DESIGN OF A MINIATURIZED WATER TREATMENT PLANT AND INTEGRATED DISPENSER SYSTEM

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A PROJECT SUBMITTED IN THE DEPARTMENT OF INDUSTRIAL ENGINEERING, UNIVERSITY OF BENINBENIN CITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR DEGREE (B.Eng.) OF ENGINEERING, UNIVERSITY OF BENIN, BENIN CITY.

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CERTIFICATION

This is to certify that this project work was carried out by ISAAC HARMONY CHIBUIKEM with Matriculation Number ENG2006310, in partial fulfillment of the requirement for the Award of Bachelor of Engineering (B.Eng), in the Department of Industrial Engineering at the Faculty of Engineering, University of Benin, Benin City, Edo State.

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DEDICATION

This project is dedicated to God almighty who has helped me this far and has seen me through every step of the way from my bench work to the completion of my project

ACKNOWLEDGEMENTS

I appreciate God almighty for the gift of life,strength,wisdom and preservation all through the study.

I thank my supervisor Engr.Dr, Chris.I.Eboigbe,for his unwavering support and selflessness towards making this research a success.I am also grateful to the Head of Department Prof.P.E.Amiolemhen.

I am grateful to my Parents Mr and Mrs Nwoko for their love and support.

Special appreciation to my siblings,my close friends for their support,love and sacrifice in ensuring my project was a success.

God bless you all and thank you for the moral supports and words of encouragement

I love you all

ABSTRACT

The provision of safe drinking water remains a critical global challenge, particularly in remote, underserved, or disaster-stricken areas. This project presents the comprehensive design and theoretical analysis of a miniaturized water treatment plant and integrated dispenser system.

The design methodology involved a systematic selection and integration of treatment stages: a polypropylene sediment pre-filter for large particulates, a granular activated carbon (GAC) filter for chlorine and organic compounds, a thin-film composite reverse osmosis (RO) membrane for dissolved solids and heavy metals, and a final UV-C chamber for pathogen inactivation. The integrated dispenser system features a storage tank and a manual or electric pump to deliver water on demand. Critical design parameters, including flow rate, recovery ratio, pump specifications, and component sizing, were calculated to optimize the balance between treatment efficacy, energy consumption, and portability.

The results of the design analysis confirm that the system is capable of producing water that complies with established drinking water quality parameters. This miniaturized water treatment plants and integrated dispenser system offers a promising, sustainable solution for decentralized water purification, with significant potential for deployment in off-grid and emergency situations

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INTRODUTION

1.1 BACKGROUND TO THE STUDY

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

Over the years as human innovation has grown so have different methods for combating water pollution been developed and optimized from simple filtration and surface skimming techniques to boiling to distillation and reverse osmosis (Yang et al., 2019).

Reverse osmosis (RO) is a water purification process that uses pressure to force water molecules through a semi-permeable membrane, effectively separating them from contaminants. This process leaves behind impurities like salts, minerals, bacteria, and other harmful substances, resulting in purified water. It consists of;

Natural Osmosis: In normal osmosis, water naturally flows from an area of low solute concentration (high water potential) to an area of high solute concentration (low water potential) through a semi-permeable membrane. Reversing the Flow: Reverse osmosis applies pressure to the concentrated (impure) side of the membrane, forcing water molecules to move in the opposite direction – against the natural osmotic gradient.

Membrane's Role: The semi-permeable membrane acts as a filter, allowing only water molecules to pass through while blocking larger molecules and ions, including dissolved salts, bacteria, and other contaminants.

Contaminant Removal: This process effectively removes a wide range of impurities, making the water suitable for drinking and other uses.

Reverse osmosis is widely used for water purification, including desalination (removing salt from seawater), industrial water treatment, and producing ultrapure water for medical or industrial applications.

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

i. Intake or water supply
ii. Water treatment
iii. Storage
iv. Supply for external use

Figure1.1 Shows the schematic representation of a water purification plant

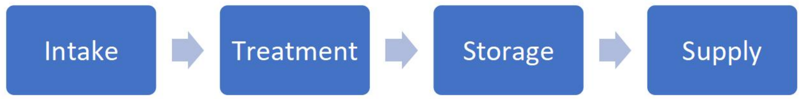

Figure1.1: Standard Modus Operandi of a Water Purification Plant

1.2 STATEMENT OF THE PROBLEM

Many communities lack access to safe drinking water due to conventional large-scale treatment plants being impractical for small or remote locations, existing portable solutions may be inefficient, costly, or difficult to operate.

The increasing demand for clean water especially in remote areas, small communities, and emergency situations, necessitates the development of compact and efficient water treatment solutions. A miniaturized water treatment plant aims to address the following;

I. Existing water quality challenge
II. Limitation of the current treatment plant
III. Need for small scale, affordable solutions
IV. Engineering and technical gaps.

It will be expected that UNIBEN's Department of Industrial Engineering would have a reliable source of clean, treated water; on the contrary, this is not the case. As a matter of fact, water supply within the department is often filled with contaminants and deterrence to experimentation and demonstration activities in the effort toward quality engineering education coupled with the safety of the laboratory environment. The quality and conventional availability of municipal water sources grossly fall short of meeting the required standards in the different engineering applications and tests. Inconsistency in this evidence leaves a critical gap in infrastructure within the department for both laboratory and project-based studies reliant on a stable supply of appropriately treated water. Because appropriate and inexpensive small-scale treatment systems are not available, this significantly limits the students and researchers in getting hands-on experience with diversified purification technologies.

The absence of a localized facility for treatment implies that there is higher reliance on sources outside the facility, in the end limiting exposure for the students in the salient areas of the engineering processes involved in water treatment. A reasonably priced, compact, and efficient water treatment system is, therefore hugely needed to address the special needs of the department and in furnishing the students with practical skills in water purification. The project, therefore, attempts to fill these gaps by designing and constructing a mini water treatment plant for the Department of Industrial Engineering, UNIBEN. It is envisioned that the plant would be designed to be equipped with all various treatment processes, which include filtration, sedimentation, and chemical treatment. These would improve water quality to acceptable standards. The initiative contributes to building further capacity within the Department for practical work in a sustainable and safe manner; it also serves as an educational tool for students in practical learning about water treatment technologies and sustainable engineering practices.

1.3 AIM AND OBJECTIVES OF THE STUDY

The aim of this project is to design and implement a mini water treatment plant that will provide a reliable source of clean and safe drinking water for the Department of industrial Engineering at the University of Benin (UNIBEN). Also, the provision of a water source that can be used for research purposes, and that will provide students and researchers with hands on experience with diversified purification technologies. The objectives are:

i. to assess and esterize the physical, chemical and microbial properties of the water;
ii. to select locally available materials;
iii. to develop a compact water treatment system;
iv. to fabricate and assembly;
v. to conduct performance evaluation test;
vi. to analyze the operational performance;
vii. to perform an economic assessment.

1.4 SCOPE OF THE STUDY

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

a. *System Design:* The project will include the design of a complete water treatment system that will be involved in the series of treatments from raw water intake through pre-treatment, filtration, disinfection to the distribution network. The design shall ensure that the water meets the Nigerian Industrial Standards for drinking water quality
b. *Procurement and Installation:* All materials necessary for the mini water treatment plant will be identified and sourced out for installation. This would cover 7 component packaging of raw water intake systems, sedimentation units, sand and activated carbon filters, disinfection units, storage tanks, and piping.

c. *Operational Testing and Commissioning:* The series of tests to be conducted in ensuring the plant operates according to intended design, and all stages of treatment will guarantee the production of clean, potable water. Commission the plant for service, proving efficiency and reliability beforehand for handover for normal use.

d. *Documentation:* This process and workflow of the entire project will be documented in the design, construction, and testing processes to allow for periodic maintenance and performance checks. This is due to the fact that proper documentation of the process would be of value during upgrading or replication of similar water treatment technology for other departments/institutions.

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

1.5 SIGNIFICANCE OF THE STUDY

The impact of the study will allow research to improve the water supply and quality of water supplied to the Department of Industrial Engineering, University of Benin (UNIBEN). In other terms, the design of the mini water treatment plant in this project will be able to create a reliable and continuous source of clean and safe drinking water for students, staff, and visitors with great concern about water contamination within the department. In addition to that, it will contribute to good health and well-being within the university community due to the provision of potable water, as most daily activities, practical learning, and research would rely on it.

Secondly, a water treatment plant will lessen dependence on insecure sources of external water supply. It guarantees a cost-effective and perpetual solution to the challenges associated with the supply of water. This is of particular importance from an educational perspective in that participants in the research will be directly exposed to water treatment technologies and engineering processes to develop practical understandings of water purification.

