RO purifier: Working and health implications attributed to low TDS levels

Aakanksha Chhokra[1], Akansha Bisht [1], Ananya Tyagi[1],
Anushka Saxena[1], Saumya Anand[1], Smita Sundaram[1]*

ABSTRACT

Water is the most essential andlife sustaining natural resource on this planet. Ensuring access to clean water is one of the major sustainable development goals. Growing population, industrial development and environmental degradation has led to severe contamination of water bodies. A large number of people are estimated to die every year from diseases caused by unsafe drinking-water. In this scenario, water purifiers/filters have become indispensable in every other home in India, particularly in metro areas. In order to ensure healthy and safe drinking water, the analysis of Total dissolved solids (TDS) concentration can be undertaken, since low TDS causes deficiency of specific elements such as magnesium and calcium and adversely affects human health. Further, Hypertension, coronary heart disease, stomach ulcers, goitre and muscle weakness have been reported due to low TDS water. Understanding of water purification techniques like Reverse Osmosis (RO), osmotic pressure, types of RO membranes, performance rates and functions are seminal to the mass availability of clean drinking water and hence the review article focuses on understanding the dynamics of mechanical mineral content regulation at human friendly TDS levels in drinking water.

Keywords: *Reverse Osmosis; Deficiency of Magnesium and Calcium: Total Dissolved Solid; Water Purifier; Health implications.*

1. Introduction

The world is facing a major issue of water shortage. Excessive water resources consumption including surface and groundwater has caused a real problem related to freshwater availability. Reverse Osmosis (RO) is a separation technology that works well in a variety of situations, notably when salt or dissolved solids need to be removed from a solution. As a result, RO is mostly utilized for desalination of saltwater and brackish water to produce both glasses of water for industrial use and beverages. It can also be enforced for ultra pure water and boiler feed water yields. RO membrane systems are also utilized to treat waste water and reuse water. RO is now regarded as one of the most cost-effective and efficient methods for removing salt, toxicity and microbes from water. As a result, it's usually the most practical approach for solutions with salt concentrations ranging from 50-150 ppm(Cath *et al.*, 2006). Brininess in solutions ranging from surface water to sea water, RO membranes can cure anything (Greenlee *et al.*, 2009). The arrangement used to separate membranes utilizing RO membranes is called counter current. The feed water stream enters the membrane in a zig-zag pattern. During this feed stream, a small amount of water flows through the membrane, but the majority of it passes along the surface. As a result, there are two streams of data: (1) Pure water(P), virtually pure

1 *Shaheed Rajguru College of Applied Sciences for Women, University of Delhi*
* *Corresponding Author* ✉ *smitasundaram1@gmail.com*

water with a low ion concentration; (2) Concentrated water (C), concentrated water with a high dissolved ion content.

During operation, feed water is continually delivered to the RO membrane device, resulting in continuous water transfer from feed to concentrate. There is little agglomeration of the eliminated solutes in cross-flow operation, and pollution or scale problems are frequently avoided (Kozisek, 2005). TDS (total dissolved solids) are found naturally in water or as a result of mining or industrial water treatment. It is made up of minerals and organic molecules that might be beneficial or harmful, such as poisonous metals and organic pollutants; which is a measurement of inorganic salts, organic matter, and other dissolved materials in water, must be monitored on a regular basis under current rules (Weber Scannell & Duffy, 2007).

