OPTIMISATION OF REVERSE OSMOSIS REJECT IN WATER TREATMENT OPERATION: A CASE STUDY OF MTU WATER TREATMENT PLANT

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Declaration

I hereby declare that the project work entitled “Optimization of Reverse Osmosis Reject: A case study of MTU Water Treatment Plant’’ submitted to Mountain Top University, is a record of an original work done by me under the guidance of my supervisor DR. E.F. SODIYA. This project is submitted in partial fulfillment of the requirements for the award of the degree of (BSc) in chemistry.

Olusemire Oluwayomife Jeremiah | Date

Certification

This is to certify that the project titled "Optimization of reverse osmosis reject in Water Treatment Operation: A case study of MTU Water Treatment Plant". Was carried out by Olusemire Jeremiah Oluwayomife with matriculation number 18010201001. This project is accepted for its contribution to education and literacy and meets the criteria for the award of a Bachelor of Science (BSc) Degree in chemistry from Mountain Top University Ogun State, Nigeria.

Dr. E. F. Sodiya
(Project Supervisor)

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(Head of Department)

Signature//Date

Dedication

I dedicate this project to the Almighty God and to my parent Mr and Mrs Olusemire and also to my lovely uncle Mr kayode Olusemire.

Acknowledgment

First and foremost, praised and thanks to the God, the Almighty, for his showers of blessings throughout my research work to successful completion

I would like to express my deep and sincere gratitude to my Project supervisor Dr. E. F. Sodiya for giving me the opportunity to do the research and providing invaluable guidance throughout this project. His dynamism, vision sincerity and motivation have deeply inspired me, I would also like to thank him for his friendship, empathy, and great sense of humor. My sincere recognition and gratefulness to the Laboratory Technologist Mrs F.W. Ayodeji who guided me through analysis of my samples.

May God continue to bless you all. Amen

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Abstract

The Mountain Top University water treatment plant has Reverse Osmosis (RO) as a component of the treatment units in compliment with filtration unit for delivery of high quality drinking water for human consumption. The RO purges70% of its input as rejects with only 30% as final treated water and 65% of the entire input into the system. This inferred the unviability of the process. The project investigated the quantity and quality of the infeed raw water, the filtered, the purged and the final treated water from the RO . Before and after the backwash of the filter beds of in feed to the Ro were considered.

Physicochemical parameters such as pH, conductivity, Hardness, Iron and Particulates content in the samples taken were determined. Hanna pH meter was used to determine pH and Conductivity, other quality parameters determined were Ca/Mg Hardness using smart titrimetric reagents and Iron (Fe) content and using Lamotte Spectrophotometer. Gravimetric methods of analysis were used to determine Total Dissolved Solids (TDS) and Total Suspended Solids (TSS). The results were within both local and international standards such as World Health Organization (WHO) limits. The accepted treated and purge can be package for drinking

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

All living organisms require water. It is crucial in several physical and chemical interactions and plays an important part in many natural processes. Water is seen as a renewable resource, with the term "renewable" referring to the fraction that circulates via the hydrological cycle. According to the United Nations’ World Water Development Report (2003), although 70% of the earth’s surface is covered by water, only 2.5% of that water is fresh and only 0.3% of that water is suitable for human consumption (Westall and Brack, 2018).

Clean water is vital for people, has a significant impact on health, and has the potential to minimize illness. Paradoxical, It serves as a channel for the transmission of disease-causing substances into people. Water impacts on human health through consumption of water consisting of pathogenic organisms or toxic chemicals. Water also impact on human health if not consumed in a required amount, leading to dehydration and/or other personal health issues (Palmer *et al*., 2018). The usage of water does not only stretch to drinking supply but also other activities such as cooking, hygiene practice etc. and the access to clean water varies today with several areas that are vulnerable of water deficiency or sufferer from scarcity (Li *et al.*, 2019). Lack of access to clean water is an issue that will likely worsen over time in both wealthy and developing nations. So far there is generally seldom a problem to find water sources, rather the problem is to get access to fresh and clean water (Boretti and Rosa, 2019).

Wolf *et al*. (2017) and Aoyama *et al*. (2020) highlights three common scenarios and circumstances where access to clean drinking water is a challenge: (1) Water deficiency when migrating or hiking. This can be refugees migrating to other countries or regions. (2) Temporary or permanent settlements where access to safe water is missing or lacking. This sites can be refugee camps, temporary tent camps after natural disasters, rural areas or slums. (3) A society where the infrastructure for water, sewage or energy systems has been destroyed or damaged due to war or nature disasters.

The process of treating water may have slight differences at various locations, based on the plant’s technology as well as the type of water that needs to be treated. Nevertheless, the basic principles are the same (Sun *et al*., 2017). Examples of water treatment method include: Coagulation/Flocculation, Sedimentation, Filtration, Disinfection, Sludge Drying, Fluoridation, pH Correction, and Reverse Osmosis Water Filtration. Reverse Osmosis is a process where water pressure is employed to force water through a semi-permeable membrane (Badruzzaman *et al*., 2019). When water is forced against the reverse osmosis membrane surface, the dissolved materials are repelled, while purer water is created on the other side as the water molecules diffuse molecule by molecule through the barrier. This "reverse osmosis" method is a popular method for the reduction of contaminants in water (Shin *et al*., 2017). Reverse osmosis water filtration is a chemical-free, economical way to improve the taste and odor of drinking water. As stated earlier, in a RO system, tap water is forced through a semi-permeable membrane to produce clean, filtered water, which is then sent to a storage tank. The water molecules that have been separated from the contaminants are flushed down the toilet. A reverse osmosis system includes pre and post filters for enhanced pollution removal (Yang *et al*., 2019).

1.1.1 Importance of water

Water is mainly a natural resource which is very important and essential to support and sustain life especially for living things (plant and animal) as well as their activities (Westall and Brack, 2018). It can be sourced from the surface of the river as well under the ground. It either case it has been contaminated due to dissolved mineral through which it percolated to the underground and the surface water contaminated by human activities. The raw form can be used for some activities but needs to purify for human consumption. Ttnis required in large volume daily by living things and so should be effortlessly accessible, contamination free, adequate, affordable, safe and available all year round in order to sustain life (Jung *et al*., 2021). It has been estimated and reported by World Health Organization (WHO) globally that about 1.1 billion people globally are drinking unsafe water and also the majority of diarrheal disease in the world (88%) is caused by consumption of unsafe water, poor hygiene and poor sanitation (Westall and Brack, 2018). It has also been estimated that thousands of children in developing countries under the age of five are dying every day due to drinking of contaminated (Wolf *et al*., 2017). Thus, lack of the potable water supply, hygiene and basic sanitation is associated with the high morbidity and mortality from water related diseases. About 22 African countries, including China, are failing to provide the potable water to half of their population (Young *et al*., 2021). Millions of lives are being lost in many developing countries due to lack of safe drinking water and proper sanitation measures which leads to a number of diseases such as typhoid, salmonellosis dysentery, and shigellosis. Therefore, this pressure that rests on the water resources include the direct contamination from domestic, industrial, and agricultural wastes and merely less direct effects that are caused by climate change and other ecological disturbances. These pressures result in water pollution which in turn contributes to waterborne disease outbreaks worldwide. Water pollution also demand an increase in chemicals used for its treatment, thereby making it very expensive for treatment (Adams and Hayes, 2021).

1.1.2 Justification of the Study

Water's importance specifically for consumption or for household purposes, has made an essential business of the day especially as developments envelopes the world. The majority of raw water sources are contaminated in one way or the other. Therefore, is highly important to purify it, particularly for drinking purposes. Purification processes come in different dimensions for modes depending on the amount of capital available to set up the process. The type of treatment techniques solely depends on the quality of the raw water.

Mountain Top University has a water treatment plant managed by a commercial venture. The product of this plant serves the university's community as well as Prayer City and its environs. This is aimed at generating revenue for the university from within. There is need for the venture to compliment filtration unit with Reverse Osmosis (RO) in order to meet with existing competition in the market. The treated water output from the RO was much lower to the input from filtered water due to much volume of purge discharged. This research looks into the quality of filtered water and final treated from the RO compared with the purge water to work out modalities on reject reduction

1.1.3 Statement of the Problem

The high volume of water lost to purge from the RO is a function of the membrane capacity and connections designed for that model. There are four housings in the system. The first two housings are connection in parallel or grouped into parallel flow streams known as a stage. This is then connected to two other housings in series to make a total of three stages. The main advantage of having RO stages in sequence is that wastewater is reduced. Wastewater can be reduced to 15% of total flow in an efficient RO staged system, although rejection flow from a single membrane can reach 50%.

This challenge has not made profit to be realized it possible for the input into the system to be realized not to talk of profit. There is need to study the quality of the purge and output to work out the acceptance of the purge for packaging.

The evaluation of the treatment system was carried out. The quantity of the water discharged by each units was determined. The inlets and outlets' quality are investigated in this research. Parameters such as turbidity, colour, and particulate content of the treated water are measured and analyzed more explicitly.

1.1.4 Aim of the Study

To determine the quality and quantity of the treated and reject water from Reverse Osmosis.

1.1.5 Objective of the Study

To determine the contaminants level in inlet and outlet of RO. The inlet is the in feed from filtration unit. There are two outlets, the treated that percolates through the RO membrane and the reject.

1.1.6 Scope of the Study

This study covers the quantity and quality monitoring of the treatment process from the final purified water from the sets of filter beds to the finally screening water through the membrane of the RO at the water Treatment plant of Mountain Top University

1.1.7 Significance of the Study

To determine the degree of quality water achieved at various stages of treatment process after filtration down to Reverse Osmosis purification process

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Water Contamination

Water contamination occurs when pollutants contaminate water sources and render the water unfit for use in drinking, cooking, cleaning, swimming, and other activities. Chemicals, garbage, bacteria, and parasites are examples of pollutants. Water is inevitably contaminated by all types of pollution. Lakes and oceans become contaminated by air pollution. Land contamination may contaminate an underground stream, a river, and ultimately the ocean. Consequently, rubbish thrown on a vacant lot may eventually contaminate a water source (Chaudhry and Malik, 2017).

Water pollutants may cause disease or act as poisons. Poorly treated sewage may contain bacteria and parasites that can get into drinking water supplies and cause illnesses like cholera and diarrhea. Toxic chemicals, pesticides, and herbicides emitted by industries, farms, residences, and golf courses can cause acute poisoning and mortality, as well as chronic toxicity, which can lead to neurological issues or cancer. Many contaminants enter our body systems when we drink or prepare food with it (Speight, 2020). The digestive system is exposed to the contaminants. And then, they can spread to the body's other organs and lead to a number of diseases. Chemicals come in contact with the skin from washing clothes, or from swimming in polluted water and may lead to skin irritations. Hazardous chemicals in water systems can also affect the animals and plants which live there. Sometimes these organisms will survive with the chemicals in their systems, only to be eaten by humans who may then become mildly ill or develop stronger toxic symptoms. The animals and plants themselves may die or not reproduce properly (Chen *et al*., 2018).

2.2 Water treatment

Water treatment involves process that alter the chemical composition or natural characteristics of water. Primary water availability include surface or ground water. Most municipal or public water comes from surface water while private water supplies usually consists of ground water pumped from wells or boreholes (Gómez-Pastora *et al*., 2017).

Water treatment mainly focused on improving both the aesthetic and chemical qualities of drinking water. As early as 4000 B.C., techniques for enhancing the taste and smell of drinking water were documented. Methods for treating water included boiling, straining, exposing to sunshine, and filtering through charcoal, according to ancient Sankrit and Greek literature. The initial water treatments were motivated by visible cloudiness (later referred to as turbidity), as many sources of water had particles that were distasteful and unsightly (Chaplin, 2019). The chemical alum was reputedly employed by the Egyptians to clear water as early as 1500 B.C. to make water's suspended particles settle out. Although the level of purity attained was not yet quantifiable, filtration was discovered to be a reliable method of eliminating particles from water in the 1700s (Gitis and Hankins, 2018).

Concerns about drinking water quality remained mostly focused on disease-causing bacteria (pathogens) in public water supplies during the late nineteenth and early twentieth century. Scientists learned that turbidity was a health hazard because it might harbor viruses in source water contaminants like feces. As a result, the necessity to reduce turbidity and subsequently eliminate microbiological pollutants that were contributing to typhoid, dysentery, and cholera outbreaks drove the design of the majority drinking water treatment systems constructed in the early 1900s (Chaplin, 2019).

While turbidity might be reduced somewhat through filtration, chlorine-based disinfectants were mostly responsible for the early 1900s decline in outbreaks of waterborne diseases. In Jersey City, New Jersey, chlorine was initially applied as a primary water disinfectant in 1908. Since the original Safe Drinking Water Act was passed in 1974, the number of water systems that use some sort of treatment has increased. Filtration and chlorination are still efficient methods of safeguarding water sources from hazardous bacteria (Chaplin, 2019).

The three primary goals of water treatment, according to von Gunten (2018), are to produce water that is safe for human consumption, water that is appealing to consumers, and water use facilities that are economical in terms of both capital and operational costs.

In the design of water treatment plants, the provision of safe water is the prime goal and anything less is unacceptable. A properly designed plant is not a guarantee of safety. However skillful and plant operation and attention to the sanitary requirements of the source of supply and distribution system are equally important (Heck *et al*., 2019). Water treatment facilities have proven they can generate safe water even under challenging circumstances. Most of the outbreaks that have occurred in recent years have been caused by inadequate control of treatment facilities, contamination of untreated supplies, storage tanks and distribution systems. These serve as remainders of the need for uninterrupted treatment and unceasing attention to operating detail (Heck *et al*., 2019).

Making water that consumers find appealing is the second fundamental goal of water treatment. Ideally, an appealing water is one that is clear and colourless, pleasant to the taste and cool. It is non-straining, and it is neither corrosive nor scale forming. Engineers, managers and operators are aware of the consumer's growing sensitivity to the quality of water served and of the demand in many places for water of better quality (Saleem and Zaidi, 2020). According to experts for those supplies of high natural quality, the treatment plant is mostly responsible for producing water that is appealing. The treatment facility must be able to handle changes in flow and raw water quality in order to produce water that is consistently of high quality. Producing water that tastes good also serves the purpose of keeping consumers away from other risky water sources. Instead of the quality at the treatment plant, the consumer is more concerned with the quality of water that is delivered to the tap at his or her house or place of business. Therefore, water utility operations should be such that quality is not impaired as water flows from the treatment plant through the distribution system to the consumer (Saleem and Zaidi, 2020).

The third basic objective is that water treatment be accomplished using facilities that are reasonable with respect to capital and operating costs. This does not mean that a plant's capacity to meet emergency situations or justifiable future condition should be sacrificed for the sake of initial savings (Saleem and Zaidi, 2020). Water of improved quality is the direct return on a community's investment in water treatment facilities.

2.3 Conventional Water Treatment Methods

Water treatment entails not only purification and removal of numerous undesired and harmful pollutants, but also enhancement of water's inherent features by the addition of deficient elements (Hiller *et al.*, 2019).

All methods of water treatment can be divided into the following main group:

(a) Those focused towards increasing water's organoleptic qualities (clarification, discoloration, deodorization),

(b) Those that guarantee epidemiological safety (chlorination, ozonization, ultraviolet irradiation) and

(c) Those that condition the mineral content of water (fluorination and deflourination, deironing (dererrization), demanganisation, softening, desalination).