The project will also raise awareness about sustainable water management within the university principles of environmental stewardship. This will help serve, in the long run, as a model study for other departments or institutions of higher learning that are in dire need of improvement in their water treatment and thereby contribute to the improvement of infrastructure and sustainability of academic and research activities in Nigeria.

From an economic perspective, the design and implementation of a mini water treatment plant can demonstrate cost-efficiency and resource optimization. For example, it explores affordable materials and energy-efficient processes, making water treatment viable in developing regions. This study will also spark innovation, such as incorporating renewable energy sources (e.g., solar-powered filtration systems) to enhance sustainability. As of today, with ongoing global efforts to combat environmental degradation, such projects are timely and could influence policy decisions or industry standards.

CHAPTER TWO

LITERATURE REVIEW

2.1 OVERVIEW OF WATER TREATMENT

Water treatment is the process of purging water of impurities and unwanted elements so that it is suitable for a certain use, usually environmental safety, industrial activities, or human consumption. Generally, the most common methods include physical processes like filtration and sedimentation, chemical processes like coagulation and disinfection, and sometimes biological processes, and sometimes more sophisticated treatments like reverse osmosis or UV irradiation, depending on the necessary water quality. (Farah et al., 2023).

2.1.1 WATER TREATMENT PROCESSES

Water treatment processes are tried-and-true procedures that guarantee water is safe to consume by eliminating pollutants and germs. Following a set of organized methods, which includes physical processes like filtration and sedimentation, chemical processes like coagulation and disinfection, and sometimes biological processes, these processes are often used in municipal and small-scale treatment facilities around the globe.

a. **Physical Processes**

   Physical process involves making changes in the physical state or position of substances without altering their chemical composition. In water treatment, it includes methods like filtration, sedimentation, and screening that remove contaminants through physical means.

   i. Filtration

It involves running water through a medium—typically activated carbon, sand, or gravel. Slow sand and quick sand filters are two popular filtration techniques; slow sand filters are frequently employed in small systems because of their affordability and ease of operation. Research shows that sand filters are good at eliminating organic debris, bacteria, and leftover coagulant particles. For instance, the usage of activated carbon to absorb chemical substances and manage problems with taste and odour is growing.

Figure2.1 Shows the schematic representation of a household sand filtration

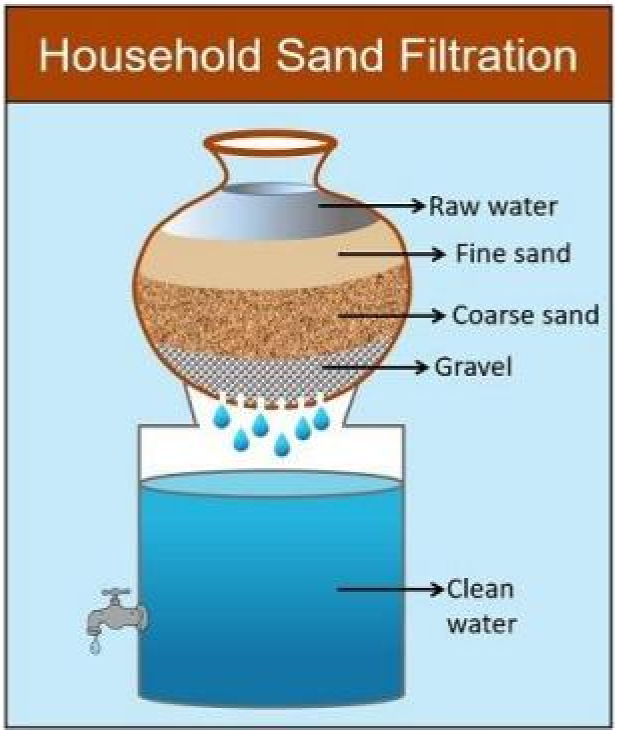

Figure 2.1: Household Sand Filtration

ii. Sedimentation

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

Figure2.2 Shows the schematic representation of the sedimentation process

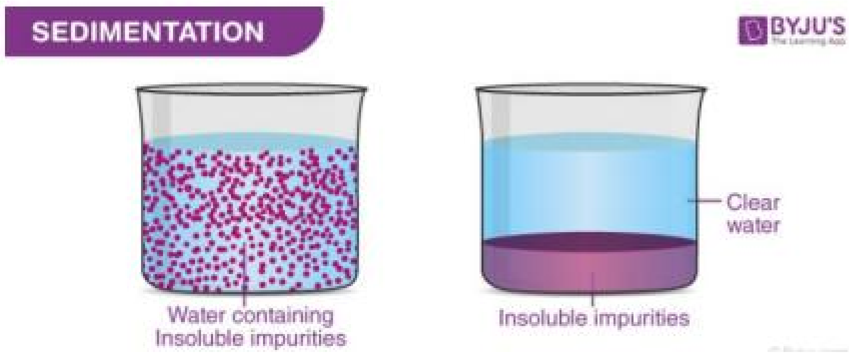

Figure 2.2: Sedimentation

iii. Screening

Screening is a crucial initial physical process in water treatment that removes large debris and solid materials from raw water or wastewater. It involves passing the water through a series of screens or filters to capture unwanted objects like trash, leaves, and large particles, preventing them from causing problems in later stages of treatment.

Figure2.3 Shows the schematic representation of screening

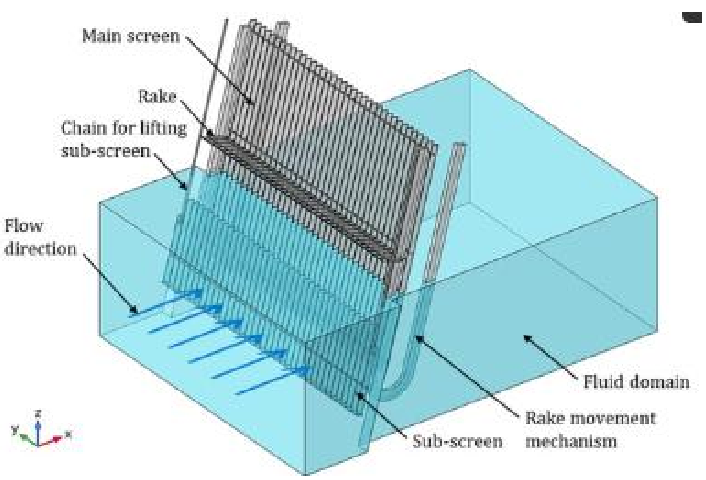

Figure 2.3: Screening

There are different types of screens. These include

I. Coarse screens:

These have large openings, often several inches wide, and are used for removing large objects like logs, branches, and bulky trash.

II. Fine screens:

These have smaller openings, typically a few millimeters wide, and are used to remove smaller debris like leaves, twigs, and other smaller solids.

III. Bar screens:

These consist of parallel bars or rods, often inclined, that allow water to pass through while trapping debris.

IV. Mesh screens:

These are made of woven wire or plastic mesh with smaller openings.

V. Automated screens:

Some systems use automated screens with mechanical rakes that continuously remove captured debris.

iv. Aeration

Aeration a physical process that involves bringing water into close contact with air to improve its quality. It primarily aims to increase dissolved oxygen, remove dissolved gases like carbon dioxide and hydrogen sulfide, and eliminate volatile organic compounds that cause unpleasant tastes and odors. This process can also facilitate the oxidation of iron and manganese, making them easier to remove through filtration.

Figure2.4 Shows the schematic representation of an aeration

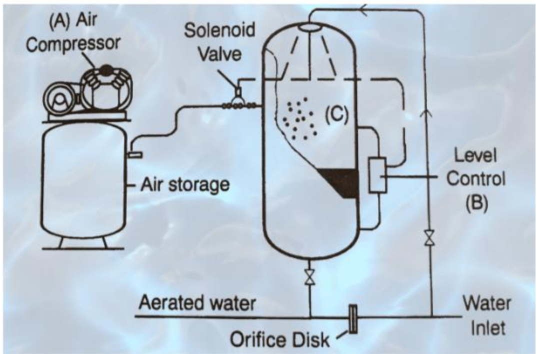

Figure 2.4: Aeration

v. Adsorption

Adsorption is a surface-based process where dissolved substances (adsorbates) are removed from water by adhering to the surface of a solid material (adsorbent). This implies the removal of substances from liquid by a solid phase. This process is used to remove a variety of contaminants, including organic pollutants, heavy metals, and taste and odor compounds, making water safe for consumption or other uses through the process of diffusion.

