TREATMENT TECHNIQUES FOR PRODUCTION OF MINERAL WATER BY COUNTER TOP WATER FILTER

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Abstract-This article focuses on design of 10 stage counter top water filter. In this, the readily available beach sand was utilized.Water sources such as lakes, rivers, and ground water supply much of the water for domestic use. Some of the water that reaches our household faucets has also been used for other purposes. Water from these various sources is treated to remove impurities and to make it suitable for human consumption. Several steps can form the treatment process. Large items and particles can be filtered out using screens. Some particles may be allowed to settle out. Additional particles can be removed by filtration through sand. Activated charcoal has been treated to increase its porosity and surface area, and is used to adsorb odors and some colored substances. Certain impurities, including carbon-based particles and chlorine, are attracted to the charcoal and remain trapped in the pores. Water is also disinfected using chemical treatments, commonly chlorine.

Keywords: water filter, filtration, charcoal, beach sand

1. INTRODUCTION

Water as it occurs in nature is very "pure", and whatever may be the source, always contains impurities either in solution or in suspension. The determination of these impurities makes analysis of water necessary and removal and control of these impurities make water treatment essential.

The major impurities of waters can be classified in three main groups:

- Non-ionic & undissolved physical impurities. [Turbidity, Odour, Colour, etc.]
- Ionic and dissolved impurities [Ca, Mg, Na, So_4, Cl, iron ,etc.]
- Microbiological impurities [Bacteria, Virus, Pathogens, etc.]

There are various processes employed to purify the water and various combinations of the processes are incorporated to ensure that final composition of the product confirms to the most stringent norms.

Typically a Mineral water Plant may consist of:

- Water Treatment Plant
- Packaging Plant

Chlorine/Hypo chlorite dosing system is done in the raw water for disinfection / oxidation of iron and manganese (if present) in the water before filtration.The hardness salts of calcium & magnesium are likely to be precipitated if concentration exceeds its solubility limit & it may scale the membranes resulting in poor treated water quality from RO System. To prevent this Antiscalant dosing (scale inhibitor) system is provided. The dosage rate is 4-5 ppm.Micron Filtration is achieved by a series of filtration with the 20/10 Micron, 5 Micron, and 1 Micron Cartridge Filters.In the Ozone Generator, Ozone is formed by energetic excitation of molecular oxygen, causing some of it to disassociate into oxygen atoms, which can recombine with oxygen.. Ozone oxidizes both organic and inorganic substances; removes unwanted taste, odor and color; and provide effective disinfection. Ozone is extremely efficient as a bactericide, fungicide and virucide, killing even chlorine-resistant Cryptosporidium. Another benefit is that ozone does not lead to the formation of trihalomethanes (THMs), which are formed when chlorine is added to raw water containing humic materials.

2. DESIGN OF WATER FILTER

A countertop water filter is a point-of-use water filtration system. This means they can be installed exactly where you need access to water. As the name implies, many attach directly to your faucet and dispense clean water right in your kitchen. Others are portable, gravity-fed designs that can be taken from a kitchen countertop to a camping excursion with ease. Countertop filters are designed to take up minimal space and do not require extensive plumbing connections to operate. Countertop filters use various filtration media, like activated carbon or ceramic, to eliminate contaminants and restore the crystal clear taste to your water when you want it. They can filter water quickly even with only moderate water pressure in the house.

