

**DEVELOPMENT OF AN IMPROVED SMART WATER
TREATMENT PLANT FOR THE DEPARTMENT OF
MECHANICAL ENGINEERING, UNIBEN**



MACAULAY ANGEL (MEE)

ENG2002470

IDUMWONYI MARCUS (MEE)

ENG2009647

ABOR PRECIOUS SOMTOCHUKWU (MEE)

ENG2006361

OLUSEGUN CLINTON (MEE)

ENG2002501

OJO NOSAKHARE (MRE)

ENG2002374

EUGENE KINGSLEY GODWIN (MEE)

ENG2006378

UNIVERSITY OF BENIN

BENIN CITY

NOVEMBER, 2025

CERTIFICATION

This is to certify that this research and fabrication project titled: DEVELOPMENT OF AN IMPROVED SMART 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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ENGR. P. O. OLAGBEGI

Project Supervisor

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Date

.....

ENGR. MARTINS OSHIKHUEMHE

Project Coordinator 2024/2025

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Date

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PROF. OSAROBO IGHODARO

Head of Department

.....

Date

DEDICATION

We dedicate this report to God Almighty, whose grace saw us through our journey in this school. To our families for their unending love care and support. To the Department of Mechanical Engineering whose, teachings, guidance, discipline and mentorship has shaped us into who we are today, preparing us for what awaits us in the future. To our project supervisor ENGR. P. O Olagbegi who has been a huge support to us. Finally, to all our friends, course mates and all those who have been an inspiration to us. Your faith in us has fueled our passion for learning and zeal to keep moving forward.

ACKNOWLEDGEMENT

As a group, we extend our deepest gratitude to God almighty who has brought us this far, we are what we are today by his grace and mercy.

We sincerely appreciate our families and loved ones for their love, care, support and continuous encouragement all through our time in this school.

Our heartfelt thanks to our project supervisor, ENGR. P. O. OLAGBEGI for his guidance and support and invaluable insight that made this project successful. He has been very wonderful indeed. We also appreciate the Department of Mechanical Engineering for the knowledge they have impacted on us, the guidance they gave us and for shaping us into who we are today making us better for the future that awaits us.

Special thanks to PROFESSOR P.O EBUNILO, Head of the Department, ENGR. MARTINS OSIKHUEMHE, our project coordinator and all our lecturers for their invaluable guidance and support.

Finally, we are grateful to all our friends, course mates and anyone that made these five years wonderful. You have all left an unforgettable mark in our hearts. Thank you.

ABSTRACT

Clean water is a very vital aspect of human survival and sustainability. This project focuses on improving the mini water treatment plant in the Department of Mechanical Engineering, University of Benin. The system is designed to improve the quality of drinking water being produced meeting the WHO standard for Nigerian drinking water.

The project involves looking into the issues with the previous design and recommending the best solution that will address those issues. This includes system redesign and replacement of complex components with simpler user-friendly component. The report also addresses various kinds of water treatment method both past and present, their advantages and disadvantages and how the various water treatment methods have evolved over time.

The results shows the efficiency of each component in the line of purification and the effect of improving the system as tests were carried out on six samples on different points along the line of purification. This project has not only enhanced drinking water quality but can also serve as a small-scale water treatment system for rural areas and areas that lack access to potable water.

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ABBREVIATION AND KEYWORD

WHO	World Health Organization
SDG	Sustainable Development Goal
UNICEF	United Nations International Children's Emergency Fund
JMPR	Joint FOA/WHO Meeting on Pesticide Residues
O ₃	Ozone
RO	Reverse Osmosis
UV	Ultraviolet
NOIPolls	Nigeria Opinion Polls
THM	Trihalomethanes
O ₂	Oxygen Molecule
Fe(II)	Iron two

Mn(II)	Manganese two
As(III)	Arsenic three
DBP	Dibutyl Phthalate
NTU	Nephelometric Turbidity Unit
NSDWQ	Nigerian Standard For Drinking Water Quality
UNIBEN	University of Benin
EPA	Environmental Protection Agency
PLC	Programmable Logical Controller
NCWR	National Centre for Water Resources
PVC	Polyvinyl Chloride
GPM	Gallons Per Minute
UV - C	Ultraviolet light in the C range
DNA	Deoxyribonucleic Acid
NIS	National Institute of Standards
pH	Potential of Hydrogen
TDS	Total Dissolved Solid
H ⁺	Hydrogen ion
ORP	Oxidation Reduction Potential
USB	Universal Serial Bus
EC	Electrical Conductivity
PC	Personal Computer

CHAPTER 1

1.1 INTRODUCTION

Water is an essential environmental resource necessary for the survival and sustainability of all life forms. However, increasing population growth, urbanization, and industrialization have intensified the demand for clean water while simultaneously contributing to its contamination. Access to safe drinking water remains a major global challenge, and the World Health Organization (WHO, 2011) provides standards to ensure the microbial, chemical, and physical safety of potable water.

In support of the United Nations Sustainable Development Goals (SDGs), particularly Goal 6 on clean water and sanitation (UN, 2020), countries like Nigeria continue to face difficulties in ensuring universal access to safe water. Less than one-third of Nigerians have piped water supply, and even those connections are often unreliable or contaminated (WHO/UNICEF, 2014; Kumpel et al., 2016). Many households depend on wells, boreholes, springs, and water vendors—sources classified as “improved” by WHO if adequately protected, though contamination still occurs (WHO, 2011; JMPR, 2013). In contrast, rivers, lakes, and streams are often “unimproved” sources, vulnerable to pollution from sewage, industrial discharges, and abattoir effluents (Omole and Longe, 2008; Bello-Osagie and Omoruyi, 2012).

Studies in Nigeria have reported microbial contamination by coliforms, *Staphylococcus aureus*, and *Pseudomonas* species (Igbeneghu and Lamikanra, 2014), as well as elevated levels of heavy metals like iron, lead, cadmium, and nickel beyond WHO permissible limits (Ayedun et al., 2015; Titilawo et al., 2018). Such contamination poses serious public health risks, contributing to widespread waterborne diseases such as diarrhoea, cholera, and typhoid

(Coleman et al., 2013; Igbiosa and Aighewi, 2017). Over 66 million Nigerians still lack access to safe drinking water (WHO, 2015).

To address these challenges, WHO recommends multiple treatment methods including filtration, coagulation, aeration, chlorination, and adsorption (WHO, 2011). However, there remains limited data on the actual treatment technologies used in Nigeria and their effectiveness. This underscores the need for small-scale or pilot water treatment systems—such as a **mini water treatment system**—to demonstrate practical, affordable, and sustainable solutions for clean water provision in developing regions.

Importance of clean water

Water purification is crucial because it has a direct impact on both public health and the health of the environment. In order to protect communities from waterborne illnesses and to ensure the general welfare of populations, clean and safe water is necessary for drinking, cooking, and personal hygiene. Effective water purification methods are essential for assuring a consistent and sustainable supply of this priceless resource, which will eventually contribute to the health, prosperity, and resilience of civilizations around the world.

Traditional Water Purification Methods

Conventional water purification methods have evolved over centuries, primarily utilizing sedimentation and filtration. Sedimentation allows impurities to settle but often yields inadequate results. Filtration, using sand, gravel, or cloth, effectively cleans turbid water. Another simple yet efficient option is solar disinfection, which works particularly well in sunny places. It entails exposing clear bottles of water to sunshine for many hours, during which time the heat and ultraviolet radiation combine to kill disease-causing organisms. To summarise, conventional water purification technologies such as boiling, filtration, sedimentation and solar disinfection continue to be useful for supplying clean drinking water in areas where contemporary systems are unavailable. Heating methods like boiling are also used, though boiling has limitations in sterilization and does not remove chemical impurities, affecting taste and colour. Traditional methods are low-cost and accessible, enhancing the effectiveness and sustainability of water interventions. Culturally acceptable technologies

suited to local lifestyles are prioritized, and their evolution has been significant across regions. While primarily serving as stepping stones to modern technologies, traditional methods provide immediate protection but struggle against microbial threats and emerging micro-pollutants. Acceptance by local populations is crucial, and the effectiveness of purification varies due to cultural diversity. Adapting traditional practices to modern conditions often yields superior outcomes, such as cloth filters removing *Giardia* cysts more effectively than standard ceramic filters. Encouraging traditional methods can coexist with modern solutions, and integrating both approaches can be beneficial. Understanding traditional practices may inspire new technologies to address persistent contaminants

Advanced Methods Used in Purification of Drinking Water

- **Ion Exchange**

This water purification process mostly helps in softening water which means removing sodium-potassium ions from the water, which makes them unfit for drinking. In this process, the exchange of ions or the charge is the main motive, to begin with. The exchange of ions is made possible by passing the water through an ion-exchange resin, displaces the weakly charged metallic ions (sodium and potassium ions) through electromagnetic attraction.

- **Activated Carbon**

The use of activated carbon is always an advantage for removing impurities from any substance. Carbon filtration is done through adsorption, where the water is passed through granular carbon beds. Activated charcoal (Carbon) filtration does an excellent job in removing chlorine from the water and carcinogenic elements such as trihalomethanes (THMs).

