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Brackish water treatment using desalinating device for domestic purpose

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ABSTRACT

The cheapest and also the most unsophisticated way to attain potable water from the brackish water normally available at the taps is reverse osmosis process. Today there is strong need for appropriately treated wastewater to protect the environment and to ensure that freshwater is available for all applications. Semi permeable membranes allow the passage of water or other small molecules through them but block the passage of large solute Molecules. As a consequence of osmosis, the concentration on the solution side decreases, because the amount of liquid on this side increases considerably over the passage of time. The study involved testing the performance of the Reverse Osmosis treatment plant. Conventional tests (temp, pH, TDS, turbidity, alkalinity, hardness, chlorine residual), and special tests (Fe, Mn, Zn, Cu, Pb, Cr, F, TOC) were conducted at different sampling locations within the distribution system, over a period of about eight months to evaluate the quality of drinking water. Samples were also collected after different stages of treatment from the main R.O. treatment plant, to determine the nature of treatment provided. The main objective of the research paper is to present fundamental model for brackish water desalination system for domestic purpose and their preliminary findings using prospective design.

Keywords: Membrane; Osmosis; Concentration; Solute; Solution; Molecules; Salinity; Filtrates; Activated charcoal; Halogens; Fouling; Particulate; Scales; Brine

1. Introduction

Raw or partially treated, brackish water has been applied in many locations all over the world not without causing serious public health consequences and adverse environmental impacts, but improving the yield of several crops. This has been generating the existence of endemic and quite epidemic diseases. To take care of this crucial problem appropriate treatment of brackish water is needed.

Desalination, or desalting, is the separation of fresh water from salt water or brackish water. The magnitude of "salting out" depends on the amount of salt presented in solution [1].

Major advances in desalination technology have taken place since the 1950s, as the need for supplies of fresh water has grown in arid and densely populated areas of the world. The removal of dissolved salts from seawater and in some cases from the brackish waters of inland seas, highly mineralized ground waters (e.g., geothermal brines), and municipal waste waters is termed as desalination. This process renders such otherwise unusable waters fit for human consumption, irrigation, industrial applications, and various other purposes. Existing desalination technology requires a substantial amount of energy, and so the process is expensive. Increasing the salt content of the feed water increases the operating costs as more apparatus (such as membrane area or the number of stages of distillation) is needed [2,3,11]. For this reason, it is generally used only where

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sources of fresh water are not economically available. But our design provides fundamental model for brackish water desalination system for domestic purpose.

2. A brief overview about some available filtration techniques and membranes

During the last two decades significant advances have been made in the development and application of micro filtration (MF), ultra filtration (UF), nano filtration (NF) and reverse osmosis (RO) processes. MF membranes reject suspended particles only, UF membranes reject suspended particles and high molecular weight compounds, NF membranes also reject low molecular weight compounds, and RO membranes also rejections.

The membrane itself must be physically strong in order to stand up to high osmotic pressure. Over 100 different materials are used to make RO membranes, however the two most commonly used membranes are made from cellulose acetate (CA) and polyamide thin film composite (TFC) as shown in Fig. 1. These may come in spiral, tubular hollow fiber, plate and frame, or proprietary configurations. Hollow fiber and flat sheet are the most commonly used RO membrane configurations. Among the needed improvements in RO systems are better pretreatment of feed water to reduce the use of chemicals that often end up in the brine and cause a disposal problem [4].

Hollow fiber membrane is extruded like fishing line with a hole in the center to create a tiny (100 to 200 micron) hollow fiber strand. Flat sheet membrane, a continuous sheet rolled up like a large paper towel roll, is used in spiral wound (SW) configurations. Although HF RO elements provide more surface area, they are more prone to fouling. The characteristics and performance of these membranes differ as well. Reverse osmosis has been shown to be the most economical in many cases due to its lower energy consumption, leading to lower unit water costs. However, the process has higher up-front investment costs compared to thermal processes. Its unit water costs are primarily determined by membrane life and energy cost [5,6]. The cleaning method and frequency depend on the type of foulant and the membrane's chemical resistance. Generally, it is easier to clean a membrane that is slightly fouled. Cleaning methods include mechanical cleaning (i.e. direct osmosis, flushing with high velocity water, ultrasonic, sponge ball or brush cleaning, air sparing, etc.), chemical cleaning (use of chemical agents), or a combination of both. Membrane processes most economically achieve brackish water desalting, with reverse osmosis presently the cheapest process [7,8]. Water, with a dissolved solids (salt) content below about 1000 mg/L, is considered acceptable for a community water supply [9].