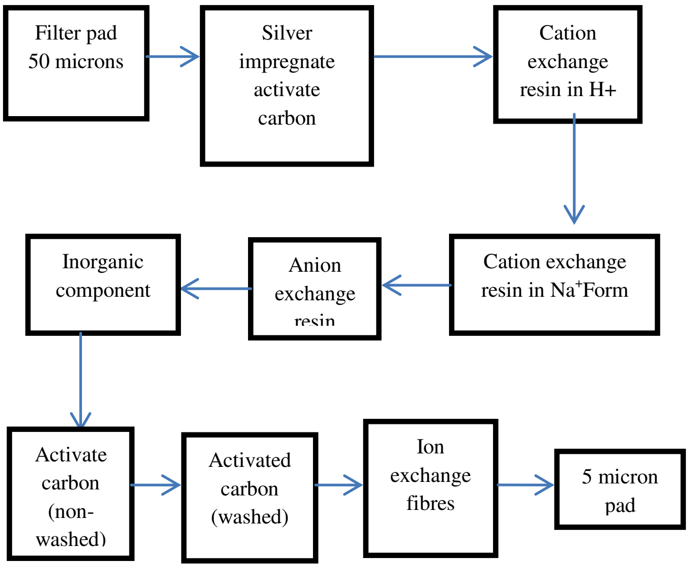
Fig: stages of filtration process

TYPES OF COUNTERTOP WATER FILTER:

- **Carbon filters**:Carbon filtration is heralded for its ability to improve the taste of water. Chlorine and chloramine are used by municipal water plants to treat water and are the most common sources of bad-tasting tap water. Carbon is also effective at removing VOCs (volatile organic compounds) as well as pesticides and herbicides. Carbon filters reduce contaminants in water by a process of adsorption.
- **Ceramic filters**:Ceramic filtration uses millions of microscopic pores to filter out sediment, debris, and bacteria from water. The porous surface of ceramic has an extremely fine micron rating, usually between 0.7-0.5 microns. Most bacteria are around one micron in size and are unable to penetrate the ceramic casing. The ceramic is impregnated with silver, which is bacteriostatic and prevents algae and living organisms from growing on the filter's exterior. Ceramic is a natural media filter, and unlike many other filters, it can be cleaned and reused multiple times.
- **Ultra filtration:**Ultrafiltration is one of the highest purity filtration methods the water filter market offers. Ultrafiltration filters water inside out, by allowing it into the filter then pushing it through a chemical-resistant hollow fiber membrane. This membrane has an extremely fine micron rating and reduces almost all water contaminants. All particles too large to permeate the fiber membrane are trapped, allowing only water and dissolved minerals to pass through the barrier. Next to reverse osmosis, ultrafiltration is one of the most rigorous means of water filtration. Ultrafiltration is able to do all this under normal household water pressure and without producing any wastewater.

TEN STAGES OF FILTER:

The schematic diagram of ten stages of water filter is given below.



- **Filter pads:**Filter pads are manufactured from pure, specially selected and treated cellulosic fibre. The filtration properties of these pads largely depends upon selected fibre size and drying techniques such as air drying, vacuum drying or squeezing.
- **Silver Impregnated Activated Carbon:**Carbon Activated makes a variety of coconut shell-based, impregnated activated carbon, in standard and custom sizes, for applications where non-treated carbon may not be effective**.**
- **Hydrogen From Cation Resin:**Ion exchange resins are used for many water treatment applications. Of these applications, in terms of the volume of resins used, water softening and demineralization of water are the most significant. Water softening has been practiced commercially for a century or more, making use of a wide range of natural and synthetic products.