- **One Micron Pre-Filter**

This is the very basic step in water purification. In this process, water is passed through multiple filters with a pore size of 1 Micron. When the water passes through such a fine pore size water filter, most microorganisms such as viruses, bacteria, cryptosporidium, and various other harmful bugs are eradicated from the water, making it fitter and safer for drinking and other purposes.

- **Ozonation (Ozone Treatment)**

Ozonation uses ozone gas (O₃) — a powerful oxidizing agent — to disinfect water and remove impurities. When ozone is dissolved in water, it destroys bacteria, viruses, and organic pollutants by breaking down their cell walls and oxidizing harmful chemicals.

- Reverse Osmosis (RO)

Reverse osmosis (RO) is a cutting-edge water purification technique that uses a semipermeable membrane to remove dissolved salts, pollutants, and microbes from water. Water is driven under high pressure through a membrane, which only enables pure water molecules to pass. Salts, heavy metals, germs, and chemicals are trapped and washed out as waste.

1.2 STATEMENT OF THE PROBLEM

Although the mechanical department already has a functioning mini water treatment system but it has some flaws which are as follows:

- The large storage tank stored water for too long thereby leading to settlement and growth of micro-organisms
- The system was power consuming as it consisted of a fridge and a heater which requires a lot of energy to power
- The appearance of the dispensing outlet didn't seem like a drinking water dispenser outlet so it was mainly abused and used as a waste bin
- The system lacked fail safe components especially when the level sensors fail leading to spillage of water
- Over all the system was complex, space consuming and used a lot of piping materials which could add to the contamination of the water

All these limitations listed above can lead to breeding of micro-organism making the water unhealthy to drink. Due to these reasons, an improvement was necessary for the project so as

to produce clean and healthy water for the Mechanical Engineering department and also to incorporate fail safe systems to prevent or reduce the risk of accident when the system fails.

1.3 AIM AND OBJECTIVE

The primary aim of this project is to improve the functionality and efficiency of the existing mini water treatment system in the Mechanical Engineering Department, ensuring the production of water that meets higher health and safety standards. Furthermore, the project seeks to develop a scalable design that can be implemented in rural areas to enhance access to clean drinking water.

OBJECTIVES

- Minimize water retention time to prevent sedimentation and bacteria growth
- Introduce a fail-safe alternative into the system
- Reduce the power consumption of the system by using low energy consumption devices
- Reduce the complexity and space consumption of the system
- Improve the appearance of the system to prevent it from being abused
- Introduce a wider drain to accommodate spilling when dispensing water

1.4 SCOPE OF THE STUDY

This study focuses on the design and improvement of a mini water treatment system serving the Mechanical Engineering department. The primary scope includes evaluating the existing system, identifying design inefficiencies—particularly the oversized storage tank—and implementing modifications to enhance water quality and operational efficiency. The study covers the redesign of the storage tank to reduce water retention time and bacterial growth, as well as general improvements in the power consumption and the overall appearance of the system. The project is limited to small-scale, decentralized treatment systems and does not include large municipal water supply systems. The following comprises the scope of the study

- System Re-design: The system will entail redesign of a part of the mini water treatment system for example the tank, the outlets and the general structure of the system.
- Procurement and installation: All the materials and devices needed for the improvement of the system will be procured and installed
- Testing: The water has to be tested again to compare the result before and after the improvement process. Also, the result has to correlate with the World Health Organisation (WHO) standards for Nigeria drinking water.
- Documentation: The results are to be documented and displayed for the public to see the quality of the water after the system improvement.

1.5 SIGNIFICANCE OF THE STUDY

Mini water treatment systems play a critical role in addressing water supply challenges, not only in Mechanical Engineering department but also in small or remote communities where centralized water treatment systems are not feasible due to cost, infrastructure, or logistical constraints. These compact systems are designed to treat water at the point of use or close to where it is needed, making them ideal for rural areas, schools, hospitals, and disaster-stricken zones.

Unlike large-scale treatment systems that require extensive distribution networks, mini water treatment systems can operate independently, often requiring less space, energy, and maintenance. They are typically designed to remove common contaminants such as suspended solids, pathogens, heavy metals, and chemical pollutants, using methods like sedimentation, filtration, and disinfection (e.g., chlorination or UV treatment).

The flexibility and scalability of mini systems allow for customization based on the quality of the raw water and the specific needs of the consumers. Furthermore, they can serve as demonstration units for water treatment education and promote local participation in water management, which is vital for long-term sustainability.

As global demand for clean water increases, and climate change further stresses water sources, mini water treatment systems represent a practical, cost-effective solution to improve water access and quality in underserved regions.

CHAPTER 2

2.1 LITERATURE REVIEW

2.2 OVERVIEW OF WATER TREATMENT

Water treatment is the process of improving the quality of water to make it suitable for specific purposes such as drinking, domestic use, irrigation, or industrial applications. The main goal of water treatment is to remove physical, chemical, and biological contaminants that can harm human health or affect water usability.

Natural water sources such as rivers, lakes, and groundwater often contain impurities like suspended solids, dissolved minerals, organic matter, and microorganisms. To make such water safe for consumption, it undergoes several treatment stages designed to eliminate these contaminants and improve taste, odor, and clarity.

A conventional water treatment system typically involves the following key stages:

1. **Coagulation and Flocculation** – Chemicals called coagulants (like alum) are added to raw water to bind fine particles and form larger clumps known as flocs.
2. **Sedimentation** – The heavy flocs settle to the bottom of a tank, allowing clear water to remain at the top.
3. **Filtration** – The water passes through layers of sand, gravel, and activated carbon to remove smaller suspended particles and microorganisms.
4. **Disinfection** – Chemicals such as chlorine or physical methods like ultraviolet (UV) light are used to kill remaining pathogens.
5. **pH Adjustment and Conditioning** – The treated water's pH is adjusted to prevent corrosion or scaling in distribution pipes.

2.3 EVOLUTION OF WATER TREATMENT METHODS

Over the last decade, water treatment has evolved significantly with a focus on advanced technologies like membrane filtration (such as reverse osmosis and ultrafiltration), ozonation, and UV light, which offer more effective removal of a wider range of contaminants. This has

enabled the treatment of alternative water sources, including wastewater and seawater, and the development of more sustainable and decentralized systems for drinking and commercial use. The industry has also seen improvements in membrane systems that reduce costs, making these advanced technologies increasingly competitive with traditional methods.

2.3.1 BOILING

Boiling is the most common method of household water treatment. A national poll by NOIPolls found that **34%** of Nigerians say they treat their water before drinking it; of those, **49%** reported using boiling as their method. According to World Health Organization WHO, water needs to be heated until the point where the first big bubbles appears to ensure that it is pathogen free. Many organizations recommend boiling both for water treatment in developing countries and to provide safe drinking water in emergency situations throughout the world - though it is quite laborious and uses a lot of energy. Boiling only kills pathogens and does not remove turbidity or chemical pollution (e.g. arsenic) from drinking water. So, prior to boiling, water can be purified by settling or filtration method

According to Clasen (2009) 'Boiling or heating with fuel is perhaps the oldest means of disinfecting water at the household level. If practised correctly, boiling is also one of the most effective [methods], killing or inactivating all classes of waterborne pathogens, including bacterial spores and protozoan cysts that have shown resistance to chemical disinfection and viruses that are too small to be mechanically removed by microfiltration ... Moreover, while chemical disinfectants and filters are challenged by turbidity and certain dissolved constituents, boiling can be used effectively across a wide range of physical and chemical characteristics'.

2.3.1.1 ADVANTAGES OF BOILING AS A MEANS OF WATER PURIFICATION

- It is an easy, simple and widely used method of disinfection :This method is simple, easy to use, and doesn't require any additional equipment.
- It kills most pathogens in water: Almost all pathogenic bacteria, viruses, and parasites found in water are eliminated by boiling.
- It is a low-cost method of water purification: Requires only a heat source and a container, making it one of the most economical purification methods

- It doesn't require any chemical additives : avoids problems with taste or byproducts by purifying water without the use of chemical additions.
- It is suitable for emergency use: reliable and quick way to guarantee water safety during emergencies, epidemics, or trips.

2.3.1.2 DISADVANTAGES OF BOILING AS A MEANS OF WATER PURIFICATION

- It alters the taste of the water: causes the water to taste flat or unappealing by removing the dissolved oxygen.
- It is not suitable for large scale treatment: extremely ineffective and impractical for purifying big amounts of water for a municipality or community
- It doesn't remove chemicals present in the water: does not eliminate dangerous chemical pollutants such as pesticides, nitrates, or heavy metals; in fact, it may even make them more concentrated.
- It is time consuming: takes a long time to bring water to a boil and then let it cool down before drinking.
- It in most cases requires high energy consumption: reliant on fuel, which makes it a process that uses a lot of energy particularly in situations where fuel is costly or rare.