A particular method of water treatment is chosen upon preliminary examination of the composition and properties of the water source to be used and comparison of these data with the consumer's requirements.

2.4 Treatment Processes

Treatment of water process starts from analysis of raw water. The results obtained from this tests guides the consulting Engineers, regulatory agencies and others concerned on the type of water treatment plant to put in place. One of the common types which is known as rapid sand filtration plants is being used in this research work to illustrate water treatment process arrangement (Hiller *et al.*, 2019). The following are the basic definition of processes involve in the modern conventional water treatment plant.

(i) Aeration:

As applied to water treatment, aeration may be defined as the process by which a gaseous phase, usually air, and water are brought into intimated contact with each other for the purpose of transferring volatile substances which may include oxygen, carbon dioxide, nitrogen, hydrogen sulfide, methane, and various unidentified organic compounds responsible for taste and odour.

$4Fe(HCO_3)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3 + 8CO_2$ ……………………….equation 1

$2Mn(HCO_3)_2 + O_2 + H_2O \rightarrow 2Mn(OH)_4 + 4CO_2$……………………..…equation 2

$O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$ …………………………………………..……equation 3

$Fe^{2+} + \frac{1}{4} O_2 + H^+ \rightleftharpoons Fe^{3+} + \frac{1}{2} H_2O$…………………………………………equation 4

(ii) Coagulation:

Coagulation is the process of adding chemicals (coagulants),such (iron or aluminum salts), such as aluminum sulphate, iron sulphate, iron chloride or polymers to the water. These compounds, known as coagulants, have a positive charge. The negative charge of the dissolved and suspended water particles is balanced by the positive charge of the coagulants.

(iii) Flocculation:

The term flocculation refers to water treatment processes that assemble or combine or "coagulate" small particles (Floc particles) which settle out of the water as sediment. Settling or sedimentation occurs naturally as flocculated particles settle out of the water.

When Alum salt are used as coagulants.

$Al_2(SO_4)_3$ or $AlCl_3$ to precipitated insoluble Aluminium hydroxide

$Al_2(SO_4)_3 + 3\ Ca(HCO_3)_2 \rightarrow 3\ CaSO_4 + 2\ Al(OH)_3 + 6CO_2$......................................equation 5

Hardness removal

Hardness removal and pH correction: A chemical that will yield alkaline solution are used such Sodium carbonate Na_2CO_3 and Lime $Ca(OH)_2$.

$Na_2CO_3 + CaSO_4 \rightarrow NaSO_4 + CaCO_3$ insoluble calcium carbonate precipitate as slugde………………………………………………………………………………… …equation 6

$Na_2CO_3 + CaCl \rightarrow NaCl + CaCO_3$ insoluble compound…………………………..equation 7

Aluminium sulphate with Hydrated lime:

$Al_2(SO_4)_3 + 3\ Ca(OH)_2 \rightarrow 3CaSO_4 + 2\ Al_2\ (OH)_3$...equation 8

(iv) Sedimentation:

Settling tanks (sedimentation tanks, sedimentation basins, settling basins or clarifier), are used in water treatment to reduce the amount of settleable solids suspended in water. Sedimentation is one of the most widely used processes in the treatment of water, second perhaps to chlorination.

(v) Filtration:

Water filtration is a physical and chemical procedure that separates suspended and colloidal pollutants from water by passing it through a porous media, typically a sand or other granular material bed. Water fills the pores of the medium and the impurities are left behind in the openings or upon the medium itself.

i. **Sand Filter.** This is done through the process of chemical feed. It helps to facilitate the flocculation or coagulation of any suspended solid. It's utilized to get rid of floating and sinkable particles, as well as suspended materials.

ii) **Carbon Filter.** This is used to remove taste from the water through the process of a bed of activated carbon to remove contaminant. They are most effective at removing chlorine, particles such as sediment, volatile organic compounds (VOCs), taste and odour.

$Pb + CaCl_2 + H_2O + C \rightleftharpoons PbC + HOCl + HCl$……………….……equation 9

Pb^+ adsorbed on Carbon (activated) in the presence of $CaCl_2$

iii) **Resin Filter.** This is use to remove the unwanted ionS from the water and add the needful ion into the water. Through a bed of ion exchange, It also attracts the calcium and magnesium ions and replaces them with sodium ions which are less harmful for water.

Cat ion Exchanger for Treatment of Permanent Hardness

RCOOH (resin) + CaCl (hard water)→RCOO2Ca (Carboxylate) + H^+ + Cl^- equation 6

Ionization $RCOO^- H^+$ + Ca^+ Cl^- → RCOOH + $MgSO_4$ → RCOOMg + H^+ + SO_4^{2-} ……………………………………………………………………equation 10

$CaSO_4$ + NaCl H+ (cat ion resin) → $NaSO_4$ + Cl- + H^+ + SO_4^2-……..equation 11
(hard water)

$CaSO_4 (s) + Na_2CO_3 \rightleftharpoons CaCO_3 + Na_2SO_4$ ………………………………..equation 12

Treatment of Temporary Hardness

$CaCO_3 (s) + CO_2 (aq) + H_2O \rightleftharpoons Ca^{2+} (aq) + 2\ HCO_3^- (aq)$…………………equation 13

$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O\ CO_2$…………………………..………...equation 14

(vi) Chlorination and disinfection:

Water disinfection is a specialized treatment that eliminates dangerous and otherwise unpleasant organisms. Classically, disinfection has been practiced for the purpose of destroying or inactivating disease producing (pathogenic) organisms more particularly, bacteria, of intestinal origin. Pathogenic organisms other than bacteria that merit attention in connection with water disinfection include a variety of viruses, intestinal protozoa and some few microorganisms (Li *et al.*, 2017).

Modern Water Treatment (High Capacity)

Modern complexes for improving the quality of water are complicated enterprises which by right may be called water-purification plants since their capacity in the final product (water of proper quality) amounts to tens or hundreds thousands cubic metres per day. According to Mazhar *et al*., (2020)

The general structural features of modern water treatment plants includes a number of units, departments and shops such as Inlet structure, Raw water chamber, Aerator, mixing and distribution structure, Clarifiers block, Filtration block and electromechanical building, Waste backwash tank and pumping station, Internal conveyance, Treated water reservoir, Treated water pumping station, Treated water measurement chamber and pipelines interconnection, Chemical plant, Chlorine gas plant, Chlorine gas plant, Reagent shop, Repair shop, Electric substation, standby power station and fuel tank, Laboratory, administrative and control building, Elevated water tank, Gate house etc. These structures sheltered highly sensitive modern equipment that are being used in the control and operation of water treatment processes (Azuma and Hayashi, 2021). Modern conventional water treatment facilities stand out for their high level of automation and mechanization. All principal characteristics of the operation of electrical and mechanical equipment and technological parameters of operation of individual water treatment installations are transmitted by telemetering devices to the central control board and control room. The day to day control and operation of modern conventional water treatment plant for instance in Nigeria is being directed and monitored from the control room through the central control board and Mccs/Control panels located in various structures or building earlier mentioned that are associated with the process units. Instruments such as pH meters, turbidity meters, flow meters etc. are also provided to monitor the water pH level, turbidity and rate of flow (Li *et al.*, 2020).

Also, among the special operation common to modern conventional water treatment plants are automatic deslugging of clarifiers, automatic filter backwash, and automatic changeover of chlorine drum, automatic operation of drain pumps in basements and waste backwash water pump, automatic operation of the filtered water pumps and chemical dosing pumps and automatic extent of throttling the inlet control valves (Xu *et al.*, 2018).

Modern Water Treatment (Medium Capacity)

The treatment operation of the modern medium process depended on the quality of the raw water which may include Aeration, Filtrations, Reverse Osmosis, Ozonization, and Disinfection

The technology of improvement of water quantity at treatment plants can also be characterized by a large diversity of the methods and processes employed and substantial differences in the design of process structures and equipment as well as in the kinds of reagents used for intensification of various stages of water treatment (Xu *et al*., 2018).

This complex technology, the high requirements to reliability and the high degree of automation and mechanization in the modern convectional water treatment plants is a major concern to the authors as a result of various problem that could truncate the set goals upon which the adoption of modern water treatment technologies.

Physicohemical Parameters

2.4.1 pH

Physicochemical characteristics such as pH, total dissolved solids, and conductivity influence the acceptability and use of potable water for recreational and other home purposes. However, inorganic minerals are the most common source of raw water pollutants, with mineral salts supplied as water flows over the soil structure. Anthropogenic activities resulting from increased industrialisation and urbanization are a major factor influencing water quality (Ubalua and Ezeronye, 2005). For example, trace metals may enter rivers from both natural and manmade sources. Water, biota, and sediments are the three primary reservoirs that can hold these trace metals (Florea and Busselberg, 2006; Hung and Hsu, 2004). Some trace metals have the potential to be hazardous because, after entering the cell, they affect the cell membrane or disrupt the cytoplasmic or nuclear processes. Therefore, its buildup in the body of a human could lead to organ malfunction (Jarup, 2003).

pH is the measure of hydrogen ion concentration or hydroxide ions concentrations in a solution. This analysis was done to find out how many hydrogen ions were present in the water sample. A pH meter was used to measure the pH after it had been calibrated with buffer solution. The electrode of the pH meter was rinsed with distilled water. Samples of 20 ml of water were measured into a labeled beakers, then the electrode was inserted into the sample measured. The reading was taken when the pH meter displayed a stable value. The electrode was rinsed with distilled water and cleaned with tissue paper after each insertion in the various samples (Ehiagbonare and

Ogunrinde, 2020). The pH of the surface water (6.30 ±0.26 - 7.35 ±0.50) was within the Nigerian Standard for Drinking Water (NSDW) range acceptable for normal consumption. The findings of this study are consistent with research conducted by Adefemi et al. (2007) using water samples from the South West Nigerian dams of Ureje, Egbe, Ero, and Itapaji. Similar outcomes were also found by Asaolu (1997) using water samples from Ondo State's coastal areas in the south-west of Nigeria.

2.4.2 Temperature

One of the most crucial factors in a natural surface water system is temperature. The temperature of surface water governs to a large extent the biological species present and their rate of activities. Temperature has an effect on most chemical reaction that occurs in natural water system. Cooler waters usually have a wider diversity of biological species. At lower temperature, the rate of biological activities that is the utilization of food supplies, growth, reproduction etc. is slower. Higher water temperatures promote the growth of microorganisms in the water, which may increase the taste, odour, turbidity and cause corrosion problems (Gupta, 2019). Seasons, time of measurement during the day, meteorological conditions, the size of the water mass, and the coordinates of the water are all factors that influence the temperature of water (latitude and longitude). Temperature has an impact on flora and fauna growth and distribution since it is the most variable factor in the environment and plays an important role in chemical and biological activities. Algae and aquatic weeds thrive in water bodies with high nitrogen levels and warmer temperatures (Welch, 1952).

Water temperature was measured and recorded using a mercury-in-glass thermometer graduated in degree Celsius (0-100 ^{o}C) (Cabon et al., 2020). Seasons, time of measurement during the day, meteorological conditions, the size of the water mass, and the coordinates of the water are all factors that influence the temperature of water (latitude and longitude). Temperature has an impact on flora and fauna growth and distribution since it is the most variable factor in the environment and plays an important role in chemical and biological activities. Algae and aquatic weeds thrive in water bodies with high nitrogen levels and warmer temperatures (Welch, 1952).

Colour

A variety of chemical and organic impurities, including copper from plumbing systems, rust from iron pipes, algae, bacteria, and more, can be detected by the color of water.

Odour

It entails presenting an observer with a succession of flasks while informing them that the samples are arranged in order of increasing concentrations and that some of the samples include scents.

2.4.3 Conductivity

Conductivity is a measure of the ability of water to allow an electrical current to flow through it. Electrical conductivity was determined by using a well calibrated electrical conductivity meter. The probe was dipped into the bottle of the samples until a stable reading was obtained and recorded according to Greenberg et al. (1992).

2.4.4 Hardness (Ca/Mg)

Hard water with high mineral content mostly calcium. Calcium occurs in the form of calcium carbonate ($CaCO_3$). The water contained about (6mg/L - 18mg/L) hardness. This result shows that the treatment facility employed in the treatment of the water is functioning at an optimal rate. However, when untreated surface and waste water find its way into the water bodies, utilized by man such hard water can lead to dry itchy skin and also influence osmoregulation in aquatic animals. The Spectrophotometer was on then was scrolled down to select 13 Ca & Mg Hard-UDV from the menu. A clean vial (0156) was rinsed with the sample and filled with 3mL of the sample, the vial was inserted into the chamber then the lid was closed and SCAN BLANK was selected. Afterwards, the vial was removed from the spectrophotometer.

3mL of the sample was added to a Calcium Hardness UDV vial (4309) and shaked vigorously for 10 seconds, the tube was inserted into the chamber to read the concentration in ppm of the Ca & Mg hardness present in the sample.

2.4.5 Calcium Hardness

A tube (0608) was filled to 12.9 ml line with the water sample and 6 drops of sodium hydroxide with metal inhibitor was added to it, the solution was capped and swirled to mix. To the solution, one calcium hardness indicator tablet (5250A) was added, capped and swirled to disintegrates the tables. Direct reading titrator (0382) was filled with hardness reagent (4487DR) and was inserted immediately into the centre hole of the test tube cap. While gently swirling the tube, the plunger was slowly pressed to titrate until clear blue colour was observed. The reading was recorded as ppm calcium hardness.

2.4.6 Iron (Fe)

Hardness minerals such as calcium and magnesium are removed by iron (Fe). Iron will clog the softener and must be removed from the softener resin on a regular basis.

The Spectro meter was on after which was scrolled down to select 51 Iron bipyr from the menu. A clean tube (0290) was rinsed with sample water and filled to the 10mL line with the sample then the tube was inserted into the chamber, the lid closed and SCAN BLANK was selected.

Afterwards, the tube was removed from the spectrophotometer, 0.5mL iron Reagent #1 (v-4450) was added to it and mixed followed by 0.1g iron reagent #2 powder (v4451). The mixture was capped and shake vigorously for 30 second. The solution was left for three minutes for maximum color development. At the end of 3 minutes, the tube was inserted into the spectrophotometer to read the concentration of Iron in ppm present in the sample.

2.4.7 Total Solids, Total Suspended Solids, and Total dissolved solid

Total dissolved solids (TDS) is a measurement of the total amount of inorganic and organic compounds that have been dissolved and are suspended as molecular, ionized, or microgranular particles in a liquid. By deducting the suspended solids values from the corresponding total solids of the samples, the total dissolved solid was calculated. The high values of TS and TSS can affect the organisms living in water bodies as these can influence the level of dissolved oxygen. Furthermore, the amount of total suspended solids expected in Nigeria, Nigerian Standard for Drinking Water (NSDW) is about 500.

Total Suspended Solids (TSS) is the dry weight of non-dissolved suspended particles in a water sample that may be captured by a filter and is measured using a filtering device called a sintered glass crucible. Using Whatman filter paper that had been rinsed in double-distilled water, dried at 105 C for precisely one hour, and then chilled in desiccators, the total suspended solid was calculated. Its residue weight (W1) was determined using a digital balance. The sample of 100 mL of water was filtered through the resin paper and then evaporated at 105°C for one hour. This weight which represents W2 of the filter paper containing the residue was noted, and TSS was calculated using $(W2 - W1) \times 100$ mg/L. t Mazhar et al., (2020)

Total solids (TS) are composed of all the suspended, colloidal and dissolved solids in the sample. This mixture includes any dissolved salts such as sodium chloride (NaCl) and solid particles such as silt and plankton. A high total solids level implies that the liquid sample contains a lot of solid particles. Total Suspended Solids (TSS) were subtracted from Total Dissolve Solids to calculate the total solids (TDS).