3. Methods and materials

We have prepared a desalinating device and installed it at Maulana Azad National Institute of Technology Bhopal, India, The design of our device is shown in Fig. 2. The successive trials were taken over it. We have checked the pH, turbidity and hardness of water on the sampling point with the help of water sampling kit. It was done on the spot, during water sampling. The entire readings are to be measured and tabulated. Then, there mean is calculated The hardness test involves a titration of the sample with an EDTA solution (which binds Mg and Ca ions) in the presence of an indicator that is color-sensitive to the presence of free Mg^{2+} ions. The experimental set up is as follows.

It consists of small cylindrical plastic filter with three washable filtrates, of height 50 mm and diameter 50 mm. A water pipe runs from v_1 to v_2. Charcoal is placed in v_2, vessel v_3 is outside the v_2, a small cylindrical membrane

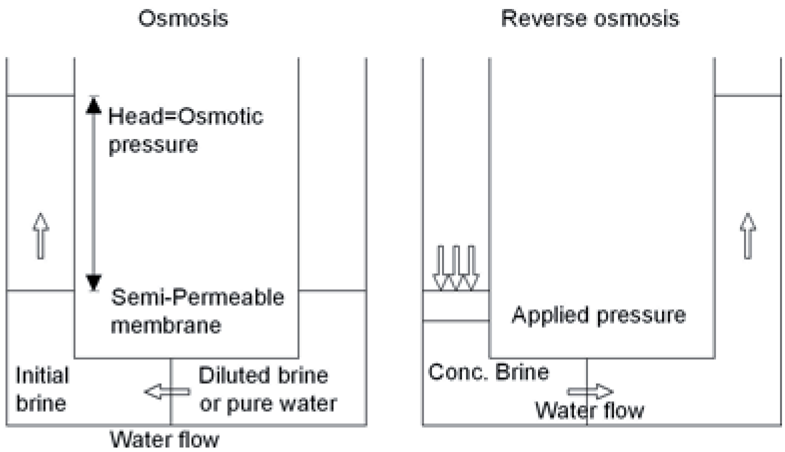

Fig. 1. Schematic diagram of osmosis and reverse osmosis process.

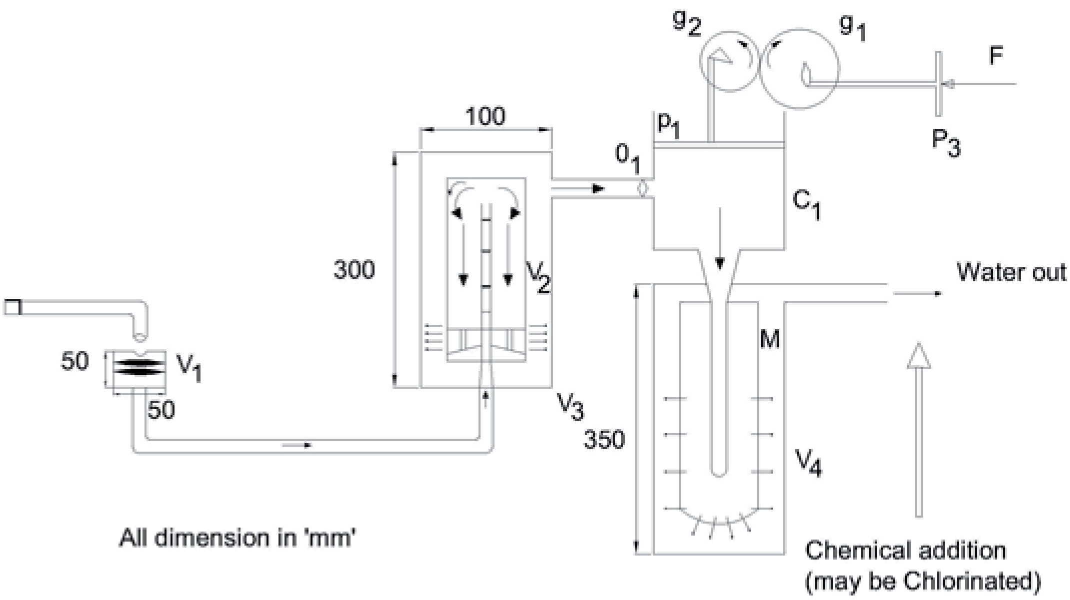

Fig. 2. Experimental set up of desalinating device installed at M.A.N.I.T., Bhopal (India).

is there at bottom of v_2 .O_1 is driven by cam mechanism. g_1 & g_2 are gears p_1 is a closed tight piston. There is a membrane 'm' outside which is vessel v_4. External pressure is to be applied over p_2.