2.3.2 FILTRATION

Filtration is the process in which solid particles in a liquid or gaseous fluid are removed by the use of a filter medium that allows the fluid to pass through while retaining the solid particles. Water filtration is primarily used for storm water, wastewater, and drinking water applications, but it also has uses in industrial manufacturing, power plants, food and beverage production facilities, mining and other heavy-duty applications. Water filtration can remove or reduce the concentration of suspended particles, parasites, bacteria, algae, viruses, fungi, and more chemical and biological contaminants.

Before the development of modern treatment technologies, humans used various natural and improvised methods to filter and purify water for drinking. These traditional techniques were based on physical straining, sedimentation, and adsorption processes that relied on readily available materials. Some of the major historical or old methods include: Cloth filtration, Sand filtration, Clay pot filtration, Sedimentation, Use of plant materials, Earthenware or Stone filters.

Modern water filtration techniques use physical, chemical, and biological processes—sometimes in combination—to remove suspended solids, microorganisms, and dissolved contaminants from water. These methods are designed for efficiency, consistency, and compliance with international drinking water standards such as those set by the **World Health Organization (WHO)**. This includes: Rapid Sand Filtration, Activated Carbon Filtration, Membrane Filtration, Pressure Filtration, Cartridge and Microfilter Systems, Ion Exchange Filtration, Ceramic Filtration, Multimedia (Layered) Filtration, Biological Filtration (Biofilters).

2.3.2.1 ADVANTAGES OF FILTRATION AS A MEANS OF WATER PURIFICATION

- Removes harmful contaminants :Through the use of materials that trap dirt, germs, and chemicals, such as sand, gravel, or activated carbon, filtration purifies water. It purifies and makes the water safe to drink by physically obstructing particles, breaking down bacteria, and chemically adsorbing toxic compounds.
- Reduces health risks :Filtration helps reduce health risks by eliminating harmful microorganisms like bacteria, viruses, and parasites that can cause diseases such as cholera and typhoid. It also removes toxic substances and impurities, ensuring cleaner, safer water that supports good health.
- Keeps beneficial minerals: Calcium and magnesium, two vital minerals for healthy bones and general well-being, are retained through filtration. It eliminates dangerous impurities from the water without removing these healthy elements, in contrast to processes like distillation or reverse osmosis.

- **Cost-effective** :In general, filtration systems are less expensive to operate and maintain than other purification techniques like distillation or reverse osmosis, which makes them accessible to both families and communities.
- **Environmentally friendly**:By eliminating the need for chemicals and the production of hazardous byproducts, filtration lowers waste and pollution in the environment.
- **Saves money and resources**: Filtration decreases the need to purchase bottled water and uses less energy for water packaging and transportation by supplying clean water straight from the source.
- **Improves taste and odour**: Chlorine, organic debris, and other contaminants that produce an unpleasant taste and odour are eliminated by filters, leaving behind cleaner, fresher water.
- **Enhances appliance performance**:Removing sediments and minerals prevents scale buildup in appliances like kettles, washing machines, and water heaters, extending their lifespan.
- **Increases efficiency**:Filtration systems ensure a consistent supply of clean water for everyday usage by rapidly and continually purifying water without the need to boil or store it.

2.3.2.2 DISADVANTAGES OF USING FILTRATION AS A MEANS OF WATER PURIFICATION

- **Does not kill all germs**: Filtration mainly removes dirt, sand, and visible particles. However, most filters cannot kill or remove very small microorganisms like viruses and some bacteria unless they are combined with other treatments such as chlorination or boiling.
- **Limited chemical removal**: Regular filters do not remove dissolved chemicals, salts, or toxic substances like pesticides, heavy metals, or nitrates that may be present in the water.

- Clogging and maintenance: Filters can **get blocked (clogged)** over time with dirt and particles, reducing their effectiveness. They need **regular cleaning or replacement**, which can be costly or inconvenient.
- Initial and Replacement Costs: Some filtration systems (especially advanced ones like reverse osmosis or carbon filters) can be **expensive to install and maintain**, especially in low-income or rural areas.
- Slow Filtration Rate: Many filters, especially ceramic or sand types, can be **slow** in processing water. This limits the amount of water that can be purified at one time.
- Requires Clean Water Source for Best Results: Filtration works best on **relatively clear water**. If the source water is very dirty or muddy (high turbidity), it can reduce the filter's performance and lifespan.
- Possible Bacterial Growth in Filters: If filters are not cleaned regularly, **bacteria can grow inside the filter**, contaminating the water instead of cleaning it.

2.3.3 CHLORINATION AS A MEANS OF WATER PURIFICATION

Chlorination is the process of adding chlorine or chlorine compounds to water to kill or inactivate harmful microorganisms and make it safe to drink. It is the most common method for disinfecting water, but it also helps control taste and odour, removes iron and manganese, and prevents the growth of algae and slime. The chlorine kills tiny organisms such as bacteria, viruses, and parasites that can make people sick. It works by breaking down the protective walls of these germs and stopping them from growing or reproducing.

2.3.3.1 ADVANTAGES OF CHLORINATION AS A MEANS OF WATER PURIFICATION

- Kills harmful and pathogenic microorganisms: Water containing bacteria, viruses, and other pathogenic microorganisms can be effectively eliminated by chlorination. Chlorine disrupts the biological activities of bacteria and causes their death through a reaction with their cell walls. This guarantees the water's safety for drinking.
- Prevents waterborne diseases: Chlorination helps prevent cholera and typhoid outbreaks by eliminating bacteria like *Vibrio cholerae* and *E. coli* and other bacteria.

- Maintains water quality during distribution Before it reaches consumers, treated water frequently passes through lengthy pipelines. Throughout the distribution system, chlorine stays active in the water, avoiding microbiological recontamination.
- Provides residual protection: After treatment, a trace amount of chlorine is still present in the water, preventing recontamination.
- Cost-effective water treatment method::Comparatively speaking, chlorination is less expensive than other purifying methods like ozonation or UV sterilization. The chemicals, which are typically inexpensive and simple to use, are calcium hypochlorite, sodium hypochlorite, and chlorine gas.

2.3.3.2 DISADVANTAGES OF CHLORINATION AS A MEANS OF WATER PURIFICATION

- Unpleasant taste and odour: Water containing chlorine may taste and smell strongly of chemicals, which some people find unpleasant.
- Formation of potentially harmful disinfection byproducts:Chlorine can create disinfection byproduct like trihalomethanes (THMs) when it combines with organic materials in water, which could be harmful if ingested over time.
- Allergic reactions in some individuals:Chlorinated water may cause mild allergic reactions in certain persons, such as skin irritation or gastrointestinal discomfort.
- Corrosive to certain materials and equipment:Chlorinated water can corrode metal pipes, tanks, and plumbing fixtures, leading to maintenance issues over time.
- Limited effectiveness against some parasites and viruses: Because they are resistant to chlorine, some microbes, such Giardia and Cryptosporidium, may endure the treatment procedure.

2.3.4 OZONATION

Ozonation (also referred to as ozonization) is a chemical water treatment technique based on the infusion of ozone into water. Ozone is a gas composed of three oxygen atoms (O₃), which

is one of the most powerful oxidants. Ozonation is a type of advanced oxidation process, involving the production of very reactive oxygen species able to attack a wide range of organic compounds and all microorganisms. The treatment of water with ozone has a wide range of applications, as it is efficient for disinfection as well as for the degradation of organic and inorganic pollutants. Ozone is produced with the use of energy by subjecting oxygen (O₂) to high electric voltage or to UV radiation. The required amounts of ozone can be produced at the point of use but the production requires a lot of energy and is therefore costly.

The effectiveness of ozone results from its powerful oxidizing effect on chemicals and microorganisms caused by the generation of reactive oxygen species during ozone transformation to oxygen. Ozone directly attacks the surface of microorganisms and destroys their cell walls. The cells thus lose their cytoplasm and can no longer reactivate themselves (STUCKI et al. 2005). Ozone can induce an oxidative degradation of many organics and leaves more biodegradable compounds (DERCO et al. 2001). Besides, ozone can oxidize metallic ions such as Fe(II), Mn(II) or As(III) producing insoluble solid oxides that can be easily separated from water by filtration or sedimentation.

2.3.4.1 ADVANTAGES OF OZONATION AS A MEANS OF WATER PURIFICATION

- Rapidly reacts with bacteria, viruses and protozoa over a wide pH range: Ozone acts quickly to destroy microorganisms across various pH levels, making it highly effective for disinfecting different water types.
- Stronger germicidal properties than chlorination: Ozone can more successfully destroy a wider range of harmful germs than chlorine because of its higher oxidizing capacity.
- No chemicals are added to water: The water is kept safe and pure through ozonation, which leaves no chemical residue because ozone spontaneously decomposes into oxygen.

- Also efficient for organics degradation and inorganics removal: Ozone enhances the clarity and the purity of water by assisting in the removal of metals, organic pollutants, and other impurities.
- Removes colour, taste and odour :By removing offensive odours, colours, and tastes brought on by dissolved organic matter, ozone makes water taste cleaner and fresher.