Microbiological analysis are also carried out on water samples to determine the bacterial status of water. This areas is not part of the scope of this work.

2.5 Reverse osmosis

RO is a technique that separates and removes dissolved solids, organics, pyrogens, submicron colloidal debris, color, nitrate, and bacteria from water using semipermeable spiral wound membranes (Badruzzaman *et al*., 2019). Under pressure, feed water is fed through the semipermeable membrane, where water permeates the membrane's minute pores and is delivered as filtered water known as permeate water. The water impurities that are concentrated in the reject stream and flushed down the drain are referred to as reject water. These membranes are semi-permeable and reject the salt ions while letting the water molecules pass. The materials used for RO membranes are made of cellulose acetate, polyamides and other polymers. The membrane consists of hollow-fiber, spiral-wound used for treatment; depend on the feed water composition and the operation parameters of the plant (Víctor-Ortega and Ratnaweera, 2017). Reverse Osmosis (RO) is a membrane based process technology used for desalination. Membrane-based saltwater desalination and wastewater reuse are commonly regarded as potential methods for increasing water supply and reducing water scarcity (Sahinkaya *et al*., 2018). Reverse osmosis (RO) and electro dialysis (ED) are the two most frequently utilized membrane technologies, however only RO competes with distillation techniques in seawater desalination (Shanmuganathan *et al*., 2017).

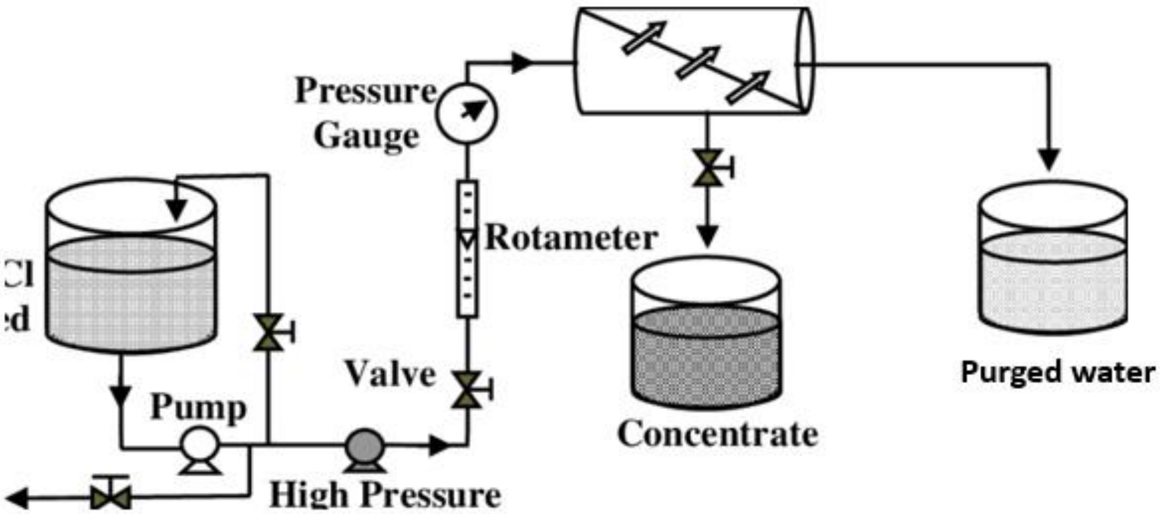

Fig. 2.1 Reverse Osmosis Flow chart

Major Components of an RO System

Below are the essential components of any reverse osmosis system:

1. RO Membranes

Depending on the use, a membrane is made of a sheet of semipermeable material that has been spiral coiled. They come in three different diameters—2 inches, 4 inches, and 8 inches—with the 4-inch and 8-inch diameter sizes being the most popular in the water treatment sector. The typical standard size that can be used with any brand of RO equipment systems is 40 inches in length. The area is calculated in square footage. There are membranes with a surface size of 350 to 450 square feet available. Thin film composite (TFC), which was first layered on top of cellulose acetate (CA), is a newer type of semipermeable membrane. Today, TFC membranes are mainly employed.

2. Housings

One housing, able to accommodate up to six membranes placed in series, is used to load membranes. The housings are essential for securely mounting the reverse osmosis filters. Their interconnection takes into account the valves and drain pipes that stop backflow and allow the water to drain properly.

3. Stages

Stages are then created by grouping housings into parallel flow streams. There can be up to three stages in series in a single reverse osmosis system. The minimization of wastewater is the main advantage of series-using RO stages. The rejection flow from a single membrane alone can be as high as 50%, whereas wastewater can be reduced to 15% of the total flow in an effective RO staged system.

4. Pretreatment Cartridge Filtration

Pretreatment cartridge filtration, as well as a pressurizing pump, are also components of a complete RO system. Before the water reaches the semipermeable membrane, the pretreatment cartridge filters filter out bigger particulates. This action is required to protect the membrane from fouling and increase its lifespan. Cartridge filters frequently have straightforward designs and are comprised of wrapped polypropylene strands.

5. Controls System

A comprehensive RO system also has a controls system. In a small RO system, the controls may be as simple as valves and rotameters. A larger system will contain the flow, temperature and pressure transmitters, as well as control valves operated from a human-machine interface (HMI) or programmable logic controller (PLC). Larger systems also incorporate variable frequency drives (VFDs) for the pressurizing pump and sometimes energy recovery devices.

The controls system enables users to keep track of and control the entire RO system. Additionally, it frequently includes alarms that can alert operators to any RO system problems that want rapid attention.

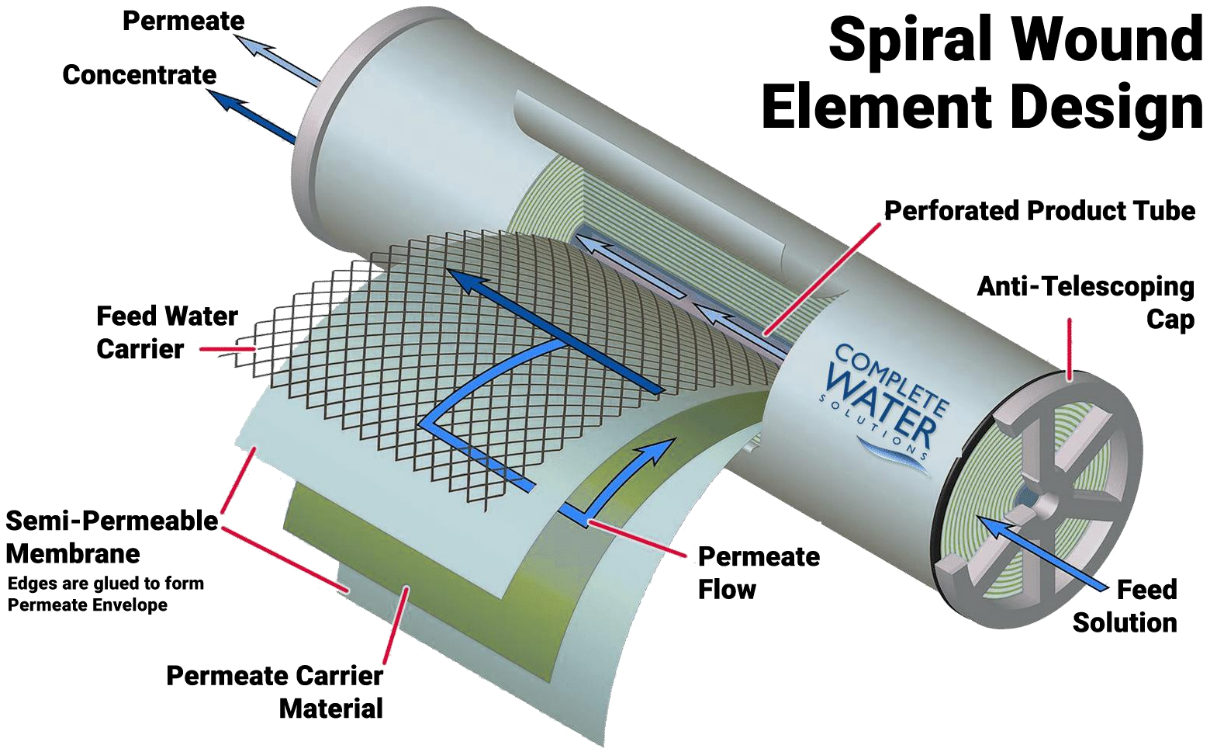

Fig. 2.2 Membrane Characteristics

A sheet of semi-permeable material that has been spirally coiled forms the reverse osmosis membrane (varies dependent on application). It is a thin, semipermeable membrane with small pores that allows only pure water to pass through while excluding larger molecules like dissolved salts that have been ionized and other contaminants. When pressure is applied on one side of the membrane, water passes through. For industrial boilers, drinking water systems, saltwater desalination, pharmaceutical and cosmetic manufacturing, food and beverage processing, and many more uses, reverse osmosis produces water that is extremely pure. One of the most efficient and affordable technologies for purifying water of various pollutants is reverse osmosis.

The membrane must to be reasonably priced and have a long, stable life. Membrane should be simple to make and somewhat permeable to salt with effective salt rejection. They should be extremely permeable to water, have a high water flux, and be less prone to fouling. In relation to the volume they occupy, they ought to enable the passage of a significant amount of water across the membrane. In saltwater, the membrane must be chemically, physically, and thermally stable. They need to be strong enough to withstand high pressures and variable feed water quality (Song *et al*., 2018; Zhang *et al*., 2019).

2.5.1 Operations of Reverse Osmosis

Municipal wastewater treatment has also been accomplished using this method. Due to the fact that dissolved solids cannot be removed by standard municipal treatment techniques, RO is employed to do so. In chemical and environmental engineering, RO is increasingly employed as a separation process to remove organics and organic contaminants from wastewater. Reverse osmosis (RO) methods have been widely employed for solute separation and concentration (recovery) in numerous disciplines, as can be shown from a review of the literature (Alsarayreh *et al*., 2020).

The use of RO in the treatment of various effluents of chemical (Al-Obaidi *et al*., 2017), petrochemical, electrochemical, food, paper and tanning industries as well as in the treatment of municipal waste waters have been reported in the literature and were studied by many researcher (Shafiq *et al*., 2017). Removal of organic contaminants by RO processes was first demonstrated by Eykens *et al.* (2017). The presence of individual contaminants can cause problems, hence the removal of individual contaminants by RO has been studied by very few researchers (Al-Obaidi *et al*., 2017; Shafiq *et al*., 2017; Ertürk *et al*., 2019). Lanjewar *et al*., (2021) studied the paper on

"Treatment of Distillery Spent Wash where UF and RO membranes used for purification of the wastewater by removing the colour and the contaminants. A number of studies (Geise, 2021) have been reported on the application of RO for the removal of Organics such as endocrine disrupting chemicals, plastic additives, pesticides, pharmaceutically active compounds (PhaC's), benzene and toluene. Cellulose acetate and polyamide membrane has good salt rejection for inorganic salts like NaCl, $Na_2SO_4^-$. However, for organics, the rejection is reported to be lower and varies widely in the range of 0.3-0.96 (Swain, 2018). RO process removes fluoride proportionately, if TDS is at tolerable level and fluoride content is high then one can use special alum-resin filter, works under gravitational force (Fujioka *et al.*, 2018).

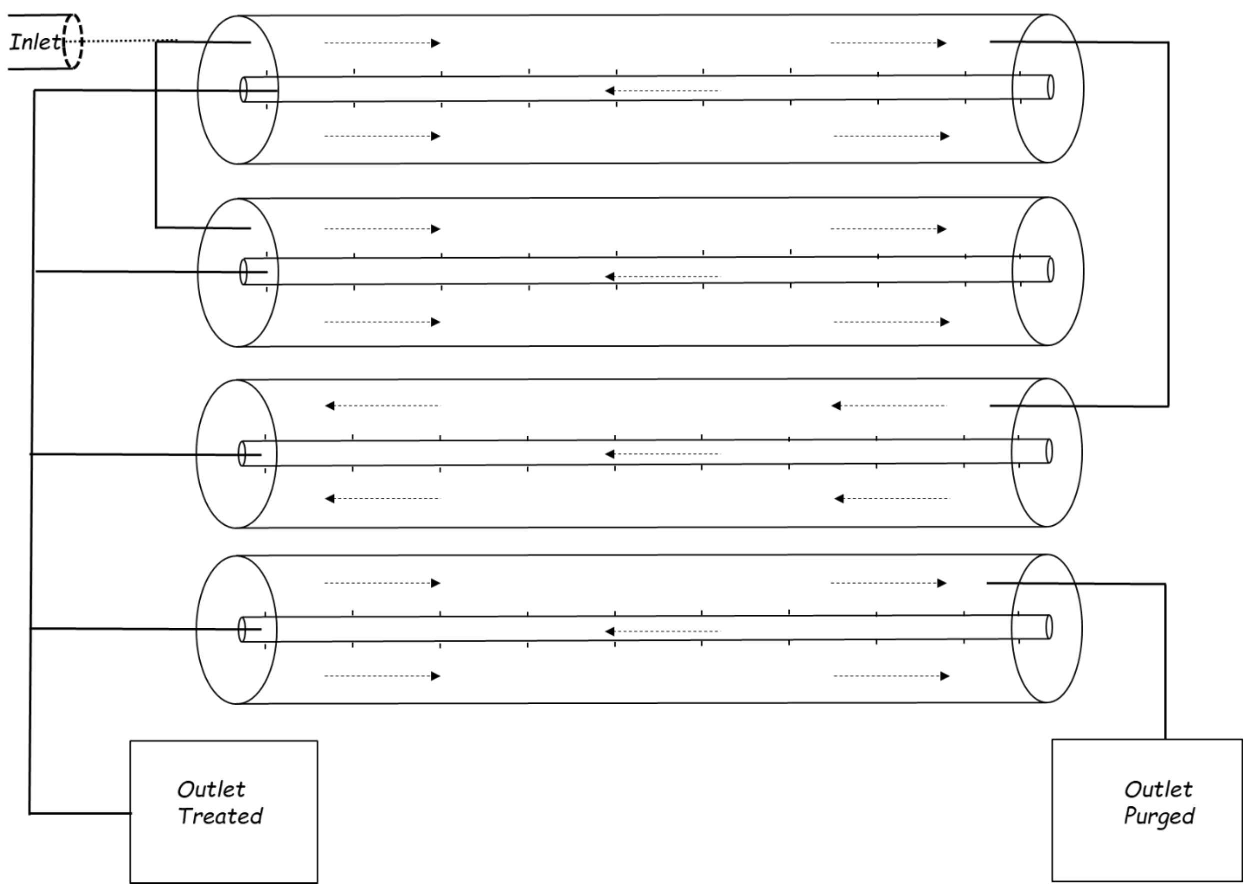

Fig. 2.3 Schematics Flow Chart of RO System of Mountain Top University

2.5.2 Reverse Osmosis Design and Process description

The RO process is made up of three streams: feed, permeate, and reject. Pretreatment of the feed water is required to remove suspended solids and inorganic solids, and the feed is then supplied through a semi-permeable membrane using a high pressure pump. Depending on the permeate's intended usage, post treatment may be required. The graphic above depicts a schematic representation of the RO process.

