thereby contribute to the improvement of infrastructure and sustainability of academic and research activities in Nigeria.

CHAPTER 2

LITERATURE REVIEW

2.1 OVERVIEW OF WATER TREATMENT

Water treatment is the process of purging water of impurities and unwanted elements so that it is suitable for a certain use, usually environmental safety, industrial activities, or human consumption. Generally, the procedure consists of many steps, such as sedimentation, filtration, disinfection, and sometimes more sophisticated treatments like reverse osmosis or UV irradiation, depending on the necessary water quality.(Farah *et al.*, 2023).

2.2 HISTORICAL DEVELOPMENTS IN WATER TREATMENT

From prehistoric times to the present, the desire for safe and pure water has motivated many to create water treatment techniques. Ancient societies recognized the practical and physiological advantages of drinkable water. They created basic filtration techniques, thus setting the groundwork for contemporary water treatment. Over several decades, the therapeutic techniques would change and progress significantly, with notable advancements occurring in the 18th and 19th centuries as scientific understanding started to grow.

Classic Water Purification Methods

- Egyptians (ca. 2000 BCE): The process of purifying water, involving sand filtering and boiling, is described in detail in Egyptian tomb murals and texts. The Egyptians filtered the water through coarsely woven linen fabric to remove any apparent contaminants. The Egyptians also believed that storing water in copper pots was a way to cleanse the water, therefore they filled them with Nile River water. (Angelakis and Zheng, 2015).
- Greeks and Romans: By building reservoirs and aqueducts for the transportation and storage of water, the Greeks and Romans capitalized on water purification.

Prior to the cities' water supply, they also employed sand and gravel filters for purification. The ancient Roman aqueducts were known to have sedimentation basins where contaminants would settle before the water was transported to public baths and fountains. In contrast, the Romans used boiling and charcoal to purify their water. Charcoal proved quite successful in eliminating bad taste and odour from drinking water (Angelakis and Zheng, 2015).

- Indian Subcontinent: Around 600 BCE, the Sushruta Samhita was recorded in early Sanskrit scriptures. Water can be made safe to drink by boiling it, exposing it to sunshine, and filtering it through sand and gravel, among other techniques described in these publications. This book constitutes one of the earliest recorded references to water purification practices and exposes the fact that there truly was ancient knowledge regarding how heat and light act upon pathogens to render them inert. (Singh, 2004).

Medieval to Early Modern Periods (Middle Ages to 17th Century)

- In order to create clean water, distillation entails boiling water to create steam and then condensing it to remove any contaminants. Although distillation gained popularity in the Middle Ages as a method of purifying water for alchemical and medical uses, its use in ordinary water supplies has been constrained by the process' complexity. Distillation was to remain a crucial procedure for laboratory and medicinal applications far into the 20th century due to its efficacy (Post, Atherholt and Cohn, 2011).
- Coagulation and Sedimentation: Coagulation techniques first appeared in the 17th century. When chemicals, mostly alum, are added to water, dispersed particles cluster together to form larger particles that will ultimately sink to the bottom. This process is known as coagulation. In order to lower turbidity in public water sources, this sedimentation process became widely accepted in European towns. According to history, certain societies, including the Egyptians, used crushed Moringa plant seeds as natural coagulants to cleanse water (Post, Atherholt and Cohn, 2011).

18th and 19th Centuries: Scientific Advances and Municipal Water Systems

- **Filtration of Sand:** The earliest known slow sand filter was created in Scotland in 1804, by a Scot named John Gibb, to provide cleaner water for domestic consumption. Sand filtration was swiftly adopted in many places across Europe and the US as it proved to be an efficient method of removing pathogens. Indeed, this became one of the important advancements of water treatment technologies up to this era, with large decreases in the broad occurrence of waterborne infections among urban populations (Zaman, 2014).
- **Chlorination:** Chlorine's ability to effectively disinfect was already recognized in the late 1800s. By treating water with sodium hypochlorite, which killed the bacterium that causes typhoid, Dr. Sims Woodhead conducted the first successful chlorination experiment in the United Kingdom in 1897. Chlorination was first used as a complete municipal water treatment in the United States in 1908 in Jersey City, New Jersey, and quickly established itself as a fundamental component of water treatment public health procedures. (Al-Abri *et al.*, 2019)
- **Ozone Treatment:** Around the same timeframe, ozone disinfection arose in Europe as an alternative to chlorination. The first application of ozone for municipal water purification occurred in Nice, France, in 1906. Although it required specialized equipment, ozone's potent oxidative qualities made it extremely effective against bacteria and viruses. It was thought to provide a chemical-free substitute for water disinfection. (Cheung, 2017).

20th Century Onward: Modern Advances in Water Treatment

- **Reverse Osmosis and Membrane Technology:** The 1950s saw the invention of reverse osmosis, which ushered in a new age in water treatment, particularly desalination. To make water suitable for drinking and industrial use, salts, ions, and other contaminants are eliminated by passing it through a semipermeable membrane. RO technology has been used at small- and large-scale water treatment plants since its conception. (Al-Obaidi, Kara-Zaitri and Mujtaba, 2020)
- **UV Treatment:** One of the more often used non-chemical ways to disinfect or inactivate germs is UV disinfection. UV, particularly in the UV-C wavelength

range, prevents bacteria from reproducing by interfering with their DNA replication. UV technology is being used in many small-scale and portable water treatment systems due to its effectiveness and environmentally favourable effects (Song, Mohseni and Taghipour, 2016).

2.3 IMPORTANCE OF WATER TREATMENT IN SCHOOL SYSTEMS

- **Health and Hygiene:** To keep students and employees safe and stop the spread of waterborne illnesses, clean water is crucial at educational institutions. For example, establishments lacking adequate treatment systems run the danger of bacterial contamination, which can result in diseases that interfere with school operations. (Chabi *et al.*, 2020)
- **Sustainability and Cost Savings:** Institutions can lessen their reliance on outside water sources, especially in areas with inadequate infrastructure, by putting water treatment on-site. This self-sufficiency is particularly beneficial for educational institutions looking to control expenses and preserve resources in a sustainable manner. (Farah *et al.*, 2023)
- **Research and Hands-on Learning:** Water treatment plants may be used as living models for students in technical subjects like mechanical engineering, giving them a first-hand look at treatment procedures. In disciplines like fluid mechanics, chemistry, and environmental engineering, this hands-on experience strengthens theoretical understanding.

To serve its students, instructors, staff, and visitors, the University of Benin's (UNIBEN) Department of Mechanical Engineering urgently needs a dependable on-campus supply of safe drinking water. Large people congregate at educational institutions on a regular basis, making access to clean water a basic requirement. Sanitation and drinking both depend on clean water, which lowers the danger of waterborne diseases that are particularly contagious in densely populated areas. Water supplies that are contaminated can include chemicals and bacteria that can cause infections, gastrointestinal problems, and long-term health problems that can interfere with learning and general health.

2.4 WATER QUALITY PARAMETERS

The following factors are essential for the planning and execution of a small water treatment plant in order to guarantee that the water satisfies quality requirements and is fit for human consumption:

- **PH:** The pH scale, which ranges from 0 to 14, shows how acidic or alkaline the water is; 7 is neutral. It is thought that water below 6.5 is too acidic, while water above 8.5 is seen to be excessively alkaline. Water that has grown too acidic or alkaline can become extremely corrosive, harming treatment systems and pipelines. The solubility of minerals in water and the inactivation of disinfectants may be similarly impacted. 6.5 to 8.5 is the optimal range for drinking water.
- **Turbidity:** Turbidity is the cloudiness or haziness of water brought on by suspended particles like silt, clay, and microbes. High turbidity might mean that the water is dangerous to drink since the suspended particles can harbour harmful organisms. Additionally, turbidity helps to protect chlorination and other disinfection procedures. Although lower values are preferred in terms of treatment efficacy, the turbidity of water immediately before to treatment should generally be less than 5 NTU (Nephelometric Turbidity Units).
- **Hardness:** Dissolved calcium ions (Ca^{2+}) and magnesium ions (Mg^{2+}) are often the cause of hard water. Hard water can cause scaling in pipes and water treatment equipment, which shortens their lifespan and decreases their effectiveness. Additionally, it may degrade the quality of detergents and soaps, rendering cleaning ineffective. In extreme situations, it may have an impact on health. Water hardness is typically categorized as:
 - Soft: 0-60 mg/L
 - Moderately hard: 61-120 mg/L
 - Hard: 121-180 mg/L
 - Very hard: >180 mg/L
- **Alkalinity:** Alkalinity refers to the capacity of water to neutralize acids; it originates largely from bicarbonates (HCO_3^-), carbonates (CO_3^{2-}), and hydroxides

(OH⁻). It also tends to buffer variations in pH, resulting in the avoidance of rapid movements toward acidity or alkalinity. This is crucial for the efficacy of flocculation and coagulation in water treatment. Alkalinity should be between 20 and 200 mg/L, depending upon the source and treatment methods used.

- **Microbial Contaminants:** Waterborne illnesses can be caused by microbial pollutants, which include bacteria, viruses, and protozoa. The biggest health concern associated with untreated or insufficiently treated water is the existence of microbiological pollutants. Typhoid fever, dysentery, and cholera can be brought on by pathogens such Giardia, Cryptosporidium, and Escherichia coli (E. coli). Indicators like as Total Coliform and E. Coli levels are typically used to track microbial contamination. There should be no detectable E. coli or coliform bacteria in drinking water.

NATIONAL AND INTERNATIONAL WATER QUALITY STANDARDS

<u>Parameter/unit</u>	<u>NSDWQ, 2017</u>	<u>WHO, 2017</u>
pH	6.5-8.5	6.5-8.5
Turbidity(NTU)	5.0	
Conductivity(μS/cm)	1000	
TDS (mg/L)	500	
Temperature °C	Ambient	Ambient
Tot. hardness (mg/L)	150	100
Chloride (mg/L)	100	250
Fluoride (mg/L)	1.0	1.5
Nitrate (mg/L)	10	50
Sulphate (mg/L)	100	200
Manganese (mg/L)	0.1	0.05

Table 2.1: WATER QUALITY INDEX (Emeka et al., 2020)

2.5 AN OVERVIEW OF CONVENTIONAL WATER TREATMENT METHODS: COAGULATION, FLOCCULATION, SEDIMENTATION, FILTRATION, AND DISINFECTION

Conventional water treatment techniques are tried-and-true procedures that guarantee water is safe to consume by eliminating pollutants and germs. Following a set of organized procedures, such as coagulation, flocculation, sedimentation, filtration, and disinfection, these techniques are often used in municipal and small-scale treatment facilities around the globe.