There are reasons why certain range of TDS level is acceptable for drinking: Less than 50 mg/l, unacceptable (as it lacks essential minerals); 50-150 mg/l, acceptable for drinking (The TDS level is ideal for areas where the water polluted by sewage or industrial waste); 150-350 mg/l, Good (the water is ideal for people with cardiovascular disease); 350-500 mg/l, fairly acceptable; 500-900 mg/l, less acceptable; 900-1200 mg/l, least acceptable (avoid drinking water which has a TDS level of 900); >1200mg/l, water is not acceptable for drinking (Kent RO system, 2022).Drinking low TDS water in long run cause mineral leaching from body. It reduced serum potassium concentration, accelerate the removal of sodium, potassium, chloride, calcium and magnesium ions from the body. It was thought that low-mineral water acts as an osmo-receptors of the gastrointestinal tract, inflicting an elevated flow of sodium ions into the intestinal lumen and mild reduction in osmotic stress in the portal venous system with next improved unleash of sodium into the blood as a variation reaction. This osmotic change inside the blood plasma results in the redistribution of body water; that is, there's a growth in the overall extracellular fluid quantity and the transfer of water from erythrocytes and interstitial fluid into the plasma and among intracellular and interstitial fluids. In reaction to the changed plasma quantity, baroreceptors and quantity receptors within the bloodstream are activated, inducing a lower in aldosterone release and as a result an increase in sodium removal. Reactivity of the volume receptors within the vessels may bring about a lower ADH release and a greater diuresis (Rosborg *et al.*, 2019).

Regular intake of low-mineral content material water can be related to the progressive evolution of the modifications mentioned above, likely without manifestation of signs or causal symptoms over the years. Nevertheless, extreme acute damage, including hyponatremic shock or delirium, may also arise following extreme physical efforts and ingestion of numerous liters of low mineral water. The so-called "water intoxication" (hyponatremia shock) may additionally arise with fast ingestion of immoderate quantities now no longer only of low-mineral water but additionally tap water. The "intoxication" threat will increase with reducing ranges of TDS. In the past, acute fitness problems have been stated in mountain climbers who had organized their drinks with melted snow that turned into now no longer supplemented with essential ions. A more extreme course of this kind of situation coupled with mind oedema, convulsions and metabolic acidosis was reported in babies whose liquids had been organized with distilled or low-mineral bottled water(Basnyat*et al.*, 2000).

2. Parts and working of RO purifier

The detailed step-by-step method of working RO water purifier and processes that helps in removing contaminants as well as delivering healthier water. An RO purifier includes sediments, a carbon filter, a RO membrane, a UV lamp, a UF membrane, and a post-carbon filter (Sharma *et al.*, 2019; Kumar & Singh, 2021).

a) Pre-filters

The job is to filter out the larger particles from the water, such as sand slits, filters, and so on. Also aids in the protection of the RO Filter membrane, which can become blocked as a result of exposure to salt, chlorine, and other contaminants. This is accomplished through the use of a Carbon filter, which aids in the removal of harmful chemicals such as pesticides and other foul odors from the water.

b) Reverse Osmosis Membrane

The RO membrane is the next filter. In this method, water is driven through a semipermeable membrane to block minute particles. The membrane is made up of synthetic plastic and other materials that stop sodium, chlorine, and even larger molecules like urea, bacteria, and infection. It can also be used to remove other elements.

c) The UV Lamp

The RO comes with a UV lamp that helps clean the water by killing all germs. UV rays can eradicate sickness caused by microbes in water by damaging their genetic code. They will be able to abolish their ability to reproduce as a result of this. This UV lamp's ultimate goal is to kill 99.99 percent of all hazardous microbes in the water, making it safe to drink.

d) Ultrafiltration

Ultrafiltration is the next phase in the filtration process. Water is pushed to travel through a hollow fibre membrane, leaving all contaminants behind and producing filtered, clear, and clean water for drinking.

e) Post Filter (activated carbon filter)

The water is passed through the post-carbon filter before being stored in the storage tank. The filter aids in the removal of all contaminants that pass through the membrane, leaving it completely clean and fit. Along with all of this, they include a TDS controller, which aids in the retention of all necessary natural minerals in filtered water, which is critical for the body's absorption of water. This method allows more than 50% of water to be recovered as purified water, resulting in less water waste, which is critical for future generations.

