DESIGN AND FABRICATION OF A WATER TREATMENT AND DISPENSING UNIT FOR THE DEPARTMENT OF PRODUCTION ENGINEERING, UNIVERSITY OF BENIN

BY

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A PROJECT SUBMITTED TO THE DEPARTMENT OF PRODUCTION ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN IN PARTIAL FULFILMENT OF THE AWARD OF POST GRADUATE DIPLOMA (PGD) IN PRODUCTION ENGINEERING

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CERTIFICATION

This is to certify that this post graduate diploma project titled **DESIGN AND FABRICATION OF A WATER TREATMENT AND DISPENSING UNIT FOR THE DEPARTMENT OF PRODUCTION ENGINEERING, UNIVERSITY OF BENIN** was carried out by GREGORY, Francis Uche with matriculation number **PG/ENG/2110359** in the Department of Production Engineering, University of Benin in partial fulfilment of the award of post graduate diploma (PGD) in Production Engineering.

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Supervisor **Date**

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Head of Department **Date**

DEDICATION

This project work is dedicated to all my friends and family. Special dedication to my wife, son and daughter who stood by me, believed in me and supported me with words and prayers. Behold a blessing in your hands! Thank you Jesus!!.

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ABSTRACT

The production engineering department of the University of Benin has often relied on existing water supply from the faculty sunk borehole. This water has been investigated through physiochemical and biological testing to be below standard required quality for drinking. This has necessitated the development and installation of a water treatment for purification and dispensing facility in the departmental Annex of production engineering for safe sustainable water utilization.

A conceptual design of the water treatment and dispensing facility was carried out and it comprises of cylindrical tanks stacked with one of the tank containing coarse aggregates of gravel, rock sand, fine aggregate of river sand, and activated carbon (charcoal) all separated with a filter mesh in the cylindrical tank. The other tank contains the clear water already treated by sedimentation tank containing the aggregated materials

Tests and performance evaluation of the developed water treatment facility showed that that the volumes of samples of water taken from the water treatment and dispensing facility had minimal variation from one another. The samples had most volumes around the 50cl mark, while others were around 49cl sometimes successive difference of 0.1cl. The little variation in the volumes is due partly to excess drop in pressure of the reservoir water. The variance is 0.24 which is a mean of the respective deviations of the volumes. This value of the variance is very minimal, showing that the machine was able to discharge given volumes of water with considerable accuracy. The observed range of BODs for the treated water was (3.20mg/L to 3.88mg/L). Electrical conductivity values ranged from 18.00 to 65.00S/cm. 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 treatment. The physio-chemical characteristics of water samples in the study area suggested that there was no harmful chemical contamination in both samples of water.

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CHARPTER ONE

INTRODUCTION

1.1 Background to the study

Water purification is a precept for clean and safe drinking water. It is a process of removing undesirable chemicals, biological contaminants, suspended solids, and gases from water (CDC, 2018). The goal is to produce water that is fit for consumption. The purification of water may also be carried out for a variety of other purposes which include medical, pharmacological, chemical, and industrial applications (Ayodele and Adelola, 2012). The United Nations Millennium Development Goals has amongst its proposals to reduce by over 50% of the number of people globally who lack access to clean safe water (UNEP, 2023). Due to the numerous deaths and illnesses caused by waterborne pathogens, various household water treatment devices and safe storage technologies have been developed to treat and manage water at the household and even commercial levels.

Beside the treatment of water to purify it, the mode of handling by way of transporting it from one point to another for dispensing is key. Significant compromise can be done to already purified water if it flows through corroded pipes or collected for use with fouled ware. The transportation and collection of water is even more a burden when conventional methods of carrying water such as use of human lifting is used. This affects the musculoskeletal system of humans and can lead to health challenges. Owing to these challenges, new approaches of water purification, transportation and collection have been explored with the desired need to make available clean and safe water gotten through sustainable purification and collection facilities. Challenges of pure water production, transportation and collection has been existing in the department of production engineering which has relied on the faculty bore hole water supply for years. The water supplied via a hydro pump have been pumped to external overhead tanks which then supplies water to the departmental toilets. Though there has not been a dedicated collection point of such water from consumption, preliminary investigation also revealed that the water as pumped from the borehole does not meet the standard purification grade for direct human consumption. These compounded problems of pipe networking, purification of water and unavailability of dedicated collection point of pure drinkable water in the department Annex of production engineering has necessitated the need to carry out a research on developing a sustainable water treatment and purification facility to be installed in the department for portable drinking water in the department.

1.2 Statement of The Problem

The global millennium development goals advocates for the provision of clean and safe drinking water for human consumption. This is applicable to every human around the world especially in a country like Nigeria where there are challenges of balancing the economic needs with developing appropriate water production facilities. This challenge has existed in the Department of Production Engineering, University of Benin which has relied on direct borehole pumped water for staff and students use. The existing water facilities in the department do not provide portable safe drinking water as there have been no pipe connectivity and dedicated point for the collection of clean and safe drinking water. This has necessitated the need to fashion out sustainable methods to develop and deploy a water treatment and dispensing facility in the department as part of not just providing water for the staff and students of the department but to meet the demands of the millennium goals of providing sustainable water solutions.

1.3 Aim and Objectives of the Research

1.3.1 Aim of the Research

The aim of the present research is to develop and install a water purification and dispensing facility for the Production Engineering Department Annex of the University of Benin.

1.3.2 Objectives of the research

The objectives of the research are to:

1. Carry out a physiochemical and biological analysis of existing water utilized by the Department of Production Engineering Annex.
2. Develop a concept of water treatment and dispensing facility for the department.
3. Develop a dedicated proof of concept of a water treatment and dispensing facility for the department.
4. Carry out performance testing of the fabricated water treatment and dispensing facility.
5. Test for the physiochemical and biological state of the treated and dispensed water in comparison with the untreated water before treatment.

1.4 Scope of Work

The present study entails the conceptualization, design and fabrication of a small to medium scale water treatment and dispensing system for the department of Production Engineering Annex. The facility is to be built as a dedicated water provision facility which can provide drinkable water for the staff, students and visitor of the department. The purification process is aimed at improving the purity state of the water from the existing borehole located in the faculty vicinity to make it safer and refreshing for human consumption. The research will involve the use of laboratory equipment to test for pH analysis, turbidity, biological and chemical dissolved solids as well as other relevant test metrics which defines pure drinkable water.

1.5 Significance of the work

The significant of the project work include the followings;

i. Water purification facilities are useful facilities which can help achieve the millennium development goals of providing clean and safe water for the human population.
ii. The provision of water use solution will not just provide clean and safe water for the staff and students of the production engineering department, it will also serve as a research observatory for the department.
iii. The ability to produce less costly and sustainable clean and safe drinking water purification system can be a source of income and job for Nigerians.
iv. The production of locally made water purification systems will boost the local content initiative of Nigeria as part of the federal government of Nigeria economic plans.

1.6 Methodology

The plan set out to achieve the aim and objectives of the project include the followings:

1. Experimentations.
3. Conceptual design and analysis.

4. Detailed design of a proof of concept.

5. Fabrication of a functional proof of concept.

6. Testing of the fabricated proof of concept.

7. Conclusion and recommendation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Water Need and Treatment Systems

One of the most important aspect in improving the health of the people is to provide people and communities with safe and clean water. It has been estimated that in the 21st century, an about 1.1 billion people worldwide still do not have access to safe portable water. In 2022, globally, at least 1.7 billion people use a drinking water source contaminated with feces. Microbial contamination of drinking-water as a result of contamination with feces poses the greatest risk to drinking-water safety (WHO, 2023). A large percentage of the world population who are subject to this deficiency in accessing clean safe water are from the developing world, especially the rural communities where there is prevalence of low-income and adequate technology. (WHO/UNICEF, 2020).