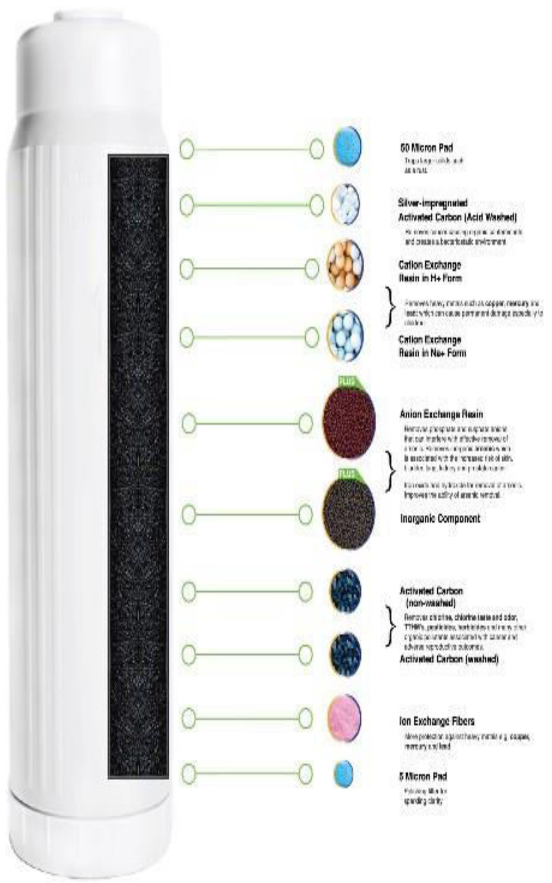


Fig: Water Filter

- **Sodium Form Cation Resin**:A continuous electro-regeneration system of ion-exchange resins is proposed, where cation and anion-exchange resin particles are simultaneously regenerated while flowing separately through anode and cathode compartments, with the help of hydrogen and hydroxide ions produced by the electrolysis of water.
- **Anion Exchange Resin:**Anion resins may be either strongly or weakly basic. Strongly basic anion resins maintain their negative charge across a wide pH range, whereas weakly basic anion resins are neutralized at higher pH levels. Weakly basic resins do not maintain their charge at a high pH because they undergo deprotonation. They do, however, offer excellent mechanical and chemical stability. This, combined with a high rate of ion exchange, make weakly base anion resins well suited for the organic salts.
- **Washed Activated Carbon**:This activated carbon is produced for use in ultra-pure water treatment systems requiring low conductivity and exceptionally high purity. This activated carbon is also specifically designed for the removal of heavy hydrocarbons from recovered condensate. The acid washing process removes soluble silica from the matrix of the activated carbon to prevent leaching into the condensate.
- **Activated Carbon Unwashed:**The iodine value better tested as the particle size of iodine molecule is small enough to penetrate the smallest of pores. The iodine value of activated carbon direct to its surface area because of the above fact. So, how does activated charcoal work? Activated charcoal works by trapping toxins and chemicals in its millions of tiny pores. Typically, however, it's not when petroleum, alcohol, lye, acids or other corrosive poisons ingested. It doesn't absorb the toxins, however. Instead, it works through the chemical process of adsorption.
- **Ion Exchange Fiber:**The design of new ion-exchange materials in the form of fibers that yield a number of important advantages over conventional ion-exchange beads. In this approach, ion-exchange fibers are prepared by (1) coating low-cost glass fiber substrates with

an appropriate oligomer, (2) cross-linking, and (3) functionalizing the coating to produce either anionic or cationic capability.

3. MATERIALS AND METHOD:

The purpose of this study is to evaluate the effect of reduction by filter and improving the water treatment by mineral. The main parameters that will be focus on are the biological oxygen demand (BOD), chemical oxygen demand (COD) and total dissolved solids (TDS). The water is collected from different industrial area and analyses initially to determine the initial pH, COD and also BOD content. It is important to analyze the initial conditions of the water to manipulate the experiments and achieving the objectives of the experiments. The main materials used in this experiment are ion exchange resin and activated carbon in adsorption column with different proportion and purchased by the Chemical Engineering Lab.

Table 1:Raw material properties

Parameter	Unit	Concentration	Parameter	Unit	Conc
pH	--	6.0	Iron	mg/L	0.07
Color	Pt.-Co.	15	Manganese	mg/L	0.010
Turbidity	NTU	0.90	Potassium	mg/L	25.4
Alkalinity as $CaCO_3$	mg/L	242.0	Sodium	mg/L	131.9
Carbon-dioxide	mg/L	203.0	Arsenic	mg/L	< 1.0
DO	mg/L	2.97 at 26°C 2.03 at 26.1°C	Lead	mg/L	0.0214
Conductivity	ms/cm	1054	Cadmium	mg/L	0.0018
Chloride	mg/L	165.0	Zinc	mg/L	0.0372
Hardness as $CaCO_3$	mg/L	338.0	Copper	mg/L	0.0467
Sulfate	mg/L	35.1	Nickel	mg/L	0.0074
Nitrate	mg/L	0.4	Mercury	mg/L	Nil
Phosphate	mg/L	0.14	Chromium	mg/L	0.0049
Fluoride	mg/L	0.35	Silica	mg/L	32.0