3. Mechanism of RO water purifier

Osmosis is a natural process that involves the passage of clean water from a low to a high concentration solution over a semi-permeable membrane. Water and a few ions pass through the membrane, but most ions and dissolved solids are not allowed through. This event (water movement) continues until the membrane achieves osmotic equilibrium, or until the chemical potential on both sides of the membrane is equal. When a pressure larger than the osmotic pressure is given to a concentrated solution, the process is known as reverse osmosis. The membrane owns the solutes and forces water to transfer from the concentrated to the diluted side (Wimalawansa, 2013).

3.1 RO membrane description

RO membranes are available in flat sheet and hollow fine fiber (HFF) structural configurations.

Three layers make up the flat sheet RO membrane (Gabr, 2007):

a) Polyester non-woven support layer

b) A coating of Poly sulfone

c) The polyamide barrier layer is placed on top of it. The polyamide, which has a molecular structure, forms the barrier layer

3.2 RO membrane performance

A RO membrane's performance is determined by a number of factors. The following are the most crucial criteria (Li & Tian, 2009):

a) Flow Rate

Three streams can be found in RO appliances. The RO membrane separates the feed stream into two streams: permeate and concentrate. These streams' flow rates are commonly expressed in cubic meters per hour (m3/h) or gallons per minute (gpm). The rate of water entering the RO system is known as the feed flow rate. The rate at which water passes through the RO membrane is referred to as permeate flow rate, whereas concentrate flow rate refers to the rate at which water does not pass through the RO membrane and exits the RO system with ionized particles removed.

b) Permeate Flux

Permeate flux describes the quantity of permeate released while membrane separation per unit of time and RO membrane area. The flux is measured in $L/hr/m^2$ (lmh) or in $gal/d/ft^2$ (gfd).

The flux is expressed as: $Jv = Qp/S$

In which, Jv = permeate flux,

S = area of the membrane,

Qp, permeate flow rate

c) Salt Rejection

Salt rejection is a percentage of feed water which describes the amount of solute removed in the permeate water.

The retention is expressed by:

$R = \{1 - Cp/Cave\} * 100$

In which: R = rejection,

Cp = permeate concentration,

Cf = feed concentration

Cc = concentrate concentration

Cave = average feed concentration, which is expressed as:

$Cave = \{Cf + Cc\}/2$

d) Recovery Rate

The recovery rate is defined as the fraction of the feed flow which moves across the membrane.

$Y = Qp/Qf$

In which, Y= recovery rate,

Qp = permeate flow rate,

Qf = feed flow rate

It is expressed in percentage.

e) Differential Pressure

The pressure drop is the difference between the feed and concentrate pressure during water transfer from one or more RO membrane constituents.

The pressure drop (dp) is expressed as:

$dp = (Pf + Pc)$

In which, Pf = feed pressure,

Pc = concentrate pressure

f) Trans-membrane pressure (TMP or ΔP)

Trans-membrane pressure is defined as the difference in pressure between two different sides of the membrane. The pressure is measured in psi or bar, and is the driving force for membrane separation and permeation. Usually, an increase in the trans-membrane pressure increases the flux across the membrane.

The trans-membrane pressure is expressed as:

$TMP = \{(Pf + Pc)/2\} - Pp$

In which: Pp = permeate pressure,

Pf = feed pressure,

Pc = concentrate pressure

3.3 Tendency of RO Performance

The average permeate flux, which determines permeate production, and salt rejection, which determines permeate quality, are the two most important factors for a RO membrane unit. Operating parameters like feed pressure, feed concentration, temperature, and so on might influence these two criteria. The operation of the RO membrane system is influenced by all of these variables. When feed concentrations change, salt rejection rises first. In the average feed salinity range, 300–500 mg/l is the greatest value of rejection. As the feed concentration rises, the salt rejection reduces as a result. The impact of feed solution pH on solute rejection is complicated because pH changes affect membrane surface charge, dissociation rate, and so on.