2.3.4.2 DISADVANTAGES OF OZONATION AS A MEANS OF WATER PURIFICATION

- Relatively high equipment costs: Ozone production equipment is complex and costly. The procedure also uses a lot of electricity, which makes it more expensive than other purifying techniques like chlorination.
- Requires large amounts of energy: Ozone production involves the breaking of oxygen molecules, which requires a large and continuous energy input. This results in a higher carbon footprint and expensive operating costs.
- Qualified professionals required for design and system maintenance: The design, functioning, and upkeep of the system are not straightforward. To make sure it operates securely and properly, they need skilled engineers and technicians, which raises the total cost of operation.
- Formation of potentially harmful disinfection by-products (DBPs) in the case of bromine existence in water: When bromide ions are present in the source water, ozonation can transform them into bromate, a possible carcinogen. It can also yield other by-products such as aldehydes and ketones, which may require further treatment processes.
- No residual effect is present in the distribution system: Ozone quickly breaks down in water. It doesn't have the same disinfecting effect over the water distribution system as chlorine. For the pipes to be protected from microbial recontamination, a secondary disinfectant, such as chlorine, is required.

2.3.5 ULTRAVIOLET (UV)

UV water purification uses ultraviolet light, a form of invisible energy from the sun or special lamps, to kill or deactivate germs in water. It is a chemical-free method that destroys harmful microorganisms such as bacteria, viruses, and parasites that cause diseases like cholera, typhoid, and dysentery. UV filters work by passing water through a chamber that contains a UV lamp. As the water flows through the chamber, the UV light targets and kills any microorganisms present, including bacteria, viruses, and protozoa.

One of the main benefits of UV filtration is that it effectively removes harmful microorganisms from the water supply, making it safe to drink. This is particularly important for individuals who may be more susceptible to waterborne illnesses, such as young children, the elderly, and those with compromised immune systems.

In addition to removing microorganisms, UV filters can also remove other impurities from the water, such as chlorine, chloramines, and other chemicals that can have a negative impact on the taste and smell of the water.

When it comes to safety, UV filters are generally considered to be safe for use. However, it is important to note that the UV lamp used in the filter should be handled with care, as it can emit harmful UV rays if misused. Additionally, the UV treated water should not be consumed until it has passed through the UV filter, as the UV light does not make the water safe to drink immediately.

2.3.5.1 ADVANTAGES OF USING UV AS A MEANS OF WATER PURIFICATION

- **Chemical Free:** UV purification does not use any chemicals like chlorine or leave any harmful by products.
- **Taste & Odor Free:** UV does not add any chemical taste or odor to the water.
- **Extremely Effective:** One of the most effective ways to kill disease-causing microbes by destroying 99.99%.
- **Requires very little energy:** Uses about the same energy as it would to run a 60 watt light bulb.
- **Low Maintenance:** Set and forget type of system, just change the UV bulb annually.

2.3.5.2 DISADVANTAGES OF USING UV AS A MEANS OF WATER PURIFICATION

- Needs Electricity: UV systems depend on continuous electricity to power the lamp. This can be a challenge in areas with unreliable or no power supply.
- Requires Clear Water: For UV light to work effectively, the water must be clear. If the water is cloudy, muddy, or coloured, the particles can block the UV rays, preventing them from reaching and killing the microorganisms.
- No residual effect: Unlike chlorination, UV treatment does not leave any disinfectant in the water. This means that if the treated water is stored improperly, it can become contaminated again.
- Limited Effectiveness on Some Organisms: While UV is excellent against most bacteria and viruses, it may be less effective against certain spores or larger parasites if the water is not properly pre-filtered.
- Regular Maintenance Required: The UV lamp and quartz sleeve must be cleaned and replaced regularly. Dirt, mineral deposits, or algae growth on the lamp can reduce its effectiveness.
- Limited Effectiveness on Some Organisms: While UV is excellent against most bacteria and viruses, it may be less effective against certain spores or larger parasites if the water is not properly pre-filtered.
- High Initial Cost (for Some Systems): Although operating costs are low, the initial purchase and installation of UV systems can be relatively expensive, especially for large-scale or household units.

2.4 MINI WATER TREATMENT IN MECHANICAL ENGINEERING

The mini water treatment system in Mechanical Engineering is aimed at creating a source of clean water supply in the department. This involves treating storing and dispensing water through five key processes which includes: Sourcing, Filtering, Disinfecting, Storage and Dispensing of water.

Although the mini water treatment system, a number of improvements is needed to improve the quality of drinking water treatment being produced

2.4.1 ISSUES WITH THE PREVIOUS DESIGN

- **High power consumption:**
The old design was high power consuming as the heating and cooling process were done using a heater and a freezer respectively which are very energy demanding. Those pieces of equipment were being underutilized because they were massive but yet used to heat and cool only a small portion of water. The new design should be able to carry out this same function yet using the lowest possible amount of power.
- **Poor System Design:**
The previous design is ambiguous; most people couldn't really tell if it was a water purification and dispensing system. It also had a lot of components consuming space leading to more risk of contamination. The old design stores water in a very large tank which also hold water for quite a long time which can aid growth of micro-organisms in the water.
- **System Misuse:**
Due to the ambiguous nature of the previous design, it was often misused as most people saw it as a hand wash basin or as a wastebin as most times people go there to wash their hands or dispose waste.
- **Lack of fail-safe components:**
The old design lacks fail-safe components as often times when the water level sensor fails, there is no fail-safe system to prevent water from spilling when the tank is filled.

All these led to the need for improvement on the mini water treatment system. The new model carefully takes care of most of the problems with the old model as it has created a system that is simpler and more effective, less power consuming, produces cleaner water, easy to maintain, has better storage and is safer and healthier to drink.

2.4.2 BENEFITS OF THE IMPROVED WATER TREATMENT SYSTEM

- **Improved Health and Safety:**
It provides safer and healthier drinking water for the department that meets the WHO standard for Nigerian drinking water
- **Reduced cost and improved efficiency:**

The improved system uses less power thereby reducing overall cost of the system.

- User convenience:

It is simpler and easier to use. It is also less ambiguous and requires lesser number of components

2.5 WATER QUALITY PARAMETERS

The following factors are essential for the planning and execution of a small water treatment system 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 harbor 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.

<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($\mu\text{S}/\text{cm}$)	1000	
TDS (mg/L)	500	
Temperature $^{\circ}\text{C}$	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)

2.6 DESIGN CONSIDERATIONS FOR SMALL-SCALE WATER TREATMENT SYSTEM

A small water treatment system'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 system 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.

2.7 THE IMPORTANCE OF NIGERIAN STANDARD FOR DRINKING WATER QUALITY

Nigerian Standard for Drinking Water Quality (NSDWQ) contains mandatory limits concerning constituents and contaminants of water that are known to be hazardous to health and/or give rise to complaints from consumers. The standard includes a set of procedures and good practices required to meet the mandatory limits.

2.8 DRINKING WATER QUALITY STANDARD USED IN NIGERIA

In 2005, the National Council on Water Resources (NCWR) recognized the need to urgently establish acceptable Nigerian Standard for Drinking Water Quality because it was observed that the “Nigerian Industrial Standard for Potable Water” developed by Standards Organisation of Nigeria and the “National Guidelines and Standards for Water Quality in Nigeria” developed by Federal Ministry of Environment did not receive a wide acceptance by all stakeholders in the country.

Since water quality is health related issues, Federal Ministry of Water Resources and the Federal Ministry of Health in collaboration with the Standards Organisation of Nigeria (the only body responsible for developing National Standards in Nigeria) and working through a technical committee of key stakeholders developed this Standard.

Principles

The effective protection of public health against water related diseases (i.e. waterborne, water washed, water based and water vectored) requires a preventive integrated management approach, these includes

- The protection of drinking water from catchments and source to its use by consumers
- A collaborative multi-agency approach that involves all agencies with responsibilities in the management of water quality.
- Water quality standard that is comprehensive, realistic and implementable within the resources of the implementing agencies.
- The development of procedures and requirements that ensure good water quality management in order to meet the maximum allowable limits. These procedures also protect the environment
- An independent surveillance agency with strong enforcement authority and functions decentralized to local government level.
- An effective drinking water quality data management system to enable generation of data for the development of coherent public health-centered policies and practices

2.9 DRINKING WATER QUALITY

In preparing the following table of parameters and maximum permitted limits, care has been taken to ensure that flexibility is carefully managed and balanced taking into consideration water system economic viability without unduly compromising the health of the consumers.

The substances in Nigerian Standard for Drinking Water Quality are simply divided into physical / organoleptic, chemical organic and inorganic constituents, disinfectants and disinfectants by-products, radionuclides and microbiological parameters.

All drinking water shall at any time meet the minimum requirements set out in Tables 2.2–2.8

All water supplies intended for human consumption shall comply with Nigerian Standards for Drinking Water Quality (NSDWQ) and shall receive authorization from Federal Ministry of Water Resources through the National Reference Water Quality Laboratories and other 17025 accredited laboratories before being supplied to the populace.