Pretreatment, high-pressure pumps, membrane systems, and post-treatment are the four main systems that make up a RO desalination plant. There is a pre-treatment system available to get rid of any suspended materials, preventing salt precipitation or microbiological growth on the membranes. A chemical feed followed by coagulation, flocculation, and sedimentation, as well as sand filtration or membrane procedures like micro filtration (MF) and ultra filtration, are examples of standard pre-treatment techniques (UF). High-pressure pumps provide the pressure required for the membrane to function properly and for the water to pass through while the salt is rejected. For brackish water, the pressure ranges from 17 to 27 bar, while for seawater, it is 52 to 69 bar. Membrane systems have a pressure vessel inside of which is a semi-permeable membrane that allows feed water to pass through. RO membranes for desalination generally come in two types: Spiral wound and Hollow fiber. Depending upon water quality of permeate and use of permeate; post treatment may consists of adjusting the pH and disinfection (Ahuchaogu *et al*., 2018; Moreira *et al.*, 2021).

2.5.3 The Functional Technicalities of RO

Reverse osmosis is a continuous water treatment process that employs pressure to push source water through a thin membrane and remove pollutants.

Reverse osmosis (RO) reverses the osmosis principle, which describes how water containing dissolved salts naturally tends to flow through a membrane from lower to greater concentrations of salt. This process is found throughout nature. Plants use it to absorb water and nutrients from the soil. The kidneys of both humans and other animals employ osmosis to draw water from the blood.

The process is turned around by the reverse osmosis principle. In a RO system, pressure—typically from a pump—is used to counteract natural osmotic pressure and force feedwater—which is loaded with dissolved salts and other impurities—through a highly developed, semipermeable membrane, which filters out a significant portion of the contaminants. Water that has undergone this procedure is extremely pure.

The system passes the rejected salts and contaminants to the drain or on to other processes once they concentrate and gather above the membrane. 75% of the feedwater is typically cleansed in commercial or industrial applications. 85% of feedwater is cleaned for applications where water conservation is crucial.

When using a RO system, the water is filtered in one direction and polluted in the other. This process is known as cross-filtration. Cross-flow filtering prevents the buildup of impurities by allowing water to flush away contaminant buildup and creating enough turbulence to maintain the membrane's surface clean.

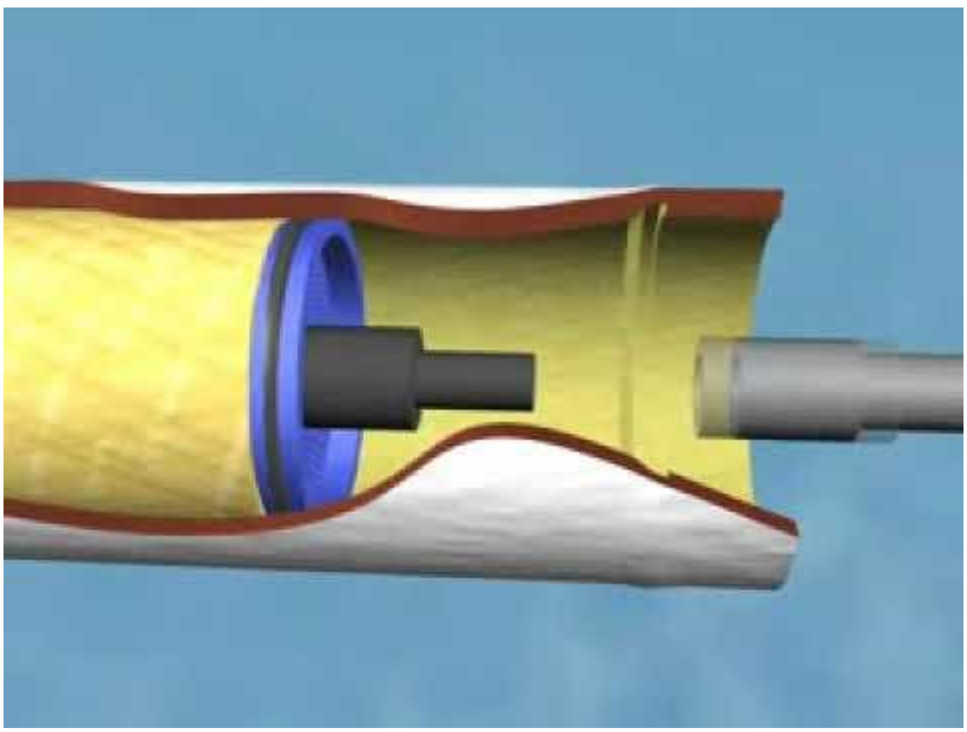

Fig.2.4 RO Housing Components

2.5.4 Removable contaminants by RO

The following water contaminants are removed by Reverse osmosis operation in water treatment system

i. Arsenic
ii. Barium
iii. Calcium
iv. Chlorine
v. Colloids
vi. Dyes
vii. Fluoride
viii. Herbicides
ix. Lead
x. Mercury
xi. Nickel
xii. VOCs
xiii. Sulphates
xiv Nitrates
xv. Proteins
xvi. Pesticides
xvii. Phosphates
xviii. Sediments
xix. Sodium
xx. Dissolved Solids

Some reverse osmosis systems can also remove organic contaminants like certain viruses and bacteria from water, though they may not be able to remove 100% of these contaminants.

2.5.5 Treatment options for Reverse Osmosis

Distilleries utilize a variety of primary, secondary, and tertiary wastewater treatment methods all around the world.

The screening and equalization processes are used, then biomethanation. The two most popular methods for disposing of effluent are fertilizer irrigation and biocomposting with sugarcane press mud (Yang et al., 2019). The treatment provided in the instance of a distillery using grain uses DWGS separation, incineration, and biomethanation. Thin slop and process condensate are the process streams that can be recycled. the waste produced after solids have been removed. The fermentation process may be impacted by the high TDS, high temperature, and other ingredients found in thin slop, such as organic acids, dead yeast cells, and carbohydrates. The process condensate from the evaporator has high temperature, low pH, organic acids etc. This can be treated by RO system and used in the process or for utility operations (Lanjewar *et al*., 2021).

2.5.6 Advantages of RO System for Wastewater treatment

The following are some benefits of the RO process that make it desirable for the treatment of diluted aqueous wastewater:

(1) They are simple to design and operate, have low maintenance requirements, and are modular in nature, making system expansion simple;

(2) RO membrane processes can remove both inorganic and organic pollutants simultaneously;

(3) allow recovery/recycle of waste process streams with no effect on the material being recovered;

(4) require less energy than other technologies; and

(5) Processes can considerably reduce the volume of waste streams so that these can be treated more efficiently and cost effectively by other processes such as incineration (Macedonio and Drioli, 2017; Kim and Hong, 2018).

(6) Because antiscalant and biodispersent are used, the plant is generally run at ambient temperature, which decreases scale development and corrosion concerns and lowers maintenance costs.

(7) The modular nature of the RO process enables flexibility in the design of desalination plants of various sizes.

(8) Specific energy requirement is significantly low 3- 9.4 kW h/m3 product.

(9) Because the process is electrically driven, it can easily be powered by solar panels.

Furthermore, RO systems can be used to replace or supplement other treatment processes like as oxidation, adsorption, stripping, or biological treatment (among many others) to generate high-quality product water that can be reused or discharged.

2.5.7 Advantages of House hold RO System for Drinking water treatment

i. **Total dissolved solids reduction:** Reverse osmosis is one of the few water treatment methods that can claim to reduce total dissolved solids. Other treatment technologies that have this capability are frequently less efficient than reverse osmosis.
ii. **Cost-effectiveness:** Because it is more cost effective than other filtration processes, reverse osmosis is widely used in industrial settings. It enables plants to process enormous amounts of water while staying within their established budgets.

iii. **Eco-friendliness:** Compared with other treatment methods, reverse osmosis is also relatively environmentally friendly. It uses less energy than other methods like thermal distillation because it does not rely on energy generation. Reverse osmosis can help a facility minimize its carbon footprint, safeguard the environment, and contribute to the fight against climate change.
iv. **Alkalinity and hardness removal:** The carbonate ions that cause undesired alkalinity as well as the calcium and magnesium ions that cause hard water are eliminated by reverse osmosis.

2.5.8 Challenges of Reverse Osmosis system

Challenges that can be encountered with this system are:

i. **Waste:** Systems for reverse osmosis consume a lot of water. Due to their ability to produce the backpressures required for wastewater recovery, industrial systems often handle this problem better than domestic systems. However, waste is a difficult issue to adequately consider. Because higher recovery rates can reduce the effectiveness of pollutant removal rates, some systems must additionally set a cap on their wastewater recovery.
ii. **Mineral removal:** In general, RO systems indiscriminately target water contaminants. Minerals like calcium and magnesium are among the solids that were removed because of their benefits. Remineralization of the treated water can be necessary to prevent pipeline infrastructure corrosion.
iii. **Waste stream challenges:** The solvent stream produced by RO procedures is typically waste that needs to be properly disposed of. Facilities must take precautions to properly and legally dispose of this trash.

2.6 Applications of Reverse Osmosis

This technique benefits from a membrane-based process that achieves concentration and separation without a change in state, the use of chemicals, or heat energy. As a result, the process is energy efficient and perfectly suited for recovery applications. The review of the literature demonstrates that reverse osmosis (RO) systems can be used to treat wastewater and sea water, as well as effluents from the beverage sector, distillery wasted wash, ground water treatment, recovery of phenol chemicals, and wastewater reclamation.

2.6.1 Basics Steps of an Industrial Reverse Osmosis System

1. Pre filteration
2. Reverse Osmosis
3. Drainage
4. Storage.

2.6.2 The functionalities of Industrial Reverse Osmosis

An industrial facility's reverse osmosis diagram could show three to five major stages in action. A semipermeable membrane, a carbon filter, and a sediment filter are all components of a three-stage reverse osmosis system. These correspond to stages 1, 2, and 3, accordingly. To remove particles that the first membrane could have missed, a four-stage system adds a second membrane.

What is the operation of a five-stage reverse osmosis system? The same sediment filter, carbon filter, and semipermeable membranes are used in a five-stage system. Additionally, it includes post-filtration, which involves passing the water through a second carbon filter to get rid of any remaining contaminants. Remineralization is a phase that some five-stage RO systems include as well. It adds useful minerals back to the cleaned water.

Below are the basic steps of an industrial reverse osmosis system:

- **Prefiltration:** Two different kinds of prefilters are used in reverse osmosis systems to remove bigger particles like silt and chlorine. Dust, dirt, and other impurities are initially removed from the water using a sediment prefilter. The water then continues on to a prefilter made of activated carbon, which binds to and eliminates contaminants including chlorine and volatile organic compounds (VOCs).
- **Reverse osmosis:** Reverse osmosis is the primary process that happens after prefiltration. The water is now sent across a semipermeable membrane by the pump, trapping smaller, more difficult-to-remove dissolved solid particles. The majority of the dissolved particles in the water can frequently be removed during this reverse osmosis step.

- **Drainage:** After the water has passed through the semipermeable membrane, the contaminants are eliminated through drainage, which flushes them into the sewer system. Because impurities can accumulate on the membrane and reduce its effectiveness, this step is crucial. The RO system's efficiency is maintained at a high level by draining the accumulated contaminants.
- **Storage:** The purified water is then put into storage until it is used. A pressure tank that is big enough to hold the treated water without creating waste is frequently used as the storage container. A second carbon filter that can catch any stray contaminants may be added after the cleansed water has passed through the first one.

2.6.3 Distillery Spent Wash

The spent wash in distillery is acidic having pH 3.94 -4.30, dark brown liquid with high BOD 45000 – 100000 mg/ l and COD 90000 – 210000 mg/ l, and emits obnoxious odour but do not contain toxic substances, when discharged in water streams gives immediate discoloration and depletion of dissolved oxygen, posing serious threat to the aquatic flora and fauna (Mane *et al.*, 2006). Membrane based separation processes like ultra-filtration (UF), nano filtration (NF), reverse osmosis (RO) and membrane bioreactor (MBR) have been applied for treating distillery effluent (Saleem and Zaidi, 2020). Gökçek (2018) studied the paper on "Treatment of Distillery Spent Wash where UF and RO membranes on pilot plant uses thin film composite membrane for purification of the wastewater for removal of colour and the contaminants. The result obtained which indicate suitability of RO for reducing freshwater consumption by recycling water which will minimize the waste disposal costs and reduction in regulatory pressure. The pilot plant gives removal of Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), sulphate and potassium with the rejection efficiency of 97.9%, 96.8%, 97.9%, 99.7% and 94.65%, respectively. The above results were obtained for feed flow of 15 lit/min and feed pressure of 20 atm. They found TDS in permeate water less than 1000 ppm and COD 500 ppm i.e. within limits as per the guidelines of the World Health Organization (WHO).

2.6.4 Ground Water Treatment

Zhou et al. (2018), studied ground water treatment in which two stage RO module was used in the beverage industry. The results of the physicochemical analysis showed that the raw water taken from the groundwater contained significant amounts of solutes and suspended solids (TDS ranging from 757 mg/l to 964 mg/l). The Feed water composition shows that the raw water was rich in sulphate, chloride and calcium and highly furring. The quality of water produced from the pre-treatment demonstrates that turbidity underwent the strongest reduction 87% i.e. reduced from 1.3 NTU to 0.167 NTU. The rejection rate varied between 97% and 98% and remained stable during the RO operation which signified that the permeate quality was constant with total conductivity decreased from 1070 µs/cm to 33 µs/cm with larger rejection of 95 % ions. The bacteria removal efficiency of microorganisms decreased from 90 UFC/100 ml to 50 UFC/100 ml, which represents a total elimination of 44%. However, the rejection of nitrate was lowest i.e. about 88.18%. Hence the obtained results showed applicability of RO for the ground water treatment.

2.6.5 Recovery of Phenol Compounds

Yu *et al.,* (2019) uses Toray composite membrane PEC-1000 (polyfuran) and found several organic rejections with 97% for acetone and 99% for phenol. Kim et al. (2019) reported separation results for several polar organic solutes (alcohols, phenols, carboxylic acids, amines, and ketones) and various phenolic derivatives for a composite membrane. They found that the main factors affecting rejection included molecular weight, molecular branching, polarity, and degree of dissociation for ionizable compounds.

Shahid *et al.,* (2018) investigated rejection and flux characteristics of FT30 membranes for separating various pollutants (PAHs, chloro phenols, nitro phenols) and found membrane rejections were more than (>98%) for the organics under ionized conditions. They also found substantial water flux decline occurred even for dilute (< 50 mg/L) solutions of non-ionized organics and observed significant organic adsorption on the membrane in some cases. Choudhury *et al.* (2018) reported separation results for several different membranes (four composite and two asymmetric) for a variety of single and multi-component organic solutions, including many organic pollutants. Rejections varied from only 25% up to >99% depending on the solute, but generally the composite membrane rejections were higher.

Marbach and Bocquet (2019), conducted experiments for the recovery of phenol compounds on a laboratory scale on spiral wound polyamide RO module and parameter were studied. The Perma-TFC polyamide RO membrane in Spiral wound configuration were used in their study. It was found that the value of rejection increases with the increasing applied pressure. The maximum rejection obtained is around 90% for phenol.