4. Detrimental effects of Reverse Osmosis (RO) water on health

- The World Health Organization has warned that drinking RO water with irregulated TDS content can result in health problems (WHO, 1979).
- Reverse Osmosis 'RO' Systems are widely used in homes to filter and detoxify tainted water and make it safe to drink. However, it also eliminates92-99 percent of essential calcium and magnesium salts.
- Deficiency of calcium and magnesium salts generates a variety of health problems and

physiological problems in people who drank uncalibrated RO filtered water (Sauvant& Pepin, 2002).

4.1 Potential consequences of drinking low mineral content water:

Drinking demineralized water has negative and detrimental health effects on the body such as hormone secretion, kidney functions and bone mineral density (YuA*et al.*, 1989).An abrupt decline of beneficial minerals and salts such as sodium, calcium, chloride, potassium ions cause electrolytes and blood-osmotic pressure imbalance. Consuming RO 'low TDS water' causes debilitating symptoms listed below that causes harm to human health. Although water is not a major source of these elements. According to research and scientific basis it is observed and proven that consuming water that has low content or is deprived of Ca and Mg salts is associated with cardiovascular disorder, fractures in children, preterm/mature birth or low birth weight, neurological disorders, low bone density in adults etc.(Levin et al., 1981;Kozisek, 2005).

For example:

- Deficiency of calcium - brittle bones,
- Magnesium and calcium deficient - hypertension and
- Reduced iron intake - interferes with blood formation.
- Deficiency of these essential elements leads to a weak immune system thus unable to fight many diseases (Iwami *et al.*, 1994).

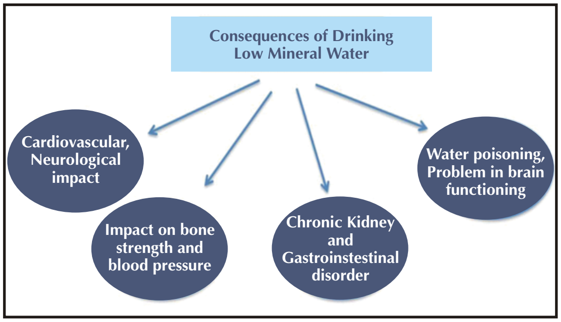

Figure1: Consequences of Drinking Low Mineral Water

5. Summary of survey report

5.1 Methodology of survey

A survey through Google Forms was developed to capture a snapshot of the experiences of people from Delhi/NCR region using RO water filtration in their household and received 113 responses in January, 2022. Furthermore, our survey was created to be open-ended, allowing for a wide range of responses.

5.2 Analysis of survey report obtained from people

a) Research found that the majority of the respondents use RO in their houses and more than 50% use a filtration system, followed by UV and boiling methods and very few of them use chemical treatment (Fig 2).

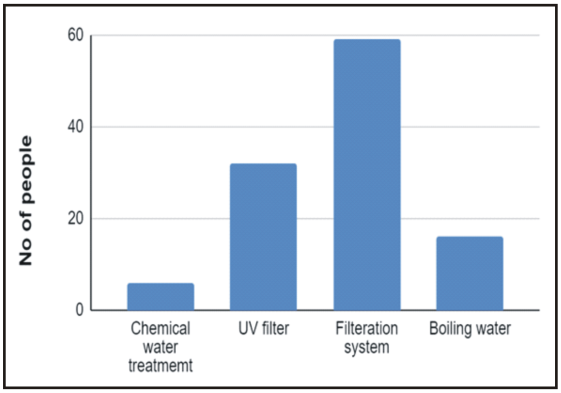

Figure 2: Methods of filtration used by people.

b) According to the given data it takes 5-15mins to filter 3 liters of water using RO purifier (Fig 3).

c) Almost half of them reported their RO purifier requires maintenance every six months.

d) On a scale of 1-10 most of them more or less were satisfied with their current RO purifier (Fig 4).