- Coagulation: The first step is coagulation, in which the water is treated with chemical coagulants such as iron salts or aluminium sulphate (alum). The negative charges on suspended particles are neutralized by these substances, which causes the particles to group together. According to studies, coagulants work well in removing suspended particles and contaminants such heavy metals and organic compounds. (Farah *et al.*, 2023)

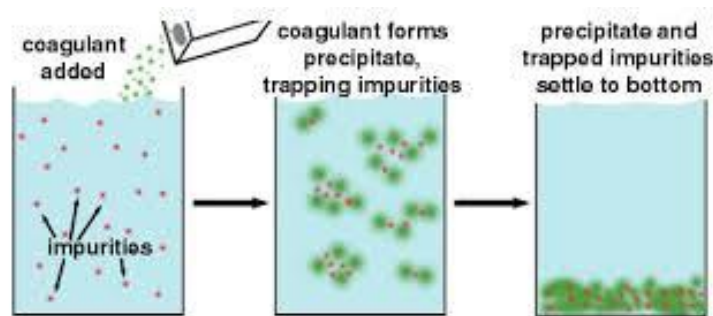


Figure 2.1: Coagulation

- Flocculation: The flocculation stage, which comes after coagulation, gently agitates the water to promote the growth of the clumped particles, or "flocs." To guarantee constant mixing, mechanical or hydraulic flocculators are frequently employed. Effective particle agglomeration requires a flocculation period and mild mixing, according to research. Natural coagulants such as extracts from moringa seeds are being investigated as environmentally friendly substitutes for conventional coagulants in small-scale systems.(Chabi *et al.*, 2020).

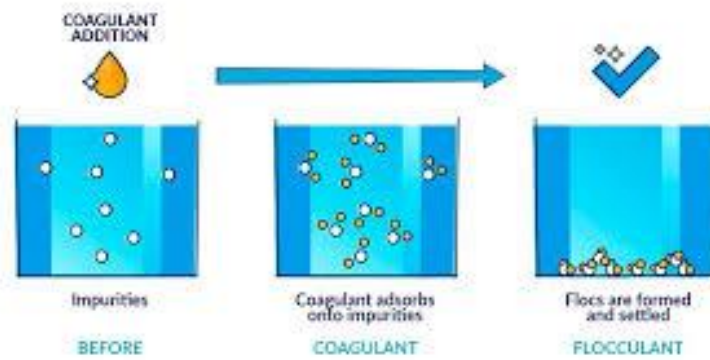


Figure 2.2: Flocculation

- **Sedimentation:** The process of sedimentation involves letting the water rest in a tank while gravity helps the bigger flocs near the bottom settle. This procedure drastically lowers the turbidity of the water. Pilot studies have shown that up to 90% of suspended particles may be removed by sedimentation, with the efficacy of sedimentation being measured by particle size and density. Sedimentation tanks are frequently modified for space-constrained small-scale treatment systems while yet retaining effectiveness.

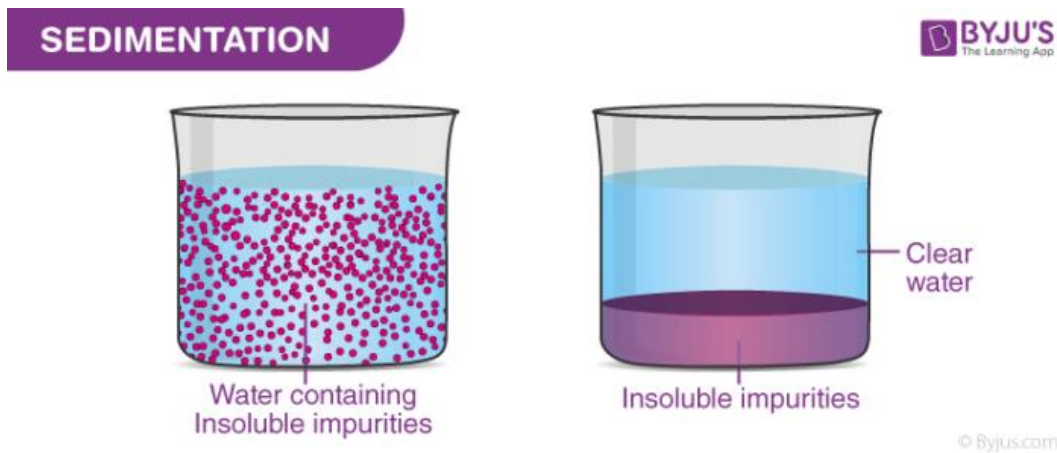


Figure 2.3: Sedimentation

- **Filtration:** Smaller particles are further eliminated by filtration, which involves running water through a medium—typically activated carbon, sand, or gravel. Slow sand and quick sand filters are two popular filtration techniques; slow sand filters are frequently employed in small systems because of their affordability and

ease of operation. Research shows that sand filters are good at eliminating organic debris, bacteria, and leftover coagulant particles. For instance, the usage of activated carbon to absorb chemical substances and manage problems with taste and odour is growing.

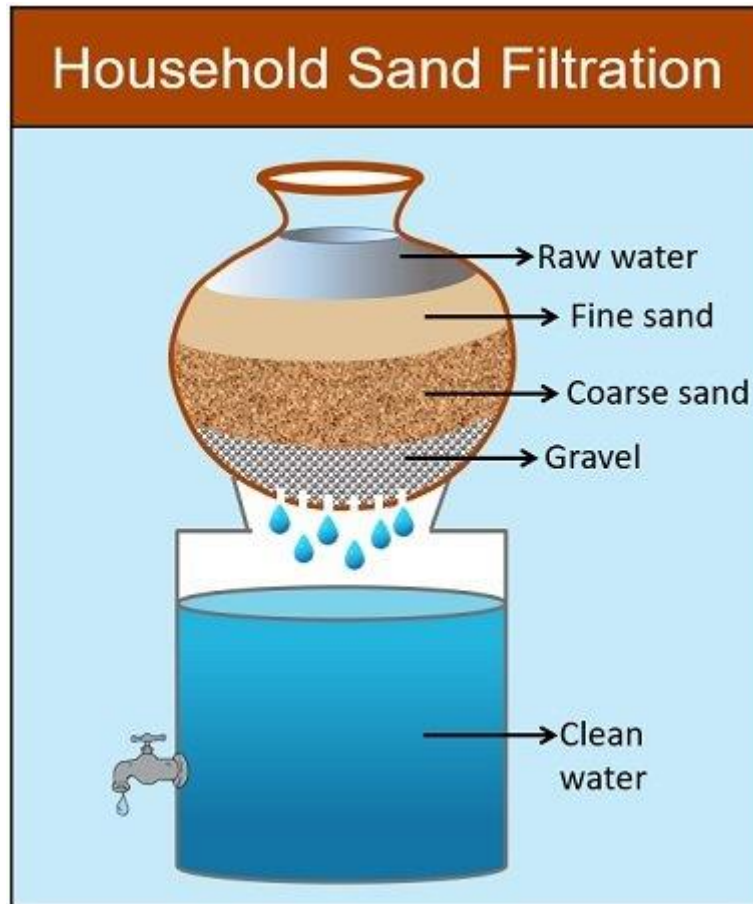


Figure 2.4: Filtration

- Disinfection: The last stage of treatment is disinfection, which inactivates microorganisms, typically by using UV light, chlorine, or chloramine. Although UV disinfection has become more popular for small-scale systems because it may inactivate organisms like *Giardia* and *Cryptosporidium* that are resistant to chlorine without producing any by-products, chlorination is still an effective and common method. Because too much chlorine can produce toxic by-products and too little chlorine cannot totally eradicate infections, studies highlight the need of correct dosage in disinfection. (Chabi *et al.*, 2020)

2.6 DISADVANTAGES OF CONVENTIONAL WATER TREATMENT METHODS

The need for chemical reagents (such aluminium or ferric salts), which increase the expense of operating the technology, is its main disadvantage. In some cases, large quantities of flocculants and coagulants are required to achieve the required level of flocculation. There is also some production of physicochemical sludge, which is usually handled externally. A sedimentation basin is a relatively simple and affordable installation. A sedimentation basin does, however, need a significant amount of room. The maximum volume of a sedimentation basin is always the basis for its design. Since traditional drinking water treatment is not made to remove new contaminants, the extensive use of chemicals, pharmaceuticals, pesticides, and solvents necessitated the implementation of modern technology. (Qadri and Alam, 2024).

2.7 AN OVERVIEW OF ADVANCED WATER TREATMENT METHODS

For small-scale water treatment systems, advanced techniques including membrane filtration, ultraviolet (UV) treatment, and ozone treatment are becoming more and more popular because of their effectiveness, advantages for the environment, and versatility in handling different types of pollutants. Since each technique has its own merits, they can sometimes be used in place of or in addition to traditional treatment stages, particularly in systems that are small or dispersed.

- **Membrane Filtration:** The physical barrier that separates the pollutants in the water is made possible by membrane technology. Membranes are made of a variety of materials, each of which has certain qualities (pore size and hydrophobicity) that limit the types of contaminants that may be contained in. Membrane filtration is an efficient way to remove particles, germs, and organic materials from drinking water and wastewater. contrasting membrane procedures with conventional therapeutic methods. It can provide better-quality water, lessen

the need for disinfectants, compress more, provide simpler operational management, needless upkeep, and generate less dirt.

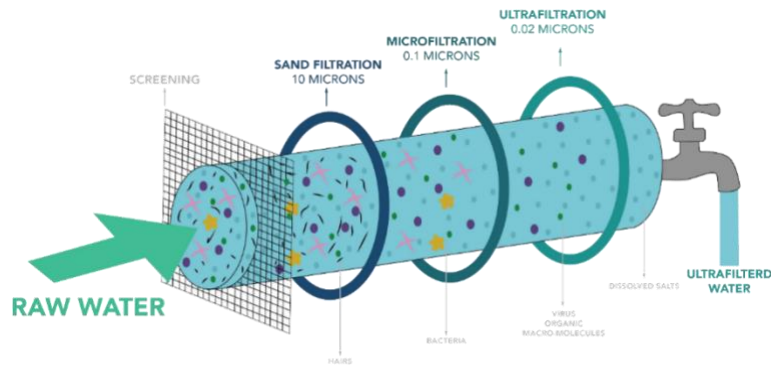


Figure 2.4: Membrane Filtration

- Ultraviolet (UV) Treatment: One physical disinfection method is ultraviolet disinfection. UV light has wavelengths between 100 to 400 nm, which is within the electromagnetic spectrum. Because of its effectiveness in eliminating microorganisms from water, UV disinfection is becoming more and more common in industrial settings. UV light has the ability to reduce or inactivate bacteria, viruses, and protozoa without altering the chemical composition of water.