2.6.6 Reclamation of wastewater

The wastewaters contain organic contaminants, including pharmaceutical compounds, pathogens, disinfection by-products, and pesticides. They are less affected by biological degradation by bacteria in activated sludge process. Due to their water solubility, they are dissolved in water and not being removed in the sludge which will create problem to the safety of reclaimed water. Thus, use of RO process for separation is a key step in the safe recovery of water from wastewater source .The recent use of RO in reclamation of wastewater is done in GWR facility in Orange County for indirect potable use. It is used to produce 280,000 m3 /d of treated wastewater that is used to augment the groundwater in the region that supplies local municipalities with drinking water (Kim *et al*., 2019). RO plays an integral role in the advanced treatment process used at this plant. In this plant, low pressure, high rejection ESPA2 membranes are used to make RO permeate with less than 50 mg/l TDS which will make reclaimed water safe for potential potable reuse.

2.6.7 Purification of Seawater

In SWRO (Sea water Reverse osmosis) unit, the operating conditions and performance of the HFF SWRO unit which received the NF product as feed. The SWRO unit consists of two vessel units, which are connected in series. During the test period, the operating pressure was maintained at 60 Kg/cm^2 and the temperature ranged from 23 to 34^o C. The average permeates recovery of the first and second vessels were around 30 and 21 percent respectively and the overall recovery of the integrated SWRO system was about 45%. Chemical analysis revealed that the majority of the hardness ions and other dissolved salts were concentrated in the brine reject. The study revealed that an increase of top Brine Temperature from 100^0C to 130^o C produces 48% increase in water production (Gökçek, 2018).

2.6.8 Water Quality Monitoring

In order to sustain and safeguard human health, the World Health Organisation (WHO) has set the international water quality (WQ) standards as guidelines of drinking water monitoring or evaluation as ways to safeguard human health. The water quality standards are set of quantitative criteria designed to maintain the quality of water. These standards prescribe which elements can be tolerated in drinking water and the maximum concentration of these substances (Li and Wu, 2019).

The quality of potable water for drinking water is determined by the concentration of physical, chemical and biological parameters found in tested and approved water through the standard procedures. If the contaminants exceed the acceptable range of concentration recommended by WHO standard of drinking water quality, then it will be regarded as a pollutant. High concentration of nitrates and heavy metals as well may result in infectious diseases and thereby causing effects on human health for an example, the blue baby syndrome (Roy, 2019). Amendments have been made on the WHO guidelines of drinking water quality as a way of eliminating and reducing the well-known microbe's risks and parameters. To ascribe water as safe for drinking, it has been set and recommended that risks should be below expected range within the WHO guidelines, but therefore it does not mean that the water will be risk free of contamination or the quality of water must not be lowered by the purifications or water treatments (Westall and Brack, 2018).

CHAPTER THREE

3.0 Materials and Methods

3.1 Collection of Samples

Newly blown 75Cl Polyethylene Terephthalate (PET) bottles from Preforms were used for collecting of samples. The bottles were rinsed with samples to be collected before sampling.

3.2 Sampling Site

Samples were taken at Mountain Top University Ventures Water treatment plant.

The samples were collected into the 75CL PET bottles containers leaving 2.5 cm of space for oxygen. Water samples collected were properly labeled with dates and kept under the condition that minimize external influences such as temperature and pressure

3.3 Sample Collection

Sampling period is from 19th January to April 20th 2022

The first sampling took place on 19th January 2022 for the period of three months (January 19th to April 13th 2022: 13 weeks).

i. Raw water
ii. Filtered water after filtration process
iii. Purged water from Reverse Osmosis
iv. Treated water from Osmosis

The required physico chemical analysis were carried out and the rate of flow each of the samples were determined

Subsequent samplings were

i. Filtered water after filtration process
ii. Purged water from Reverse Osmosis process
iii. Treated water from Reverse Osmosis process

Samples were taken in duplicates every Wednesday of the week before and after filtered bed backwash process.

Determination of inlet and outlet Flow rates

3.4 Physico Chemical analysis

The following physicochemical analysis were carried out on the samples immediately after collection of samples

3.4.1 pH

This test was carried out to determine the hydrogen ion concentration in the water sample. The pH was determined using HANNA Instrument pH meter, which was first calibrated with buffer pH. The electrode of the pH meter was rinsed with distilled water. Samples of 20 ml of water were measured into a labeled beakers, then the electrode was inserted into the sample measured. The reading was taken when the pH meter displayed a stable value. The electrode was rinsed with distilled water and cleaned with tissue paper after each insertion in the various samples

3.4.2 Temperature

While taking the pH of the sample, using the Meter mentioned above, the meter was switiched to temperature measurement to determine the temperature.

3.4.3 Conductivity

After the determination of pH and Temperature, the Electrical conductivity was also determined by using a theme instrument as above.

3.4.4 Hardness (Cal/Mg)

The Spectrophotometer was on then was scrolled down to select 13 Ca & Mg Hard-UDV from the menu. A clean vial (0156) was rinsed with the sample and filled with 3mL of the sample, the vial was inserted into the chamber then the lid was closed and SCAN BLANK was selected. Afterwards, the vial was removed from the spectrophotometer.

3mL of the sample was added to a Calcium Hardness UDV vial (4309) and shaked vigorously for 10 seconds, the tube was inserted into the chamber to read the concentration in ppm of the Ca & Mg hardness present in the sample.

3.4.5 Hardness (Ca)

A tube (0608) was filled to 12.9 ml line with the water sample and 6 drops of sodium hydroxide with metal inhibitor was added to it, the solution was capped and swirled to mix. To the solution, one calcium hardness indicator tablet (5250A) was added, capped and swirled to disintegrates the tables. Direct reading titrator (0382) was filled with hardness reagent(4487DR) and was inserted immediately into the centre hole of the test tube cap. While gently swirling the tube, the plunger was slowly pressed to titrate until clear blue colour was observed. The reading was recorded as ppm calcium hardness

3.4.6 Iron (Fe)

The Spectro meter was on after which was scrolled down to select 51 Iron bipyr from the menu

A clean tube (0290) was rinsed with sample water and filled to the 10mL line with the sample then the tube was inserted into the chamber, the lid closed and SCAN BLANK was selected.

Afterwards, the tube was removed from the spectrophotometer, 0.5mL iron Reagent #1 (v-4450) was added to it and mixed followed by 0.1g iron reagent #2 powder (v4451). The mixture was capped and shake vigorously for 30 second. The solution was left for three minutes for maximum color development. At the end of 3 minutes, the tube was inserted into the spectrophotometer to read the concentration of Iron in ppm present in the sample.

3.4.7 Total Solids (TS), Total Suspended Solids (TSS), and Total Dissolved Solid (TDS)

Total Dissolved Solids (TDS)

This is a measure of the total amount of dissolved matter, determined by evaporation. High concentrations of dissolved matter causes process interference and foaming in boilers.

Porcelain dish, electric oven, electric water bath, dessicator.

The water sample is filtered through Whatman No.42 filter paper to obtain a clear sample. Take 100ml to an already weighed porcelain dish and evaporate to dryness in the water bath. Dry the residue for one hour at 103ºC in the over and after cooling, weigh the dish again.

Calculation of Test Result

$$\text{TDS (mg/l)} = \frac{W \times 10^6}{V}$$

Where:

W = Weigh in gram of residue obtained

V = Volume in ml of the sample taken

Total Solids

Total solids is the sum of dissolved and suspended solids gravimetrically determined.

Porcelain dish, Sand bath, Electric oven, Dessicator.
100ml of a well shaken sample is taken and transferred into a previously weighed porcelain dish. It is evaporated completely on a sand bath, before taking it to the oven set at 103 ^{o}C for drying for one hour. The dish is cooled and re-weighed.

Calculation of Test Result

$$\text{Total Solids Mg/l} = \frac{W \times 10^6}{V}$$

W = Weight in grams of residue obtained

V = Volume in ml. of the sample taken.

Suspended Matter

Suspended matter is the difference between Total Solids and the Total Dissolved Solids.

CHAPTER FOUR

4.0 Results and Discussion

4.1 Flow rate of Water in process

The flow rates of some of the treatment processes were determined. As indicated on Table 4.1, about the volume of raw water pumped was filtered. The quantity of purge water which was rejected was over thrice the treated water from the RO. This implies that quantity of the treated water finally accepted through the process about one fifth of the input.

Table 4.1 Flow rates of the process

S/N	Samples	Time (s)	Quantity (mL)	Flow rate (mL/s)
1.	Raw water	5	5,500	1,100
2.	Filtered water	10	10,593	1,059
3.	RO (Purged water)	3	2,149	716
4.	RO (Treated)	10	2,093	209

4.2 Physicochemical analysis results

pH of RO treated and Purge are interwoven, about the same. Before and after Back wash are both within acceptable limit.

Results obtained a week after backwash were considered. The pH of RO Accepted treated water ranges from 6.79 to 7.10 in Fig. 4.2 Graph of pH against Period (weeks) of RO Treated and Purge (After Backwash)

, and the purge ranges from 6.73 to 7.07. Conductivity (µs/cm) of RO accepted ranges from 101.4 to 108.4 in Fig.4.3 Graph of Conductivity (µs/cm) against Period(weeks) of RO Treated and Purge (Before Backwash) and the purge from 101.3 to 109.2. Total Hardness (mg/L) of RO accepted ranges from 9.0 to 15 in Fig4.5 Graph of Total Hardness (Ca/Mg) (mg/L) against period (weeks) of RO Treated and Purge (Before Back Wash)

, and purged ranges from 12 to 16. Iron (Fe) (mg/L) RO accepted ranges from 0 to 0.06in Fig 4.7 Graph of Iron (Fe) against period (weeks) of RO Treated and Purge (Before Back Wash)

and purge ranges from 0 to 0.07. Total Dissolved Solids (mg/L) RO accepted ranges from 4 to 60 in Fig.4.21 Graph of Total Dissolved Solids TDS (mg/L) against Period(weeks) of RO Treated

and purge ranges from 6 to 55. Total Suspended Solids (mg/L) RO accepted ranges from 4 to 55 in Fig.4.24 Graph of Total Suspended Solids TSS (mg/L) against Period(weeks) of RO Reject

and purge ranges from 6 to 60.

Table 4.2 pH of Treated and Reject Sample Before and After Back Wash

Weeks	Treated		Reject	
	Before	After	Before	After
1	6.95	7.06	7.0	6.92
2	7.02	6.74	6.98	6.98
3	6.79	7.03	7.04	7.01
4	7.10	7.12	6.81	7.05
5	6.8 2	7.03	6.73	6.81
6	7.06	7.01	7.01	7.03
7	7.02	6.97	7.05	6.88
8	6.89	7.05	7.03	6.88
9	6.82	6.92	6.91	6.82
10	6.79	6.98	6.99	6.92
11	7.03	6.84	7.06	7.03
12	7.07	6.91	7.01	7.01
13	7.10	7.04	7.04	7.07

Table 4.3 Conductivity (µs/cm) Test of Treated and Reject Sample Before and After Back Wash

Weeks	Treated		Reject	
	Before	After	Before	After
1	101.4	98.7	102.3	101.1
2	106.1	102.4	102.3	101.4
3	102.9	101.1	109.2	108.8
4	103.6	105.7	101.3	100.4
5	105.5	104.1	108.8	108.6
6	102.6	101.5	103.9	102.8
7	106.3	101.9	106.3	102.7
8	108.4	101.6	102.7	103.1
9	104.2	103.6	107.3	104.5
10	103.7	101.8	105.3	103.1
11	105.3	103.9	106.3	104.8
12	105.3	103.7	103.6	101.3
13	103.5	102.0	105.2	103.7

Table 4.4 Total Hardness Test (mg/l) Before and After Back Wash for RO Treated and Reject

Weeks	Treated		Reject	
	Before	After	Before	After
1	15	14	16	14
2	12	9	12	10.4
3	11.5	9	14	12.2
4	12	9.3	13.7	11.6
5	12.8	10	14	12
6	13	8	13.6	11
7	12.6	10.1	14.3	14.3
8	12.4	11	13.3	12.8
9	10.2	9.6	14	12
10	9	8.1	14	10
11	9	7.4	12	10. 7
12	9.4	8	13	10.9
13	9.7	7.3	12.2	11

Table 4.5 Iron (Fe) Before and After Back Wash for RO Treated and Reject

Weeks	Treated		Reject	
	Before	After	Before	After
1	0.05	0.05	0.06	0.03
2	0.06	0.04	0.07	0.04
3	0.03	0.00	0.05	0.03
4	0.04	0.04	0.05	0.03
5	0.04	0.02	0.04	0.02
6	0.02	0.01	0.03	0.03
7	0.02	0.01	0.05	0.04
8	0.01	0.00	0.06	0.02
9	0.01	0.01	0.04	0.02
10	0.01	0.00	0.04	0.01
11	0.01	0.00	0.03	0.01
12	0.00	0.00	0.01	0.01
13	0.00	0.00	0.01	0.00

Table 4.6 Total Suspended Solids (mg/l) Before and After Back Wash for RO Treated and Reject

Weeks	Treated		Reject	
	Before	After	Before	After
1	90	100	100	100
2	90	99	90	80
3	90	100	100	100
4	90	90	100	100
5	100	89	113	99
6	124	100	134	100
7	79	100	101	83
8	125	83	124	85
9	100	100	100	100
10	113	70	124	89
11	100	100	100	90
12	125	80	99	100
13	125	100	100	80

Table 4.7 Total Dissolved Solids before and After Back Wash (mg/l) for RO Treated and Reject

Weeks	Treated		Reject	
	Before	After	Before	After
1	6	24	20	25
2	4	21	6	11
3	18	36	18	24
4	4	14	20	25
5	31	22	37	28
6	53	36	55	32
7	6	30	12	10
8	50	17	42	10
9	31	39	21	25
10	38	7	40	17
11	30	37	16	12
12	60	20	16	26
13	60	7	30	11

Table: 4.8 Quality Analysis of Water Samples Before Backwash

pH differences from 7.21—7.13 is 0.08

Conductivty differences from 109.2—108.4 is 0.8(µ cm)

Total hardness(mg/L) differences from 16.0 — 15.0 is 1(mg/L)

Iron (Fe) differences from 0.07— 0.06 is 0.01(mg/L)

Total Suspended Solids differences from 134 – 125 is 9(mg/L)

Total Dissolve Solids differences from 60 – 55 is 5(mg/L)

	PARAMETERS	TYPE OF SAMPLE	RANGE OF RESULTS	STANDARD
1	pH	Treated	6.79 – 7.21	6.5 – 8.5
		Reject	6.81 – 7.13	
2	Conductivity (µ cm)	Treated	101.4 – 108.4	500 max
		Reject	101.3 – 109.2	
3	Total Hardness (mg/L)	Treated	9.0 – 15.0	500 max
		Reject	12.0 – 16.0	
4	Iron (Fe)	Treated	0 – 0.06	0.3 max
		Reject	0 – 0.07	
5	Total Suspended Solids (mg/L)	Treated	79 -- 125	500 max
		Reject	90 -- 134	
6	Total Dissolve Solids (mg/l)	Treated	4 -- 55	500 max
		Reject	6 – 60	