Small communities face the greatest difficulty in receiving water of an adequate quality and quantity because they lack experienced water managers to maintain and upgrade their water treatment and distribution facilities. Violations of drinking water standards are contributory causes to consumers who are at risk of waterborne diseases. There has been proliferation of substandard water purifying facilities, while others are quite expensive to acquire making it difficult for people to have access to clean, less costly and sustainable water systems. The most common cause of illness and deaths in the developing world is a watery diarrhea called cholera (WHO, 2023: Clasen et al., 2006) caused by a bacterial pathogen classified as Vibrio cholera (Shultz et al., 2009). In view of these shortcomings, it has become pertinent to develop cheap but efficient and sustainable small to medium scale water treatment solutions for the production of clean and safe drinking water using local technology. Figure 2.1 shows a glass of clean portable water.

Figure 2.1 Purified water

Water treatment system include various scientific and technological facilities of process that have been explored in the purification of water. These systems and their sub categories include the followings: (McGuire et al., 2002).

i. Physical process which include filtration, sedimentation, and distillation;
ii. Physiochemical process such as microporous sorbent treatment
iii. Biological processes such as slow sand filters or biologically active carbon.
iv. Chemical processes such as flocculation and chlorination; and
v. Electromagnetic radiation such as ultraviolet light.

Water treatment can reduce the concentration of particulate matter including suspended particles, parasites, bacteria, algae, viruses, and fungi as well as reduce the concentration of a range of dissolved and particulate matter (Edzwald, 2011). The standards for consumable water quality are typically set by governments or by international standards. These standards usually include minimum and maximum concentrations of contaminants, depending on the intended use of the water. A visual inspection cannot determine if water is of appropriate quality. Simple procedures such as boiling or the use of a household activated carbon filter are not sufficient for treating all possible contaminants that may be present in water from an unknown source. Even natural spring water considered safe for all practical purposes in the 19th century must now be tested before determining what kind of treatment, if any, is needed. Chemical and microbiological analysis, while expensive, are the only way to obtain the information necessary for deciding on the appropriate method of purification. The choice of method of water treatment depends on;

i. The quality of the water being treated,

ii. The cost of the treatment process.

iii. The quality standards expected of the processed water.

The Standards Organization of Nigeria has a section on its website where the Nigerian Standard for Drinking Water Quality (NSDWQ) (2007) is published. Various methods of water purification however exist. Water treatment is a systematic line up of procedure which include the followings: (McGuire et al., 2002).

i. Pumping and containment: This involves pumping of water from its source to a reticulated pipe system or a holding tank.

ii. Screening: A vital step in purifying surface water is to remove large debris such as sticks, leaves, and other unwanted large particles which may interfere with subsequent purification steps.

iii. Storage: Water may also be stored in bankside reservoirs for periods between a few days and many months to allow natural biological purification to take place. This is especially important if treatment is by slow sand filters.

iv. Pre-chlorination: The incoming water is chlorinated to minimize the growth of fouling organisms on the pipe-work and tanks.

Water purification process that follows after preliminary treatment process can be any of or a combination of other processes which include the followings:

i. pH Adjustment

Pure water has a pH close to 7 (neither alkaline nor acidic). Sea water can have pH values that range from 7.5 to 8.4 (moderately alkaline). Fresh water can have widely ranging pH values depending on the geology of the drainage basin or aquifer and the influence of contaminant inputs (acid rain). If the water is acidic (lower than 7), lime, soda ash, or sodium hydroxide can be added to raise the pH during water purification processes.

ii. Coagulation and flocculation

One of the first steps in most conventional water purification processes is the addition of chemicals to assist in the removal of particles suspended in water. Particles can be inorganic such as clay and silt or organic such as algae, bacteria, viruses, protozoa and natural organic matter. Inorganic and organic particles contribute to the turbidity and color of water.

iii. Sedimentation

Water exiting the flocculation basin may enter the sedimentation basin, also called a clarifier or settling basin. It is a large tank with low water velocities, allowing floc to settle to the bottom. The sedimentation basin is best located close to the flocculation basin so the transit between the two processes does not permit settlement or floc break up. Sedimentation basins may be rectangular, where water flows from end to end, or circular where flow is from the center outward.

iv. Sludge storage and removal

As particles settle to the bottom of a sedimentation basin, a layer of sludge is formed on the floor of the tank which must be removed and treated. The amount of sludge generated is significant, often 3 to 5 per cent of the total volume of water to be treated. The cost of treating and disposing of the sludge can impact the operating cost of a water treatment plant.

v. Floc blanket clarifiers

A sub-category of sedimentation is the removal of particulates by entrapment in a layer of suspended floc as the water is forced upward. The major advantage of floc blanket clarifiers is that they occupy a smaller footprint than conventional sedimentation. The disadvantages are that particle removal efficiency can be highly variable depending on changes in influent water quality and influent water flow rate (Crittenden et al., 2005).

vi. Dissolved air flotation (DAF)

When particles to be removed do not settle out of solution easily, DAF is often used. After coagulation and flocculation processes, water flows to DAF tanks where air diffusers on the tank bottom create fine bubbles that attach to the floc resulting in a floating mass of concentrated floc. The floating floc blanket is removed from the surface and clarified water is withdrawn from the bottom of the DAF tank (Ntobela et al., 2023).

vii. Filtration

After separating most floc, the water is filtered as the final step to remove remaining suspended particles and unsettled floc. After separating most floc, the water is filtered as the final step to remove remaining suspended particles and unsettled floc. The filtration process may be Rapid sand filters, Slow sand filters, bank filtration and Membrane filtration

viii. Removal of ions and other dissolved substances

Ultra-filtration membranes use polymer membranes with chemically formed microscopic pores that can be used to filter out dissolved substances avoiding the use of coagulants. The type of membrane media determines how much pressure is needed to drive the water through and what sizes of micro-organisms can be filtered out. a typical process in this regard is the membranous microporous sorbents. when compared with traditional separation technologies, the membrane separation method has the advantages of having a low cost, flexibility, scalability, and having a small footprint (Li and Liu, 2022). In modern times, membrane technology has received increasing attention in CH_4/N_2 separation. The core of the membrane separation method is membrane materials. Ideally, an efficient membrane usually requires good structural stability, highly uniform pore structure, long service life, excellent separation selectivity, and great permeability. Two important indicators for evaluating membrane performance are permeability and selectivity. (Li and Liu, 2022).

ix. Disinfection

Disinfection is accomplished both by filtering out harmful micro-organisms and by adding disinfectant chemicals. Water is disinfected to kill any pathogens which pass through the filters and to provide a residual dose of disinfectant to kill or inactivate potentially harmful micro-organisms in the storage and distribution systems. Various disinfection process may include Chlorine dioxide disinfection, Chlorination, Chloramination, Ozone disinfection, Ultraviolet disinfection, Ionizing radiation, Hydrogen peroxide dozing, Bromination and Iodinization

x. Reverse osmosis

Reverse osmosis involves mechanical pressure applied to force water through a semi-permeable membrane. Contaminants are left on the other side of the membrane. Reverse osmosis is theoretically the most thorough method of large scale water purification available, although perfect semi-permeable membranes are difficult to create. Unless membranes are well-maintained, algae and other life forms can colonize the membranes (Puretec, 2021).

xi. Bioremediation

Bioremediation uses microorganisms to remove waste products from a contaminated area. Bioremediation has seen success because perchlorates are highly soluble, making them difficult to remove. (Trump et al, 2008).

xii. Crystallization

Carbon dioxide or other low molecular weight gas can be mixed with contaminated water at high pressure and low temperature to exothermically form gas hydrate crystals. Hydrate may be separated by centrifuge or sedimentation. Water can be released from the hydrate crystals by heating (Osegovic et al, 2009).