5.3 Strategies for re-purposing the RO waste water

In a survey report a group of people recommended diverse strategies to re-purpose

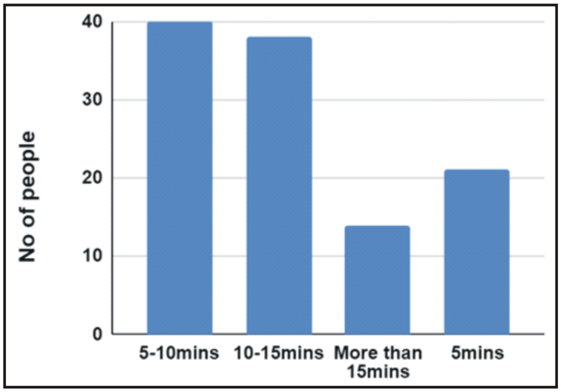

Figure 3: Time taken to purify three liters of water by RO purifiers.

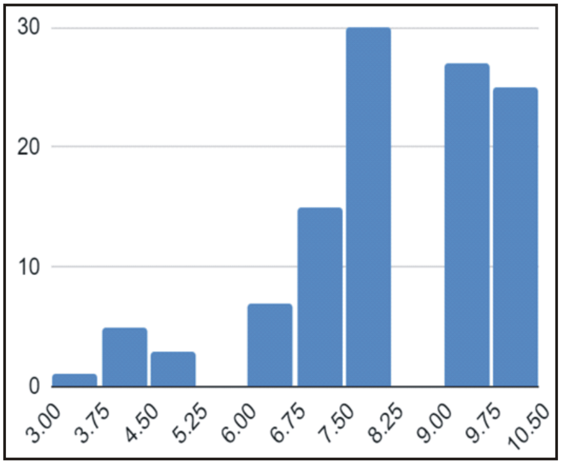

Figure 4: Scale on which people were satisfied from their RO

the RO waste water. The following are the main ideas that have been proposed:

- Automobiles washing and cleaning.

  In order to reduce water wastage by RO purifier you can use waste water in washing your automobiles and you will be astonished to learn that a single car wash consumes 14 liters of water via buckets.

- Watering Plants or Home Garden.

  Another technique to repurpose waste RO water is to water your plants if you enjoy gardening. This is beneficial to people who live in cities with high TDS levels in their municipal water.

- Washing utensils.

  Another useful application of using RO waste water is you can use a tank to which you can connect a motor and provide a supply to a tap, and then you can use that waste water by RO in the tank through washing your utensils.

- Floor mopping.

  Using RO waste water to mop the floor is a wonderful alternative to save water and put that waste water to good use. If the TDS level of waste water exceeds 2000 ppm. Because high TDS leaves a stain you can dilute it by mixing it with equal amounts of tap water.

- Pre rinsing Laundry.

  You can use it for everyday laundry, however RO water with a high TDS level is not recommended for delicate fabrics. Most Indian households have washing machines as they save time, but they waste a lot of water. You can attach a tank over a washing machine and install outlet by RO so you can get that water directly for washing garments in washing machines.

- Toilet cleaning and Flushing.

  Every single flush waste approximately 5 to 7 liters of potable water. The utilization of RO waste water can help to reduce the amount of clean water wasted.

The questionnaire included seven questions related to Purification of water using RO purifiers and some techniques for re-purposing RO-waste water were suggested. Statistical analysis using graphs was done using Word Excel Sheets.

6. Discussion

If re-mineralization is a concern for you, there are a plethora of techniques to contemplate. You shouldn't rely on your tap water supply providing all of the nutrients you require. You must not, however, eliminate all minerals from your water. Enabling minerals to reintroduce to your purified water enhances its taste while also boosting your well being. Mineral cartridges and mineral drops will enhance the quality of your potable water substantially. We highly recommend people to check the TDS levels offeredby the RO purifier before purchasing it and a purifier incorporating Mineral guard. The technology safeguards vital minerals that are naturally present in water but are eliminated by conventional water purifiers, culminating in wholesome water rich in minrals (Grzebisz, 2011).

To compensate for the lost minerals in water, we also urge people who consume RO purified water on a daily basis to adopt a mineral rich dietary intake to counteract nutritional insufficiency and to provide the fundamental necessitis of the human body (Table1).