3.1. Working of the desalinating device

Water from tap goes into v_1 vessel and after getting somewhat filtered goes to v_2 through pipe. Water comes down through activated charcoal. Thereafter it goes into v_3 from where it is supplied to cylinder c_1. Where water is pressurized against 'm' so that pure water goes to v_4 while salinity remains inside spiral, tubular hollow fiber RO membrane {which can be washed within 60–70 days}.

Small suspended impurities (if present) are remained till it reaches to v_2. Activated charcoal absorbs poisonous gases, substance or dissolved impurities (if present) in it, without causing any harm to its pure nature. The activated carbon filter absorbs low molecular weight organics and reduces the amount of chlorine or other halogens, but does not remove any salts. This absorption process takes time, so service rates are limited to a maximum of about 5 gpm/ft. The accumulation of solids can require backwashing; however this can result in loss of the relatively fragile activated carbon material. Over a period of months to years, the adsorption capacity of the carbon diminishes, requiring replacement or reactivation, a process not easily accomplished in the field. These filters may also need to be changed periodically to avoid bacterial growth.

Gear reduces the actual pressure to be applied compared to needed one. Membrane stops salinity and other impurities (if present) from going to v_4. RO removes virtually all-organic compounds and up to 99% of inorganic ions. Presently, it will fit in cuboids of size $30 \times 30 \times 60$ cm.

3.2. Problems associated with the set up

Membrane surfaces are prone to fouling by particulate matter, inorganic scales (i.e. carbonate and sulfates salts of alkaline earth metals), oxides and hydroxides of aluminum and iron, organic material (i.e., humic, tannic, etc.) and biological material (e.g. bacteria, fungi, algae). Sodium chloride, being nonvolatile, remains mostly in the residue wastewater. A low quantity of sodium chloride in gas phase comes from mechanical and selective schlepp of vapour [10].

- RO membrane fouling is a complex phenomenon involving the deposition of materials on the membrane surface rather than plugging of the system. Scaling of RO membrane surfaces is caused by the precipitation of sparingly soluble salts from the concentrated brine (especially $CaCO_3$ and $BaSO_4$). A number of chemicals may be added to prevent membrane fouling. For example, sulfuric or hydrochloric acid is employed to reduce pH and prevent $CaCO_3$ precipitation. Sulfuric acid, while safer and less expensive than HCl, will increase the content of sulfate ions in the feed water and consequently the risk of $CaSO_4$ precipitation. The addition of polyphosphates or, more recently, poly carboxylates is employed for preventing $CaSO_4$ scaling.
- The accumulation of solids in activated charcoal can require backwashing; however this can result in loss of

the relatively fragile activated carbon material. Over a period of months to years, the adsorption capacity of the carbon diminishes, requiring replacement or reactivation, a process not easily accomplished in the field.

4. Brackish water treatment analysis

The study shows that M.A.N.I.T. Bhopal drinking water quality was exceeding the acceptable limit of World Health Organization (WHO) in terms of TDS (300 mg/L), hardness (100 mg/L as CaCo), iron (0.1 mg/L), and fluoride (0.7 mg/L). Chlorine residual was also observed to be below the desired concentration of 0.1–0.4 mg/L quite often.

The pH of water, whether it's reverse osmosis water or normal water, will be 7 or extremely close to 7. Reverse osmosis water is simply cleaner than normal because it has passed through special membrane filters that filter out molecules larger than water (H_2O), but it's still H_2O. pH simply means the power of hydrogen and is not affected by the cleanliness of the water.

In order to solve the problem, it was agreed to change the range of pH from 7.0–8.0 to 6.5–9.2. The pH of the desalinated water was then increased by readjusting lime and carbon dioxide dosages. Later, from June 2007 for further increase of hardness of the desalinated water, magnesium sulphate is added at the post-treatment stage in addition to the lime and carbon dioxide.

The summary data of M.A.N.I.T. desalination plant is given below in Table 1.