Figure2.5 Shows the schematic representation of an adsorption process

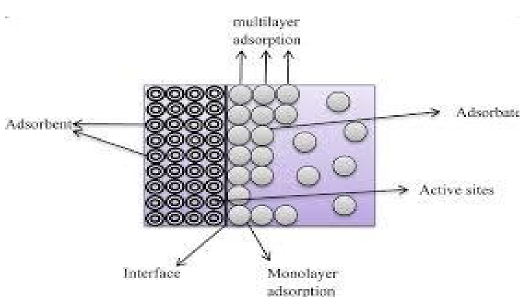

Figure 2.5: Adsorption

b. Chemical Processes

It involves reactions that change the chemical composition of substances. In water treatment, this includes adding chemicals to remove contaminants, disinfect, or alter pollutants chemically.

A. Coagulation and Flocculation

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

Figure2.6 Shows the schematic representation of a coagulation process

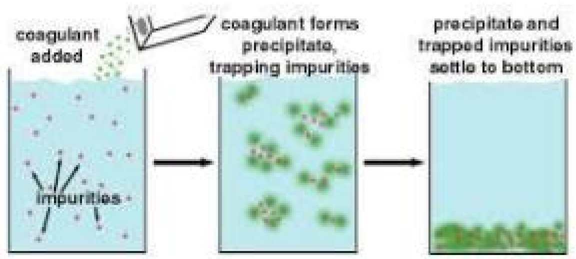

Figure 2.6: Coagulation

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

Figure2.7 Shows the schematic representation of a flocculation process

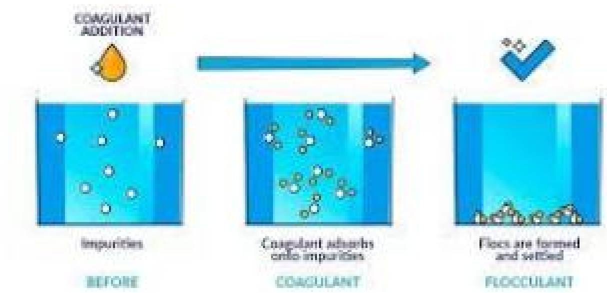

Figure 2.7: Flocculation

B. Disinfection

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

C. pH Adjustment

pH adjustment involves using chemicals to neutralize water, either by adding acids to lower the alkalinity or bases to lower the acidity. The pH indicator ranges from 1-14, the desired pH range, often falls between 6.5 and 8.5, for optimal treatment and to prevent corrosion or scaling. Common chemicals include sulfuric acid, hydrochloric acid, sodium hydroxide, and lime.

Figure2.8 Shows the schematic representation of a pH adjustment

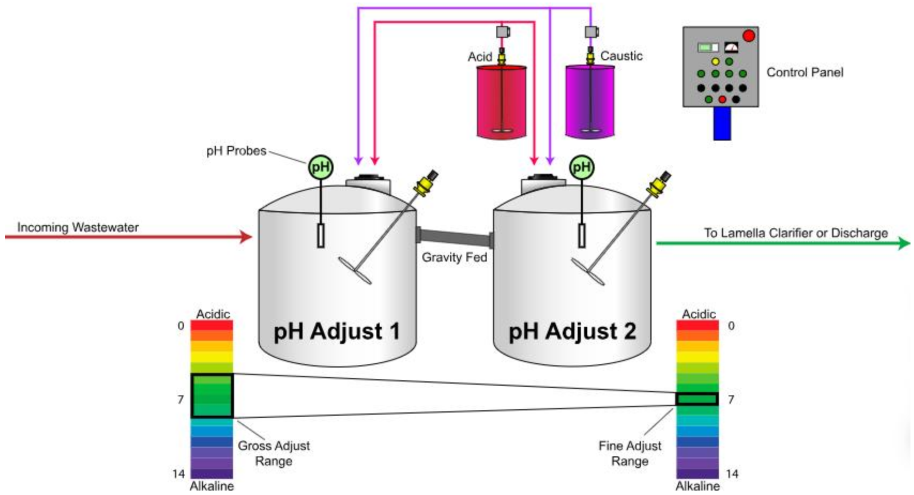

Figure 2.8: pH Adjustment

D. Oxidation

Oxidation is a chemical process that removes contaminants by converting them into less harmful forms, often through reactions with oxygen or other oxidizing agents. This process can involve direct oxidation, where the contaminant reacts with an oxidant, or indirect oxidation, where an oxidant like ozone or hydrogen peroxide generates highly reactive species like hydroxyl radicals that then react with the contaminants.

Figure2.9 Shows the schematic representation of an oxidation process

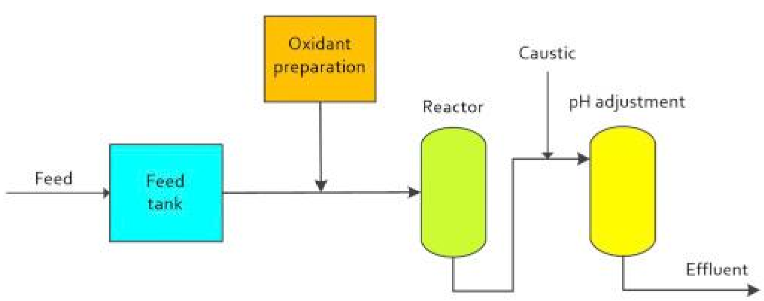

Figure 2.9: Oxidation

c. Biological Processes

Biological process uses living organisms, such as bacteria or algae, to break down or remove contaminants from water. It relies on natural biological activity to treat pollutants, especially organic matter and nutrients.

A. Activated Sludge

The activated sludge wastewater treatment method uses microorganisms to break down organic pollutants. It involves the suspension of biological growth, an aeration tank where wastewater is mixed with activated sludge (a microbial floc) and oxygen, followed by a settling tank to separate the treated water from the sludge. A portion of the sludge is recycled back to the aeration tank to maintain the microbial population.

Figure2.10 Shows the schematic representation of an activated sludge

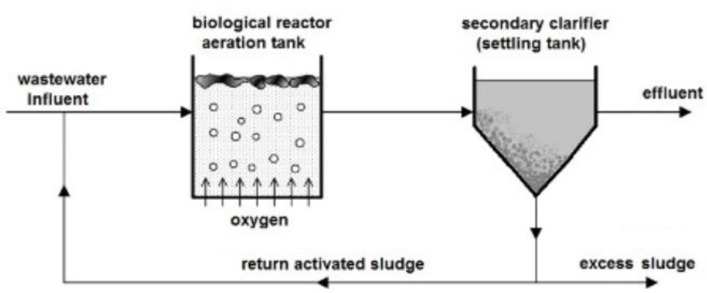

Figure 2.10: Activated sludge

B. Slow Sand Filtration

Slow sand filtration is a biological water treatment process where water is purified by passing it through a bed of sand. This process relies on a biological layer called the "Schmutzdecke" that develops on the sand surface, composed of bacteria, protozoa, and other microorganisms. These organisms break down organic matter and remove particulate matter, resulting in clean, potable water.

Slow sand filtration works primarily through biological activity that takes place on the surface of a sand bed (Baruth, 2005)

Figure2.11Shows the schematic representation of a slow sand filtration

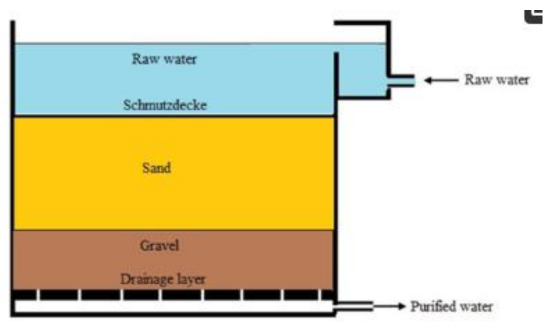

Figure 2.11: Slow Sand Filtration

d. Other Processes

A. Softening

Water softening is a crucial water treatment process that removes minerals like calcium and magnesium, which cause water hardness. The most common method is ion exchange, where hard water passes through a resin bed, exchanging hardness ions (calcium and magnesium) for sodium or potassium ions. This process effectively reduces scale buildup in pipes and appliances.

I. Ion Exchange Process

a) Resin Bed: This process utilizes a tank filled with tiny resin beads, typically made of polystyrene or acrylic, that are coated with sodium or potassium ions.

b) Hard water passage: When hard water flows through the resin bed, the calcium and magnesium ions in the water are attracted to the resin beads.

c) Ion Exchange: These hardness ions replace the sodium or potassium ions on the resin beads effectively removing them from the water

d) Softened Water: The water that exists the softener is now softened, containing primarily sodium or potassium ions instead of calcium and magnesium

e) Resin Regeneration: over time, the resin beads become saturated with calcium and magnesium and need to be recharged. This is di=one by flushing the resin with a concentrated salt solution (Brine), which replaces the hardness ions with sodium or potassium ions restoring the resins softening capacity

Hard Water (Ca2+, Mg2+) --> Resin Bed (Na+ or K+) --> Softened Water (Na+, K+)

Hard Water: Represents water containing calcium and magnesium ions, which cause hardness.