2.2 Water Collection for Utilization

Efficient utilization of water entails the transportation of water from one point to another. In doing so water can be transported in pipe channels or collected with the use of polymer, wooden or metallic ware which can be a bucket, cup, flexible polymer or large vessels such as marine vessels and tankers. The objective is to move water from point A to B. This is no different in a domestic or commercial setting where water is required to be collected from a mains supply from a dedicated point such as a water dispenser. Water dispensing entails controlled collection of water from a dedicated point. It comprises of water storage, channels to move it and valve to allow for a controlled flow of water at a collecting end. Water dispensing have been analyzed on two premises which are pipet dispensing and Peristaltic pump dispensing. (Jason, 2007).

2.2.1 Pipet Dispensing

Pipets are especially useful for dispensing liquid in milliliter, microliter, or smaller volume ranges since most are highly precise and accurate. Pipets, especially multichannel pipets, accurately and precisely deliver a predetermined fluid volume. Pipet dispensing can be froth with challenges such as operator error and surface tension within the tip walls, which is of concern if using expensive reagents. These problems can be compounded by repetitive strain injuries such as carpal tunnel syndrome. To mitigate these, dry pipet tips must be preconditioned by repeatedly drawing up and dispensing a chosen volume of liquid to reduce strain. Since pipets contain moving parts, they must be regularly cleaned and calibrated to ensure optimal dispense performance without damage from aerosols or deposits created from the liquids used.

2.2.2 Peristaltic pump dispensing

Peristaltic pumps are commonly used for continuous or semi-continuous liquid dispensing such as water dispensing. Since the liquid is entirely contained within flexible tubing, they are ideal for sterile applications without risk of cross-contamination. They are also well suited for use when conservation or recycling of reagents is desired because the liquid can be pumped back to the source reservoir. Peristaltic pumps incorporate rollers fixed to a rotating rotor which, when encircled by flexible tubing, compress the tubing at regular intervals between two consecutive rollers, forcing a volume of liquid to pass through the tube. This volume is defined as a slug. Volume adjustments are determined by the distance between the rollers, rotor position, tubing tension, inner diameter of the tubing, and tip geometry. This dispensing style is suited for automated systems with a high degree of precision and accuracy. Since there are no moving parts in contact with the liquid, these pumps are relatively inexpensive to maintain, requiring only periodic replacement of the tubing. The disadvantage of many peristaltic pumps is that, by design, their volume ranges are often not suitable for micro- dispensing since it is increasingly difficult to effectively overcome cohesive forces of the liquid for accurate dispensing at very low volume levels. Accuracy is also compromised if the pump dispenses volumes of liquid (slugs) in fractions rather than full volumes, because the variation between the fractions is significant when compared to full volumes. This is especially problematic at micro volumes because the liquid is no longer forced out of the tubing by the force of the roller, but rather the speed of the rotor itself. Cohesive forces in the liquid cause uneven distribution of the liquid. Liquid dispensers can be classified on the basis of their applications (Rajesh et al, 2012): the classification of the dispensers is as follows:

i. Dispense-only: dispense only unit is designed to dispense liquid like water only. It does not mix, nor does it have any metering capabilities. This includes manual and power driven dispensers.

ii. Mix and dispense type: This type mix two or more items at a determined ratio and then dispense

iii. Meter, mix and dispense type: This type meter, mix and dispense items with a determined mix ratio and shot size.

iv. Hot, treat and dispense application: hot melt dispense units melt a media from a solid form and dispense as a liquid. One example is a hot glue gun.

Liquid dispensers or fillers can also be classified on the basis of their mounting (Rajesh et al. 2012) as follows:

i. Container mounted,

Container mounted dispensers are mounted on the container from which the fluid is dispensed.

ii. Hand held

Hand held dispensers are hand held to manually control dispense rate and application location.

iii. Machine-mounted

Machine mounted dispensers are mounted on the machine from which the fluid is dispensed. This includes items such as wall-hung soap dispensers.

iv. Robotic dispensers

Robotic dispensers are mounted on a robotic mechanism to control dispense rate and application location.

v. Rotary Units

Rotary units have rotating platforms from which the media can be accurately dispensed. Model features may be manual or fully adjustable in rotation-speed, circle diameter and dispensing time.

Liquid dispensers can also be classified based on their mode of operation which include the followings:

i. Continuous dispensing; continuous type dispenser is that which is capable of continuously supplying a media.
ii. Foot control; A foot pedal can be included to control the rate and length of material flow
iii. Manual driven: this can be operated manually using human effort.
iv. Power driven; Power driven fluid dispensers are powered by an auxiliary source; typically air or electricity.
v. Programmable microprocessor; the automated liquid dispensers have widely utilized the programmable microprocessor. With the help of microcontrollers and relays it is efficient to dispense liquids in exact desired amount.

This study focusses on water treatment and dispensing which therefore encompasses a design method that considers an integrated system of water purification, flow and collection from a dedicated point. Successful implementation of water processing for safety depends not only on pollutant removal but also on the techno economic evaluation of the entire process (Piyush, 2024).

2.3 Review of Related Literatures

Ntobela et al., (2023) designed and developed a water purification system. The authors asserted that many people from developing countries are struggling daily to have access to potable water and sustain their lives. Their research paper therefore explored the development of a purifier system to address the poor quality of water in a rural community. Solar photovoltaic (PV) cells were selected to power the proposed system. The Reverse Osmosis (RO) method was adopted to remove contaminants during the treatment process. The system

Comprised of solar PV modules, a structural mounting frame, centrifugal and vertical water pumps, activated carbon and sand filters, micron filter filters, RO membrane filters, a flywheel

energy storage system (FESS), an electrical Distribution Board (DB), a chemical dosing pump, and a water distribution piping. The water purification facility developed by the authors is shown in Figure 2.2.

Figure 2.2 the Ntobela et al, (2023) water purification system

Ruhairi, (2009) designed and implemented an automated multiple water dispenser using Programmable Logic Controller (PLC). The system was suitable for liquid product that required exact amount of liquid and have 2 different flavor of liquid (water) to be filled in a receiving ware such as a bottle. The author asserted that it was a batch operation where a set amount of inputs to be process is received as a group, and an operation produced the finished product. The function of the machine was to fill the water automatically into bottles through a conveyor and in the process, the bottle that was filled with the flavored water was marked with 2 color stickers where each color sticker represented each flavor of water The objective of the project was to be applied in drinking water industries and to automate the water filling process which can save time and cost. The research project was the combination of PLC, and electrical DC motor system. The project was divided into 4 sections; the loading section, the conveyor section, path divider section and filling section, where the whole sections was controlled by PLC.

Yusuf (2015) designed and fabricated an automatic water to bottle dispensing machine suitable for use in the bottling and general metering of water in Nigeria. The machine was produced using locally sourced materials and it consists of a water reservoir, pipe and valves network, a hydro pump, an electro/mechanical actuator, a rotating conveyor, an electric gear motor, micro controllers and electrical circuit. The machine was operated to discharge sample volumes of water and they were measured for variation. Inference from the measurement of the various discharged volumes showed maximum variation between any two discharges as 1.6 and a variance of 0.68 showing that the machine performed with a very high precision of 90 percent.

Rajesh et al designed and fabricated touch screen operated liquid dispenser machine. Using a touch screen interface, the authors effectively increased operator accuracy, reduced training time and improved overall efficiencies, thus keeping cost down. A properly designed touch screen interface could improve overall accuracy according to the authors. The liquid dispensing machine was for use in a cooler making industry.