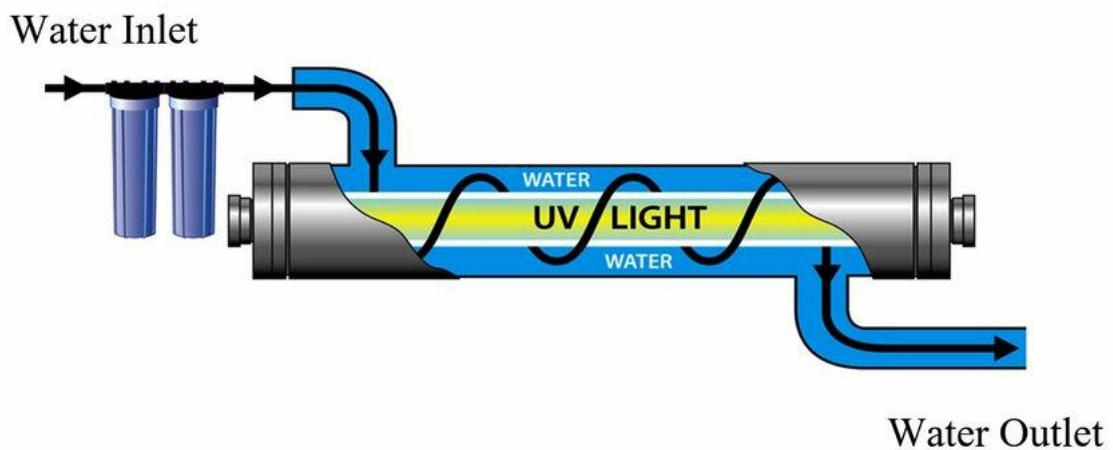


Figure 2.5: UV light

- **Ozone Treatment:** Ozone is a potent oxidizing agent that may react with both organic and inorganic compounds. In the water treatment sector, this method has grown in significance due to its high oxidation potential ($E^\circ = 2.08 \text{ V}$) and lack of hazardous by-products throughout the operation. The main disadvantage is that in order to produce ozone from oxygen, an electric discharge must be placed over either pure oxygen or an air stream. Due to the significant energy consumption of this stage, the process cannot be scaled down.

SMALL SCALE WATER TREATMENT PLANTS

Growing water scarcity, pollution, and the necessity for decentralized water management are all factors contributing to the rising need for small-scale, neighbourhood water treatment plants. In university settings, these plants become highly significant for providing treated water for laboratory and research activities, as well as for all other elements of university operations efficiency.

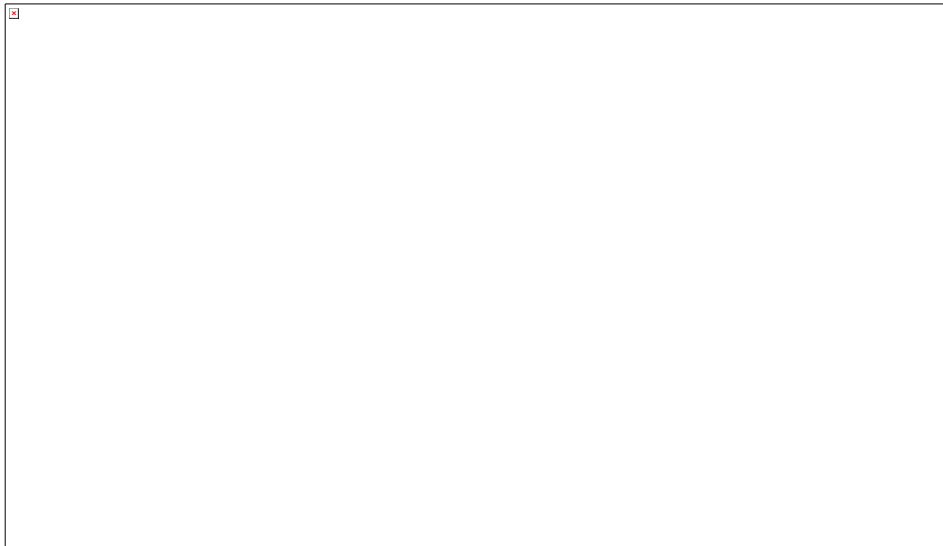


Figure 2.5: A Three Tank Water Filter

2.8 DESIGN CONSIDRATIONS FOR SMALL-SCALE WATER TREATMENT PLANT

A small water treatment plant's design takes into account a number of elements that affect its durability, cost-effectiveness, performance, and environmental impact. In this regard, a well-designed small water treatment plant for a school like UNIBEN should be able to handle various water types, be affordable to operate, and, most importantly, be ecologically friendly. Below, several important design factors are looked at in detail.

- **Source Water Quality:** Depending on where it comes from—rainwater, surface water, or groundwater—source water quality can vary significantly. While surface water often has more organic matter and turbidity, groundwater may have higher amounts of minerals like iron and manganese. Microbial pathogens, organic compounds, dissolved minerals, and suspended solids are all involved in determining the pollutants that are present. The choice of chemicals, filtering techniques, and treatment procedures may vary depending on the kind of contamination.
- **Treatment Goals:** Specify if the treated water will be used for drinking, research, or other purposes. Industrial or laboratory water may have varied quality standards, but drinking water needs the most thorough microbiological and chemical elimination. The level of filtration, disinfection, and pH correction needed will be influenced by the permissible limits for various pollutants set by national and international water quality regulations (e.g., WHO, EPA).
- **Capacity and Scalability:** Calculate the daily water demand using the department's stated use trends. Overestimating or underestimating the capacity might result in inefficiencies or an inability to satisfy peak demand. This plant's modular design allows it to be scaled up in response to increased demand, which is crucial in an institutional setting where enrolment or departmental activity may cause changes in water usage.
- **Space Constraints:** The amount of space available in the designated location must be carefully considered in order to ensure that all of the equipment that has to be placed can fit there without becoming cramped. This can be either stacking or

space-saving equipment; if not, multipurpose items should be taken into account. To facilitate simple access during routine maintenance, repairs, or inspections, leave enough space surrounding each unit. A design that is overcrowded may experience more downtime and require more maintenance.

- **Treatment Technologies:** To evaluate the cost-effectiveness and suitability of filtering techniques including sand, activated carbon, and membrane filtration, create contaminant profiles. For example, membrane filtration, such as microfiltration and ultrafiltration, is effective in eliminating pathogens, whereas activated carbon is effective at eliminating organic pollutants. In order to make water safe, especially drinking water, disinfection is also essential. Ozone, UV therapy, and chlorination are often used techniques. Regarding cost, residual disinfectant strength, and ease of use, each of them has pros and cons of its own.
- **Automation and Monitoring:** Additionally, automation increases treatment reliability since it reduces the possibility of human mistake through maximally consistent processes. With PLCs, it is possible to automate activities like chemical dosing, pH correction, and pump operation. For ideal conditions and early issue detection, sensors that monitor factors including pH, turbidity, chlorine residuals, and flow rates may be placed. Additionally, remote monitoring, which enables plant managers to oversee performance from any location, might facilitate improved administration, particularly in institutional setups. In order to minimize downtime and uncover issues, it could be helpful.
- **Cost Considerations:** The plant needs to be cheap and reasonably priced, keeping in mind that durable materials must be employed without going over budget. Take into account all of the continuous costs, including labour, chemicals, electricity, and spare components. The lifecycle cost may be reduced by using low-maintenance systems or parts that need to be replaced relatively seldom. Since most university programs have strict budgetary requirements, cost-cutting measures (such as sharing equipment or obtaining supplies locally) must be taken into account wherever feasible without compromising the quality of the therapy.
- **Maintenance and Operational Simplicity:** In order for non-specialists to run and maintain the plant, systems must also be easy to use and straightforward. Design

simplicity lowers the likelihood of operational mistakes and lessens reliance on technical expertise. Choose components and equipment that are readily available in your area. Generally speaking, if replacements are not easily accessible, using rare or imported components may result in longer maintenance periods and higher operating costs. Because fewer types of replacement parts need to be stored on hand, system-wide part standardization helps facilitate repairs.

- **Reliability and Redundancy:** Pumps and other critical systems need a backup so that the plant may continue to function even if one of its major parts fails. Dual-pump systems, for instance, enable maintenance without requiring downtime. Given that power stability is occasionally an issue, backup power options like solar or battery storage may be included to maintain services for a while during outages.

2.9 ANALYSING A SMALL SCALE WATER TREATMENT PLANT BUILT IN A REMOTE AREA

In this work, they developed and built a drinking water treatment unit on a pilot scale to offer high-quality drinking water at a low operating cost. This device was helpful for treating water in remote locations, based on the determined findings of the final treated water's physicochemical and microbiological characteristics.