Resin Bed: A column containing resin beads charged with sodium or potassium ions.

Softened Water: Represents water that has passed through the resin bed, with calcium and magnesium ions replaced by sodium or potassium ions.

Figure2.12 Shows the schematic representation of an ion exchange

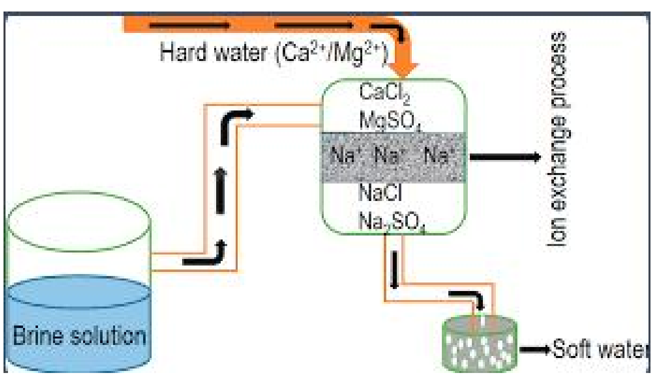

Figure 2.12: ion exchange

II. *Lime-Soda Softening*: This method involves adding lime (calcium hydroxide) and soda ash (sodium carbonate) to precipitate out calcium and magnesium, which are then removed by sedimentation and filtration

III. *Reverse Osmosis*: This process uses semi permeable membrane to filter out impurities including hardness ions

IV. *Chelation:* This method uses chemicals called chelating agents to bind with hardness ions preventing them from causing problems

B. Desalination

Desalination is a water treatment process that removes dissolved salts and minerals from saline water, most commonly seawater, to produce fresh water for drinking, irrigation, and other uses. The two main categories of desalination technologies are thermal and membrane-based.

Thermal methods, like distillation, heat water to create vapor, which is then condensed into freshwater. Membrane methods, primarily reverse osmosis, use pressure to force water through a semi-permeable membrane, separating it from the dissolved salts.

I. *Thermal Desalination*:

This process involves heating saline water to produce steam which is then condensed back into freshwater leaving behind the salts. Common distillation methods include;

i. Multi stage flash (MSF) distillation: Seawater is heated and then passed through chambers with decreasing pressure, causing it to flash into steam

ii. Multi effect distillation (MED): Similar to MSF but uses multiple vessels in series to improve efficiency

iii. Vapor compression distillation: Uses the heat from compressed water vapor to evaporate more feedwater

II. Membrane Desalination

a) Reverse Osmosis (RO): Sea water is forced through a semi permeable membrane under high pressure. The membrane allows water molecules to pass through but blocks most dissolved salts and minerals. RO is widely used particularly for brackish water desalination

Figure2.13 Shows the schematic representation of reverse osmosis

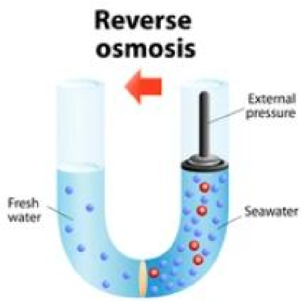

Figure 2.13: Reverse Osmosis

b) Electrodialysis (ED): This process uses an electrical field and ion selective membranes to separate ions (charged particles) from the water. Its more commonly used for brackish water than seawater

C. Fluoridation

Fluoridation is a water treatment process that involves adding fluoride to the public water supply to help prevent tooth decay. It's a supplementary treatment, often added after other processes like filtration and disinfection. The process involves introducing fluoride-releasing compounds like sodium fluoride, sodium fluorosilicate, or fluorosilicic acid into the water.

2.2 HISTORICAL DEVELOPMENTS IN WATER TREATMENT

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

2.2.1 CLASSIC WATER PURIFICATION METHODS

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

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

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

2.2.2 MEDIEVAL TO EARLY MODERN PERIODS (MIDDLE AGES TO 17TH CENTURY)

I. In order to create clean water, distillation entails boiling water to create steam and then condensing it to remove any contaminants. Although distillation gained popularity in the Middle Ages as a method of purifying water for alchemical and medical uses, its use in ordinary water supplies has been constrained by the process' complexity. Distillation was to remain a crucial procedure for laboratory and medicinal applications far into the 20th century due to its efficacy (Post, Atherholt and Cohn, 2011).

II. Coagulation and Sedimentation: Coagulation techniques first appeared in the 17th century. When chemicals, mostly alum, are added to water, dispersed particles cluster together to form larger particles that will ultimately sink to the bottom. This process is known as coagulation. In order to lower turbidity in public water sources, this sedimentation process became widely accepted in European towns. According to history, certain societies, including the Egyptians, used crushed Moringa plant seeds as natural coagulants to cleanse water (Post, Atherholt and Cohn, 2011).

2.2.3 18TH AND 1TH CENTURIS: SCIENTIFIC ADVANCES AND MUNICIPAL WATER SYSTEMS

I. Filtration of Sand: The earliest known slow sand filter was created in Scotland in 1804, by a Scot named John Gibb, to provide cleaner water for domestic consumption. Sand filtration was swiftly adopted in many places across Europe and the US as it proved to be an efficient method of removing pathogens. Indeed, this became one of the important advancements of water treatment technologies up to this era, with large decreases in the broad occurrence of waterborne infections among urban populations (Zaman, 2014).

II. Chlorination: Chlorine's ability to effectively disinfect was already recognized in the late 1800s. By treating water with sodium hypochlorite, which killed the bacterium that causes typhoid, Dr. Sims Woodhead conducted the first successful chlorination experiment in the United Kingdom in 1897. Chlorination was first used as a complete municipal water treatment in the United States in 1908 in Jersey City, New Jersey, and quickly established itself as a fundamental component of water treatment public health procedures. (Al-Abri et al., 2019)

III. Ozone Treatment: Around the same timeframe, ozone disinfection arose in Europe as an alternative to chlorination. The first application of ozone for municipal water purification occurred in Nice, France, in 1906. Although it required specialized equipment, ozone's potent oxidative qualities made it extremely effective against bacteria and viruses. It was thought to provide a chemical-free substitute for water disinfection. (Cheung, 2017).

2.2.4 20TH CENTURY ONWARD: MODERN ADVANCES IN WATER TREATMENT

I. Reverse Osmosis and Membrane Technology: The 1950s saw the invention of reverse osmosis, which ushered in a new age in water treatment, particularly desalination. To make water suitable for drinking and industrial use, salts, ions, and other contaminants are eliminated by passing it through a semipermeable membrane. RO technology has been used at small- and large-scale water treatment plants since its conception. (Al-Obaidi, Kara-Zaitri and Mujtaba, 2020)

II. UV Treatment: One of the more often used non-chemical ways to disinfect or inactivate germs is UV disinfection. UV, particularly in the UV-C wavelength range, prevents bacteria from reproducing by interfering with their DNA replication. UV technology is being used in many small-scale and portable water treatment systems due to its effectiveness and environmentally favourable effects (Song, Mohseni and Taghipour, 2016).

2.3 IMPORTANCE OF WATER TREATMENT IN SCHOOL SYSTEMS

I. Health and Hygiene: To keep students and employees safe and stop the spread of waterborne illnesses, clean water is crucial at educational institutions. For example, establishments lacking adequate treatment systems run the danger of bacterial contamination, which can result in diseases that interfere with school operations. (Chabi et al., 2020)

II. Sustainability and Cost Savings: Institutions can lessen their reliance on outside water sources, especially in areas with inadequate infrastructure, by putting water treatment on-site. This self-sufficiency is particularly beneficial for educational institutions looking to control expenses and preserve resources in a sustainable manner. (Farah et al., 2023)

III. Research and Hands-on Learning: Water treatment plants may be used as living models for students in technical subjects like Industrial Engineering, giving them a first-hand look at treatment procedures. In disciplines like fluid mechanics, chemistry, and environmental engineering, this hands-on experience strengthens theoretical understanding.