Table 2.2 - Physical/Organoleptic Parameters

Parameter	Unit	Maximum Permitted Levels	Health Impact	Note
Colour	TCU	15	None	
Odour	-	Unobjectionable	None	
Taste	-	Unobjectionable	None	
Temperature	°Celsius	Ambient	None	
Turbidity	NTU	5	None	Note 1

Table 2.3 - Inorganic Constituents

Parameter	Unit	Maximum Permitted	Health Impact	Note
Aluminium (Al)	mg/L	0.2	Potential Neuro-degenerative disorders	
Arsenic (As)	mg/L	0.01	Cancer	
Barium	mg/L	0.7	Hypertension	
Cadmium (Cd)	mg/L	0.003	Toxic to the kidney	
Chloride (Cl)	mg/L	250	None	
Chromium (Cr ⁶⁺)	mg/L	0.05	Cancer	
Conductivity	µS/cm	1000	None	
Copper (Cu ⁺²)	mg/L	1	Gastrointestinal disorder,	

Cyanide (CN ⁻)	mg/L	0.01	Very toxic to the thyroid and the nervous system	
Fluoride (F ⁻)	mg/L	1.5	Fluorosis, Skeletal tissue (bones and teeth) morbidity	
Hardness (as CaCO ₃)	mg/L	150	None	
Hydrogen Sulphide (H ₂ S)	mg/L	0.05	None	
Iron (Fe ⁺²)	mg/L	0.3	None	
Lead (Pb)	mg/L	0.01	Cancer, interference with Vitamin D metabolism, affect mental development in infants, toxic to the central and peripheral nervous systems	
Magnesium (Mg ⁺²)	mg/L	20	<i>Consumer acceptability</i>	
Manganese (Mn ⁺²)	mg/L	0.2	Neurological disorder	
Mercury (Hg)	mg/L	0.001	Affects the kidney and central nervous system	
Nickel (Ni)	mg/L	0.02	Possible carcinogenic	
Nitrate (NO ₃)	mg/L	50	Cyanosis, and asphyxia ('blue-baby syndrome') in infants under 3 months	
Nitrite (NO ₂)	mg/L	0.2	Cyanosis, and asphyxia ('blue-baby syndrome') in infants under 3 months	
pH	-	6.5-8.5	None	
Sodium (Na)	mg/L	200	None	
Sulphate (SO ₄)	mg/L	100	None	

Total Dissolved Solids	mg/L	500	None	
Zinc (Zn)	mg/L	3	None	

Table 2.4 - Organic Constituents

Parameter	Unit	Maximum Permitted Levels	Health Impact	Note
Detergents	mg/L	0.01	Possibly carcinogenic	
Mineral oil	mg/L	0.003	Possibly carcinogenic	
Pesticides	mg/L	0.01	Possibly carcinogenic	
Phenols	mg/L	0.001	Possibly carcinogenic	
Poly Aromatic Hydrocarbons	mg/L	0.007	Possibly carcinogenic	
Total Organic Carbon or Oxidisability	mg/L	5	Carcinogenic	

Table 2.5 - Disinfectants and their by-products

Parameter	Unit	Maximum Permitted Levels	Health Impact	Note
Free residual chlorine	mg/L	0.2 - 0.25	None	Note 3
Trihalomethanes (Total)	mg/L	0.001	Carcinogenic	Note 3
2,4,6-trichlorophenol	mg/L	0.02	Carcinogenic	Note 3

Table 2.6 - Radioactive Limits

Parameter	Unit	Maximum Permitted Levels	Health Impact	Note

Radionuclides	Bq/L	0.1	Carcinogenic	
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Table 2.7 – Maximum Permissible Microbiological Limits

Parameter	Unit	Maximum Permitted Levels	Health Impact	Note
Total Coliform count	cfu/mL	10	Indication of faecal contamination	
Thermo tolerant Coliform or <i>E.coli</i>	cfu/100mL	0	Urinary tract infections, bacteraemia, meningitis, diarrhea, (one of the main cause of morbidity and mortality among children), acute renal failure and haemolytic anaemia	
Protozoa-giardia <i>Cryptosporidium oocyst</i>		3 log reduction and/ or inactivation	Commonly associated with gastrointestinal upset (nausea, vomiting, diarrhea); less common health effects can include respiratory symptoms central nervous system infections, liver infections and muscular syndromes.	Note 4
Faecal streptococcus/enterococcus	cfu/100mL	0	Indication of recent faecal contamination	
<i>Clostridium perfringens</i> spore	cfu/100mL	0	Index of intermittent faecal contamination	

Table 2.8 - Routine Monitoring Parameters

Parameter	Notes
Taste	
Odour	
Colour	
Turbidity	

pH	
Conductivity	
Iron	
Nitrates	
Aluminum	Note 2
Residual chlorine	Note 3
<i>E. coli</i>	Note 4
Fluoride	Note 4
Nitrite – NO ₂	

CHAPTER 3

3.1 MATERIALS AND METHODS

This chapter talks about the materials used in constructing the mini water treatment system and also the process of purification right from the source to the dispenser.

3.1.1 MATERIALS

- Sand filters
- Carbon filter
- Pump 0.5hp
- UV
- Storage tank
- Flexible connector
- 1/2 and 1 inch Adaptors
- Elbows and sockets
- Ball valves
- Water level controller
- Water dispenser
- Solenoid valve
- Cartridge filter

Sand Filter

An essential aspect of the small water treatment system is the sand filter, which uses a multi-layer filtering system housed in a tank to remove contaminants and particle matter from the water. The sand filter 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 system's filtration system is made up of two sand filters, 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. The carbon filter has a lot of surface area and is very porous, allowing contaminants to be absorbed as water flows through it. 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: Sand Filtration Unit

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.

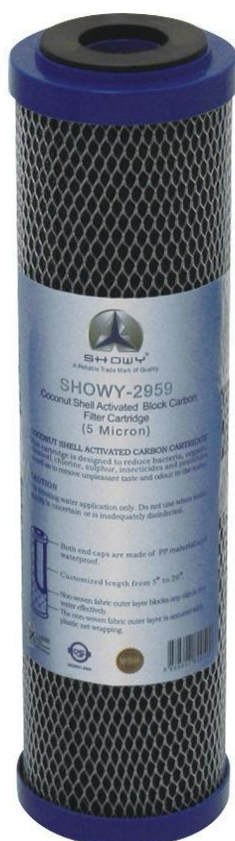


Figure 3.2: Activated carbon Filter Cartridge

Pump

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 3.3: Pump

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 3.4. Ultraviolet Device

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 system, a flexible connector helps to maintain a smooth water flow and avoid pressure on the piping.



Figure 3.5: Flexible Hose Connector

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 joining pipes of various diameters or switching from one kind of material (like PVC) to another (e.g., metal).



Figure 3.6: 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 centre to either permit or prohibit water flow.



Figure 3.7: Ball valve

Water level controller

The water level controller is meant to monitor the level of water in the tank. It basically uses an ultra-sonic sensor to carry out this task. The sensor turns on and turns off the pump based on if the tank is almost empty and if the tank is almost completely filled.



Figure 3.8: Level switch

Water dispenser

The water dispenser helps to serve the purpose of dispensing hot, cold and room temperature water rather than using three independent means thereby consuming more power and occupying more space.



Figure 3.9: Water dispenser

Solenoid valve

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).



Figure 3.10: Solenoid Valve

Cartridge filter

Its main purpose is to remove suspended solids and particulate matter from water; such as sand, silt, rust, or other fine debris before the water moves on to the final treatment stages.



Figure 3.11: Cartridge Filter

3.2.1 METHOD

3.2.1.1 REDESIGN OF THE MINI WATER TREATMENT SYSTEM

Previously the mini water treatment system had a very ambiguous design making it difficult to tell what it actually is causing abuse and misuse of the project. In addition to those flaws it was also power consuming and difficult to maintain making it prone to being contaminated. All these led to the need for an improvement of the system.

The first step in redesigning the system is the removal of some part of the old system. This includes removal of the following components:

Freezer

This is a 90W freezer used for the purpose of cooling. The volume of this freezer is 50L which is quite large compared to the amount of water stored and cooled in it therefore, it is being under-utilized



Figure 3.12: Freezer

Water heater

This heater has a power rating of about 1.2KW which is quite high compared to the rating of a typical water dispenser. This consumes power and hence needs to be replaced by something less power consuming.



Storage tank

This is a 50L storage made from polypropylene plastic. This material is not ideal for water storage as it is designed primarily for general long-term dry goods storage and organization. Also, the size is too large thereby holding water for a long time aiding microbial growth. This needs to be removed and replaced with something smaller and made of a better material.



Figure 3.14: Storage Tank (50L)

Sink and dispensing outlets

Removal of the old dispensing outlets and the sink as they do not give a proper representation of an outlet for a mini water treatment system. This sink is made of wood which is not the ideal material for a sink as it pouring water on wood continuously can have detrimental effect on the wood.