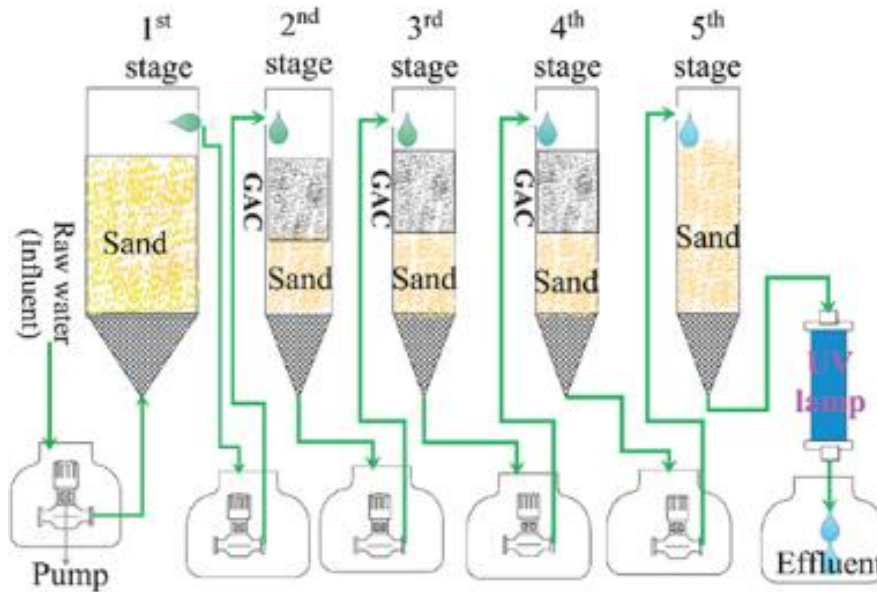


Figure 2.6: Six treatment phases

Six treatment phases, including UV disinfection as the last stage, made up the pilot-scale system. Sand (pore size: 2–3 mm, height: 1 m) and gravel (pore size: 12–16 mm, height: 0.1 m) were the two distinct media used in the initial treatment step. Gravel (diameter: 5–10 mm; height = 0.1 m) was found at the bottom of the second, third, and fourth phases, followed by sand (diameter: 0.5–1.25 mm; height = 0.6 m) in the center, and biological activated carbon (BAC) (diameter: 1–2 mm; height = 0.6 m) at the top. Sand (diameter: 0.5–1.2 mm; height = 1 m) at the top and gravel (diameter: 5–10 mm; height = 0.1 m) at the bottom made up the fifth level. We used a high-pressure UV lamp (type C: 16 watts, wavelength = 254 nm, intensity = 5 mWcm⁻²) to sterilize the final effluent of our pilot-scale machine.

The drinking water's pH ranged from 7.09 to 7.99 in this current investigation. The concentration of chemical components was found to decrease as the pH rose slightly. According to the data, 95.33 percent of the turbidity was eliminated from the final effluent following full treatment. Furthermore, the results met the standards of the international drinking water standard. Numerous bacterial species are present, according to research on the bacterial population. In order to thrive, these many bacterial species that were present in the ecosystem needed nutrition. Their findings showed that when water was

treated, the composition of the bacterial community altered, with a higher diversity of bacterial species seen at various phases of treatment.

HRT (Hydraulic Retention Time) is a crucial metric for managing water treatment effectiveness. HRT significantly affects both the contact time and the hydrodynamic conditions (Pan et al. 2004). The contaminants were effectively removed by our 0.03 day HRT treatment unit (e.g. 85.71 percent removal of ammonium).

This pilot research demonstrated how well UV disinfection, physical filtration, and bio filtration removed contaminants from source water. Along with DOC, the bio filtration method demonstrated a high removal of turbidity, nitrite, and ammonium. The outcomes of the microbiological and physicochemical parameters meet international standards. The drinking water quality in our developed unit improved across several biological phases. Turbidity and organic contaminants were removed in large part because to BAC. The removal of NH_4^+-N through the microbial nitrification process was significantly aided by *Nitrospira* and *Nitrosomonas*, which mostly inhabit the surface layer of the BAC medium in our system.

Because of its strong germicidal properties and capacity to reduce the generation of disinfectant by-products, UV irradiation is advised for the disinfection of drinking water. Our study offers a concept for a drinking water treatment system that may be deployed in distant locations, generating potable water that satisfies national and international standards while also having lower running costs.

CHAPTER 3

MATERIALS AND METHODS

A practical, small-scale model for water purification must be developed methodically in order to build and construct a tiny water treatment facility. In order to ensure that the treatment plant satisfies the requirements for potable water quality within the Department of Mechanical Engineering, UNIBEN, this chapter describes the materials and procedures utilized in its construction and operation.

3.1 MATERIALS

- Filtration tanks
- Carbon filter 2
- Pump 0.5hp
- UV
- Storage tank
- Refrigerator
- Heater
- Flexible connector
- 1/2 and 1 inch Adaptors
- Elbows and sockets
- Ball valves
- Float switch and solenoid valve

Filtration Tanks

An essential aspect of the small water treatment plant is the filtration tank, which uses a multi-layer filtering system to remove contaminants and particle matter from the water.

The filtration tank might have a rectangular or cylindrical form. PVC and stainless steel are two examples of materials that are strong, resistant to corrosion, and able to withstand water pressure and many pollutants. Water enters through the top port, and filtered water exits through the bottom port, which serves as the disinfection unit's outlet.

Our mini water treatment plant's filtration system is made up of two filtration tanks, each of which has layers intended to filter the water through many stages. The initial layer of carbon (charcoal) in each tank is very good at adsorbing organic compounds, chlorine, and smells, which improves the flavour of the water and cleans it of chemicals. Underneath the layer of charcoal lies Adolite, a unique filtering medium that improves the removal of certain contaminants, such as chemicals and metals. Retin, the following layer, improves the overall clarity of the water by acting as a fine filtering medium and catching tiny particles that the higher layers miss. Lastly, gravel and fine sand make up the foundation layer. The sand efficiently removes suspended solids and particles, providing the last filtering before the water leaves the tank, while the gravel offers structural support, keeping finer media from blocking the outlet. Water moves from one tank to the next in a sequential fashion, guaranteeing maximum water quality and improved filtration. Consistent filtering performance over time requires routine maintenance, such as media replacement and backwashing.



Figure 3.1: Filtration Tanks

Carbon Filter: A crucial part of the small water treatment plant, the carbon filter purifies water by eliminating organic compounds, chlorine, and bad smells, enhancing the flavour and general quality of the treated water. Usually composed of activated charcoal, the carbon filter has a lot of surface area and is very porous, allowing contaminants to be absorbed as water flows through it. The carbon filter is integrated into our water treatment plant at two points before entering the filtration tanks.



Figure 3.2: Activated Carbon Filter

UV Treatment

In water treatment systems, UV (Ultraviolet) treatment is a disinfection technique that inactivates or eliminates dangerous microorganisms, such as bacteria, viruses, and protozoa. By eliminating microorganisms without the use of chemical disinfectants like chlorine, this method ensures that the treated water is safe to drink. A specific wavelength of ultraviolet light, typically UV-C at a wavelength of around 254 nanometres, is passed through the cells of microorganisms in water as part of the UV treatment process. When infections are exposed to UV-C light, their DNA absorbs the rays and becomes damaged.

This stops the germs from reproducing and renders them dormant, which either kills them or renders them incapable of causing diseases. We made use of two UV lights producers.



Figure 3.3: UV Treatment set-up

Storage Tank

A small water treatment plant's storage tanks act as reservoirs for water at various stages of treatment and for retaining purified water prior to its distribution for usage. These tanks are essential for preserving the quality of the water and guaranteeing a consistent flow of clean water. After treatment is complete, purified water is stored in a dedicated tank to prevent contamination before distribution. This storage tank maintains the water quality until it is ready for use.



Figure 3.4: Transparent Storage Tank

Refrigerator

A refrigerator is a cooling device or system used to bring treated water down in temperature prior to delivery to end users. Particularly in hot areas, this cooling procedure guarantees that the water is pleasant and refreshing. The refrigerator in this setup functions as an integral part of the water distribution process, using controlled cooling to maintain the desired temperature of the water for optimal consumer satisfaction. Cooling the water can be especially important as we are in a warm climate, where high ambient temperatures might affect the taste, feel, or quality of the water.

Heater

The purpose of the heater is to guarantee that the water reaches the ideal temperature prior to being distributed after being kept in the treatment system. Maintaining water quality,

stopping microbial development, and making sure the water is at the right temperature for use are all made possible by this system.



Figure 3.5: Refrigerator and Heater Stations

Flexible Connector

An essential part of plumbing and piping systems, a flexible connector joins two pipes or parts while allowing for misalignment, movement, and vibration. In systems where thermal expansion, contraction, or displacement may occur, it is very helpful. When connecting the heater, storage tanks, and dispensing units in our miniature water treatment plant, a flexible connector helps to maintain a smooth water flow and avoid pressure on the piping.



Figure 3.6: Flexible Connector For Heater

Adaptors

Fittings called pipe adaptors are used to join two pipes of various shapes, diameters, or compositions. They let you switch between pipe systems that are incompatible, such as joining pipes of various diameters or switching from one kind of material (like PVC) to another (e.g., metal).

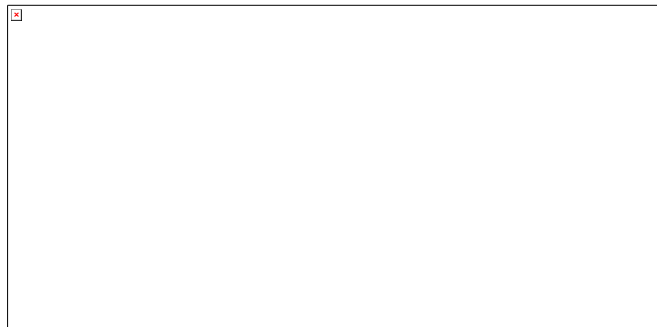


Figure 3.7: Pipe Adaptors

Ball valves

Ball valves, which regulate the flow of water via pipes, are crucial parts of water systems. Their ease of use, robustness, and efficient shut-off control make them very useful in our small water treatment facility. A ball valve provides on/off control by rotating a spherical ball with a hole in the center to either permit or prohibit water flow.



Figure 3.8: Ball valve

Float Switch and Solenoid Valve

A straightforward but crucial tool for managing or keeping an eye on the water level in a tank or system is a float switch. It uses a floating gadget to sense the water level and initiate an action, working on the idea of buoyancy (such as turning on or off a pump, valve, or other system components). By signalling the solenoid valve to cut off the inflow, a float switch positioned at the high water level can prevent water from spilling.

A solenoid valve is an electrically powered valve that uses an electromagnetic solenoid to open or close in order to regulate the flow of water (or other fluids). It is an essential part of automated water systems where flow control must be controlled according to predetermined parameters (e.g., water level, pressure, or time).

Your storage tank's water level is tracked via the float switch. When the water level hits a certain level, the solenoid valve will either open, letting more water enter, or close (stopping further flow).