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

2.4 WATER QUALITY PARAMETERS

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

B. 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.

C. 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).

D. 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:

a) Soft: 0-60 mg/L

b) Moderately hard: 61-120 mg/L

c) Hard: 121-180 mg/L

d) Very hard: >180 mg/L

E. 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.

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

NATIONAL AND INTERNATIONAL WATER QUALITY STANDARDS

Parameter/unit	NSDWQ, 2017	WHO, 2017
pH	6.5-8.5	6.5-8.5
Turbidity(NTU)	5.0	
Conductivity(µS/cm)	1000	
TDS (mg/L)	500	
Temperature ℃	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

WATER QUALITY INDEX (Emeka et al., 2020)

2.5 AN OVERVIEW OF CONVENTIONAL WATER TREATMENT METHODS

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

Figure2.14 Shows the schematic representation of the conventional water treatment methods

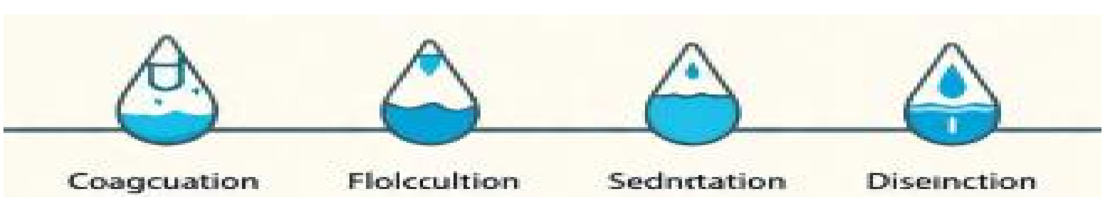

Figure 2.14: Conventional Water Treatment Methods

2.6 DISADVANTAGES OF CONVENTIONAL WATER TREATMENT

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

2.7 AN OVERVIEW OF ADVANCED WATER TREATMENT METHODS

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

A. <u>Membrane Filtration</u>: The physical barrier that separates the pollutants in the water is made possible by membrane technology. Membranes are made of a variety of materials, each of which has certain qualities (pore size and hydrophobicity) that limit the types of contaminants that may be contained in. Membrane filtration is an efficient way to remove particles, germs, and organic materials from drinking water and wastewater. contrasting membrane procedures with conventional therapeutic methods. It can provide betterquality water, lessen 19 the need for disinfectants, compress more, provide simpler operational management, needless upkeep, and generate less dirt.

Figure2.15 Shows the schematic representation of a membrane filtration

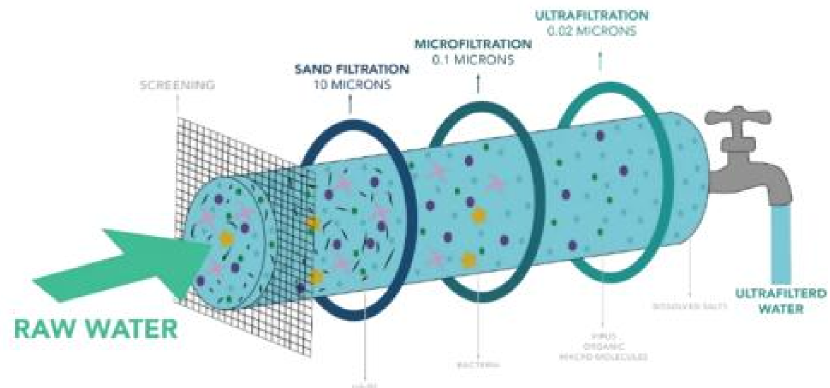

Figure 2.15: Membrane Filtration

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

Figure2.16 Shows the schematic representation of a UV light

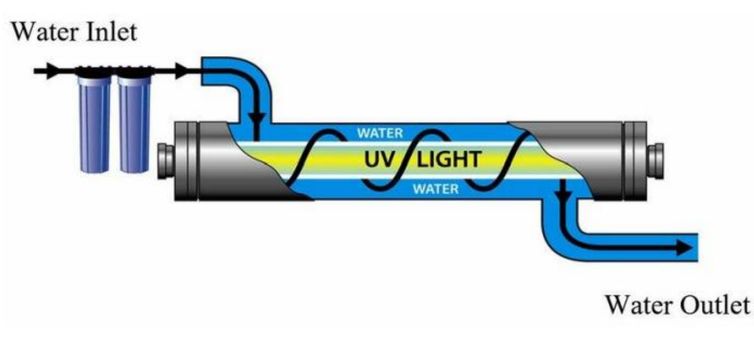

Figure 2.16: UV light

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

2.8 SMALL SCALE WATER TREAMENT PLANTS

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

Figure2.17 Shows the schematic representation of a three-tank water filter

Figure 2.17: A Three Tank Water Filter

2.8.1 DESIGN CONSIDRATIONS FOR SMALL-SCALE WATER TREATMENT PLANT

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

A. 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.

B. 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).

C. 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.

D. 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 considered. 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.

E. 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.

F. 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.

G. Cost Considerations: The plant needs to be cheap and reasonably priced, keeping in mind that durable materials must be employed without going over budget. Consider all of the continuous costs, including labor, 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 considered wherever feasible without compromising the quality of the therapy.

H. 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.

I. 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.

2.8.2 ANALYSING A SMALL-SCALE WATER TREATMENT PLANT BUILT IN A REMOTE AREA

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

Figure2.18 Shows the schematic representation of a six treatment phases

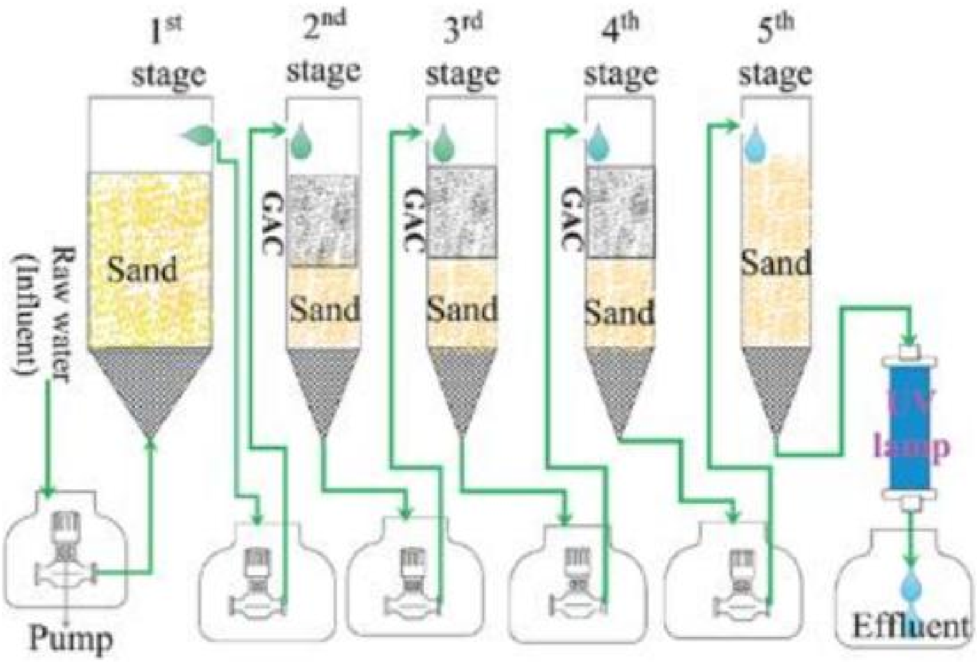

Figure 2.18: Six treatment phases

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

The drinking water's pH ranged from 7.09 to 7.99 in this current investigation. The concentration of chemical components was found to decrease as the pH rose slightly. According to the data, 95.33 percent of the turbidity was eliminated from the final effluent following full treatment. Furthermore, the results met the standards of the international drinking water standard. Numerous bacterial species are present, according to research on the bacterial population. In order to thrive, these many bacterial species that were present in the ecosystem needed nutrition. Their findings showed that when water was 25 treated, the composition of the bacterial community altered, with a higher diversity of bacterial species seen at various phases of treatment.

HRT (Hydraulic Retention Time) is a crucial metric for managing water treatment effectiveness. HRT significantly affects both the contact time and the hydrodynamic conditions (Pan et al. 2004). The contaminants were effectively removed by our 0.03-day HRT treatment unit (e.g. 85.71 percent removal of ammonium). This pilot research demonstrated how well UV disinfection, physical filtration, and bio filtration removed contaminants from source water. Along with DOC, the bio filtration method demonstrated a high removal of turbidity, nitrite, and ammonium. The outcomes of the microbiological and physicochemical parameters meet international standards. The drinking water quality in our developed unit improved across several biological phases. Turbidity and organic contaminants were removed in large part because to BAC. The removal of NH_4^+-N through the microbial nitrification process was significantly aided by Nitrospira and Nitrosomonas, which mostly inhabit the surface layer of the BAC medium in our system.