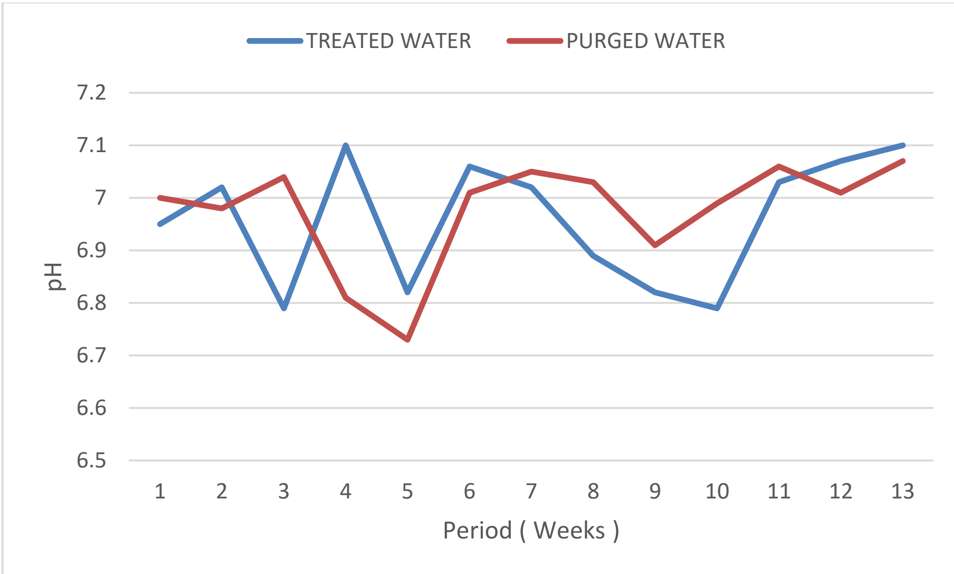

Fig. 4.1 Graph of pH against Period (weeks) of RO Treated and Purge (Before back wash)

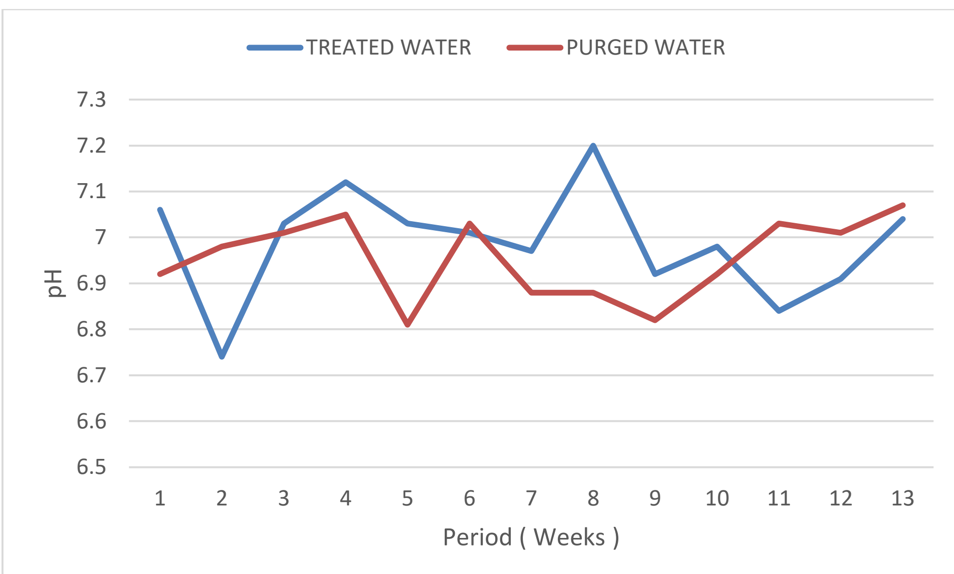

Fig. 4.2 Graph of pH against Period (weeks) of RO Treated and Purge (After Backwash)

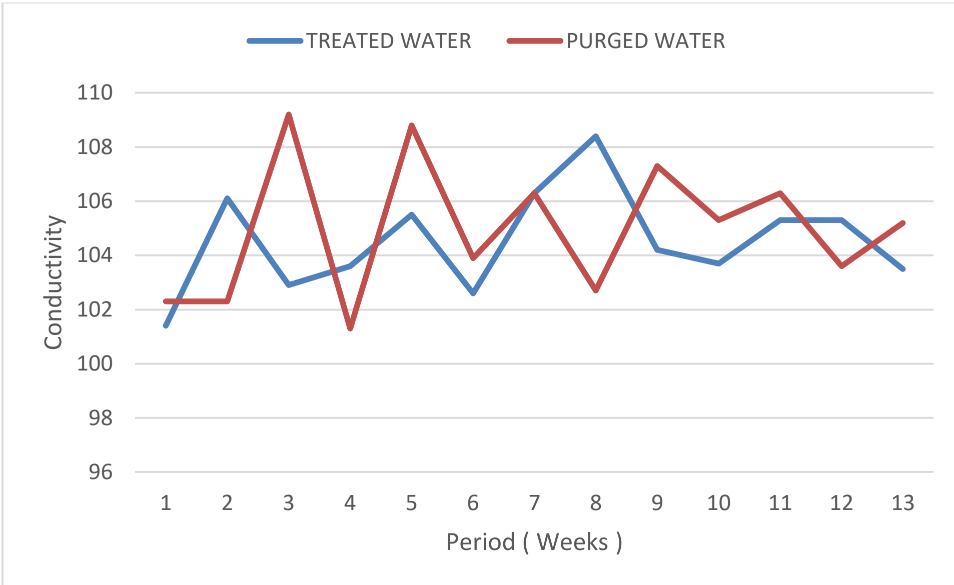

Fig.4.3 Graph of Conductivity (µs/cm) against Period(weeks) of RO Treated and Purge (Before Backwash)

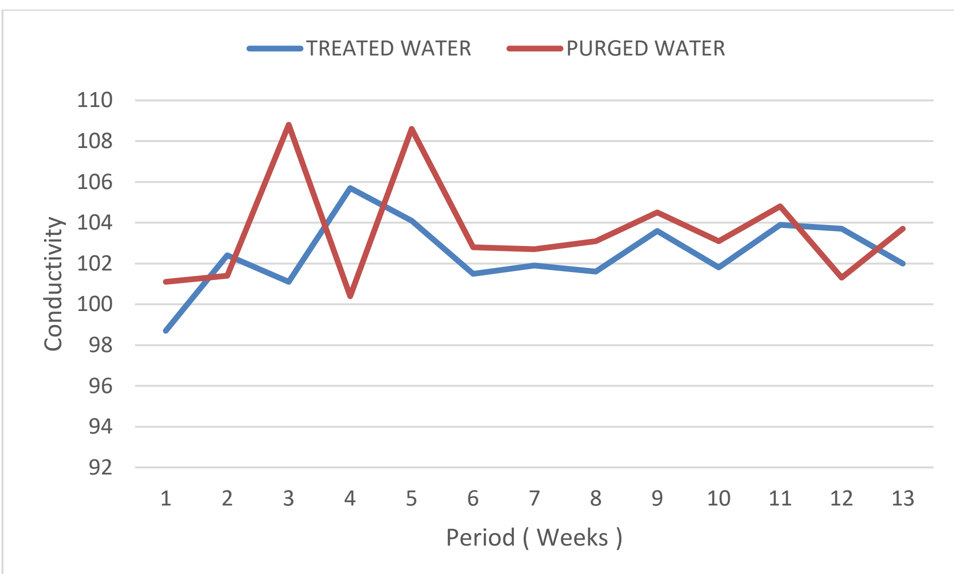

Fig.4.4 Graph of Conductivity (µs/cm) against period(weeks) of RO Treated and Purge (After backwash)

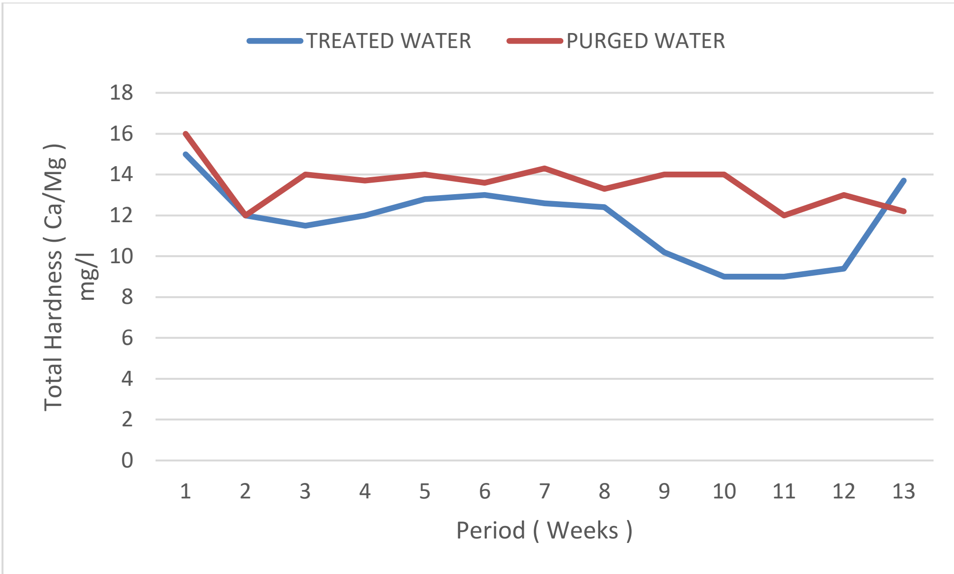

Fig4.5 Graph of Total Hardness (Ca/Mg) (mg/L) against period (weeks) of RO Treated and Purge (Before Back Wash)

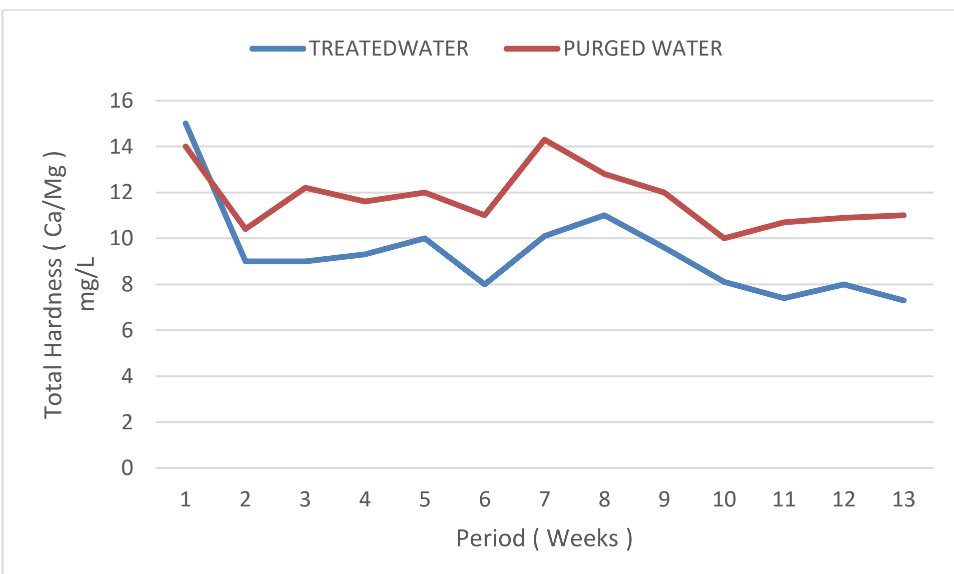

Fig 4.6 Graph of Total Hardness (Ca/Mg) (mg/L) against period (weeks) of RO Treated and Purge (After Back Wash

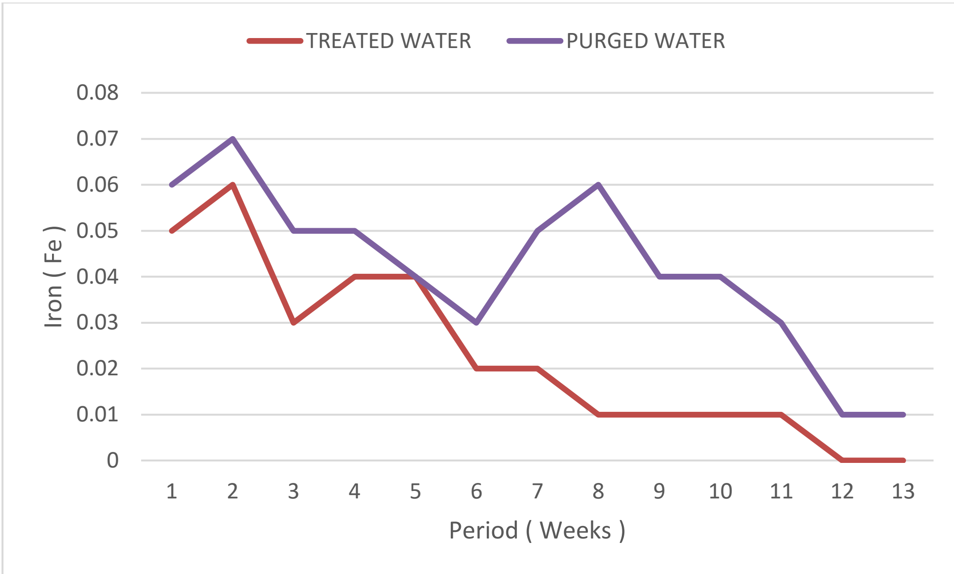

Fig 4.7 Graph of Iron (Fe) against period (weeks) of RO Treated and Purge (Before Back Wash)

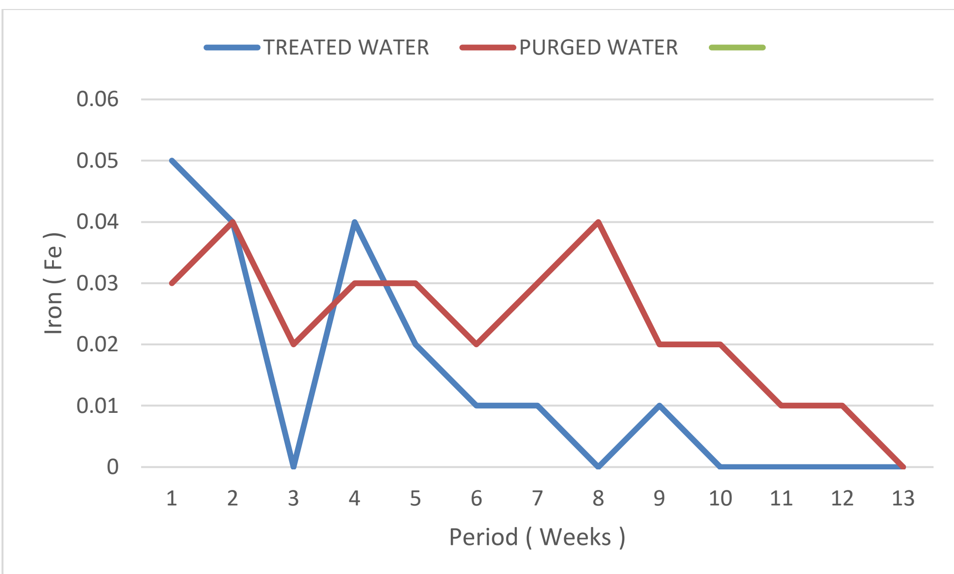

Fig 4.8 Graph of Iron (Fe) against period (weeks) of RO Treated and Purge (After Back Wash)