Different filter materials such as gravel, quartz sand, manganese sand, activated carbon and anthracite coal were purchased from the local company, and sea sand was collected from the beach of Da Nang city, Vietnam. After washing with distilled water several times, the sieve sizes of gravel, quartz sand, sea sand, manganese sand, activated carbon and anthracite coal were controlled at 2.0–4.0 mm, 0.8–1.2 mm, under 0.8 mm, 1.2–2.5 mm, 2–4 mm and 3.0–5.0 mm, respectively.

TRIAL MODELS OF WATER FILTRATION:

The experimental models comprised of columns which were made of polyvinyl chloride (PVC), diameter 90 mm. Each column was connected by male sockets and filled with 1 kg of material by various formulas to investigate the capacity of Fe and Mn^-ions removal (Table). After filtration process, the water was run into the clean water tank, and the concentrations of Fe and Mn^-ions were measured.

Table 2:Layers of water filter

No.	Material layers	1st formula	2nd formula	3rd formula	4th formula
1	1st layer Top layer	Gravel (h = 11 cm)	Gravel (h = 11 cm)	Gravel (h = 11 cm)	Gravel (h = 11 cm)

2	2nd layer	Sea sand (h = 11 cm)	Quartz sand (h = 11 cm)	Quartz sand (h = 11 cm)	Quartz sand (h = 11 cm)
3	3rd layer	Activated carbon (h = 15 cm)	Anthracite carbon (h = 20 cm)	Activated carbon (h = 15 cm)	Activated carbon (h = 15 cm)
4	4th layer	Ion exchanger (h = 12 cm)	Ion exchanger (h = 12 cm)	Ion exchanger (h = 12 cm)	Ion exchanger (h = 12 cm)
5	5th layer	Sea sand (h = 11 cm)	Quartz sand (h = 11 cm)	Quartz sand (h = 11 cm)	Quartz sand (h = 11 cm)
6	6th layer Bottom layer	Gravel (h = 11 cm)	Gravel (h = 11 cm)	Gravel (h = 11 cm)	Gravel (h = 11 cm)

WHAT WILL REVERSE OSMOSIS REMOVE FROM WATER?

Reverse Osmosis is capable of removing up to 99%+ of the dissolved salts (ions), particles, colloids, organics, bacteria and pyrogens from the feed water (although an RO system should not be relied upon to remove 100% of bacteria and viruses). An RO membrane rejects contaminants based on their size and charge. Any contaminant that has a molecular weight greater than 200 is likely rejected by a properly running RO system. Likewise, the greater the ionic charge of the contaminant, the more likely it will be unable to pass through the RO membrane. For example, a sodium ion has only one charge (monovalent)and is not rejected by the RO membrane as well as calcium for example, which has two charges. Likewise, this is why an RO system does not remove gases such as CO_2 very well because they are not highly ionized (charged) while in solution and have a very low molecular weight. Because an RO system does not remove gases, the permeate water can have a slightly lower than normal pH level depending on CO_2 levels in the feed water as the CO_2 is converted to carbonic acid. Reverse Osmosis is very effective in treating brackish, surface and ground water for both large and small flows applications. Some examples of industries that use RO water include pharmaceutical, boiler feed water, food and beverage, metal finishing and semiconductor manufacturing to name a few.