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

CHAPTER THREE

MATRIALS AND METHODS

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

3.1 MATERIALS

I. Filtration
II. Carbon filter (2)
III. Pump 0.5hp
IV. UV
V. Storage tank
VI. Refrigerator
VII. Heater
VIII. Flexible connector
IX. 1/2- and 1-inch Adaptors
X. Elbows and sockets
XI. Ball valves
XII. Float switch and solenoid valve

Filtration Tanks

An essential aspect of the small water treatment plant is the filtration tank, which uses a multi-layer filtering system to remove contaminants and particle matter from the water. The filtration tank might have a rectangular or cylindrical form whose total surface are can be calculated by the formula below;

TSA= L×W (For Rectangular Tanks) …1

Where;

TSA= Tank Surface Area

L= Length

W= Width

$TSA=\pi r^2$ …2

Where;

TSA= Tank Surface Area (For Circular Tanks)

π =pi

r = Radius

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.

Flow rate (gpm) = flow rate (gpd) ÷ 1440 min/day …3

Where;

Gpm = Gallons per minute

Gpd = Gallons per day

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

$$Fr = fr \div sa \qquad \ldots 4$$

Where;

Fr = Filtration rate

fr = flow rate

sa = surface area

$$Tv = A \times H \qquad \ldots 5$$

Tv = Tank volume

A = Area

H = Height

Figure3.1 Shows the schematic representation of a filtration tank

Figure 3.1: Filtration Tanks

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

$$\text{Airflow cfm} = (L \times W \times H) \div (\text{Minute}/\Delta\text{Air}) \quad \ldots 6$$

Where;

Cfm = Cubic feet per minute

L = Length

W = Width

H = Height

ΔAir = Air change

Figure3.2 Shows the schematic representation of an activated carbon filter

Figure 3.2: Activated Carbon Filter

UV Treatment

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

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

$$\text{UV Dose} = \text{UV Intensity} \times \text{Exposure Time} \quad \ldots 7$$

Where;

UV Dose = mJ/cm^2

UV Intensity = mW/cm^2

Exposure Time = Seconds

$$\%\text{UVT} = \text{UV Intensity} \div (\text{UV Dose} \times \text{Time}) \quad \ldots 8$$

Where;

%UVT = Transmittance

UV Intensity = mW/cm^2

UV Dose = mW/cm^2

Time = Second

Figure3.3 Shows the schematic representation of a UV treatment setup

Figure 3.3: UV Treatment set-up

Storage Tank

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

Figure3.4 Shows the schematic representation of transparent storage tank

Figure 3.4: Transparent Storage Tank

Refrigerator

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

Efficiency;

For an Ideal Carnot refrigerator

$$COP = \frac{\mathrm{TC}}{\mathrm{TH}-\mathrm{TC}} \qquad \ldots 9$$

COP = Coefficient of Performance

TC = Temperature of the cold reservoir in kelvin

TH = Temperature of the hot reservoir in kelvin

For a real refrigerator

$$COP = \frac{QC}{|W|} \qquad \ldots 10$$

Where

QC = Heat absorbed from the cold reservoir

W = Work done by the compressor

Refrigerator capacity

$$BTU = lbs \times \Delta T \times Cp \qquad \ldots 11$$

Where;

Where;

BTU = A common unit for cooling capacity

lbs = weight of the water

ΔT = Change in temperature

Cp = Specific heat for water (1 Btu/lb°F)

Figure3.5 Shows the schematic representation of an experimental stand for the investigation of a refrigeration single stage centrifugal compressor

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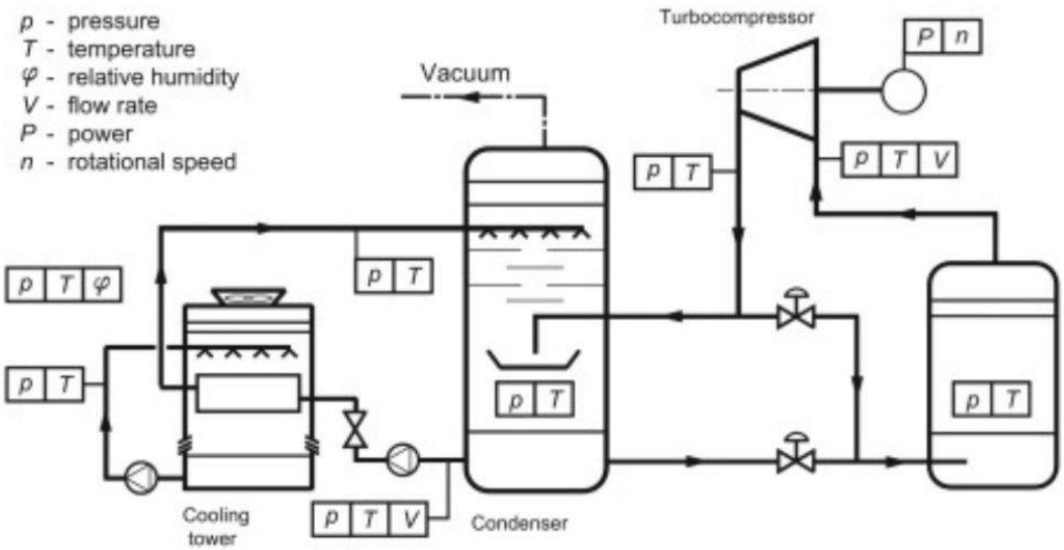

Figure 3.5 Experimental Stand for the investigation of a refrigeration single stage centrifugal compressor

Heater

The purpose of the heater is to guarantee that the water reaches the ideal temperature prior to being distributed after being kept in the treatment system. Maintaining water quality, stopping microbial development, and making sure the water is at the right temperature for use are all made possible by this system. The formula for the electrical power used is;

Single-phase system: $P = V^2/R$ …12

Where;

P =Power

V = Voltage

R = Resistance

Single-phase (amperage) $I = V/R$ …13

Where

I = Current

V = Voltage

R = Resistance

To Calculate the wattage

$Q = m \times Cp \times \Delta T$ …14

Where;

Q = heat load

m = mass flow rate in lb/hr

Cp = Specific heat of the material in $BTU/LB^{O}F$

ΔT = Change in temperature

Figure3.6 Shows the schematic representation of a refrigerator and heater stations

Figure 3.6: Refrigerator and Heater Stations

Flexible Connector

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

Figure3.7 Shows the schematic representation of a flexible connector for a heater

Figure 3.7: Flexible Connector for Heater

Adaptors

Fittings called pipe adapters 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). They have a fitting allowance which is gotten from the formula;

$$PIPE_{lenght} = \text{Center-to-center}_{measurement} - Fitting_{allowance} \quad \ldots 15$$

Figure3.8 Shows the schematic representation of a pipe adaptors

Figure 3.8: Pipe Adaptors

Ball valves

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

$$C_v = \frac{Flow\ rate}{\sqrt{Pressure\ drop}} \quad \ldots 16$$

Where;

C_v = Flow coefficient

TORQUE; This is required to operate the ball valve and is calculated with the formula

$$T \approx C \times D^2 \times \Delta P \quad \ldots 17$$

Where;

C = Constant

D = Diameter of the ball

ΔP = change in pressure

VOLUME

For the ball the formula below is used;

$V_{sphere} = \frac{4}{3}\pi r^3$ …18

For the body the volume is more complex and is calculated using the external and internal dimensions.