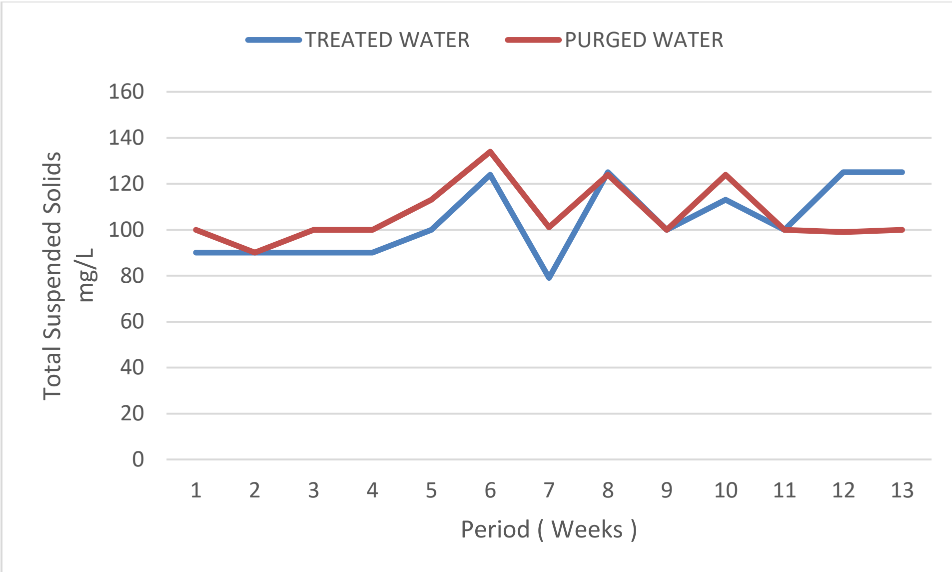

Fig 4.9 Graph of Total Suspended Solids (mg/L) against period (weeks) of RO Treated and Purge (Before Back Wash)

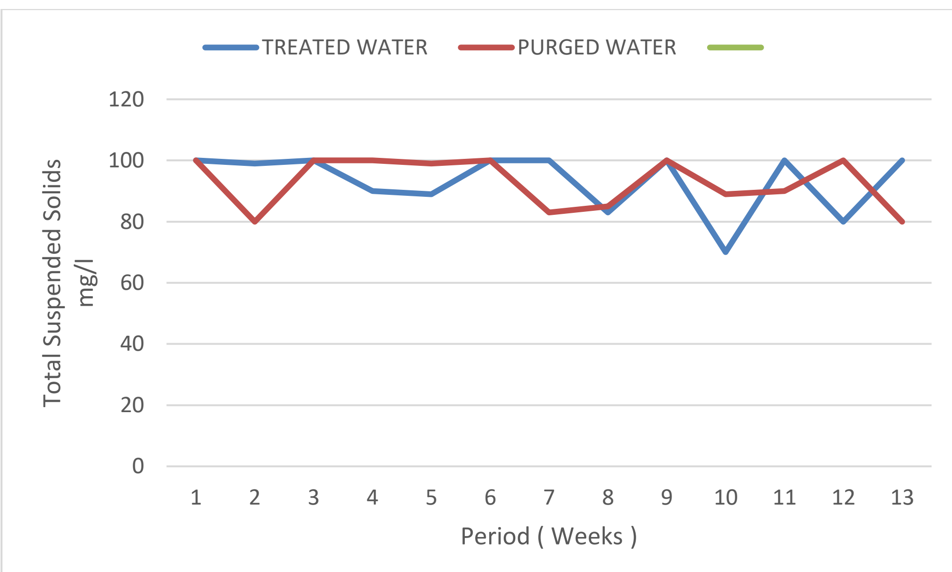

Fig 4.10 Graph of Total Suspended Solids (mg/L) against period (weeks) of RO Treated and Purge (After Back Wash)

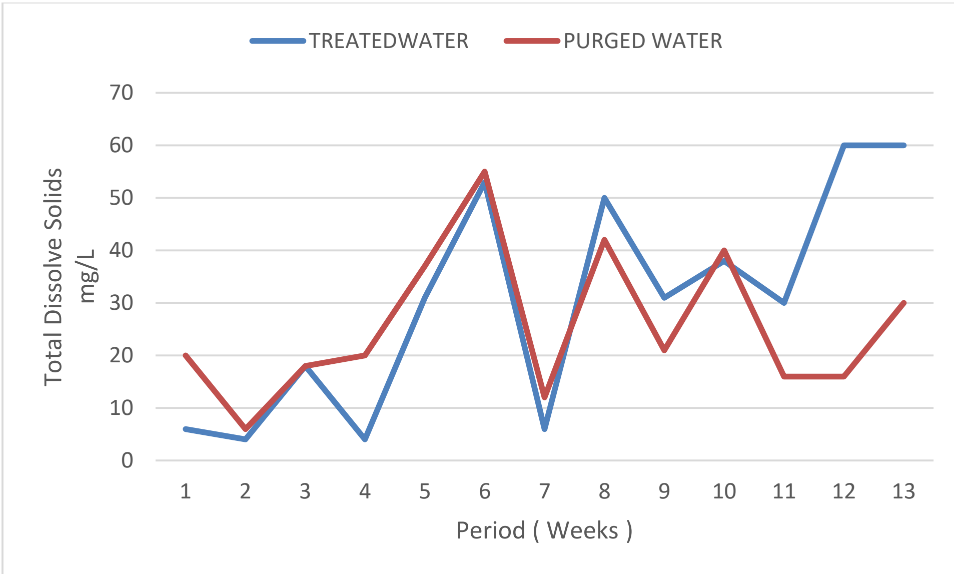

Fig 4.11 Graph of Total Dissolve Solids (mg/L) against period (weeks) of RO Treated and Purge (Before Back Wash)

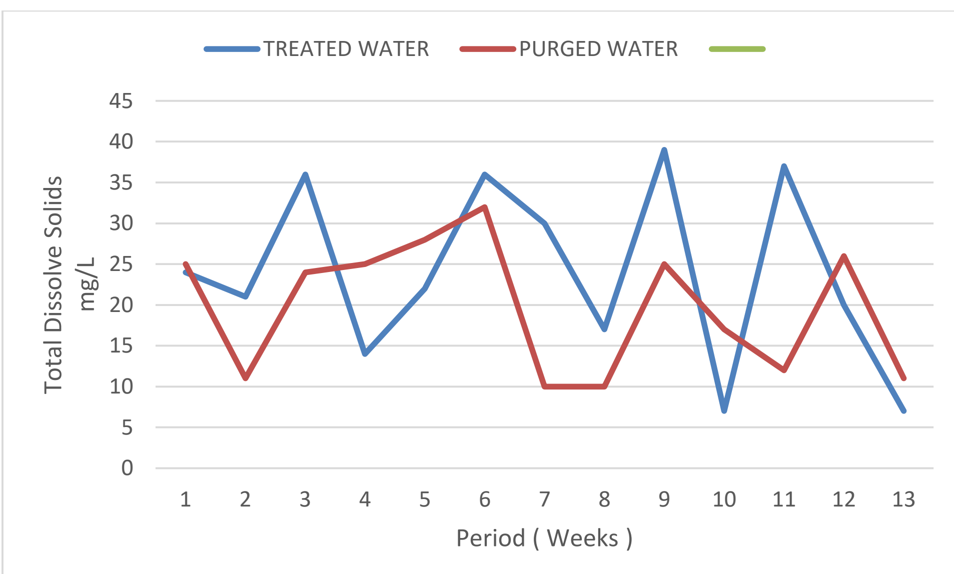

Fig 4.12 Graph of Total Dissolve Solids (mg/L) against period (weeks) of RO Treated and Purge

(After Back Wash)