Figure 3.15: Dispensing outlet and drain

Float switch

The float switch which monitors the level of water in the tank to turn on and off the pump is always in contact with the water and therefore aid water contamination as micro-organism can stick to it and grow over time. Also, frequent failure of this switch has been recorded as most times it fails to turn off the pump leading to water spillage when the tank is full.



The next step was the installation of the new components. These includes:

Water dispenser

This is 520W water dispenser that dispenses hot, cold and room temperature water eradicating the need for need for three separate outlets and it also has its own sink but this sink had to be modified because of the frequent spillage when taking water. Also, the power rating is less than that drawn from the heater and freezer used previously.



Storage tank

This is an 18.9L tank made of polycarbonate. This tank holds water for a lesser period and also uses a material which is specifically designed for holding water.



Figure 3.18: Storage Tank (18.9L)

Ultrasonic sensor

This replaces the float switch which is used for water level control. It doesn't get in contact with the water and doesn't fail easily



Figure 3.19: Ultrasonic sensor

3.2 OPERATION OF THE MINI WATER TREATMENT SYSTEM

The untreated water is gotten from a borehole where it is tapped and sent to the treatment facility. The source water is very important as its properties determines what treatment method should be used for the water. Benin water is known to be acidic therefore increasing the pH should be one major treatment done on the water.

After moving from the source, the water is sent to the treatment house for treatment. The first stage of treatment is passing the water through the sand filters in the sand filter. The sand filter is made up of some layers of sand and activated charcoal. The activated charcoal that has porous layers 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 then flows through two other cartridge filters to remove anything thing still left suspended in the water to produce a clearer water.

Next, the water flows through a UV disinfection equipment. 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.

After going through the UV, the water is stored in a dispenser bottle inside the dispenser and then dispensed out giving the hot, cold and room temperature water.

Refilling of the dispenser bottle

On top the bottle, there are water level controllers made up of an ultrasonic sensor, relays and Arduino board. When the water in the tank is empty, the ultrasonic sensors send a signal to the pump, solenoid valve and the UV to come on at the same time so the UV is only on when water flows to the tank rather than it being on all the time. When the water in the tank gets to the desired level, the ultrasonic sensor sends a signal to the relay to turn off the pump, UV and close the solenoid valve.

3.2.1 REGULAR MAINTENANCE PRACTICES TO BE CARRIED OUT

For the system to operate optimally and produce safe drinkable water, it has to be maintained regularly and the frequency of maintenance depends on the component. Also, periodic testing is required to know the corrective actions to take if required.

Maintenance on the water dispenser

The surface of the dispenser should be cleaned regularly to have a good outer appearance. Clean the reservoir monthly, rinse thoroughly, drain and refill. Clean or replace filters at an interval of 3-6 months of use. Inspect the parts annually and check for leaks, wear and damage.

Benefits

- **Extends the Life of Equipment:** A more durable dispenser is the outcome of routine maintenance and inspection, which minimises wear, stops obstructions, and limits corrosion.
- **Prevents Leaks and Breakdowns:** Early identification of leaks or broken parts enables prompt repair, preventing significant malfunctions and water damage.
- **Enhances Performance and Efficiency:** A properly maintained dispenser uses less energy and performs better by heating and cooling water more effectively.

- Prevents Microbial growth: By keeping the reservoir and surfaces clean, you can improve hygiene by preventing the formation of bacteria, mould, and algae.

Sand filter

Backwash should be carried out on the tanks at an interval of 2-3 weeks. Backwashing is the process of reversing the flow of water through a filter (such as a sand filter) to remove the dirt, debris, and trapped particles that have built up during normal filtration.

Benefits

- Enhances Water Quality: Ensures that suspended particles, dirt, and microbes are effectively removed.
- Prevents Clogging: Consistent backwashing maintains smooth water flow by preventing blockages in the sand media.
- Ensures Consistent Filtration Rate: Maintains the necessary flow and output while keeping filtration performance constant.
- Increases Filter Lifespan: By protecting internal components and minimizing media wear, proper maintenance prolongs filter life.
- Lowers Operating Costs: By preventing frequent malfunctions, repair and replacement costs are reduced.
- Prevents Contamination: Removes accumulated contaminants to keep treated water from becoming contaminated again.

Cartridge filter

Regular maintenance for a cartridge filter involves a rinse-out cleaning every 1-3 months, a deeper cleaning with a filter solution every 3 months and replacing the cartridge every 1-2 years.

Benefits

- **Guarantees High-Quality Treated Water:** Ensures that fine particles are effectively removed prior to final disinfection or distribution.
- **Prevents Clogging and Pressure Drop:** Frequent replacement and cleaning maintains steady flow and stops the system from losing pressure.
- **Preserves Downstream Equipment:** Prevents debris and silt from harming membranes, pumps, and other parts.
- **Enhances Overall Treatment Efficiency:** Makes the system run more smoothly while using less energy.
- **Increases Filter and System Service Life:** Wear is decreased and early failure is avoided with proper maintenance.
- **Lowers Operational Costs:** This lowers costs related to frequent filter replacement, energy waste, and repairs.
- **Prevents Microbial Growth and Contamination:** Bacterial accumulation that could lower the quality of treated water is less likely to occur in clean housings.

Storage tank

Regular maintenance for a water dispenser bottle includes daily/weekly wiping of the exterior, drip tray, and taps with a sanitizing wipe, and monthly deep cleaning with a mild soap or vinegar solution to sanitize the reservoir and internal components. It is also recommended to sanitize the dispenser thoroughly every 3-6 month

Benefits

- **Maintains clean and safe water:** Frequent sanitization keeps water safe to drink by eliminating dirt and microbes.

- Prevents microbial growth: Cleaning stops bacteria, mould, and algae from growing and contaminating the water.
- Improves taste and odor: Eliminating deposits and residue keeps water smelling fresh and odourless.
- Reduces sediment and scale buildup: Routine cleaning stops mineral deposits and dirt from accumulating, which could affect water quality.
- Preserves system efficiency: A clean tank prevents obstructions or performance problems by enabling appropriate dispensing and smooth flow.
- Encourages user confidence and hygiene: A well-kept tank gives users the impression that the water is safe to drink.

General maintenance

Annually, general inspection can be carried out on all the components of this system to check for leaks, faults and wears. This also help prevent faults and equipment run to failure.

- Regular maintenance removes accumulated dirt, sludge, and microorganisms, ensuring that the treated water meets health and safety standards.
- Well-maintained filters, pumps, and pipes allow water to flow smoothly, reducing energy use and improving overall performance.
- Preventive maintenance helps detect and fix small issues early—avoiding costly repairs or replacements later.
- Cleaning, lubrication, and timely part replacement reduce wear and tear, allowing equipment (like pumps, filters, and valves) to last longer.
- Routine checks reduce the chances of sudden breakdowns that could interrupt the water supply.
- By regularly inspecting chemical dosing, filter performance, and sediment buildup, the plant consistently produces high-quality treated water.
- Many local and national water authorities require regular maintenance and record-keeping to meet water safety standards.

CHAPTER 4

4.1 TEST, RESULT AND ANALYSIS

4.1.1 TEST

The test was carried out on 6 samples taken from different points along the line of purification; the source, after the sand filter, after the UV, hot, cold and room temperature outlet. The purpose of this is to observe the change in the properties as it goes through different stages and even up to the outlet, compare the results and prescribe maintenance activities to be carried out.

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.

Test carried out and the instrument used

Parameters

- pH: It is the measure of how acidic or basic the water is. The pH for potable water ranges from 6.5 – 8.5.
- Turbidity: Turbidity describes the clarity or transparency of water. Turbidity value for potable water normally ranges from 0 – 5 NTU.
- Alkalinity: Alkalinity is the total concentration of bases (such as bicarbonates, carbonates, and hydroxides) in water that can react with and neutralize hydrogen ions (H^+).
- Total Dissolved Solids (TDS): is the measure of the combined content of all dissolved substances in water, including minerals, salts, metals, cations, and anions. The maximum TDS value for potable water is 500 mg/L

- **Conductivity:** Conductivity, in relation to water properties, refers to the ability of water to conduct an electric current. This property depends on the presence and concentration of dissolved ions (charged particles) in the water. The maximum conductivity value for potable water is 1000 $\mu\text{S}/\text{cm}$.
- **Salinity:** Salinity is the measure of the total dissolved salts in water, determining its freshness or saltiness, and is a key factor in assessing water quality, usability, and environmental impact.
- **Oxidation Reduction Potential (ORP):** It is the electrical potential (measured in millivolts, mV) that indicates the oxidizing or reducing power of a water sample.
- **Hardness:** Water hardness is the measure of the amount of calcium and magnesium ions (and sometimes other multivalent metal ions) dissolved in water, which can react with soap to form scum and cause scaling in pipes and boilers. Soft water ranges from 0-60 mg/l, Moderately hard 61-120, Hard 121-180, very hard >180.



Figure 4.1: Hanna HI98194 Multiparameter Meter

This multiparameter meter is a waterproof, portable logging meter used to measure various water quality parameters.