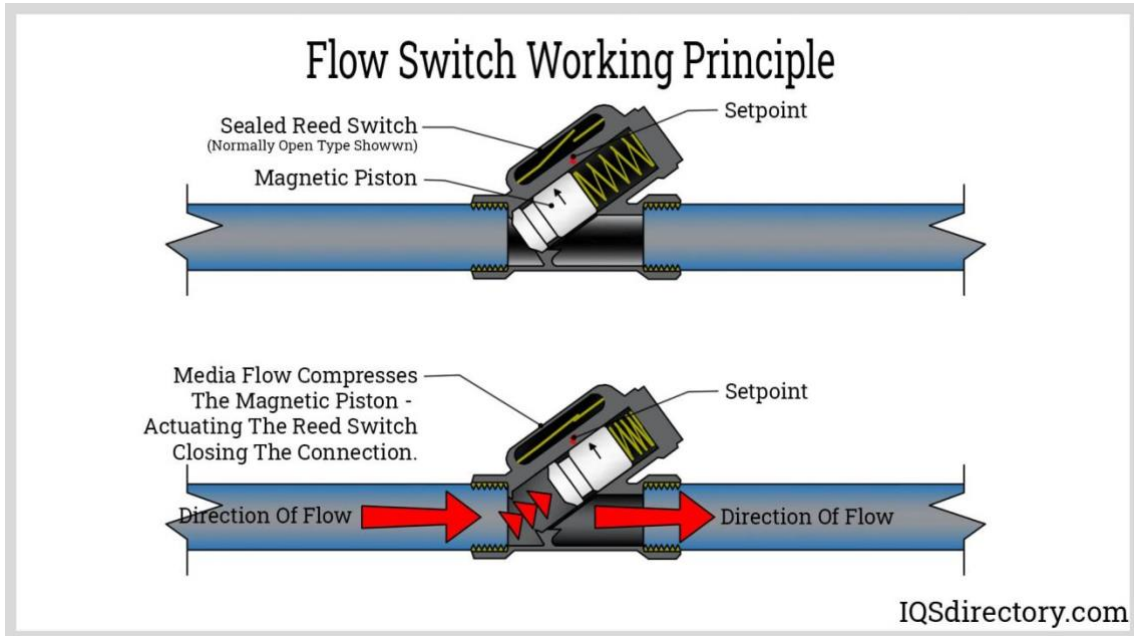


Figure 3.9: Flow Switch

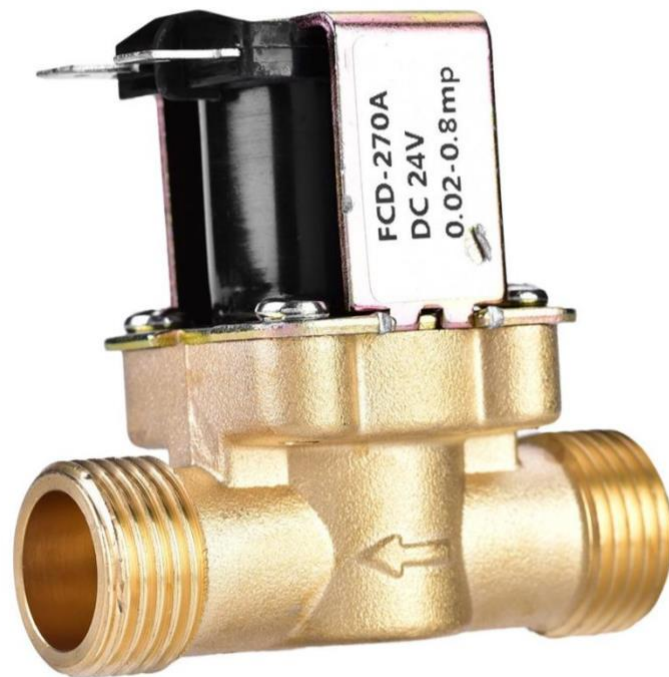


Figure 3.10: Solenoid Valve

Pump

A water pump with a 0.5 horsepower (HP) motor is known as a 0.5 HP pump. One horsepower (HP) is equivalent to around 746 watts of energy. When transporting water or other fluids in systems like water treatment plants, circulation systems, filtration systems, or irrigation setups, this kind of pump is usually utilized for moderate flow applications. The pump's usual flow rate is 10–20 gallons per minute (GPM), however this can change based on a number of variables, including pipe size and system pressure (head).



Figure 3.11: 0.5 HP Pump

Dispensing Station

The specified locations where treated water is made accessible for immediate use or filling containers are known as dispensing stations in small water treatment plants. They serve as regulated outlets from which water can be extracted for internal usage, drinking, or laboratory work. Our station has three outlet faucets, for hot water from the heater, for cold water from the refrigerator and for room temperature water directly from the tank.



Figure 3.12: Dispensing station

3.2 METHODS

Installation of Our Mini Water Treatment Plant

The procedure of installing our mini water treatment system was intricate but worthwhile. In order to feed untreated water into the setup, we began with the raw water intake system. We carefully positioned intake pipe to ensure smooth water flow from the source, using the PVC $\frac{1}{2}$ inch pipes.

The pre-treatment system came next. We put a screen at the input point that efficiently filters out particles like leaves and grit in order to capture larger material and lessen the strain on our filtration tanks. We placed a sedimentation tank after the screen. In order to

clear the water before it filters into the filtration tanks and lessen the strain on the next filtration stages, particles heavier than water sink to the bottom of this tank.

We installed two main filtration tanks for the filtration system. To capture silt and smaller particles, we covered the first filtering chamber with a layer of sand. After that, the water enters the second filtering chamber, where gravel was placed at the bottom. Before the water moves on to the next phase, the gravel serves as a secondary filtering layer, assisting in the removal of any leftover contaminants. In order to lower the water hardness, we also coated adolite in the tanks. Retin resin was then added to stabilize the chemical levels.

We also placed charcoal filters at various locations along the pipelines in addition to the tanks. As the water passes through the system, these carefully positioned filters remove any remaining contaminants, lessen smells, and enhance flavour.

We then proceeded to discuss the disinfection system. To eradicate any leftover germs or pathogens, we set up a UV disinfection equipment. In order to guarantee continuous operation and high-quality water production, the device was correctly placed and linked to a power supply.

To collect treated water in distribution, we modelled a storage tank. Water is now pushed into this storage tank by the same pump that powers the UV system in order to maintain pressure and flow. In order to do this, a solenoid valve and a flow switch are also installed in the storage tank to automate and regulate water flow. The solenoid valve automatically opens and closes to regulate the water supply while the flow switch tracks the water's movement. In addition, the storage tank houses a heater, refrigerator, and dispensing station, which allows us to control temperature and other conditions related to storage.

Flexible connections were employed at important spots, particularly on the hot water pipes, to increase flexibility and facilitate maintenance. Using elbows, sockets, and adapters, all connections were made leak-proof and secured. Finally, when everything was set up, a number of tests were conducted to confirm the water quality and flow rates, making any required modifications to fine-tune the entire system for optimal operation.

We were able to establish and improve a small water treatment plant that effectively stores, filters, disinfects, and distributes clean water by following these processes. Every part is essential, and we are happy with the system's dependability and effectiveness.



Figure 3.13: Full Setup

Process Flow

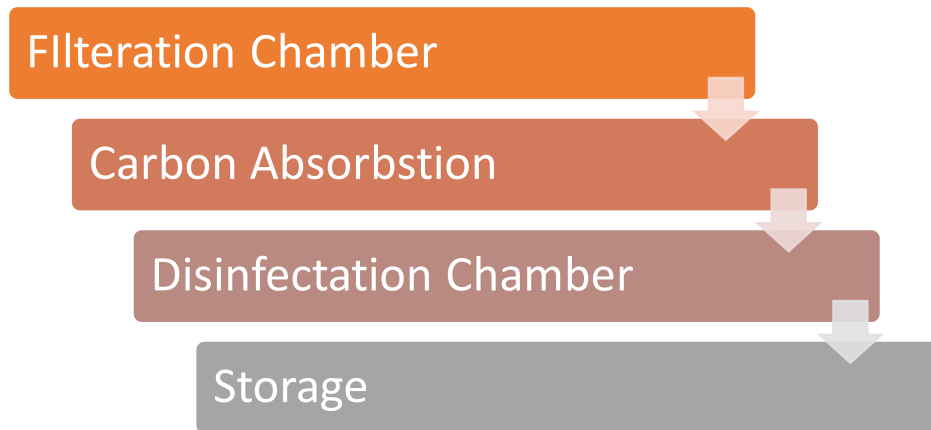


Figure 3.1: Process flow diagram

The raw water intake point, where untreated water from a borehole is tapped into the system, is where the water journey begins. After that, the raw water travels via the intake pipe system, which is built to provide a steady, uninterrupted flow into the treatment facility. As water tries to enter the system, the intake pipes are positioned carefully to prevent any possible debris and guarantee the least amount of congestion. Before the water enters the treatment process, it is filtered by a screen that is often placed over the input to remove bigger particles like leaves, twigs, and other debris.

The water moves on to the filtration system after passing through the intake system. Water gently percolates through a bed of sand in the main chamber of filtration, which is where the initial step of this filtration takes place. To get rid of dirt, debris, and tiny particles that the pre-screening might have overlooked, the sand works as a mechanical filter. In this manner, the majority of the suspended particulates are eliminated, making the water extremely clear as it flows past this layer of sand. For a more effective filtering process as the water moves through the stages, the sand serves as the first barrier, guaranteeing that the water entering the subsequent stages is free of big particles.

After passing through the first chamber, the particulate-containing water enters a second filtering chamber with gravel at the bottom. Any leftover particles that could have gotten past the sand are filtered out by the gravel, which serves as a secondary filter. The water is further purified by this secondary filtration before proceeding to the following stages of treatment. Before the following step of treatment, gravel's greater particle size enables a separate filtering operation to capture any leftover material and guarantee that the water

is as clean as possible. The majority of the significant physical impurities will have been eliminated from the water by the end of this dual-filtration operation.

The water proceeds to the carbon removal step once the majority of the solid pollutants have been eliminated. Here, water flows through charcoal filters that are positioned at several pipe connections. Activated carbon, the material used to make these filters, has a porous structure that allows it to absorb a variety of pollutants, such as chemicals, organic compounds, and chlorine. Charcoal absorbs undesirable tastes and smells in addition to aiding in the removal of any last contaminants from the water. This process is essential for enhancing the water's flavour and aroma while making sure that there are no lingering organic or chemical contaminants. As a very effective filter, the activated carbon ensures that the water is not only transparent but also chemically pure.