Abdulkareem et al., (2015) conducted a research on the development of a filtration system for a small scale water treatment plant for a rural community around Maiduguri area in Borno state, Nigeria. The authors asserted that the provision of safe clean water is one of the paramount responsibilities of all government. This is more difficult to achieve in rural communities, hence the need for a simplified and economic design of a filtration system. The daily water consumption for the treatment plant was 0.057 mgd (million gallons daily). The filter area was evaluated as $24m^2$ with the sand occupying 1m deep of the total length of bed. The gravel used covered a deep of 1.05m thereby giving the length of the bed as 3.60m to avoid overflow. The gravel was arranged asymmetrically below the sand from round washed gravel to stone gravels.

Ahmed et al., (2022) utilized high surface area activated charcoal for water purification. in the research an activated charcoal with a high surface area of 4320–3800 m^2/g with significant adsorption properties was prepared by the chemical and thermal processing of walnut residues. The mixture was then calcined at different temperatures using an electric oven until the best thermal conditions for a very high activated surface area and performance were identified. The resulting activated charcoal was further purified to remove residual KOH and metal impurities. Investigations revealed that the quality of the prepared activated charcoal was comparable to or surpassed that of commercially available counterparts in both the physical and adsorption properties. It was characterized for methylene blue degradation and the removal of heavy elements during water purification.

Mwabi et al, (2011) carried out a research on household water treatment systems as a solution to the production of safe drinking water by the low-income communities of Southern Africa.

The authors asserted that due to the numerous deaths and illnesses caused by waterborne pathogens, various household water treatment devices and safe storage technologies have been

developed to treat and manage water at the household level. These new approaches that are continually being examined need to be durable, lower in overall cost and more effective in the removal of the contaminants. In their study therefore, an extensive literature survey was conducted to regroup various household treatment devices that were considered suitable for the inexpensive treatment of water on a household basis. The survey resulted in the selection of four household treatment devices: the biosand filter (BSF), bucket filter (BF), ceramic candle filter (CCF) and the silver-impregnated porous pot filter (SIPP). The flow rates obtained during the study period were within the recommended limits (171 l/h, 167 l/h, 6.4 l/h and 3.5 l/h for the BSF, BF, CCF and SIPP, respectively). Using standard methods, the results of the preliminary laboratory and field studies with spiked and environmental water samples indicated that all filters used decreased the concentrations of contaminants in test water sources. The most efficiently removed chemical contaminant in spiked water was fluoride (99.9%) and the poorest removal efficiency was noted for magnesium (26–56%). A higher performance in chemical contaminant removal was noted with the BF. For pathogenic bacteria, the mean percentage removals ranged between 97% and 100%.

Although the concentrations of most chemical parameters were within the recommended limits in raw surface water, poor removal efficiencies were recorded for all filters, with the poorest reduction noted with fluorides (16–48%). The average turbidity removals from surface water ranged between 90% and 95% for all filters. The highest bacterial removal efficiency was recorded by the SIPP (99–100%) and the lowest by the BF (20–45%) and the BSF (20–60%).

Stauber et al., (2006) have reported that various water treatment devices and safe storage technologies, such as the use of disinfectants (such as chlorine and iodine), filtration, distillation, reverse osmosis, solar disinfectant and water purifiers, have decreased endemic diarrhea caused by waterborne pathogens and improved the microbial and chemical quality of drinking water.

Ayodele and Adelola (2012) designed and constructed a prototype household water purifier system. The authors asserted that prevalent water sources in the Ogbomoso township of Oyo State, Nigeria, were close to septic's and soak away which results in a sizable percentage of the indigent residents exposed to contaminated water. This water was largely responsible for the prevalence of water-borne diseases in the township. To stem the menace on the short run, a simple and affordable preliminary Household Water Purifier System (HWPS) was designed and constructed. The purification system consisted of composite filters (containing: sand, gravel and activated carbon), cartridges, as well as Ultra-Violet (UV) Lamp. Raw water samples (well water) were pumped into the system through Polyvinyl Chloride (PVC) pipes. Water samples from both the source and the outlet (purified water) were collected and then taken to the laboratory for physical, chemical and bacteriological analyses. The results from the tests were compared to Nigerian Industrial Standards (NIS) drinking water guidelines. It was observed that the HWPS was able to reduce to permissible levels physical contaminants, as well as most of the regularly checked chemical and bacteriological contaminants. It was observed that the HWPS filter media (aggregates, anthracite etc.) turned to a culture medium for bacteria growth when left for few weeks of inactivity.

2.4 Research Gap

The various previous studies on water purification and dispenser systems explored were mostly aimed at either evaluating the efficacy of using a water treatment process or dispensing of bulk materials which were not necessarily water but other fluids. In addition to this, regional consideration were in focus as different water treatments were dependent on nature of contamination of water in a particular location and the availability of locally sourced materials that could be utilized in the water purification. In all of the related research works reviewed no research work was found to have explored water purification and dispensing system development in the Production Engineering Department of the University of Benin which is a significant gap in research. To cover the research gap, this study therefore is aimed at developing a water purification and dispensing facility for the Production Engineering Department.

CHAPTER THREE

MATERIALS AND METHOD

3.1 MATERIALS

The materials required for this project are listed in Table 3.1.

Table 3.1 Materials Required for the Water Treatment and Dispensing System.

S/N	Materials	Function
1.	Water from sunk borehole	This is the raw water to be treated.
2.	Drums	Cylindrical Polymer containers for holding water.
3.	Faucet	For water dispense
4.	PVC pipes	Polymer channels for water flow.
5.	Atomic Spectrometric Machine	For water testing
6.	Water pump	Pumping of water.
7.	HANNA pH meter (model HI8424).	It is used to measure the pH of water samples
8.	Filter	For segregation of water and particulates.
9.	Coarse aggregate Gravel and Rock sand	It is used for producing the filter media
10	Fine aggregate: river sand	For use in developing the filter media
11	Activate carbon	For purification through absorption
12	Conductivity meter (model HACH 44600-00).	To measure the TDS (total dissolved solids)
13	Visible spectrophotometer VS72IG	Used to quantify the turbidity in NTU (Nephelometric Turbidity Units).
14	Water reservoir and hoses	For storage and dynamic transfer of grey water
15	Wrenches, plumbers gum, O-rings, saw	For plumbing installations and fittings
16	Math lab Programing Software.	For computational analysis.
17	Intel Core Duo Personal Computer.	For typing, CAD designs and program execution.

18	Desk Jet HP Printer.	For type setting and printing

3.2 METHOD

The method for the project execution is detailed as follow:

3.2.1 Design Specifications

Input parameters for the development of the water purification and dispensing system include the followings:

i. Amount of water to be purified daily: this is a function of the target human population and their daily water requirement = 8 litters per day/person (WHO, 2020) in the department.

ii. Contamination level of water before purification: based on the biochemical test carried out on the faculty of engineering overhead tank water, the result is presented in Table 3.2.

iii. Volume of water in storage reservoir was estimated to be 2000 litters.

iv. Height of the overhead storage tank = 4m

v. Distance of water storage reservoir from the proposed purification system = 15m

vi. The hydraulic pump rating

vii. Water dispenser and operational components capacity.

3.2.2 Conceptual Design

Preliminary consideration of the project design structure is carried out here. This include detailing the materials and structure of the water treatment and dispensing system using a computer aided design (CAD) detailing. The conceptual design of the system is shown in Figure 3.1.

Figure 3.1 Conceptualization of water treatment and dispensing facility

3.2.3 Detail design

1. Determination of water capacity demand

Per person daily water demand for general work place = 45L (WHO recommended)

Total estimated population of the department = x persons

Total water demand = x*45 = 45xL (3.1)

Main water tank is expected to hold the 3 x the estimated amount of water.