- Product Name: Hanna Instruments Multiparameter Meter (e.g., HI98194, HI98195, HI98196)
- Key Features: Measures multiple parameters such as pH, ORP, conductivity (EC), dissolved oxygen (DO), temperature, and pressure.
- Purpose: Used for water quality testing in various environments like rivers, lakes, and marine cultivation.
- Package Contents: The meter, a multi-sensor probe, and other accessories are included in a rugged carrying case.
- Connectivity: Logged data can be transferred to a PC using a micro-USB cable and specific software.

Method

- a. Remove electrode from storage.
- b. Thoroughly flush all probes with distilled water and blot dry with microfiber cloth.
- c. Rinse beaker with enough distilled water followed by sample water
- d. Fill beaker with enough water for measurement
- e. Place the probe inside the sample and stir gently and allow reading to be stable
- f. Record values displayed on the screen
- g. Rinse electrode after measurement and store inside storage container
- h. **Electrometric Determination of pH, conductivity and Total dissolved solids, The Probe is rinsed in a beaker with demineralized/distilled water. The sample is then poured into a beaker, after which the probes is placed into the beaker. Read off your values as displayed on the screen.**

Turbidity meter



A turbidity meter is an instrument that measures the cloudiness of a liquid, caused by suspended solid particles. It works by shining a light into the liquid and measuring the amount of light that is scattered or absorbed, with higher readings indicating more suspended particles. These meters are crucial for monitoring water quality in applications like drinking water, wastewater, and environmental testing, and they are available in various forms such as portable, benchtop, and in-line systems

Procedure

Nephelometric method

Shake the sample to disperse the solids. Wait until air bubbles disappear. Pour the sample into turbidimeter tube and read turbidity directly from the instrument display.

Rinse the cuvette with demineralized/distilled water. Calibrate the instrument using demineralized water as the zero mark and formazine suspension for 100 and 200 standard. Wash and rinse the cuvette with demineralized water. Pour the sample in it until it gets to the designed mark on the cuvette. Place the cuvette with the sample into the machine. Cover it and read the off the value from the screen. The value of turbidity for portable water ranges from 0-5, beyond 5 the water is no longer acceptable.

**Thermo
Orion**



Scientific

Figure 4.3: Thermo-scientific Auto titrator T940 All in one Potentiometric

The product shown is the Thermo Scientific Orion Star T940 All-in-One Titrator. This instrument is designed to automate titrations, making them easier and more reliable than manual methods.

- **Functionality:** It can perform a variety of titrations including pH, redox, and ion concentration measurements.
- **Features:** The titrator includes a high-accuracy burette, an automated titrant delivery system, and a touchscreen display for easy setup.
- **Applications:** It is used for tasks such as measuring the titratable acidity of juices and wines, alkalinity of water, and chloride/salt in food products

Procedure

Rinse the probes and beaker with demineralized/distilled water. Measure 100mL of the sample and pour it into a beaker. Put the probes into the sample in the beaker and allow to titrate. Measure the alkalinity value as displayed on the screen. Repeat the same procedure for the remaining samples. According to WHO, alkalinity value up to 300mg/L is generally acceptable.

Colony counter

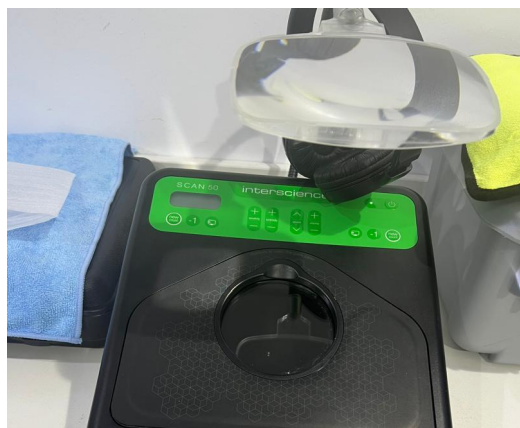


Figure 4.4: Inter-science Semi-Digital Colony Counter

This is a manual colony counter. It is used in microbiology for counting colonies on Petri dishes. It is suitable for various media types, including Petri dishes from 55 to 90 mm in diameter, Petri film, and other membranes. The device features a "Dark Field 2" system that provides high-contrast lighting to protect the user's eyes while counting. The Scan 50 Pro model includes a HandPad for ergonomic support. Counting is performed by a simple touch, and the results can be exported to a computer via a USB port for data traceability.

Procedure

Sterilize the petri dishes and 1mL pipette in an oven till the temperature gets to 120 degrees. Prepare the Agar solution and keep it in a water bath at a temperature of about 45-50 degrees. Leave the petri dishes under UV light for about an hour for further sterilization. Pipette 1mL of the sample unto a petri dish, add the Agar solution and shake in the clockwise and anti-clockwise direction till it solidifies. Place it in an oven for 24 hours.

Table 4.1- Result

Parameters	Source	After filter	After UV	Cold	Room Temperature	Hot
pH	5.08	7.73	7.50	7.71	7.62	7.58

ORP (nV)	446.7	319.2	335.5	327.8	311.4	329.3
Conductivity (μS/cm)	17	188	211	154	165	171
TDS (PPM)	8	94	105	76	83	86
Temperature (°C)	28.40	28.52	28.28	28.60	28.26	29.08
Salinity (PSU)	0.01	0.09	0.10	0.07	0.08	0.08
Turbidity (PPM)	0	0	0	0	0	0
Alkalinity (Mg/L)	0.6296	52.69	46.91	49.67	43.56	43.46
Hardness (Mg/L)	45.07	65.15	65.15	65.15	65.15	65.15
Colour	nil	nil	nil	nil	nil	nil
Odour	nil	nil	nil	nil	nil	nil
Taste	nil	nil	nil	nil	nil	nil

Microbial test result
Source



Figure 4.5: Source water sample

A microbial test was conducted on the source to determine the total bacterial count in 1mL of the sample. A total bacteria count of about 98 was recorded.

After filter



Figure 4.6: After filter water sample

A drastic reduction in the bacteria count in 1mL can be observed as the water goes through the sand filters.

After UV

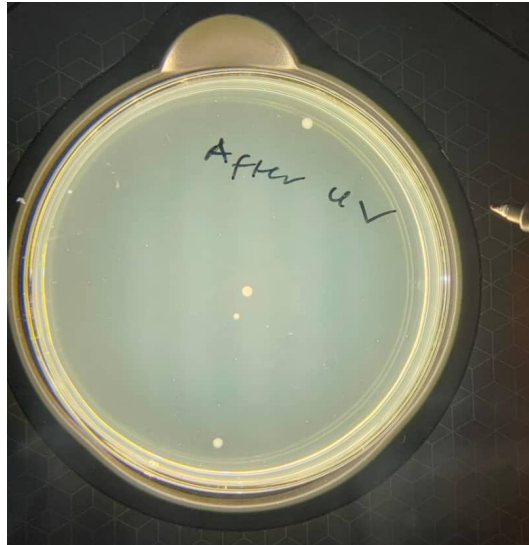


Figure 4.7: After UV water sample

After going through the UV, it can also be observed that there is a great reduction in the bacterial count which can even be negligible since it is less than 5.

Hot

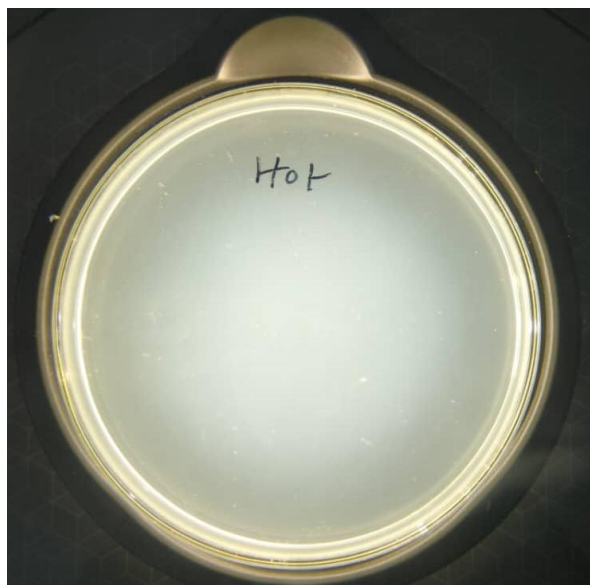


Figure 4.8: Hot water sample

Zero bacteria count is observed in the hot water as boiling also helps to destroy bacteria in the water.

COLD

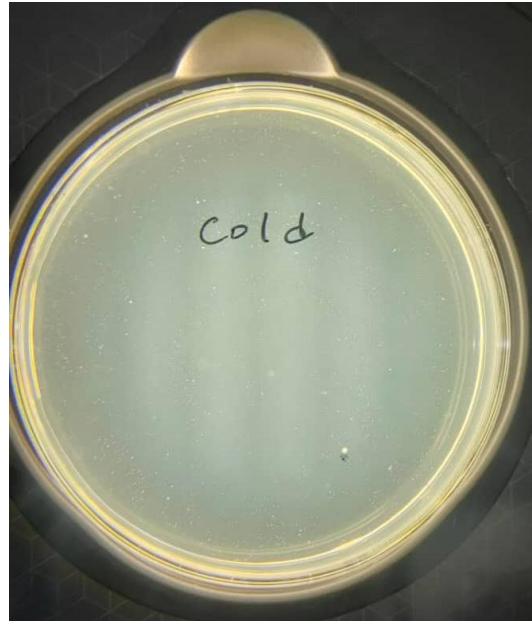


Figure 4.9: Cold water sample

Zero bacteria count is also observed in the cold outlet as cooling also does not support some bacteria growth.