Figure3.9 Shows the schematic representation of a ball valve

Figure 3.9: Ball valve

Float Switch and Solenoid Valve

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

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

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

$$C_v = Q\sqrt{\frac{G}{\Delta P}} \qquad \ldots 19$$

Where;

C_v = Flow coefficient

Q = Flow rate

G = specific gravity

ΔP = pressure drop across the valve

ELECTRICAL CALCULATION

$$F_m = N \times I \qquad \ldots 20$$

Where;

N = number of turns

I = current

F_m = Magnetomotive Force

$$\text{Relative Duty Circle\%} = \left(\frac{ON\ Time}{ON\ Time + OFF\ Time}\right) \times 100 \qquad \ldots 21$$

Figure3.10 Shows the schematic representation of a flow switch

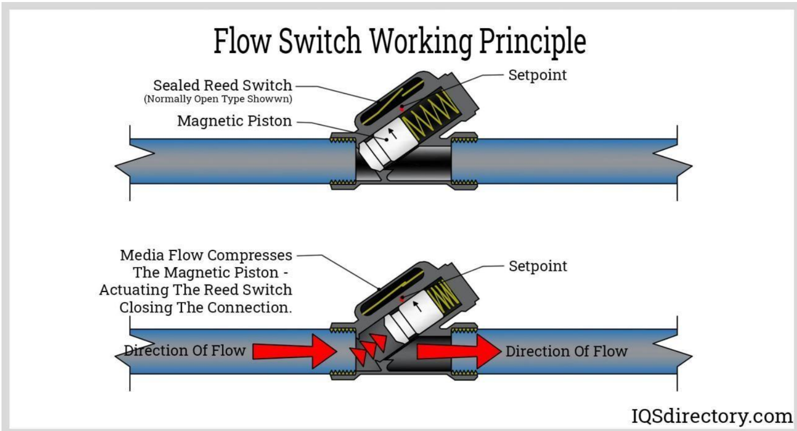

Figure 3.10: Flow Switch

Figure3.11 Shows the schematic representation of a solenoid valve

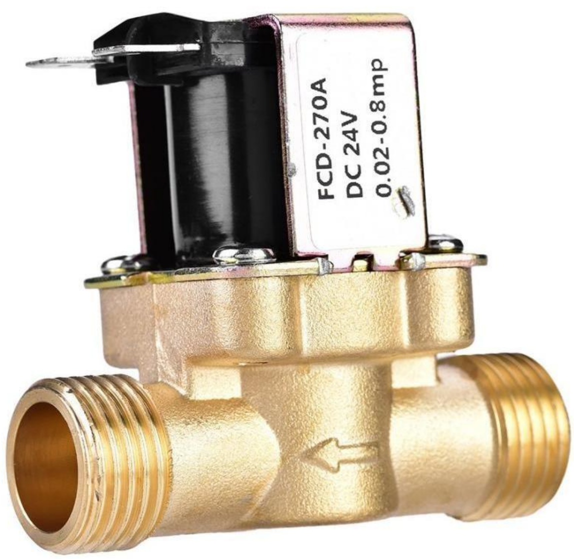

Figure 3.11: Solenoid Valve

Pump

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

$$P_{shaft} = \frac{Q \times H \times SG}{3670 \times \eta} \quad \ldots 22$$

Where;

P_{Shaft} = shaft power

Q = pump capacityin m^3/h

H = pump head in meters

SG = specific gravity of the medium

Ƞ = pump efficiency in %

Pump head; This is the measure of energy imparted to the water and is calculated using the formula;

$$h_F = \frac{10.67LQ^{1.85}}{C^{1.85}D^{4.87}} \quad \ldots 23$$

Where;

Hf = Head loss(meters)

L = Length of pipe (meters)

Q = Flow rate (L/s)

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

D = Diameter of pipe(cm)

FLOW RATE

$$Flow\ rate = \frac{Horsepower \ \times 746}{Total\ Head \ \times Water\ weight\ per\ liter} \quad \ldots 24$$

PUMP EFFICIENCY

$\eta = {}^{Poutput}/_{Pinput} \times 100\%$ …25

Figure3.12 Shows the schematic representation of a 0.5 HP Pump

Figure 3.12: 0.5 HP Pump

Dispensing Station

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

Figure3.13 Shows the schematic representation of a dispensing station

Figure 3.13: Dispensing station

3.2 METHODS

3.2.1 Installation of Our Mini Water Treatment Plant

The procedure of installing our mini water treatment system was intricate but worthwhile. In order to feed untreated water into the setup, we began with the raw water intake system. We carefully positioned intake pipe to ensure smooth water flow from the source, using the PVC ½ inch pipes.

The pre-treatment system came next. We put a screen at the input point that efficiently filters out particles like leaves and grit in order to capture larger material and lessen the strain on our filtration tanks. We placed a sedimentation tank after the screen. In order to clear the water before it filters into the filtration tanks and lessen the strain on the next filtration stages, particles heavier than water sink to the bottom of this tank.

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

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

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

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

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

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

Figure3.14 Shows the schematic representation of a six treatment phases

Figure 3.14: Full Setup

Figure3.15 Shows the schematic representation of a process flow diagram

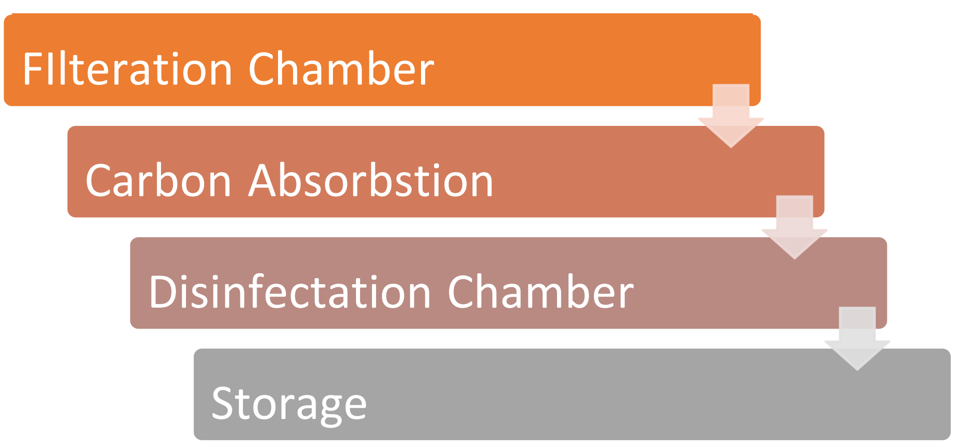

Figure 3.15: Process flow diagram

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

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

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

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

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

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

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

3.2.2 Maintenance

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

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

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

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

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

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

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

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

D. **Maintenance of pumps:**

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

II. Cleaning and Lubrication: Check the inlet screen and pump casing for any debris accumulation that might impede water flow. To lessen wear, lubricate moving parts every three to six months using the manufacturer's recommended lubricants.

III. Pressure and Flow Tests: Conduct tests in the pump's pressure and flow rates every 3 months for the purpose of ensuring that the pump is adequate for the system requirements. If flow or pressure is reduced, then check for blockages or worn-out impellers.

IV. Replacement Frequency: Depending on usage patterns and maintenance standards, medium- to long-lasting pumps can often be changed after three to five years.

E. **Valves and Connectors:**

I. Ball Valve and Solenoid Valve: These are the water flow controls; the latter is electrical, and the former is mechanical. Additionally, they must be examined every three months.

II. Testing and Cleaning: Make all manual valve actions more fluid for movement and sensation. To prevent seizing, remove any deposits from the area around the valves and use the proper lubricant.

III. Solenoid Valve Testing: It is crucial to ensure that the solenoid valve functions properly so that it opens and closes at the proper times, particularly after prolonged usage or even during inactivity. Additionally, this would be a good time to give the solenoid coil a thorough cleaning and carefully check it for any potential electrical issues or noticeable corrosion build-up over time.

IV. Flexible Connectors and Pipe Fittings: To maintain them tight and free of leaks or other indications of degradation, all of the flexible connections and pipe fittings should undergo a quarterly inspection.

V. Replacement: Immediately replace any worn or cracked connectors, as leaks can affect system performance and safety.

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

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

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

3.2.3 Bill of Engineering Material and Evaluation

The bill of engineering materials for the water purification system is shown in the Table 3.3

Table 3.3 Bill of Engineering Materials and Evaluation of the Water Purification System

S/N	Materials	Description	Size	Quantity	Unit cost (N)	Total cost (N)
1	2 filtration tanks	Metal		2	220,000	440,000
2	Carbon filter	Cylindrical Polymer		1	24,000	24,000
3	PVC pipes	Polymer	Various	Sum	25,000	25,000
4	Gravels	Earth rock	150kg	sum	20,000	20,000
5	Dispenser	Integrated cooler and heater		1	280,000	280,000
6	Activated charcoal	Natural blackwood lignite	60kg	Sum	48,000	48,000
7	PVC nipple	Polymer	½ inch	10	600	6000
8	Elbow	Polymer	½ inch	10	600	6000
9	Tee	Polymer	½ inch	10	600	6000
10	Union	Polymer	½ inch	10	600	6000
11	Valve	Polymer	½ inch	2	600	6000
12	Miscellaneous				73,000	73,000
13	Labor	Workmanship			300,000	300,000
14	UV			1	180,000	180,000
15	Adaptors	polymers		6	80,000	80,000
16	Stainless steel frame	steel			100,000	100,000
17	**Total**				1,343,600	1,600,000

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 RESULTS

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

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

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

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

$$h_F = \frac{10.67 L Q^{1\cdot 85}}{C^{1\cdot 85} D^{4\cdot 87}}$$

Where

Hf = Head loss (meters)

L = Length of pipe (meter)

Q = Flow rate (L/s) C = Hazen-Williams roughness coefficient (typically 130-150 for new pipes)

D = Diameter of pipe (cm)

1-inch pipe = 25.4 mm diameter

2-1/2-inch pipe = 12.7 mm diameter

Length of each pipe = 20 meters

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

Hazen-Williams roughness coefficient

C = 130 (for typical PVC pipes)

For 1-inch pipe:

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

Head loss = 0.8 meters

For ½ inch pipe:

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

Head loss = 3 meters

Total Head loss = 0.8 + 3 = 3.8 meters

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

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

Water weight per liter = 9.81 Newtons (N)

$$flow\ rate = \frac{0.5\ \times 746}{3.8\ \times 9.81}$$

= 10L/s

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

However, it's was important to check the pump's performance curve to ensure that at our required head loss of 3.8 meters, the pump still maintains an optimal flow rate of around 50 LPM. Most

0.5 HP pumps will be able to provide that, but we had to verify the exact flow rate at 3.8 meters' head before we purchased the pump.