2. Determination of water dispensing tank capacity

This is determined from the hourly water demand in the department using the dispenser. For the number n of people who utilize water dispenser per hour considering a time t (s) interval of time in between usage = 3600/nt (3.2)

Therefore; hourly water demand = 3600/nt x. (3.3)

3. Compressive force on depressible valve

f is a downward compressive force required to depress a push button to initiate water flow from the dispenser.

For the compressive effect using hooks law,

F = kx (3.4)

where f = load on the spring, k = constant of proportionality and it depends on the material of the springing effect of the push button, x = extension per unit length of the spring.

4. Flow rate along pipe and faucet

Considering the existing 15mm diameter pipe from overhead water reservoir to dispenser

Water enters the dispensing water holder from the overhead tank via pump action.

For the given pipe diameter, flow velocity along its internal diameter is expressed as;

v = (3.5)

where; A = area of the pipe, Q = volumetric flow rate.

Q of water = (3.6)

where; *m* = mass flow rate of water (kg/s), ρ = density of water

Considering pressure drop in pipe internal surface characteristics and plumbing fixtures (valves, elbows) resistances in the long channels, pressure or head losses H_L/m may be computed for the pipe using the Hazel-William equation expressed as;

$H_L/m = 32.875$ (3.7)

where:

Q = quantity of water flowing through pipe channel (L/s),

d = diameter of pipe (cm).

If the expression in equation (3.7) is multiplied by the entire length of pipe from the overhead tank to the point of entry into the dispensing water reservoir the total head loss is achieved.

v. The height of the discharge (hydraulic head)

The Hydraulic head or piezometric head is a specific measurement of liquid pressure above a geodetic datum and it is expressed as:

$$h = \psi + z \quad (3.8)$$

where

h = the hydraulic head (Length in m or ft), also known as the piezometric head.

ψ = the pressure head, in terms of the elevation difference of the water column relative to the piezometer bottom (Length in m or ft), and

z = the elevation at the piezometer bottom (Length in m or ft)

vi. **Pressure head and head losses**

The pressure head of the overhead tank water flow to the purification/dispenser units is expressed as:

$$\psi = \frac{P}{\gamma} = \frac{P}{\rho g} \tag{3.9}$$

where: P = the pressure of atmosphere (Force per unit area, often Pa or psi) =1

γ = unit of water (force per unit volume in $N \cdot m^{-3}$ or kg/cm^3) = $0.001 kg/cm^3$

ρ = the density of the water (Mass per unit volume, frequently $kg \cdot m^{-3}$)

- = the gravitational acceleration (velocity change per unit time, often $m \cdot s^{-2}$)

Considering the head losses, In any real moving fluid, energy is dissipated due to friction; turbulence dissipates even more energy for high Reynolds number flows. Head loss is divided into two main categories:

a. Major losses this is associated with energy loss per length of pipe.

b. Minor losses in design, minor losses are usually estimated from tables using coefficients or a simpler and less accurate reduction of minor losses to equivalent length of pipe. It is associated with bends, fittings, valves.

Older, more empirical approaches are the Hazen-Williams equation and the Prony equation. The Hazen-Williams equation is used for calculating the head loss due to its empirical soundness. The head losses must be considered and added to the hydraulic head and the farthest internal wall from a central axis of the tank to achieve the delivering pressure (P) of the pump. For the system the lengths of pipe and fittings and their losses are computed in Table 3.2.

Table 3.2 Equivalent losses in pipes and fittings

Item	Length l (m)	Losses = l/L
Pipe	0.9	0.9
	1.8	0.6
Total		**1.5**
bends	4 x 0.75	1.2
Tees	1 x 0.3	0.3
Valves	1 x 0.1	0.1
		1.6
Total losses		**3.1**

The total head the pump must have to overcome to discharge water is expressed as:

$H = h_L + h_D$ (3.10)

where:

h_L = head losses

h_D = dynamic losses = (3.11)

where;

v = velocity in the pipe (m/sec)

g = acceleration due to gravity (m/sec^2)

K = loss coefficient = $K_{pipe} + K_{fittings}$ (3.12)

K_{pipe} =

where:

f= friction coefficient = 0.01

l = pipe length

D = length

4. Pipe sizing

The pipe sizing is done in accordance with the Hazel Williams expression for pipe sizing as contained in reference Tables for hydraulic pipes. Selected pipes diameter for the 1cm, 1.5cm and 3cm diameter pipes were utilized at different sections of the pipe reticulation system of the water purification and dispensing facility.

5. Sizing of purification tank

This estimated based the volume of water in the overhead storage tank, water requirement and the height of the tank. It is estimated that the system should be able to collect and purify a 500 litters of water per operational run. For the existing pipe diameter in the tank = 25mm and length = 4000mm

The purification tanks may take up 250liters of water in addition to the contained purification aggregates.

The volume of the tank is expressed as:

$$V_t = \pi r^2 * h - (v_{agg}) \quad (3.13)$$

where

V_t = total volume of the cylinder

r = radius of the cylinder

h = height of the cylinder

V_{agg} = volume occupied by the sedimentation aggregate.

The water purification drum is shown in Figure 3.2

Figure 3.2 Water purification drum

6. The hydraulic pump capacity sizing **($P_{h(kw)}$)**

The pump capacity rating and selection is dependent on the total head calculated plus a factor of safety required to deliver the required pressure. The hydraulic pump is shown in Figure 3.3.

Figure 3.3 Hydro-pump and interconnections

The ideal hydraulic power to drive a pump depends on

i. the mass flow rate
ii. the liquid density
iii. the differential height

$$P_{h(kW)} = q\ \rho\ g\ h / (3.6 \times 10^6) \quad (3.14)$$

where

$P_{h(kW)}$ = hydraulic power (kW)

q = flow capacity (m^3/s) = v/h = $0.0001m^3/s$ =

ρ = density of fluid (kg/m^3) = $1000kg/m^3$

g = gravity ($9.81\ m/s^2$)

h = differential head (m) = 10m

Therefore, $P_{h(kW)}$ = 0.0001 x 1000 x 9.81 x 10.55 / (1000) = 0.14kw

The hydraulic Horse Power can be calculated as:

$$P_{h(hp)} = P_{h(kW)} / 0.746 \qquad (3.15)$$

7. water Sample Collection and Characterization

Water samples before and after the treatment of the water dispensed from the facility was collected. Chemical and physical studies on the water samples was conducted to determine significant properties of the water which include; pH, Turbidity, TDS, TSS, COD, BOD.

A. Determination of Turbidity

The apparatus required for turbidity test of the water include:

i. Nephelometer or turbidimeter
ii. Cuvettes
iii. Formazin
iv. Lint-free cloth

The turbidity meter shown in Figure 3.4 is used for the turbidity test. It is calibrated using series of calibration standards by diluting formazin stock suspension to desired NTU levels of 0, 5, 10, 20, 40, 100 and 400 NTU. The cuvette is filled with each standard and placed in the turbidity meter to calibrate it.

Figure 3.4: Turbidity meter (Yaka, 2018)

The sample is stirred gently to distribute any settled particles and prevent creation of air bubbles, if large particles are present, they will be decanted carefully to avoid affecting measurement readings. The water sample is placed in a clean cuvette ensuring no air bubbles are formed. The exterior of the cuvette is wiped clean with a lint-free cloth to remove fingerprints and moisture before it will be placed into the nephelometer. A stable reading of the turbidity will be recorded after 10-20 seconds in Nephelometric Turbidity Unit (NTU).