Pre-treatment filtration anti-scalant addition & cartridge filtration

- Prevents both calcium carbonate and calcium sulphate crystal formation process
- Represses formation of other potential scalants such as manganese, silica and oxides or hydroxides of iron,
- Removes turbidity, suspended solids and other materials to prevent scaling of fouling of membrane

Reverse osmosis desalination process

- Pre-treated water is forced under pressure through a semi permeable membrane for removal of chemical impurities and solids like salt
- Single pass system with protected recovery rate of 67%. Water is desalted in one pass of membrane desalination.
- Permeate water quality: Total dissolved solids = 280 mg/L; pH = 5.8; hardness = 20 mg/L; Alkalinity = 2 mg/L (corrosive characteristics)

Post-treatment (lime & carbon dioxide addition; post-chlorination)

- To settle corrosive characteristics of permeate produced from the reverse osmosis process
- Addition of hydrated lime to increase calcium hardness and raise pH
- Addition of carbon dioxide to increase alkalinity (carbon dioxide converted to bicarbonate after hydrated lime addition)
- Water quality after post treatment: Total dissolved solids = 380 mg/L; pH = 8.5
- Chlorine is added in the final stage for disinfection

The Maulana Azad National Institute of Technology Bhopal Laboratory performs extensive water quality monitoring in order to ensure safe drinking water supply. One water sample from each of five MANIT residences is collected and analyzed on each Thursday. A different set of five samples are analyzed each week in a month, so there are a total of 20 different individual residences from which water is collected In addition, desalinated water is monitored for pH, turbidity, conductivity, and total dissolved solids daily. Chloride and sulphate are analyzed on a weekly basis.

The first filter has a coarse (8 mm) sand media bed. The second filter contains finer (4-mm) sand media. Both filters have instrumentation for continuous turbidity monitoring and data logging. The second filter is also equipped with a particle counter. The reverse osmosis system is designed to run in a range of 45–55% recovery and typically operates at 50% recovery. The effects of operation at higher and lower than 50%recovery on key system parameters such as permeate TDS concentration, feed pressure and other parameters are planned to be tested over the course of the demonstration study.

Table 1
Summary data of desalination plant.

Startup year	2007
Process	Desalinating
Capacity (MGD)	0.27
Actual production (MGD)	0.24
Recovery rate (%)	45
Pretreatment	Cartridge filtration, anti-scalant
Post-treatment	Carbon dioxide, lime, chlorination
Feed water composition	Salinity: 15,000 mg/L
Product water composition	TDS = 280 mg/L; pH = 8.5
Concentrate composition	Brine

5. Economic feasibility

It is clear that the cost of desalting is determined by a number of technical and economic factors. Desalination costs are competitive with the operation and maintenance costs of long-distance water transport system [11]. The market is also driven by the falling costs of desalination, which are due to the technological advances in the desalination process [12].

Major characteristic of all desalination processes is their requirement for thermal or electric energy input, which can represent 50–75% of operating costs [13]. The major categories are capital costs, and operating and maintenance costs. These two categories are interdependent; that is, if one component is increased the other component usually decreases [14]. The operating and maintenance costs are not subject to economies of size, but are directly affected by the water quality to be treated [15] Theoretically, all desalination processes, including those yet to be invented, have certain minimum requirements for energy. However inefficiencies arise in all desalination processes due to the transport of energy in the process, or transport of matter at phase boundaries [16,17]. These inefficiencies increase the energy requirements of desalination methods, thus raising costs. The forms of energy available and environmental constraints related to the energy source contribute to the cost of energy for desalination [18,19]. Wood 1982 [20] observed that rising world energy prices would alter the relative costs of different desalination methods, increasingly favoring reverse osmosis.

6. Conclusion

Today water reuse is the most important issue for the developing countries. This paper presented our fundamental model for modelling brackish water. Several experiments were conducted over the desalinating device. The initial results obtained from the successive trial of the desalinating device are satisfactory. We have got physicochemical parameters for domestic purpose within the range as per prescribed by WHO standard [21]. They are as follows turbidity 25 NTU, pH value 6.5–9.2, chloride 600 ppm and total hardness 500 ppm Desalination appears to be an option deserving serious analysis and investigation. The brackish RO plant operation cost consists of electrical power, membrane replacement cost, chemical cost and manpower cost. The indicative operational cost for brackish water is about Rs 30 per 1000 liters of good water produced. It appears that, in India, based on current prices charged for water desalination is currently only competitive with traditional water sources in remote locations.

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