REVERSE OSMOSIS PERFORMANCE & DESIGN CALCULATIONS

There are a handful of calculations that are used to judge the performance of an RO system and also for design considerations. An RO system has instrumentation that displays quality, flow, pressure and sometimes other data like temperature or hours of operation. In order to accurately measure the performance of an RO system you need the following operation parameters at a minimum:

1. Feed pressure
2. Permeate pressure
3. Concentrate pressure
4. Feed conductivity
5. Permeate conductivity
6. Feed flow
7. Permeate flow
8. Temperature

SALT REJECTION %

This equation tells you how effective the RO membranes are removing contaminants. It does not tell you how each individual membrane is performing. A well-designed RO system with properly functioning RO membranes will reject 95% to 99% of most feed water contaminants (that are of a certain size and charge). We determined effective theRO membranes are removing contaminants by using the following equation:

Salt Rejection = Conductivity of Feed Water – Conductivity of Permeate Water Conductivity of Feed

The higher the salt rejection, the better the system is performing. A low salt rejection can mean that the membranes require cleaning or replacement.

SALT PASSAGE %

This is simply the inverse of salt rejection described in the previous equation. This is the amount of salts expressed as a percentage that are passing through the RO system. The lower the salt passage, the better the system is performing. A high salt passage can mean that the membranes require cleaning or replacement.

Salt Passage % = (1--- Salt Rejection%)

RECOVERY %

Percent Recovery is the amount of water that is being 'recovered' as good permeate water. Another way to think of Percent Recovery is the amount of water that is not sent to drain as concentrate, but rather collected as permeate or product water. The higher the recovery % means that you are sending less water to drain as concentrate and saving more permeate water. However, if the recovery % is too high for the RO design then it can lead to larger problems due to scaling and fouling. The % Recovery for an RO system is established with the help of design software taking into consideration numerous

factors such as feed water chemistry and RO pre---treatment before the RO system. Therefore, the proper % Recovery at which an RO should operate at depends on what it was designed for. By calculating the % Recovery you can quickly determine if the system is operating outside of the intended design. Thecalculation for % Recovery is below:

$$\% \text{ Recovery} = \frac{\text{Permeate Flow Rate (gpm)} \times 100}{\text{Feed Flow Rate (gpm)}}$$

For example, if the recovery rate is 75% then this means that for every 100 gallons of feed water that enter the RO system, you are recovering 75 gallons as usable permeate water and 25 gallons are going to drain as concentrate. Industrial RO systems typically run anywhere from 50% to 85% recovery depending the feed water characteristics and other design considerations.

CONCENTRATION FACTOR

The concentration factor is related to the RO system recovery and is an important equation for RO system design. The more water you recover as permeate (the higher the % recovery), the more concentrated salts and contaminants you collect in the concentrate stream. This can lead to higher potential for scaling on the surface of the RO membrane when the concentration factor is too high for the system design and feed water composition.

Concentration Factor = (1 / (1---Recovery %)

The concept is no different than that of a boiler or cooling tower. They both have purified water exiting the system (steam) and end up leaving a concentrated solution behind. As the degree of concentration increases, the solubility limits may be exceeded and precipitate on the surface of the equipment as scale.For example, if your feed flow is 100 gpm and your permeate flow is 75 gpm, then the recovery is(75/100) x 100 = 75%.

To find the concentration factor, the formula would be 1 ÷ (1---75%) = 4.

A concentration factor of 4 means that the water going to the concentrate stream will be 4 times more concentrated than the feed water is. If the feed water in this example was 500 ppm, then the concentrate stream would be 500 x 4 = 2,000 ppm.

FLUX

$$\text{Gfd} = \frac{\text{gpm of permeate} \times 1{,}440 \text{ min/day s}}{\% \text{ of RO elements in system} \times \text{square footage of each RO element}}$$

For example, you have the following:

The RO system is producing 75 gallons per minute (gpm) of permeate. You have 3 RO vessels and each vessel holds 6 RO membranes. Therefore you have a total of 3 x 6 = 18 membranes. The type of membrane you have in the RO system is a Dow Filmtec BW30---365. This type of RO membrane (or element) has 365 square feet of surface area.