B. Determination of Total Dissolved Solids (TDS)

The apparatuses for carrying out the TDS of the water samples include:

i. Weighing balance (±0.1 mg sensitivity)

ii. Drying oven

iii. Desiccator

iv. Filtration apparatus

v. Evaporating dish

vi. Graduated cylinder

viii. Distilled water

ix. Wash bottle

x. Lint-free wipes

The evaporating dish is cleaned, dried and placed in the drying oven at 103–105°C for at least 1 hour. It is allowed to cool in a desiccator at room temperature and weighed using a weighing balance with its weight recorded as $W_{1.}$ The filter paper is placed on the filtration set up (flask and funnel) and washed using distilled water and then allowed to drain. It is oven dried at 103–105°C for at least 1 hour and allowed to cool in a desiccator at room temperature before being weighed using a weighing balance with its weight recorded as $W_{2.}$

The sample is shaken thoroughly and then filtered through the pre-weighed filter paper, to separate the dissolved solids and water (filtrate) from the suspended solids (residue).

A volume of 100cm^3 of the filtrate is measured and placed in the pre-weighed evaporating dish which is now placed in a steam bath or hot plate at about 100°C until it is near-dryafter which, it is placed in the drying oven at 103–105°C for at least 1 hour. The dish is allowed to cool in a desiccator at room temperature and weighed using a weighing balance with its weight recorded as W_3. The TDS is then computed in mg/l to the nearest whole number using.

(3.16)

where.

W_1 is the weight of the empty evaporating dish.

W_3 is the weight of the evaporating dish and oven dried filtrate. The residue and filter paper will be placed in the drying oven at 103–105°C for at least 1 hour and then allowed to cool in a desiccator at room temperature. The oven dried filter paper and residue will be weighed using a weigh balance and the value read will be recorded as W_4. The TSS will then be computed in mg/l to the nearest whole number using.

(3.17)

Where, TSS is the Total Dissolved Solids.

W_2 is the weight of the filter paper.

W_4 is the weight of filter paper and oven dried residue.

The total solids (TS) will then be computed using:

$$TS = TDS + TSS \quad (3.18)$$

C. Determination of COD

The apparatus for determination of the water samples COD are:

i. Reflux apparatus with condenser (or digestion vials with heating block for closed reflux)

ii. 50cm3 Burette

iii. Volumetric flasks

iv. Pipettes

v. Hot plate

b. Reagents

i. Standard potassium dichromate solution (0.0417M of $K_2Cr_2O_7$)

ii. Concentrated sulfuric acid (H_2SO_4) with silver sulfate (Ag_2SO_4) catalyst

iii. Mercuric sulfate ($HgSO_4$)

iv. Standard ferrous ammonium sulfate (FAS) titrant (0.1 N)

v. Ferroin indicator

vi. Distilled or deionized water

vii. Standard COD solutions (potassium hydrogen phthalate for calibration)

Procedure

50cm3 of the sample will be measured into a conical flask, 1g of $HgSO_4$ and 5 mL H_2SO_4-Ag_2SO_4 reagent will be added and mixed before 25 cm3 of 0.0417M of $K_2Cr_2O_7$ will be added. A reflux greaseless condenser will be attached, and the compound will be heated gently for 2 hours and allowed to cool at room temperature. The excess dichromate will be titrated using FAS and ferroin as indicator. The ed point will be a change of color from bluish-green to reddish-brown.

A blank determination will be performed with 50cm3 of distilled water in place of the water sample and the procedure will be repeated.

The Chemical Oxygen Deman will be calculated using.

$$\text{COD (in mg/l)} = \frac{(V_A - V_B) \times M \times 8000}{\text{Volume of sample}} \quad (3.19)$$

where:

V_A = volume of FAS used for the blank

V_B = volume of FAS used for the sample

M = the molarity of FAS

8000 is the equivalent weight of oxygen × 1000

D. Determination of BOD

The apparatus for determination of the water samples BOD are:

i. BOD bottles (300 mL, air-tight with ground-glass stoppers)

ii. Incubator (20°C ±1°C, dark)

iii. DO meter (electrometric) or Winkler titration kit

Reagents

i. Phosphate buffer (pH 7.2)

ii. Magnesium sulfate, calcium chloride, ferric chloride (nutrients)

iii. Nitrification inhibitor

iv. Sodium sulfite

v. Glucose-glutamic acid (GGA) solution

Procedure

If the sample has high BOD, it will be diluted with oxygen-saturated dilution water. If it is low in microorganisms, a standard seed (e.g., effluent from a biological treatment plant or treated wastewater supernatant) will be added. The BOD bottles will be filled completely without air bubbles and the initial dissolved oxygen (DO_0) will be measured. The sample will then be incubated at 20°C for 5 days in the dark to prevent photosynthesis. After the 5-day period, the final dissolved oxygen (DO_5) will be measured.

The 5-day BOD will be calculated using.

$$BOD_5 = \frac{(DO_0 - DO_5)}{\text{Dilution factor}} \quad (3.20)$$

E. Determination of pH

The apparatuses for the determination of the water samples pH are

i. pH meter (calibrated, with temperature compensation)

ii. Combination pH electrode (glass electrode + reference electrode)

iii. pH buffer solutions (pH 4.01, 7.01, and 10.01 at 25°C)

iv. Beakers

v. Stirring rod or magnetic stirrer

vi. Distilled water

vii. lint-free wipe

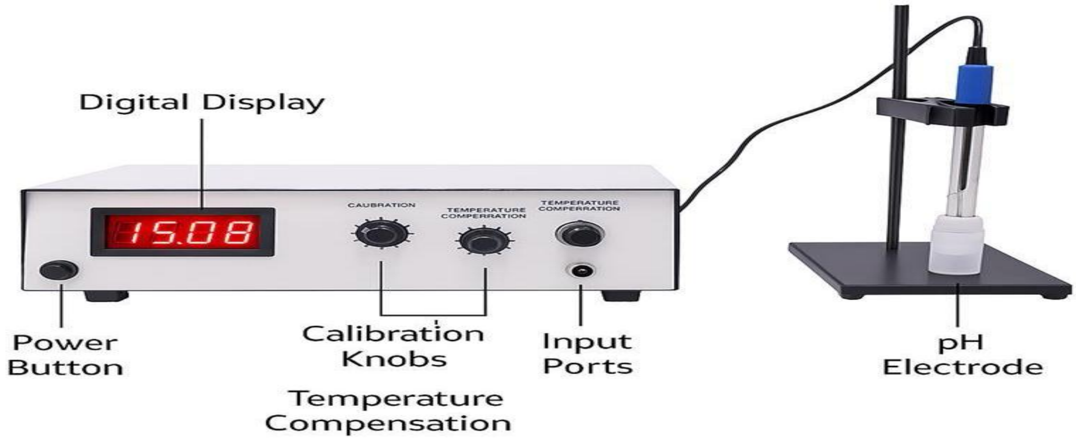

Figure 3.5: pH meter

Procedure

The pH meter will be turned on and allowed to be stabilized for 30 minutes. It will then be calibrated using at least two standard buffer solutions. The electrode will be rinsed with distilled water between buffer solutions to avoid contamination.

The electrode will be rinsed using distilled water and a small portion of the water sample. The sample to be tested will be placed in a beaker and temperature compensation will be applied in the case of discrepancies between buffer and sample temperature. The electrode will be immersed by at least 2cm ensuring the glass bulb and reference junction are fully submerged in the sample. The sample will be stirred gently to ensure homogeneity without introducing air bubbles. At a stabilized reading the pH value will be recorded.

3.2 4 Materials selection for the water purification media

The materials required for the purification system based on the nature of contamination and purification required include:

i. Coarse aggregate
ii. Fine river sand as filter
iii. Rock sand
iv. Activated carbon
v. Polymer drums
vi. Polymer wire mesh
vii. Structural materials

1. Sand filter design calculations involve determining the filter bed depth, the amount of sand needed, and the size of the coarse aggregate.