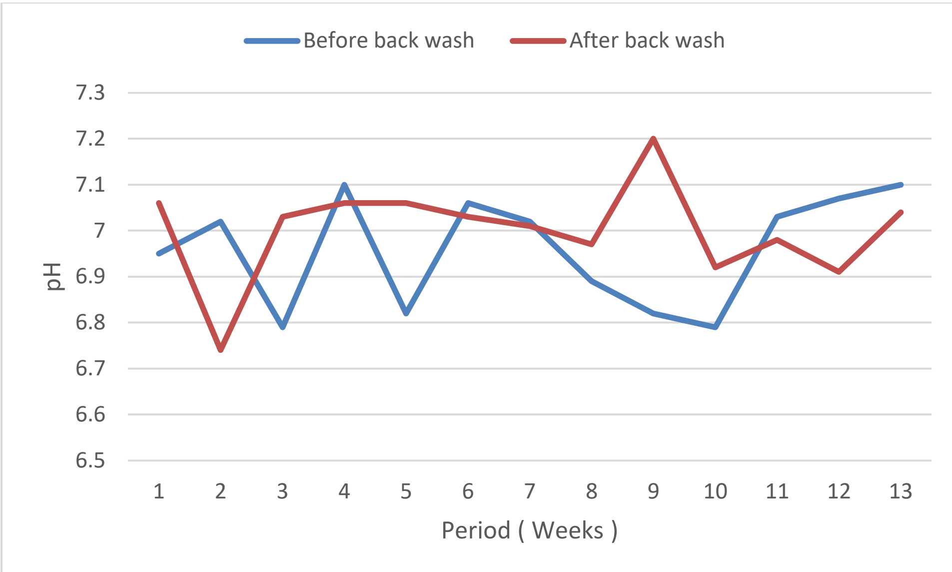

Fig. 4.13 Graph of pH against Period (weeks) of RO Treated

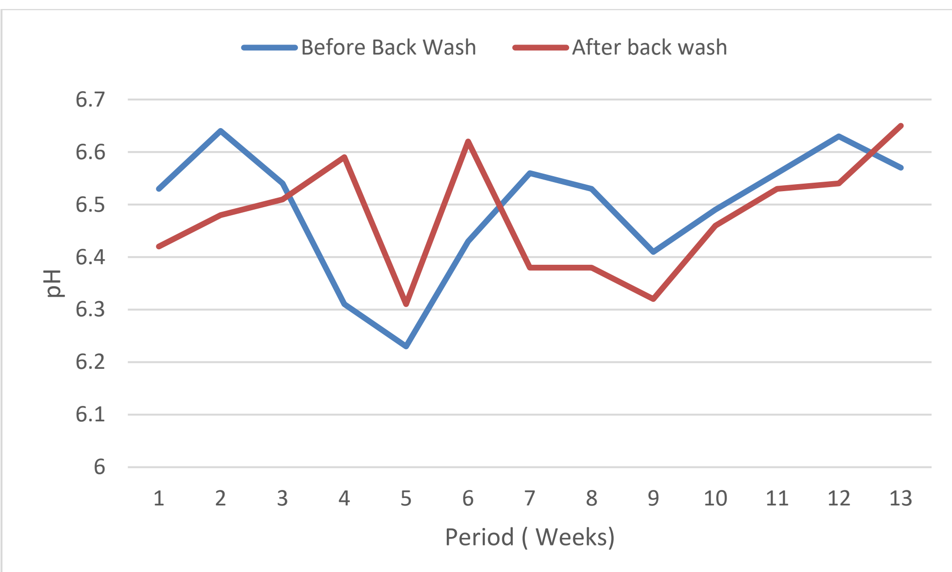

Fig. 4.14 Graph of pH against Period(weeks) of RO Reject

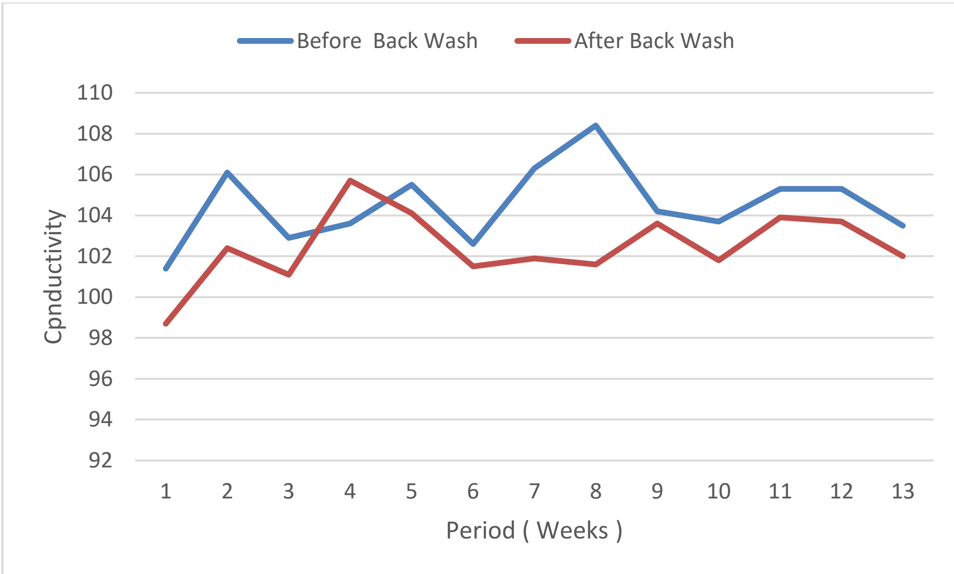

Fig. 4.15 Graph of Conductivity (µs/cm) against Period(weeks) of RO Treated

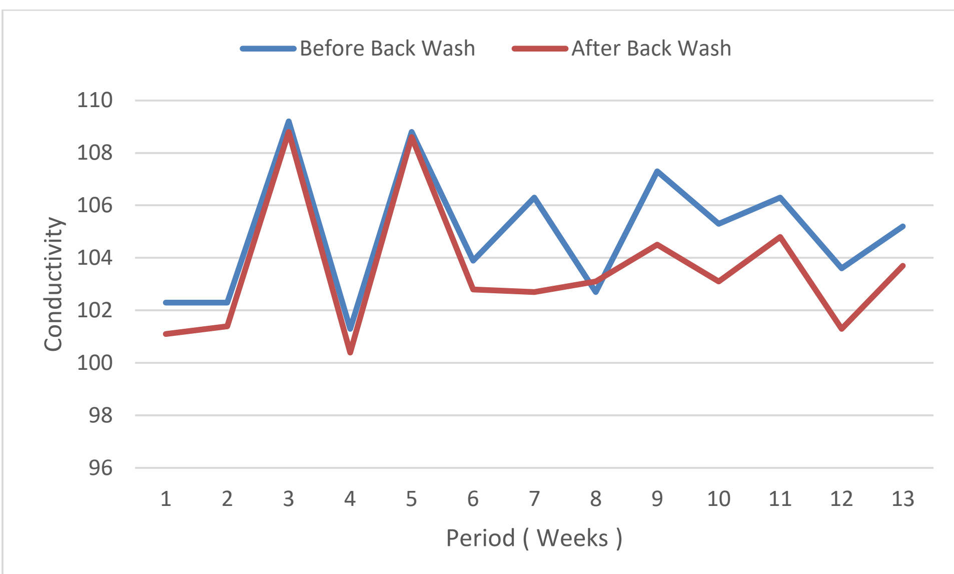

Fig. 4.16 Graph of Conductivity (µs/cm) against Period(weeks) of RO Reject

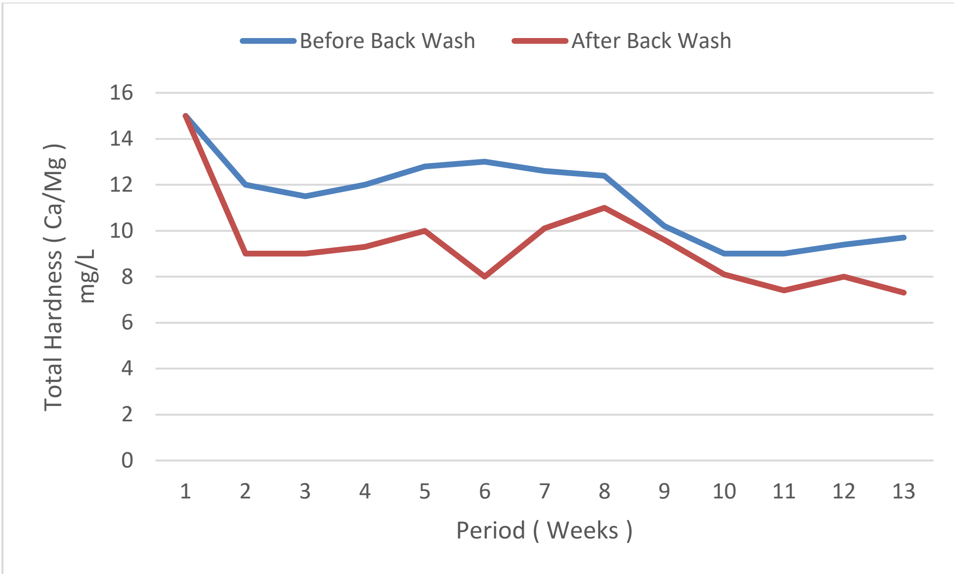

Fig.4.17 Graph of Total Hardness (mg/L) against Period(weeks) of RO Treated

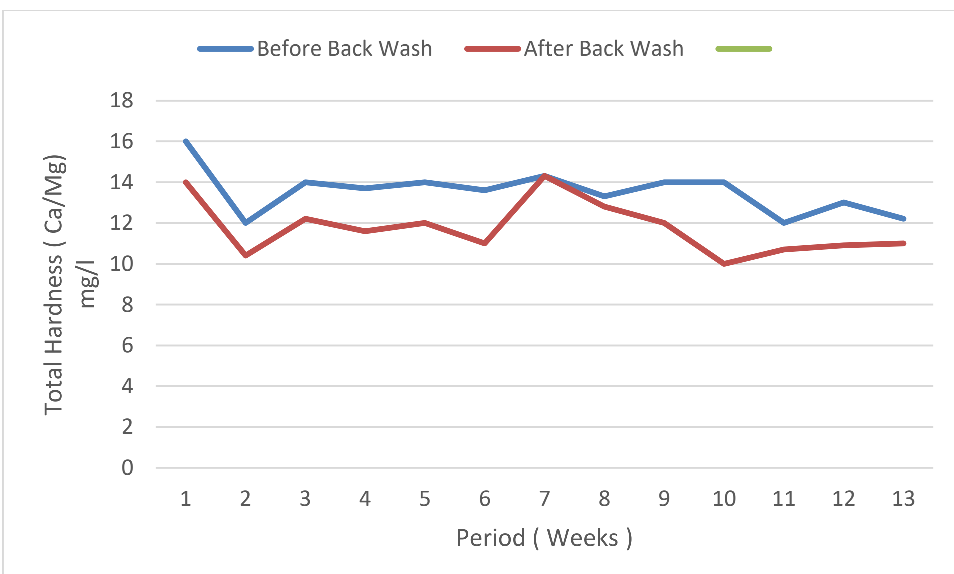

Fig.4.18 Graph of Total Hardness (mg/L) against Period(weeks) of RO Reject

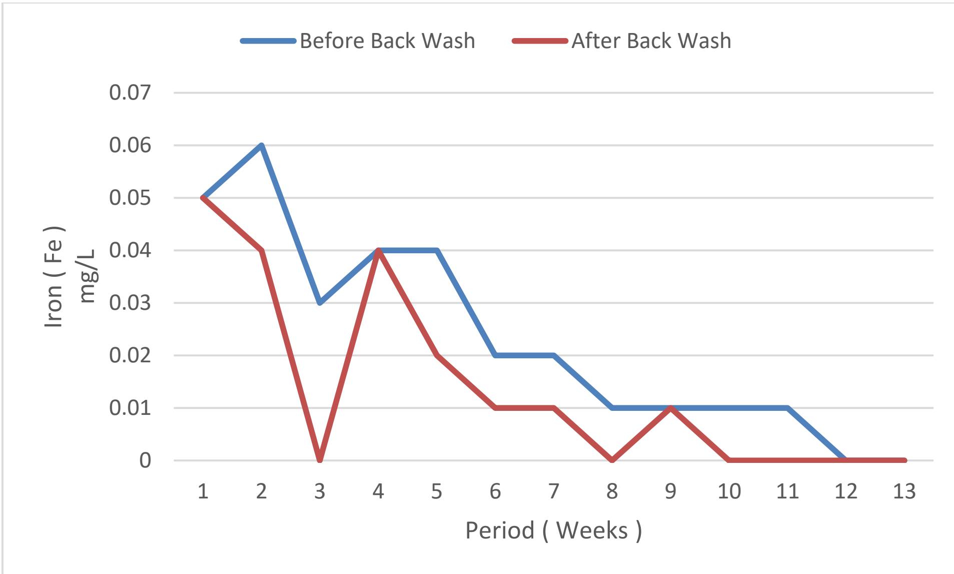

Fig.4.19 Graph of Fe (mg/L) against Period(weeks) of RO Treated

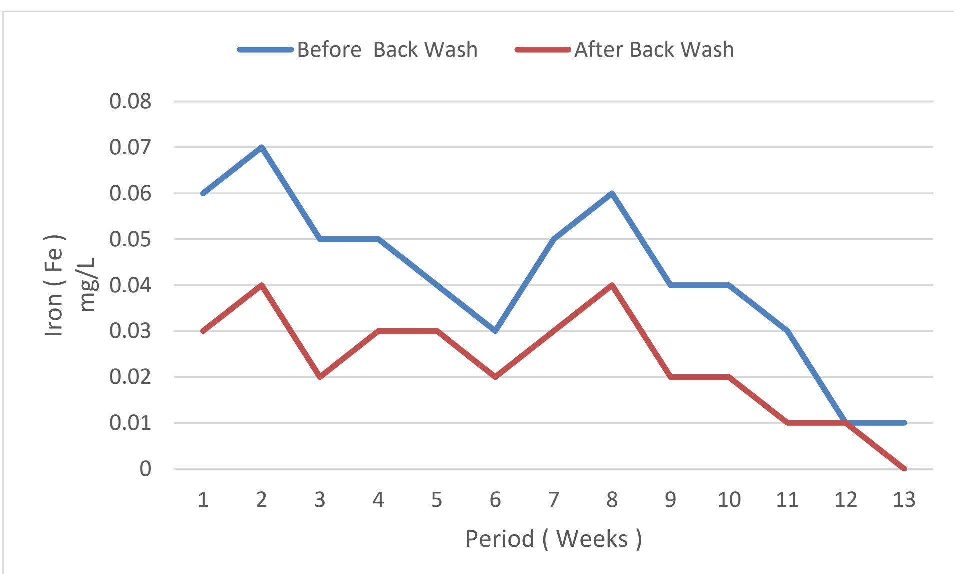

Fig.4.20 Graph of Fe (mg/L) against Period(weeks) of RO Reject

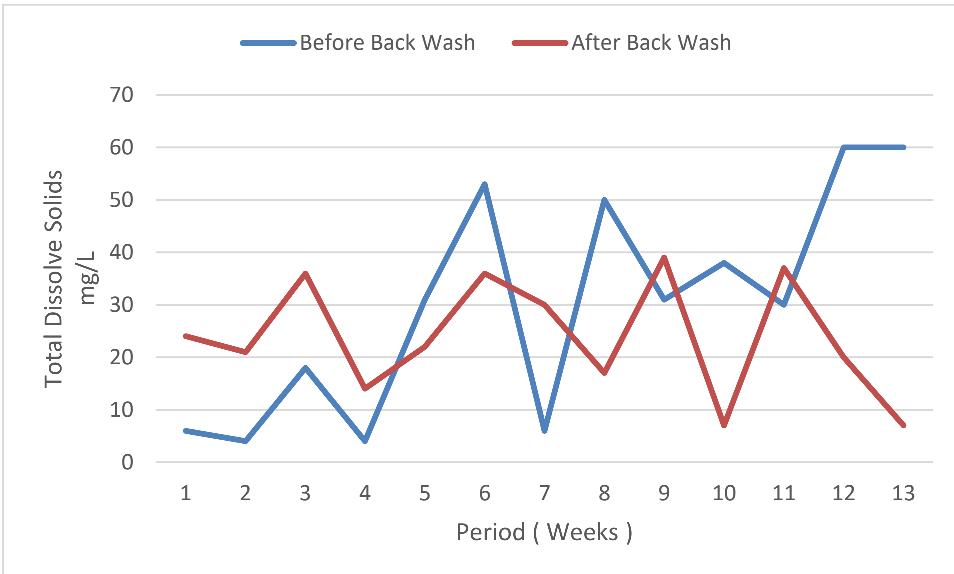

Fig.4.21 Graph of Total Dissolved Solids TDS (mg/L) against Period(weeks) of RO Treated

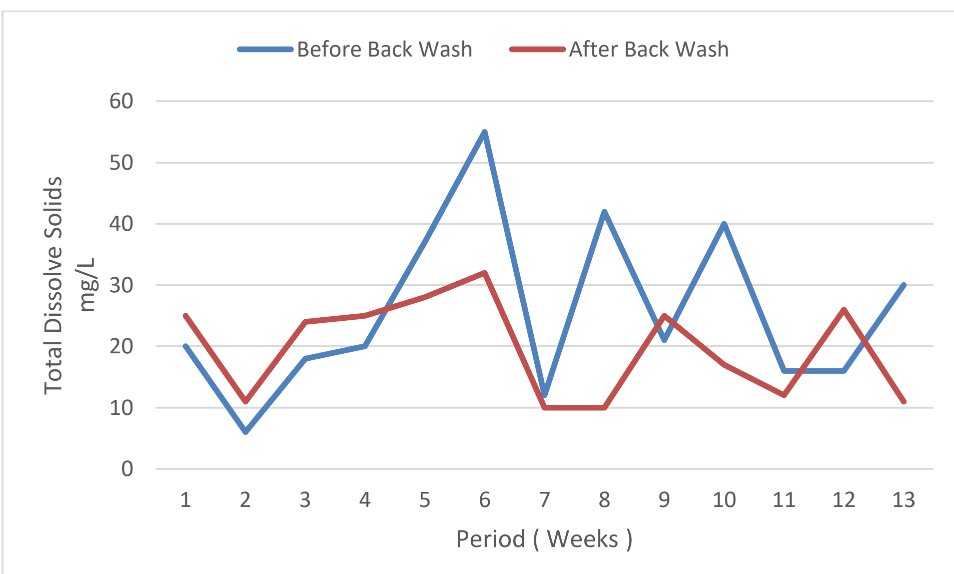

Fig.4.22 Graph of Total Dissolves Solids TDS (mg/L) against Period (weeks) of RO Reject

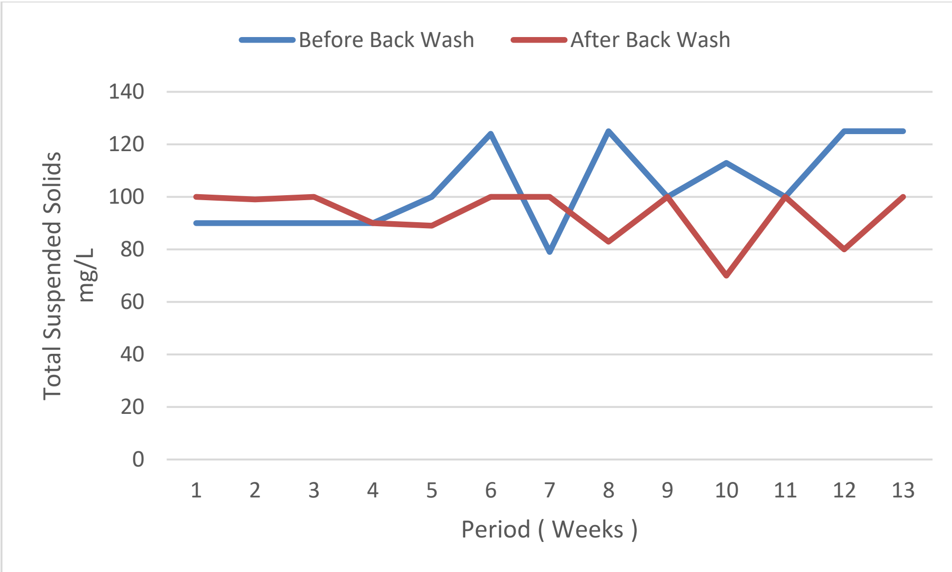

Fig.4.23 Graph of Total Suspended Solids TSS (mg/L) against Period(weeks) of RO Treated

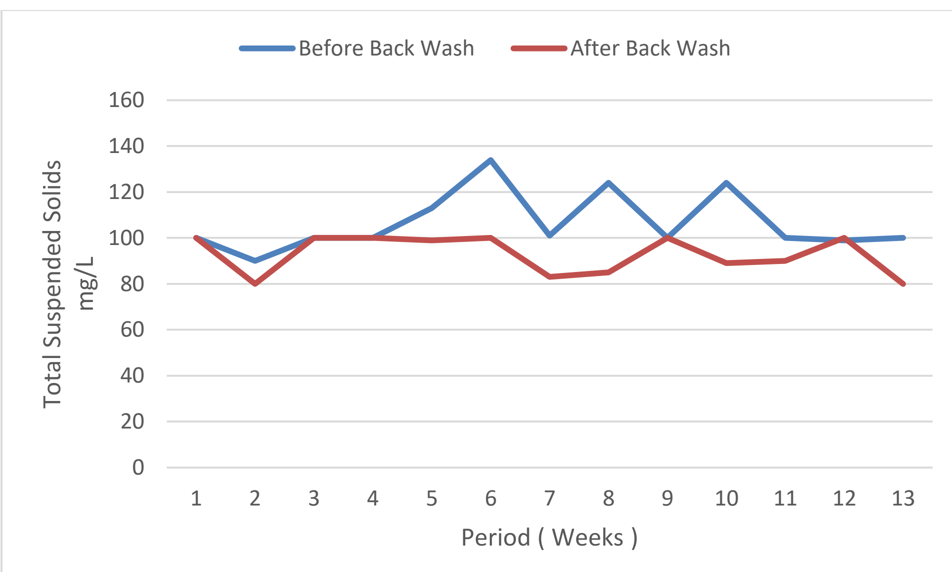

Fig.4.24 Graph of Total Suspended Solids TSS (mg/L) against Period(weeks) of RO Reject

The values of before backwash is higher in before backwash of both RO Treated and Purge than after backwash because the dissolved matters have been removed by filter beds, so the content is left with ionizable contents but both within acceptable limit.

CHAPTER FIVE

Conclusion

The quality of treated and reject water were marginally difference : pH – 0.08, Conductivity 0.8**(**µs/cm), Iron(Fe) 0.01mg/L, Total Hardness(mg/L) 1mg/L,Total Suspended Solids 9mg/L, Total Dissolve Solids 5. However, the quality of treated and reject from RO are within the acceptable limit of local and international standards for human consumption or for drinking water .

To improve the quantity(volume) of treated water delivered by RO ,the following modifications are needed on the RO equipment

i. To remodify the existing connection of two parallel housing with other two in series to three stages of two parallel housing each connected in series
ii. To increase pump pressure of the RO system
iii. To substitute the existing membrane with little more porous type
iv. To dislodge the contaminants from the surface of the membrane periodically

Pending when the above shall be effected, in other for the quality of the treated output to be confirmed, the Reject for now cab considered for now along with the treated for human consumption

The results obtained on the quality parameters from before and after backwash samples signifies the effectiveness of the filteration process.

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