UF and UV Purifier for Municipal Water Supply can be used as an Alternative for Ro Purifiers

The membrane of UF purifiers has considerably wider holes and water may move through it naturally using gravity, UF purifiers can work without electricity. This implies there is no need for external pressure or a water pump. There is also no water waste because UF purifiers do not hold back any water. UF can only extract undissolved particles and bigger pollutants due to its higher pore size. It is unable to remove dissolved solids or reduce TDS levels.

The use of ultraviolet light to purify water is known as UV purification. A UV purifier destroys

Table1: Mineral Rich Food Sources (Source: Akramet al., 2020; Gupta & Gupta, 2014; Srikumar, 1993)

Calcium rich food source	Measure of Ca (mg)	Magnesium rich food source	Measure of Mg (mg)	Sodium rich food source	Measure of Na (mg)	Potassium rich food source	Measure of K (mg)	Chlorine rich food source	Measure of Cl (mg)
Plain yogurt, low fat	415	Spinach	157	Table salt	2300	Aduki beans, cooked	612	Raisin bran cereal	352m
Chia seeds	76	Pumpkin seeds	92	Bouillon cubes	1200	Black beans	306	Quinoa	159
Tofu, firm made with CaSO4	204	Chard	154	Soy sauce	1005	Molasses	293	White bread	29
Milk low fat	305	Avocado	43.5	Beef jerky	590	Edamame beans	285	Swiss chard	961
Sardine canned with bones	325	Lentils, Cooked	35.7	Olives	42	Banana	537	Potato	926
Beans	79	Tuna	109	Ham	320	White beans	502	Orange juice	496
Sesame seeds	137	Tofu, firm	46.6	Salami	226	Tofu, firm	186	Acorn squash	896
Soy milk	299	Soy milk, unsweetened	38.9	bacon	194	Soy milk, unsweetened	292	Cantaloupe	426
Kidney beans	31	Kidney beans, cooked	37.2	pickles	160	Avocado	727	Banana	422
Almonds	37.3	Almonds	37.9	Parmesan cheese	390	Potatoes	592	Yogurt	625
Kale	90.5	Potatoes	34.4	French bread	837	Kale	299	Egg	156

or inactivates disease-causing bacteria and viruses by discharging high-intensity UV rays into the water. UV purifiers, on the other hand, cannot remove any pollutants or compounds from water, whether dissolved or undissolved.

A UF+UV water purifier can be used if the water has low TDS but is polluted with bacteria and viruses and appears muddy. Both the techniques doesn't affect the TDS levels hence can be used as an potential alternative for RO purifiers which tends to lower down the TDS levels of water.

7. Conclusion

The objective of this literature review is to bring into knowledge the health implications associated with low TDS levels of RO water as well as discussing and recommending a possible solution to the stated problem. The TDS level of RO purified water can fall below the required range further causing health threats. Before installing RO water purifiers, people ought to have a comprehensive grasp of the situation and the health implications of consuming demineralized RO water in their everyday life. The regime outlined in this article is derived from previously executed experiments and trials and is based on assessment of the existing literature. Future research is required in order to assert justification for setting standards (TDS) and a potential solution to the existing problem.

8. Abbreviations

RO, Reverse Osmosis; TDS: Total Dissolved Solid; PPM: Parts Per Million; P: Pure water; C: Concentrated water; ADH: Antidiuretic Hormone; HFF: Hollow Fine Fiber; GPM: Gallons Per Minute; TMP: Trans-Membrane Pressure; pH: Potential of Hydrogen; Ca: Calcium; Mg: Magnesium; Cu: Copper; GIT: Gasto-Intestinal Tract; UV: Ultra-Violet; UF: Ultra-Filtration; mg: milligram.

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Centre for Multidisciplinary Research, Innovation & Entrepreneurship

Shaheed Rajguru College of Applied Sciences for Women

University of Delhi, India

Vasundhara Enclave, Delhi - 110 096