The water enters the disinfection stage following the removal of carbon. Here, a UV disinfection equipment filters the water. The UV system employs ultraviolet light to destroy any bacteria, viruses, or other pathogens that could still be present in the water. UV radiation has the ability to harm microorganisms' DNA, which might impair their ability to reproduce and, in the end, kill any living things that are deemed dangerous. The water is exposed to ultraviolet radiation for a sufficient amount of time to guarantee total disinfection. Water safety is truly ensured at this point, even before it is consumed or stored. It is now deemed physiologically acceptable for human consumption and devoid of harmful bacteria.

The water is sent into the storage tank after being disinfected. It is kept here until it is required for delivery. Because it offers a reservoir of usable, clean water, the storage tank is a crucial part of the system. To keep the system informed of the water's condition at all times, a flow switch is put within the storage tank to track the water's movement. Any variations in flow rates may be detected by this flow switch, which will notify the system of any possible problems. The water release is managed by a solenoid valve in addition to the flow switch. The storage tank is effectively supplied or emptied thanks to the solenoid valve, which automatically opens or closes in response to water demand. With connections to a heater, refrigerator, and dispensing station, the storage tank is made to keep water in ideal conditions while enabling temperature control and storage for a variety of applications.

The pump pulls water from the storage tank and delivers it to the dispensing station when it is required for drinking or other uses. In order to enable effective distribution, the pump maintains pressure throughout the system and guarantees a constant water flow. The purified water is available for drinking, cleaning, and other household use at the dispensing station. Before being distributed, the water may go via a heater or refrigerator to change its temperature, depending on the user's preferences or particular requirements. Users may choose the ideal water temperature—hot, cold, or room temp—using the controls on the dispensing station. After undergoing extensive filtration, carbon removal, UV disinfection, and storage procedures, the water is prepared for consumption once it reaches the dispensing station.

Maintenance

This mini water treatment system will operate more efficiently and stably for a longer amount of time with regular maintenance. In order to prevent the accumulation of pollutants or overall degradation in the functionality of systems over time, this will need regular cleaning and inspections of different components.

1. **Filter Media Cleaning:** Filtration is supported by layers of sand, gravel, and carbon filters that will take out the debris, impurities, and contaminants in the water. Of course, all of these filter medias will eventually clog up with filtered particles over time and reduce filtration effectiveness. Thus, respective filter medias must be cleaned and replaced at certain points in time. Sand and gravel beds must be inspected for compaction or blocking. Carbon filters are to be replaced at periodic intervals recommended by the manufacturer or in relation to the volume of contamination in the supplied water. Another thing is regular cleaning of the sedimentation tank. In such a type of tank, heavier particles in the water are allowed to settle. With time, these particles start building up on the bottom of the tank, and if the tank is not cleaned from time to time, it will start harbouring bacteria and microorganisms, thus affecting the water quality. This sedimentation tank is supposed to be emptied and scrubbed in order to get rid of all such built-up sludge and debris that might hamper the normal operation of the tank.

2. **Activated Carbon Filters:** The taste and fragrance of water are enhanced by activated carbon filters, which absorb organic compounds and odours. As their pores are saturated, they become less effective.

I. **Replacement Interval:** Activated carbon filters should be changed every three to six months, or sooner if tests of the water quality indicate that they are no longer as efficient in eliminating taste and odour compounds.

II. **Cleaning Procedure:** Pre-filtering water to remove big particles helps extend the life of carbon filters, even if they cannot be backwashed.

3. **UV Disinfection Unit:** It's possible that over time, some dirt or scale will accumulate on the quartz sleeves and UV lights. This tends to make things less effective. Regular cleaning of the lamps and sleeves is necessary for the best possible transmission of UV radiation. In order to ensure that the water is receiving the right amount of UV radiation.

I. **Cleaning Frequency:** As directed by the manufacturer, clean the quartz sleeve once a month using a gentle cloth and nonabrasive cleanser. Don't scratch the sleeve, please.

II. **Replacement Interval:** UV lamps are used in many applications and have a maximum operational life of about 9,000 hours, which equates to approximately one year of continuous use under optimal conditions. The lamp needs to be replaced annually or as recommended by the manufacturer's specifications, even if it seems the lamp is working at the present time, since the lamp will slowly start losing its intensity and efficiency over time, lowering its performance and effectiveness.

4. Maintenance of pumps:

I. **Scheduled Inspections:** The pump should be inspected every month for any leaks, noise, or vibration that might point to the emergence of issues like seal wear or even potential impeller damage.

II. **Cleaning and Lubrication:** Check the inlet screen and pump casing for any debris accumulation that might impede water flow. To lessen wear,

lubricate moving parts every three to six months using the manufacturer's recommended lubricants.

- III. **Pressure and Flow Tests:** Conduct tests in the pump's pressure and flow rates every 3 months for the purpose of ensuring that the pump is adequate for the system requirements. If flow or pressure is reduced, then check for blockages or worn-out impellers.
- IV. **Replacement Frequency:** Depending on usage patterns and maintenance standards, medium- to long-lasting pumps can often be changed after three to five years.

5. Valves and Connectors:

- I. **Ball Valve and Solenoid Valve:** These are the water flow controls; the latter is electrical, and the former is mechanical. Additionally, they must be examined every three months.
- II. **Testing and Cleaning:** Make all manual valve actions more fluid for movement and sensation. To prevent seizing, remove any deposits from the area around the valves and use the proper lubricant.
- III. **Solenoid Valve Testing:** It is crucial to ensure that the solenoid valve functions properly so that it opens and closes at the proper times, particularly after prolonged usage or even during inactivity. Additionally, this would be a good time to give the solenoid coil a thorough cleaning and carefully check it for any potential electrical issues or noticeable corrosion build-up over time.
- IV. **Flexible Connectors and Pipe Fittings:** To maintain them tight and free of leaks or other indications of degradation, all of the flexible connections and pipe fittings should undergo a quarterly inspection.
- V. **Replacement:** Immediately replace any worn or cracked connectors, as leaks can affect system performance and safety.

- 6. **Storage Tank Maintenance:** Drain the storage tank completely every 6 months for cleaning. Biofilm and sediments will begin to grow inside it if not cleaned.

After cleaning, disinfect the tank with a mild chlorine solution as instructed by the manufacturer. Then, it will kill residual bacteria. After proper rinsing, refill with treated water. The functionality of the float switch should be checked every 3 months; it should control the water level accordingly. Testing on level sensors quarterly, which is to be done to ensure they are correctly signalling the solenoid valve against overflow or dry running.

7. **Heater and Refrigerator Units:** Every six months, inspect and clean the heater element to prevent scaling, which reduces heating efficiency and mineral accumulation. For the refrigerator's cooling efficiency to be at its best, the condenser coils need to be cleaned every six months. Additionally, look for icing inside the device; this might indicate a problem or the need for defrosting.

Why a 0.5 H. P pump?

To determine the type of pump needed for our water treatment system and ensure optimal flow rates for maximum cleaning, we need to consider several key factors, such as pipe sizes, flow rate, and pressure requirements.

Given that we used a hybrid system with **1-inch** and **1/2-inch** pipes,

The flow rate for standard mini water treatments plants is 50 litres per minute (LPM) (Qadri and Alam, 2024)

For pipe flow, the head loss due to friction can be estimated using the Darcy-Weisbach equation, or we can use the Hazen-Williams equation, which is commonly used in water systems. The Hazen-Williams equation is given by:

$$h_F = \frac{10.67LQ^{1.85}}{C^{1.85}D^{4.87}}$$

Where

H_f = Head loss (meters)

L = Length of pipe (meter)

Q = Flow rate (L/s)

C = Hazen-Williams roughness coefficient (typically 130-150 for new pipes)

D = Diameter of pipe (cm)

1-inch pipe = 25.4 mm diameter

1/2-inch pipe = 12.7 mm diameter

Length of each pipe = 20 meters

Flow rate = 50 LPM (which equals 0.833 liters per second)

Hazen-Williams roughness coefficient

C=130 (for typical PVC pipes)

For 1-inch pipe:

$$h_f = \frac{10.67 \times 20 \times (0.833)^{1.85}}{130^{1.85} \times (2.54)^{4.87}}$$

Head loss = 0.8 meters

For 1/2 inch pipe:

$$h_f = \frac{10.67 \times 20 \times (0.833)^{1.85}}{130^{1.85} \times (1.27)^{4.87}}$$

Head loss = 3 meters

Total Head loss = 0.8 + 3 = 3.8 meters

For a 0.5 h.p pump flow rate is gotten below

$$\text{Flow rate} = \frac{\text{Horsepower} \times 746}{\text{Total Head} \times \text{Water weight per liter}}$$

Water weight per liter = 9.81 Newtons (N)

$$\begin{aligned} \text{flow rate} &= \frac{0.5 \times 746}{3.8 \times 9.81} \\ &= 10\text{L/s} \end{aligned}$$

A 0.5 HP pump can easily handle the required flow rate of 50 LPM (0.833 L/s), and even provide up to 600 LPM under the assumed head. Therefore, a 0.5 HP pump should be more than sufficient for your system.

However, it's was important to check the pump's performance curve to ensure that at our required head loss of 3.8 meters, the pump still maintains an optimal flow rate of around 50 LPM. Most 0.5 HP pumps will be able to provide that, but we had to verify the exact flow rate at 3.8 meters' head before we purchased the pump.

CHAPTER FOUR

TEST, RESULTS AND DISCUSSION

4.1 TEST

The water treatment system upon completion was tested to ensure functionality and effectiveness, this test involved the taking two samples of water from the sources available within the faculty of engineering in the University of Benin. One of the samples was passed through the water treatment system while the other was kept as is to serve as a control sample then both samples properly labelled were sent to be tested at the department of Chemistry Faculty of Physical Sciences University of Benin.

The tests carried out at the lab consisted of both physio chemical analysis as well as microbiology analysis to determine the suitability of both water samples according to the standards set by National Institute of Standards (NIS) for potable water.