4.2 TEST

The water treatment system upon completion was tested to ensure functionality and effectiveness, this test involved the taking two samples of water from the sources available within the faculty of engineering in the University of Benin. One of the samples was passed through the water treatment system while the other was kept as is to serve as a control sample then both samples properly labelled were sent to be tested at the department of Chemistry Faculty of Physical Sciences University of Benin. The tests carried out at the lab consisted of both physio chemical analysis as well as microbiology analysis to determine the suitability of both water samples according to the standards set by National Institute of Standards (NIS) for potable drinking water, suitable for consumption.

4.2.1 NIS STANDARDS IN NIGERIA

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

1. Physical and Organoleptic Properties
   i. Colour: Clear, but not to exceed 15 TCU.
   ii. Odour and Taste: Water must be odourless and the taste must be neutral.
   iii. Turbidity: It should not exceed 5 NTU.
   iv. PH Level: The pH ranges from 6.5 to 8.5.

2. Chemical Properties
   i. TDS: Acceptable limit: 500 mg/L, yet up to 1000 mg/L may be acceptable in some instances.

ii. Hardness: Not exceed 150 mg/L as $CaCO_3$.
iii. Chloride: Up to 250 mg/L to avoid problems of taste and corrosion.
iv. Nitrate: Intake shall not exceed 50 mg/L. It is particularly critical to avoid methemoglobinemia in infants.
v. Fluoride: Less than 1.5 mg/L, since intakes exceeding this value can cause dental and skeletal fluorosis.
vi. Iron: Shall not exceed 0.3 mg/L, to prevent problems on taste and discoloration.
vii. Sulphate: Less than 100 mg/L.
viii.

3. Toxic Substances

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

4. Microbiological Standards

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

5. Pesticides and Other Organic Chemicals

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

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

The physiochemical and biological characteristics of the sample water is shown in Table 4.1

PHYSICO CHEMICAL ANALYSIS		
Parameter, Unit	Limit, N.I.S STD	Result
Temperature °C	Ambient	Ambient
Colour, TCU	3.0	Colourless
Odour	Odourless	Odourless
Taste	Tasteless	Tasteless
pH	6.5-8.5	6.65
Turbidity, NTU	5.00	NIl
Conductivity, uS/cm	1000.00	37.02
TDS, Mg/l	500	20.36
Suspended Solid "	0.00	0.00
Hydrocarbon, "	0.0002	Nil
Sodium"	100	0.42
Nitrate,"	10.00	0.15
Nitrite, "	0.10	Nil
Sulphate,"	100	7.00
Hardness, $CaCO_3$	100	12.00
H_2S, "	0.01	Nil
Detergents,"	0.01	Nil
Iron,"	0.30	0.02
Fluoride"	1.00	Nil
Chloride,"	100.00	1.58

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

Table 4.1: Physico chemical analysis (Borehole waater)

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

Table 4.2: Microbiology (Borehole waater)

PHYSICO CHEMICAL ANALYSIS		
Parameter, Unit	Limit, N.I.S STD	Result
Temperature °C	Ambient	Ambient
Colour, TCU	3.0	Colourless
Odour	Odourless	Odourless
Taste	Tasteless	Tasteless
pH	6.5-8.5	7.02
Turbidity, NTU	5.00	0.00
Conductivity, uS/cm	1000.00	118.70
TDS, Mg/l	500	65.29
Suspended Solid "	0.00	Nil
Hydrocarbon, "	0.0002	Nil
Sodium"	100	0.56
Nitrate,"	10.00	0.02
Nitrite, "	0.10	0.00
Sulphate,"	100	2.10
Hardness, $CaCO_3$	100	14.00
H_2S, "	0.01	Nil
Detergents,"	0.01	NIl
Iron,"	0.30	0.01
Fluoride"	1.00	Nil
Chloride,"	100.00	1.26
Magnesium,"	0.20	0.00
Manganese"	0.05	Nil

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

Table 4.3: Physico chemical analysis (Treated water)

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

Table 4.3:Microbiology (Treated water)

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

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

Other test carried out are as follows

i. Conductivity test

Result 184 micro semens per cm

Limit: 1000 micro semens per cm

The pictures below shows the result of the tested water on the equipment used in the laboratory

Parameters	Source	After filtration	After UV	Cold Outlet	Room Temperature Outlet	Hot Outlet
pH	5.08	7.73	7.50	7.71	7.62	7.58
ORP (nano volts)	446.7	319.2	335.5	327.8	311.4	329.3
Conductivity (micro siemens/cm)	17	188	211	154	165	171
TDS (PPM)	8	94	105	76	83	86
Temperature (Degree Celsius)	28.4	28.52	28.28	28.6	28.26	29.08
Salinity (PSU)	0.01	0.09	0.1	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

Discussion

From Table 4.1, When comparing the results of this investigation to those of Aluyi et al. (2003), the observed range of BOD5 (3.20mg/L to 3.88mg/L) were in agreement. Biological Oxygen Demand (BOD5) is a measure of the amount of biological waste in water that reduces amount of oxygen available. Oxygen demand and biodegradable organic material in water may be measured directly with BOD5 and indirectly with the BOD5 index. According to Federal Ministry of Environment (FME, 2007) normal pH values varied from 5.83 to 7.04, while electrical conductivity values ranged from 18.00 to 65.00S/cm. This pH range has also been recorded by, Olatayo (2014) (6.71), and Ikhuoriah and Oronsaye (2016). (5.76 to 6.01). Water's typical electrical conductivity varies from 400 to 600 S/cm, according to the World Health Organization (WHO). The contaminants in the water, as well as the ion concentration, may have an impact on this. Chemical contaminants and pollutants like chloride and sulphate, sodium and potassium, are often found in water with a high EC, which does not indicate the presence of specific elements.

From Table 4.2 it was inferred that there was no significant change in the pH value during the observation period; the observed values were in the range 6.9 to 7.5 for both samples of water before and after purification. The physio-chemical of chemical characteristics of water samples in the study area suggested that there was no harmful chemical contamination in both samples of water.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

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

The untreated control sample, which came directly from the Faculty of Engineering, used to satisfy some of the NIS requirements in regard to the physicochemical properties of pH and turbidity, devoid of hazardous heavy metals. This sample was organically contaminated by yeast and mold both pose health risks; therefore, it is not fit for consumption without further treatment. On the other hand, the treated water sample, which had been treated by the newly designed mini water treatment plant, was satisfactory in all aspects and conformed to all NIS requirements for potable water. The major parameters, such as turbidity and pH, were greatly improved, while most important were microbial contaminants, which include yeast and mold brought to zero. Of more importance, the significant parameters included TDS, conductivity, and hardness that were brought within safety limits.

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

5.2 RECOMMENDATION

To enhance the performance, sustainability, and adaptability of the small-scale water treatment project, the following recommendations are proposed:

5.2.1. Integration of Automation and Smart Controls:

Incorporating sensors and programmable control systems can help automate monitoring and regulate flow rates, pressure, and water quality parameters such as pH, turbidity, and chlorine levels. This will improve efficiency, reduce manual supervision, and ensure consistent water quality output.

5.2.2. Incorporation of Renewable Energy Sources:

The system can be powered by solar energy to reduce dependency on the national grid and cut down operational costs. A solar-powered pump and control system would make the plant more sustainable and suitable for rural or off-grid communities.

5.2.3. Water Quality Monitoring and Data Logging:

Implementing a simple digital monitoring system with data logging capabilities would help track parameters like turbidity, temperature, and total dissolved solids (TDS). This data can be used for performance analysis, predictive maintenance, and process optimization.

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