Room Temperature

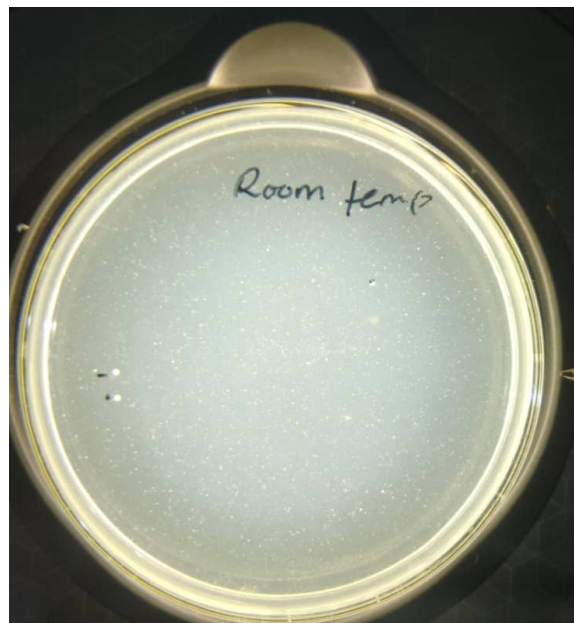


Figure 4.10: Room temperature water sample

Negligible bacteria count is also observed in the room temperature water.

The above shows the reduction in bacteria quantity as the water goes through the purification process from the source to the dispenser.

CHAPTER 5

5.1 CONCLUSION

The development and evaluation of a mini water treatment plant for drinking purposes has demonstrated that small-scale treatment systems can reliably produce safe, potable water when properly designed, operated, and maintained. This project confirms that the essential processes involved in large municipal plants—such as screening, coagulation and flocculation, sedimentation, filtration, and disinfection—can be effectively miniaturized to serve small communities, schools, health centers, construction camps, and domestic clusters, especially in regions with limited infrastructure.

The results show that the selected treatment train successfully reduced turbidity, suspended solids, colour, objectionable taste/odour, and microbial contaminants to acceptable levels in accordance with WHO and national drinking-water quality guidelines. The filtration stage proved effective in removing fine particulate matter, while disinfection (with UV) ensured the elimination of pathogenic organisms and secured a residual effect to protect water during storage and delivery.

The project highlights several merits of mini treatment systems:

- Low cost of construction, operation, and maintenance compared to centralized plants.
- Scalability and modularity, enabling capacity increases based on demand.
- Ease of installation and simplicity of use, making them suitable for rural and underserved communities.
- High efficiency and reliability, provided that proper monitoring of turbidity and disinfectant residual is maintained.

Furthermore, the compact design and use of simple yet robust technologies make local fabrication, repair, and community-level management possible. The plant is environmentally

friendly, with low energy demand, minimal chemical requirements, and manageable sludge generation.

Overall, this project demonstrates that a mini water treatment plant is a practical, cost-effective, and sustainable solution for providing clean drinking water, especially in areas lacking access to centralized treatment facilities. With proper implementation, training, and community involvement, such systems can significantly reduce waterborne diseases, improve public health, support local development, and contribute to the achievement of global goals related to clean water access.

5.2 RECOMMENDATIONS

Automation of the back wash process

A way ensuring clean water is continuously produced is by carrying out backwash at regular interval to ensure the sand filters are clean. This process is usually done manually requiring human intervention.

The backwash process should be fully automated so that backwash would be done at the required time without the need for any human intervention.

Routine maintenance and monitoring of the mini water treatment

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.

Expansion of the mini water treatment plant to other departments and faculties in the University

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.

Periodic evaluation of the treatment process for further upgrade

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.

Continuous testing for quality assurance

Regular quality assurance program, which shall focus on the performance of the mini water treatment plant should be carried out. The quality assurance program should include, but 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.

Documentation and further 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.

CHAPTER 6

REFERENCES

- Al-Abri, M. *et al.* (2019) ‘Chlorination disadvantages and alternative routes for biofouling control in reverse osmosis desalination’, *npj Clean Water*, 2(1). Available at: <https://doi.org/10.1038/s41545-018-0024-8>.
- Al-Obaidi, M., Kara-Zaitri, C. and Mujtaba, I.M. (2020) *Wastewater treatment by reverse osmosis process*. CRC Press.
- Alkhadra, M.A. *et al.* (2022) ‘Electrochemical methods for water purification, ion separations, and energy conversion’, *Chemical reviews*, 122(16), pp. 13547–13635.
- Angelakis, A.N. and Zheng, X.Y. (2015) ‘Evolution of water supply, sanitation, wastewater, and stormwater technologies globally’, *Water (Switzerland)*, 7(2), pp. 455–463. Available at: <https://doi.org/10.3390/w7020455>.
- Chabi, K. *et al.* (2020) ‘Small-scale drinking water treatment unit of filtration and UV disinfection for remote area’, *Water Science and Technology: Water Supply*, 20(6), pp. 2106–2118. Available at: <https://doi.org/10.2166/ws.2020.109>.
- Cheung, P.C.W. (2017) ‘A Historical Review of the Benefits and Hypothetical Risks of Disinfecting Drinking Water by Chlorination’, *Journal of Environment and Ecology*, 8(1), p. 73. Available at: <https://doi.org/10.5296/jee.v8i1.11338>.
- Emeka, C. *et al.* (2020) ‘Water Quality Index for the Assessment of Selected Borehole Water Quality in Rivers State’, *European Journal of Environment and Earth Sciences*, 1(6), pp. 1–4. Available at: <https://doi.org/10.24018/ejgeo.2020.1.6.101>.
- Farah, E. *et al.* (2023) ‘Conceptual Design of a Compact Water Purification Unit Using Reed Bed Filtration’, *Separations*, 10(3). Available at: <https://doi.org/10.3390/separations10030194>.
- Ghernaout, D. (2017) ‘Water treatment chlorination: An updated mechanistic insight review’, *Chemistry Research Journal*, 2, pp. 125–138.
- Jiang, J.-Q. (2015) ‘The role of coagulation in water treatment’, *Current Opinion in Chemical Engineering*, 8, pp. 36–44.

- Jjagwe, J. *et al.* (2021) 'Synthesis and application of granular activated carbon from biomass waste materials for water treatment: A review', *Journal of Bioresources and Bioproducts*, 6(4), pp. 292–322.
- Khan, M.Z.H. *et al.* (2015) 'Water purification and disinfection by using solar energy: towards green energy challenge', *Aceh International Journal of Science and Technology*, 4(3), pp. 99–106.
- Post, G.B., Atherholt, T.B. and Cohn, P.D. (2011) 'Water quality and treatment: a handbook on drinking water', *Health and aesthetic aspects of drinking water*, 6th edn. McGraw-Hill, New York, pp. 1–2.
- Qadri, A. and Alam, M. (2024) 'Drinking water treatment using advanced oxidation processes', *International Journal of Chemical and Biochemical Sciences*, 25(14), pp. 154–163. Available at: <https://www.iscientific.org/wp-content/uploads/2024/03/19-IJCBS-24-25-14-19.pdf>.
- Singh, N. (2004) 'Water management traditions in rural India: Valuing the unvalued', *18th European Conference on Modern South Asian Studies*, (18), pp. 6–9.
- Singh, N.B., Nagpal, G. and Agrawal, S. (2018) 'Water purification by using adsorbents: a review', *Environmental technology & innovation*, 11, pp. 187–240.
- Song, K., Mohseni, M. and Taghipour, F. (2016) 'Application of ultraviolet light-emitting diodes (UV-LEDs) for water disinfection: A review', *Water research*, 94, pp. 341–349.
- Verma, S., Daverey, A. and Sharma, A. (2017) 'Slow sand filtration for water and wastewater treatment—a review', *Environmental Technology Reviews*, 6(1), pp. 47–58.
- Vincent, M., Hartemann, P. and Engels-Deutsch, M. (2016) 'Antimicrobial applications of copper', *International journal of hygiene and environmental health*, 219(7), pp. 585–591.
- Wei, C. *et al.* (2017) 'Ozonation in water treatment: the generation, basic properties of ozone and its practical application', *Reviews in Chemical Engineering*, 33(1), pp. 49–89.
- Yang, Z. *et al.* (2019) 'A review on reverse osmosis and nanofiltration membranes for water purification', *Polymers*, 11(8), p. 1252.
- Zaman, S. (2014) 'Low-cost sustainable technologies for the production of clean drinking

water—a review', *Journal of Environmental Protection*, 5(01), p. 42.