TO FIND THE FLUX (Gfd):

$$\text{Gfd} = \frac{75\text{gpm} \times 1{,}440 \text{ min/day}}{18 \text{ elements} \times 365 \text{ sq ft}}$$

$$= \frac{108{,}000}{6{,}570}$$

The flux is 16 Gfd.

This means that 16 gallons of water is passed through each square foot of each RO membrane per day. This number could be good or bad depending on the type of feed water chemistry and system design. Below is a general rule of thumb for flux ranges for different source waters and can be better determined with the help of RO design software. If you had used Dow Filmtec LE---440i. RO membranes in the above example, then the flux would have been 14. So it is important to factor in what type of membrane is used and to try and keep the type of membrane consistent throughout the system.

FEED WATER SOURCE Gfd:

Sewage Effluent 5---10

Sea Water 8---12

Brackish Surface Water 10---14

Brackish Well Water 14---18

RO Permeate Water 20---30

MASS BALANCE:

A Mass Balance equation is used to help determine if your flow and quality instrumentation is reading properly or requires calibration. If your instrumentation is not reading correctly, then the performance data trending that you are collecting is useless.You will need to collect the following data from an RO system to perform a Mass Balance calculation:

1. Feed Flow (gpm)

2. Permeate Flow (gpm)

3. Concentrate Flow (gpm)

4. Feed Conductivity (µS)

5. Permeate Conductivity (µS)

6. Concentrate Conductivity (µS)

The mass balance equation is:

(Feed flow * Feed Conductivity) = (Permeate Flow * Permeate Conductivity) + (Concentrate Flow* Concentrate Conductivity)

Feed Flow = Permeate Flow + Concentrate Flow

For example, if you collected the following data from an RO system:

Permeate Flow = 5 gpm

Feed Conductivity = 500 µS

Permeate Conductivity = 10 µS

Concentrate Flow = 2 gpm

Concentrate Conductivity = 1200 µS

Then the Mass Balance Equation would be:

(7 x 500) = (5 x 10) + (2*1200)

$3{,}500 \neq 2{,}450$

Then find the difference:

$$\frac{\text{Difference} * 100}{\text{Sum}}$$

$$\frac{3500 - 2450 * 100}{3500 + 2450} = 18\%$$

A difference of +/- 5% is ok. A difference of +/- 5% to 10% is generallyadequate. A difference of > +/-10% is unacceptable and calibration of the ROinstrumentation is required to ensure that you are collecting useful data.

For 1000 LPH Supply RO System :

- Cost Of Unit - Rs. 5,80,000/-
- Electricity Requirement - 4.25KW = 4.25x16 = 68KW (Assuming 16Hrs. Working Daily. Power Consumption By The Equipment Is Taken As Provided By Manufacturer)
- Electricity Charges @Rs.8.36/- Per KW For 365 Days = 68x365x8.36 = Rs.2,07,495/-
- Labour AMC Cost For Year - 9,700/-
- Consumables (Assuming Normal Service Requirement) – Rs.127210/-

Assuming Life Of RO System As 5Years, Annual Cost Of One Unit - Rs.1,16,000.00

Total Cost Involved For A Year= Rs. 1,16,000.00 + Rs. 2,07,495.00+ Rs. 9,7000.00 + Rs.127210.00= Rs. 4,60,405.00

Cost Of Per Litre RO Treated Water = $\frac{\text{Rs. } 4{,}60{,}405.00}{1000\text{x}16\text{x}36}$ = Rs. 0.08 Per Litre

4.CONCLUSION:

A total of 30 L of sample was aerated by the aerator with the aeration flow of 5 L/min for 15 min. After 2 h of sedimentation, the water was filtered through layers of pads, activated carbon(washed and unwashed),resins and fibres of different cm. All the parts of models made of PVC were connected by male sockets, so it was easy to dismantle. Therefore, the materials can be washed easily and conveniently. The study also showed the ability of the sea sand and the low-cost material in the water filtration. The simple operation, inexpensive cost and effective removal of toxic substance from the water show the ability of application of this model for groundwater purification in the small and medium households in rural areas.

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