4.1.1 NIS STANDARDS IN NIGERIA

In Nigeria, the Standards Organisation of Nigeria, popularly known as SON, sets the National Industrial Standards for potable water. This standard, popularly referred to as NIS 554: 2015, stipulates acceptable physical, chemical, and microbiological parameters to ensure drinking water is safe for consumption in Nigeria. Some key components of this regulation include:

1. Physical and Organoleptic Properties
 - Colour: Clear, but not to exceed 15 TCU.
 - Odour and Taste: Water must be odourless; the taste must be neutral.
 - Turbidity: It shall not exceed 5 NTU.
 - pH Level: The pH ranges from 6.5 to 8.5.
2. Chemical Properties

- TDS: Acceptable limit: 500 mg/L, yet up to 1000 mg/L may be acceptable in some instances.
- Hardness: Not exceed 150 mg/L as CaCO₃.
- Chloride: Up to 250 mg/L to avoid problems of taste and corrosion.
- Nitrate: Intake shall not exceed 50 mg/L. It is particularly critical to avoid methemoglobinemia in infants.
- Fluoride: Less than 1.5 mg/L, since intakes exceeding this value can cause dental and skeletal fluorosis.
- Iron: Shall not exceed 0.3 mg/L, to prevent problems on taste and discoloration.
- Sulphate: Less than 100 mg/L.

3. Toxic Substances

- Arsenic: For Carcinogenic risk, the allowable limit is 0.01 mg/L.
- Lead: Shall not be more than 0.01 mg/L due to nervous system and developmental effects.
- Mercury: Shall not exceed the limit of 0.001 mg/L because of its toxicity.
- Cadmium: Shall not exceed the limit of 0.003 mg/L since this element may cause kidney and bone health issues.

4. Microbiological Standards

- Total Coliform Bacteria: Must not be present in any sample of 100 ml, since a single positive result indicates the risk of pathogenic contamination.
- E. coli: Must be absent in 100 ml since it gives an indication of fecal contamination.
- Pathogens: Other microorganisms of infection, such as Salmonella and Shigella, should also be absent.

5. Pesticides and Other Organic Chemicals

The NIS standard allows the presence of a number of pesticides and industrial contaminants like benzene, toluene, and xylene within certain limits since this type of contamination can pose a danger even at low concentrations if exposure is sufficiently long-term.

These parameters are therefore set up to protect against health hazards, making water aesthetically acceptable without creating health problems in the long term. Public water suppliers in Nigeria are compelled by law to comply with the NIS 554:2015; hence, it has been a regulatory framework for both government and private water supply services in ensuring safe drinking water.

4.1.2 LABORATORY TESTS

Water quality analysis involves a series of tests to be carried out on water with the view to ascertaining whether it meets requirements set by NIS for potable water in Nigeria. These will range from physicochemical parameters to microbiological analysis aimed at determining harmful substances, contaminants, or generally undesirable traits in water.

1. Physicochemical Analysis

Physicochemical analysis inspects the physical and chemical parameters of water that might render the water unsafe or unsuitable for drinking.

Apparatus and Equipment Used:

- pH Meter: This is used for measuring acidity or alkalinity in a water sample.
- Conductivity Meter: It measures the ability of water to conduct electricity; this is related to total dissolved solids (TDS).
- Spectrophotometer: This device measures the amount of certain chemicals in water, such as iron, fluoride, nitrate, and sulphate, by measuring how much light they absorb at specific wavelengths. Turbidity Meter or Nephelometer: Accurately measures turbidity in cloudiness in NTU (Nephelometric Turbidity Units). Atomic Absorption Spectrophotometer (AAS): Suitable for the

detection of metals such as lead, cadmium, and mercury. UV-Visible Spectrophotometer: Used in the measurement of nitrates and some other specific compounds by detecting light absorbed.

- Reagents: Testing of colour, taste, and odour of chemicals, preparation of samples for specific tests.

Key Parameters Tested:

- pH: The acidity or alkalinity of water must be in the range 6.5 – 8.5. Highly acidic or alkaline water can corrode pipes and thereby affect the taste.
- Turbidity: Must be less than 5 NTU. Highly turbid water can harbour micro-organisms and bstract (abstract) the effectiveness of disinfection.
- Total Dissolved Solids: It gives an idea about the quantity of dissolved substances. The limit is generally 500 mg/L.
- Hardness: Represents the concentrations of calcium and magnesium, which shall not be in excess of the limit of 150 mg/L to avoid scaling and health effects. Chloride: Shall not be greater than 250 mg/L to avoid taste and corrosion problems. Nitrate: Shall not exceed 50 mg/L to prevent methemoglobinemia ("blue baby syndrome") in infants. Fluoride: Shall not be greater than 1.5 mg/L to avoid dental and skeletal fluorosis. Iron: Shall not exceed 0.3 mg/L to avoid staining and unpleasant taste.
- Heavy Metals (e.g., Arsenic, Lead, Mercury, Cadmium) This analysis measures toxic metals at very low levels. Typical detection limits are less than 0.01 mg/L. The procedure uses an atomic absorption spectrophotometer.

2. Microbiological Analysis

Microbiological analysis entails the identification and enumeration of microorganisms such as bacteria, viruses, and protozoa in water. The pathogenic ones, which cause diseases, have to be absent when the water is potable.

Apparatus and Equipment

- Autoclave: It is used in sterilizing equipment and culture media to prevent any case of contamination during tests.
- Membrane Filtration Apparatus: This is essential in filtering water samples to capture microorganisms on a membrane, which then can be placed on growth media to assess the microbial presence. Incubator: To incubate microbial cultures at an exact temperature. Agar Media Petri Dishes, such as Nutrient Agar, MacConkey Agar, EMB Agar: These would provide the places where bacterial colonies will grow and can be counted and analysed thereafter. Microscope: Spotted specific types of microorganisms after staining.
- Coliform Test Kits: Includes reagents and media specifically for the detection of coliform bacteria and E. coli.

Key Parameters Tested:

- Total Coliforms: This would show the presence of bacteria that generally come from the environment. Coliforms should be absent in any 100 ml sample.
- Faecal Coliforms (e.g., E. coli): It shows faecal contamination, which can transport pathogens. E. coli should be absent in any 100 ml sample; the presence of E. coli signifies contamination from human or animal waste.
- Pathogens: The pathology of specific tests for injurious pathogens like Salmonella, Shigella, others, and viruses. Should not contain pathogenic microorganisms.

4.1.3 TESTING PROCEDURE OVERVIEW

Valid or accurate microbiological tests require that the samples be analysed within 6–12 hours of sample collection.

Steps Involved in Physicochemical Analysis:

- pH, Conductivity, and TDS: Determination can be carried directly in the water sample with the aid of probes/meters.
- Turbidity: Measured by turbidity meter

- Colour and Odour: Measured visually and odour; subjective but has given initial clues about the quality of water.
- Chemical Tests: Nitrate, Chloride, Fluoride, etc. According to requirements using a spectrophotometer or certain reagents for measuring the concentration, for example,
- Nitrate Test: A water sample is mixed with reagents, and colour changes are measured by spectrophotometry. Heavy Metals: For example, lead and cadmium; thus, samples analysed through atomic absorption spectrophotometry or by means of inductively coupled plasma (ICP) spectrometry.

Steps for Microbiological Analysis Sterilization:

- All apparatus are sterilized in an autoclave in order to avoid contamination. Filtration: The water sample is filtered through a membrane filter in order to capture the bacteria.
- Culturing: The membrane is placed on selective media and incubated at a fixed temperature. Enumeration and identification: After incubation, the number of colonies of bacteria are counted; if necessary, identification under the microscope or with biochemical tests will be done.

4.1.4 Reporting and Compliance

The test results are checked against the standards in the NIS 554:2015. Where the results meet NIS standards, the water is considered potable; otherwise, additional treatment is recommended before usage.

A combination of these thorough tests ensures that water quality in Nigeria is closely monitored to meet safety standards for protection of public health and promoting access to safe drinking water.

4.2 RESULTS

The results of the laboratory test carried out by the department of chemistry in the University of Benin.

The Control Specimen

This specimen of water was sourced from the sources within the Faculty of engineering, University of Benin and sent to the laboratory for testing within the laboratory and the results gotten from the laboratory are as follows:

PHYSICO CHEMICAL ANALYSIS		
Parameter, Unit	Limit, N.I.S STD	Result
Temperature °C	Ambient	Ambient
Colour, TCU	3.0	Colourless
Odour	Odourless	Odourless
Taste	Tasteless	Tasteless
pH	6.5-8.5	6.65
Turbidity, NTU	5.00	Nil
Conductivity, uS/cm	1000.00	37.02
TDS, Mg/l	500	20.36
Suspended Solid “	0.00	0.00
Hydrocarbon, “	0.0002	Nil
Sodium”	100	0.42
Nitrate,”	10.00	0.15
Nitrite, “	0.10	Nil
Sulphate,”	100	7.00
Hardness, CaCO ₃	100	12.00
H ₂ S, “	0.01	Nil
Detergents,”	0.01	Nil
Iron,”	0.30	0.02
Fluoride”	1.00	Nil
Chloride,”	100.00	1.58

Magnesium,”	0.20	0.02
Manganese”	0.05	0.00
Zinc,”	5.00	0.28
Lead,”	0.01	Nil
Cadmium,”	0.003	Nil
Mercury,”	0.003	Nil
Barium,”	0.05	Nil
Cyanide as CN,”	0.01	Nil
Arsenic,”	0.01	Nil
Copper”	1.000	0.30
Benzene,”	0.002	Nil
Potassium	100.00	0.61

Table 4.1: Physico chemical analysis (Borehole waater)

MICROBIOLOGY		
Parameter, Unit	Limit	Result
Coliform, 100cfu/ml	Nil	Nil
Faecal Streptococci	“	Nil
Specific E. Coli	“	Nil
Yeast/Mould after 5 days	“	22.00

Table 4.2: Microbiology (Borehole waater)

Comment: This water (borehole water) sample requires treatment to meet acceptable standard for portable water.

This sample according to the NIS standard for potable water does not meet the required standards for potable water showing the necessity of a water treatment plant for the faculty of Engineering in the University of Benin.