The sand filter bed depth H is expressed as:

$$H = \frac{Q}{A \cdot V} \tag{3.21}$$

where

H is the filter bed depth in meters

Q = the design flow rate in m^3/hr

A = the filter area in m^2

V = the filter bed loading rate in m/hr

The filter bed dimensions should be such that

i. The minimum depth of the sand bed is calculated to prevent the beds from breaking through water quality volume
ii. The water quality volume that must be treated in the sand filter can be calculated using the expression:

The amount of river and rock sand required is evaluated as:

$$(0.6 \text{ to } 0.7) \times H \times A \times \rho s \qquad (3.22)$$

where

ρs is the density of sand in kg/m^3

The coarse aggregate size is estimated as:

$$l = 2.54 * k *(\log d) \qquad (3.23)$$

where

l = the requisite depth in cm of a component

d = the size of gravel in mm

The Filter cylinder depth is expressed based on the free board, water depth, depth of sand, depth of gravel, and depth of under drain

2. Preparation of the activation adsorbent (activated charcoal)

The moisture content of the activated charcoal ss weighed as much as 0.5 grams and put into a known-weight porcelain dish. Then put it in the furnace at 600°C for 1 hour to `form ash. Furthermore, it was cooled in a desiccator and then then weighed until its weight was constant and the ash content was determined in percent (%). And it is expressed as:

$$\text{Ash content \%} = \frac{\text{weight of ash (g)}}{\text{weight of activated carbon (g)}} \times 100\% \qquad (3.24)$$

3. **Adsorption capacity of activated carbon**

It is estimated that each pound of activated carbon will adsorb an average of 33- $\frac{1}{3}$ % of its weight. (Park et al, 2023).

This implies that the amount of activated carbon in the adsorption tank should be such that it can absorb biochemical materials equivalent in weight from 200 liters of water which should be 1'3rd of the real amount of activated carbon.

If weight of a liter in (kg) of 200 liters' water = 200kg

Therefore $\frac{1}{3}$ x 200 = 66kg

This amount may be reduced by a reduction ratio to minimize weight and enhance compactness of the purification system.

4. **Flow Through Filter and Detention Time**

The average flow through the filter is estimated as:

$$q_f = k * A_f * i = = k * A_f * \frac{h_{max}}{2d_f} \quad (3.25)$$

where

q_f = average flow through the filter (ft^3/hr)

k = sand permeability (ft/hr) = 0.6 ft/hr for mixed sand

A_f = surface area of filter layer (ft2) = 80 ft2

i = hydraulic gradient (ft/ft)

d_f = thickness of the sand layer = 18 inches

h_{max} = [(d + H) - (perforated pipe diameter / 2)]

3.2.5 Production of the water purification media

The production of the water purification media includes the systematic packing of coarse aggregate (gravel), semi-fine aggregate (rock sand) and fine aggregate (river sand) as shown in Figure 3.6.

Figure 3.6 Left frame: Gravel (coarse grad) Middle frame: Rock sand (semi coarse aggregate). Right frame> River sand (fine aggregate)

The particulate media comprising of the coarse, semi coarse, fine aggregate and the activated carbon shown in Figure 3.7 is stacked and separated between each in the cylindrical purification and clear water drums with the use of a semi-permeable filter membrane shown in Figure 3.8,

Figure 3.7 Activated charcoal

Figure 3.8 Filter membrane

Measured weights of each of the materials which include fine sand, gravel, rock sand and activated carbon were washed, dried weighed and loaded inside the cylindrical polymer drums in given weights ratio. The stack arrangement of aggregates is shown in Figure 3.9

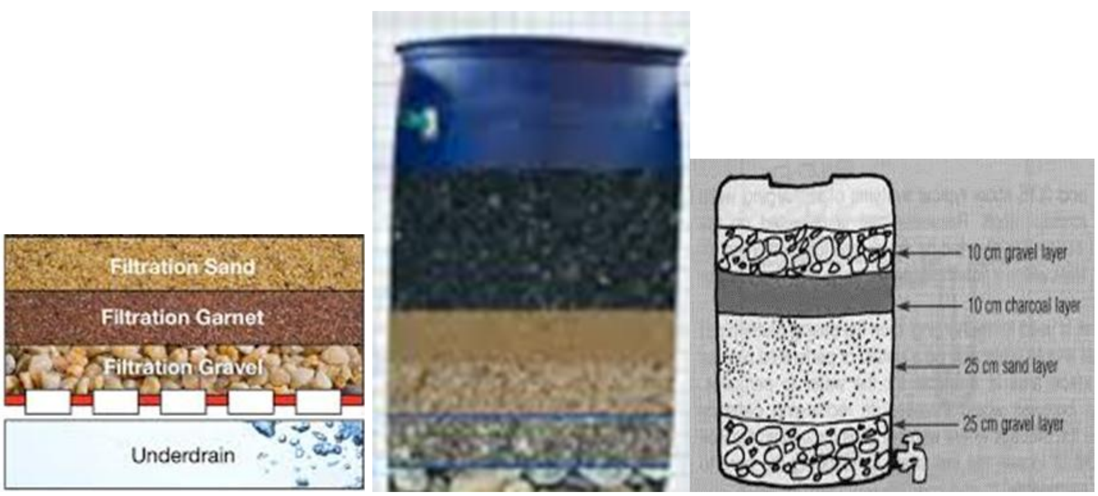

Figure 3.9 Aggregated filter media of fine and coarse aggregates

The cylindrical drums contain fine river sand, rock sand and gravel and activated charcoal and it is known as the sedimentation chamber. The activated carbon dosing does the biochemical purification of the water. The charcoal is grind to smaller particle sizes before parking inside the cylindrical tank. The second cylindrical drum is the clear water tank. The developed water treatment and dispensing facility in the department of production engineering, university of Benin is shown in the Figure 3.6.

Figure 3.6 The Fabricated Water Treatment and Dispensing Facility at the Production Engineering Department Annex

3.3 BILL OF ENGINEERING MATERIALS AND EVALUATION

The bill of engineering materials and evaluation of the fabricated water treatment and dispensing facility at the production engineering department Annex is presented in Table 3.3.

Table 3.3 Bill of Engineering materials and evaluation for the water processing facility

S/No	Item description	Quantity	Dimension	Rate =N=	Amount =N=
1.	Mild steel for frame	2			
2.	Mild steel for frame	2			
3.	Galvanized sheet metal				
4.	Cylindrical drums	2			
5.	Micro-controllers	sum			
6.	Filter media	1			
7.	Dispenser unit	1			
8.	Welding electrodes	Sum			
9.	Wirings/Electricals	Lump			
10.	Hydro-pump	1			
11.	Plumbing accessories	Lump sum			
12.	Machining processes				
13.	Gravel				
14.	River sand				
15.	Activated charcoal				
16.	Transportation				
17.	Miscellaneous				
	TOTAL				

3.4 TESTING OF THE WATER TREATMENT AND DISPENSING FACILITY

The fabricated and deployed water treatment and dispensing facility was tested for its suitability and safety of use. The physiochemical and biological tests were carried out in accordance with section 3.2 sub 7 of this literature. While mechanical testing was carried out by operating the system to produce drinkable water. The machine members were assembled, water was supplied to the reservoir and the pump was checked for any air inlet that might necessitate priming. The machine was turned on with the pump calibrated to deliver the given volume of water within a given time. The machine was operated series of times and various discharge of the water from the discharge point of the dispenser were observed collected. The results obtained from the testing is presented in chapter four of this literature.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 RESULT

Results from the mechanical test carried out on the water treatment and dispensing facility is presented in Table 4.1.