The Treated Specimen

This specimen of water was sourced from the sources within the Faculty of engineering, University of Benin and passed through the water treatment system before being sent to the laboratory for testing within the laboratory and the results gotten from the laboratory are as follows:

PHYSICO CHEMICAL ANALYSIS		
Parameter, Unit	Limit, N.I.S STD	Result
Temperature °C	Ambient	Ambient
Colour, TCU	3.0	Colourless
Odour	Odourless	Odourless
Taste	Tasteless	Tasteless
pH	6.5-8.5	7.02
Turbidity, NTU	5.00	0.00
Conductivity, uS/cm	1000.00	118.70
TDS, Mg/l	500	65.29
Suspended Solid “	0.00	Nil
Hydrocarbon, “	0.0002	Nil
Sodium”	100	0.56
Nitrate,”	10.00	0.02
Nitrite, “	0.10	0.00
Sulphate,”	100	2.10
Hardness, CaCO ₃	100	14.00
H ₂ S, “	0.01	Nil
Detergents,”	0.01	Nil
Iron,”	0.30	0.01
Fluoride”	1.00	Nil
Chloride,”	100.00	1.26
Magnesium,”	0.20	0.00
Manganese”	0.05	Nil

Zinc,”	5.00	0.33
Lead,”	0.01	Nil
Cadmium,”	0.003	Nil
Mercury,”	0.003	Nil
Barium,”	0.05	Nil
Cyanide as CN,”	0.01	Nil
Copper”	1.000	0.30
Potassium	100.00	0.30

Table 4.3: Physico chemical analysis (Treated water)

MICROBIOLOGY		
Parameter, Unit	Limit	Result
Coliform, 100cfu/ml	Nil	Nil
Faecal Streptococci	“	“
Specific E. Coli	“	“
Yeast after 5 days	“	“
Mould after 5 days	“	Nil

Table 4.3:Microbiology (Treated water)

Comment: This water (treated water) sample meets acceptable standard for portable water.

This sample according to the NIS standard for potable water meets the required standards for potable water showing the efficacy of the water treatment plant designed for the faculty of Engineering in the University of Benin.

Other test carried out are as follows

- Conductivity test

Result 184 micro semens per cm

Limit: 1000 micro semens per cm



- Total dissolved solids (TDS)

Result: 95 ppm

Limit: 500ppm



- Test for pH

pH: 6.66

Limit: 6.5-8.5



- Test for chloride

Chloride: 4.6 mg/l
Limit: 250 mg/l

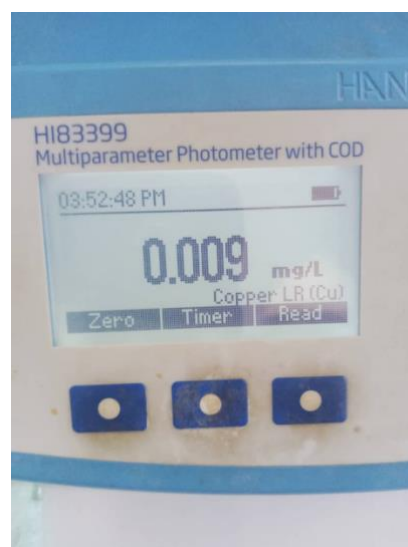


- Test for copper

Result: 0.009 mg/l

Limit: 1 mg/l

Health impact if the limit is exceeded: Gastrointestinal disorder



- Hardness test

Result: 92

Limit: 150

Burette reading		Difference	Volume of titrant solution used (ml)	No.	Volume of water sample taken
Initial	Final				
38.8	43.4	4.6		1	50
		0	11.2	2	50
		0		3	50
			4.6		

Result: 92

10 ml EDTA titrant

NB: 1 mg CaCO₃ = 1 ml 0.01M EDTA = 1 mg CaCO₃ equivalent

- Turbidity test

Result: 01.2



4.3 DISCUSSION OF RESULTS FOR CONTROL AND TREATED WATER SPECIMENS

The physicochemical analyses of untreated and treated water samples obtained from the Faculty of Engineering, University of Benin, will help in ascertaining the differences that

occur in their water quality and the efficacy of the latter's water treatment system to meet the NIS for potable water in Nigeria.

Physicochemical Analysis

The results for many parameters were within acceptable NIS limits in the untreated control specimen-water. Areas of concern showed that:

- pH was 6.65, thus within the NIS limit of 6.5–8.5, hence presenting acceptable levels of acidity;
- turbidity was nil, thus in compliance with the standard of <5 NTU;
- conductivity and TDS gave relatively low values: 37.02 $\mu\text{S}/\text{cm}$ and 20.36 mg/L, respectively, hence showing a minimal quantity of dissolved ions and solids.
- Heavy Metals and toxic substances presence of lead, mercury, cadmium, and arsenic were below the detection limit, hence within the safety limits according to the NIS.

What is of essence, though, is that there was a critical problem realized in yeast / mould count recorded as high as 22 CFU/ml after 5 days of incubation. This creates health problems. The water was therefore organically contaminated and not fit for consumption unless appropriately treated.

The sample of the treated water had the following drastic improvements:

- The pH slightly increased to 7.02, closer to the middle value of the NIS recommended range of stability and neutrality on acidity levels.
- Turbidity was so much low at 0.00 NTU, hence clarity was realized. The reduction in turbidity amount evidences good filtration or removal of sediments.
- Conductivity and TDS slightly rose to 118.7 $\mu\text{S}/\text{cm}$ and 65.29 mg/L, respectively, well within the limits prescribed by the NIS, indicating acceptable mineral content.
- Heavy metals and toxic substances also showed the absence of such elements in the treated sample, indicating no contamination with possibly hazardous elements.
- Yeast and mould also weren't detected in the treated sample; this proved that disinfection and microbial treatment steps were applied.

Microbiological Analysis

The following microbiological analysis verifies the importance of the treatment regarding ensuring microbial safety:

- **Control Sample:** The un-treated sample met the NIS standard since there was no level of coliform bacteria, faecal streptococci, or specific E. coli, which indicates that there is no presence of faecal contamination in it. However, the existence of yeast and mould within 22 CFU/ml remains a factor of serious concern since the said organisms can bring spoilage to the food and, at the same time, cause health risks to individuals.
- **The Treated Sample:** All microbial contaminants tested for, in the treated water, were absent, including yeast and mould. This evidences a high-quality, safe, potable water sample, hence reinforcing the effectiveness of the treatment process in eliminating microbial hazards, rendering the water suitable for drinking.

Overall Analysis and Implications

The comparison between the untreated and the treated samples realizes the importance and effectiveness of a well-maintained water treatment system:

- **Improved Physicochemical Quality:** pH, TDS, and turbidity levels were tremendously improved upon treatment; this ensures compliance with NIS standards while also improving aesthetic appeal: clarity, taste, and odor.
- **Microbiological Safety:** The treatment completely eliminated the presence of yeast and mould, an extremely important enhancement of the key safety concern present in the control sample.
- **Health and Safety Compliance:** In meeting the NIS potable water standards, the treated sample can be regarded as safe for consumption, hence posing no threat to public health within the faculty.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The designs and implementations of a mini water treatment plant for the Department of Mechanical Engineering, UNIBEN are presented in this report and show how effectively the system can produce treated water in order to achieve the specifications set by the NIS for potable water. Untreated-control water and specimens of treated water were analyzed for physicochemical and microbiological qualities with a view to ascertaining improvements in critical areas necessary for making such water safe for consumption.

The untreated control sample, which came directly from the Faculty of Engineering, used to satisfy some of the NIS requirements in regard to the physicochemical properties of pH and turbidity, devoid of hazardous heavy metals. This sample was organically contaminated by yeast and mold both pose health risks; therefore, it is not fit for consumption without further treatment.

On the other hand, the treated water sample, which had been treated by the newly designed mini water treatment plant, was satisfactory in all aspects and conformed to all NIS requirements for potable water. The major parameters, such as turbidity and pH, were greatly improved, while most important were microbial contaminants, which include yeast and mold brought to zero. Of more importance, the significant parameters included TDS, conductivity, and hardness that were brought within safety limits.

Overall, these results confirm that the mini water treatment plant designed for the Department of Mechanical Engineering is indeed able to raise the quality of water to a level where it is fit and safe for drinking. It underpins the necessity and efficiency of water treatment in removing impurities and microbial hazards and, hence, is one of the major contributors to public health. In doing so, the treatment plant meets its objective of serving as an appropriate long-term solution to supplying clean water to the faculty staff and students-a reflection of its paramount importance in the interest of health and well-being within the department.

5.2 RECOMMENDATION

The recommendation based on the success of the mini water treatment plant, and findings from this study, has been done to make sure there is a constant water quality and further guide improvements that the department ought to do in their water treatment practices.

5.2.1 ROUTINE MAINTENANCE AND MONITORING OF THE MINI TREATMENT PLANT

The treatment system should be subjected to regular inspection, maintenance, and testing in order to ensure its long-term effectiveness. Ongoing testing of the physicochemical and microbiological parameters will enable problems that may develop over time to be identified early, and will help maintain compliance with the NIS standards.

5.2.2 QUALITY ASSURANCE PROGRAM IMPLEMENTATION

It shall establish a regular quality assurance program, which shall focus on the performance of the mini water treatment plant. The quality assurance program shall include, but is not limited to, quarterly water quality testing to ascertain whether the system is continually producing drinking water. Results of these shall be documented and referred to as confirmation of the continued efficiency of the treatment system.

5.2.3 SAFETY AND WATER AWARENESS

The faculty and staff need to inform the students about the treated water so that their health and safety can be taken care of. Awareness programs can be provided to the people to make them realize the risks due to the untreated water and also report any change in taste, colour, or odour of water that indicates system performance.

5.2.4 PERIODIC EVALUATION OF THE TREATMENT PROCESS FOR POSSIBLE UPGRADES

While the current setup of the treatment has served well, further development of water treatment technology can provide even greater enhancements. This periodic assessment

of the system's functionality will deliver all signals whether any added steps of treatments such as UV disinfection or activated carbon filtration will become beneficial for future upgrade considerations.

5.2.5 MINI TREATMENT PLANT MODEL EXPANSION ACROSS CAMPUS

Given the success of the system design, a similar water treatment system can be performed for other departments around University of Benin. With such expansion in place, it is expected to increase access to treated water, hence contributing to public health and underlining university concerns to ensure that safe drinking water is provided among students and staff.

5.2.6 DOCUMENTATION AND FUTURE RESEARCH

It is envisaged that the detailed design, implementation, and performance results of the treatment plant will be supportive, and possibly informative, for future research in the development of similar systems at other institutions or regions facing conditions of poor water quality.

These are recommendations that may be considered by the Department of Mechanical Engineering for continuing in order to ensure high-quality potable water from its mini water treatment plant and to maintain health and well-being in the community. This would serve as a model for sustainable water treatment practices in educational institutions.

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