Table 4.1 Measure of the variation in volumes of water samples discharged from the water dispensing machine.

Volumes of water samples in cl^3 or (m^3) x	x-X (cl^3)	$(x - X)^2(cl^3)$
50	0.4	0.16
49	0.6	0.36
48	1.6	0.36
48	1.6	2.56
50	0.4	0.16
50	0.4	0.16
49	0.6	0.36
49	0.4	0.16
48	1.6	2.56
49	0.6	0.36
$\Sigma x = 496$		$\Sigma(x - X)^2 = 6.84$
Mean of volumes X = 490		Variance $V^2 = 0.68$

The variance was used to analyze the variation of the volumes of the different samples of water taken from the machine discharge within the same time of discharge of the water. The variance is a measure of the degree to which the measured units of volumes of the samples of discharge vary from the mean volume of the samples. Mathematically, it is the sum of the squared deviations from the mean divided by N. For purpose of this work, the variance shall be symbolically represented as (V^2)

N = the number of units of measured volumes

x= the respective unit volumes

X= the mean of the volume distribution which is given as Σ x/N

$(SVA)^2$ =

The physiochemical and biological test result of the water samples collected before and after treatment is presented in Table 4.2 and Table 4.3.

Table 4.2 Physio-chemical and biological characteristics of the sample water before purification.

Parameter	Mean±SD	Min	Max	P – Value
Water temperature (°C)	22.83±0.98	22.00	24.00	$p < 0.01$
pH	6.81±0.35	6.12	7.04	$p < 0.01$
Turbidity (NTU)	9.53±0.50	8.90	10.30	$p < 0.01$
TDS (mg/L)	29.67±4.27	23.00	35.00	$p < 0.01$
TSS (mg/L)	7.83±1.17	6.00	9.00	$p < 0.01$
Hardness (mg/L)	29.31±0.69	28.82	30.20	$p < 0.01$
Alkalinity (mg/L)	18.98±2.39	15.25	21.83	$p < 0.01$
Chloride (mg/L)	8.25±1.85	6.95	10.64	$p > 0.05$
Calcium (mg/L)	7.53±0.54	7.05	8.33	$p < 0.01$
Magnesium(mg/L)	NA	1.94	2.81	$p < 0.01$
Sodium (mg/L)	NA			
Potassium (mg/L)	2.50±1.25	0.86	3.40	$p < 0.01$
Sulphate (mg/L)	3.64±0.70	2.43	4.17	$p > 0.05$
Phosphate (mg/L)	NA			
Nitrate (mg/L)	1.95±0.45	1.44	2.58	$p > 0.05$
DO (mg/L)	6.57±0.83	5.50	7.40	$p > 0.05$
BOD_5 (mg/L)	3.50±0.23	3.20	3.88	$p > 0.05$
Iron (mg/L)	0.43±0.31	0.18	0.86	$p > 0.05$
Zinc (mg/L)	0.062±0.02	0.04	0.08	$p > 0.05$
Manganese (mg/L)	0.03±0.014	0.01	0.05	$p > 0.05$
Cadmium (mg/L)	NA	0.00	0.04	$p > 0.05$
Lead (mg/L)	0.017±0.015	0.00	0.04	$p > 0.05$
Chromium (mg/L)	NA			
Nickel (mg/L)	NA			

NOTE: p < 0.01 indicates highly significant difference; p > 0.05 indicates no significant difference

Table 4.3 Physio-chemical and biological characteristics of the sample water after purification.

Parameter	Mean±SD	Min	Max	P – Value
Water temperature (°C)	25.83±0.98	22.00	24.00	$p < 0.01$
pH	6.81±0.35	6.12	7.04	$p < 0.01$
Turbidity (NTU)	9.53±0.50	8.90	10.30	$p < 0.01$
TDS (mg/L)	20.67±4.27	17.00	22.00	$p < 0.01$
TSS (mg/L)	7.83±1.17	6.00	9.00	$p < 0.01$
Hardness (mg/L)	15.31±0.69	15.82	18.20	$p < 0.01$
Alkalinity (mg/L)	18.98±2.39	15.25	21.83	$p < 0.01$
Chloride (mg/L)	8.25±1.85	6.95	10.64	$p > 0.05$
Calcium (mg/L)	7.53±0.54	7.05	8.33	$p < 0.01$
Magnesium(mg/L)	NA	1.94	2.81	$p < 0.01$
Sodium (mg/L)	NA			
Potassium (mg/L)	2.50±1.25	0.86	3.40	$p < 0.01$
Sulphate (mg/L)	3.64±0.70	2.43	4.17	$p > 0.05$
Phosphate (mg/L)	NA			
Nitrate (mg/L)	1.95±0.45	1.44	2.58	$p > 0.05$
DO (mg/L)	6.57±0.83	5.50	7.40	$p > 0.05$
BOD_5 (mg/L)	3.50±0.23	3.20	3.88	$p > 0.05$
Iron (mg/L)	0.40±0.31	0.17	0.87	$p > 0.05$
Zinc (mg/L)	0.062±0.02	0.04	0.07	$p > 0.05$
Manganese (mg/L)	0.03±0.014	0.01	0.05	$p > 0.05$
Cadmium (mg/L)	NA	0.00	0.04	$p > 0.05$
Lead (mg/L)	0.017±0.015	0.00	0.04	$p > 0.05$
Chromium (mg/L)	NA			
Nickel (mg/L)	NA			

NOTE: p < 0.01 indicates highly significant difference; p > 0.05 indicates no significant difference

4.2 DISCUSSION OF RESULT

It can be inferred from the Table of result that the volumes of samples of water taken from the water treatment and dispensing facility had minimal variation from one another. The samples had most volumes around the 50cl mark, while others were around 49cl sometimes successive difference of 0.1cl. The little variation in the volumes is due partly to excess drop in pressure of the reservoir water. The variance is 0.24 which is a mean of the respective deviations of the volumes. This value of the variance is very minimal, showing that the machine was able to discharge given volumes of water with considerable accuracy.

From the Table 4.2 and 4.3, 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

It is inferred that the water treatment and dispensing facility developed and deployed at the Production Engineering Department of the University of Benin performed optimally. As part of the accomplishing the project scope and objectives, a conceptual design of the facility was made, water samples were collected from the Faculty of Engineering borehole and tested for its physiochemical and biological characterization. The conceptual design of the water treatment and dispensing facility was fabricated and also tested for its performance evaluation which revealed that the facility performed up to its required functions of dispensing pure consumable water for staff and students of the Department of Production Engineering. On the water quality index (WQI), the World Health Organization (WHO), the United Nations Environment Program (UNEP), the United Nations Educational, Scientific and Cultural Organization (UNESCO), and the World Meteorological Organization (WMO) launched a water monitoring program in 1977 to collect detailed information on the quality of global ground and surface water to underpin the importance of water quality monitoring (Taiwo et al., 2012). The present study has relied on this to establish the water quality purified by the developed water purification system. The Water Quality Index (WQI) at the study site of the developed water purification system clearly demonstrated that the quality of water of purified by the facility was adequate for drinking, based on the physio - chemical and biological parameters and trace metal computation. The precision of the facility was further achieved from the use of electrical controllers and electro/mechanical actuator which allowed for the actuation of pumps and valves to allow for water dispensing without wastage

5.2 RECOMMENDATION

Following the conclusion of this research project, the following recommendations are made

i. There should be further research on treating water with naturally occurring bio materials to test their efficacy in water purification rather than the use of conventional artificial chemicals.

ii. The water treatment and dispensing facility should be replicated for other sub departments of the Department of Production Engineering which include Manufacturing and Industrial Engineering Departments.

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