

COMPARATIVE ASSESSMENT OF GROUNDWATER AND ITS RO REJECT FROM INDUSTRIAL AND DOMESTIC RO SYSTEMS IN JAIPUR, INDIA

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ABSTRACT

RO water has been in higher demand over the past few decades because it provides safe and healthy water. However, one of the biggest problems with this process is that it makes reject water. There are more and more RO plants, and the water they throw away makes the problem of not having enough water even worse, especially in dry and semi-arid areas. This research paper briefly talks about how far we've come in reusing reject water and looks at other possible uses by comparing the quality of feed water and reject water. The current study collected 40 samples with TDS (20 raw and 20 rejected) from industrial plants and domestic water systems. Tests on water samples show that the TDS of feed water at the Sitapura site in Jaipur was between 2550 mg/L and 3350 mg/L. The TDS of feed water at all other places in Jaipur was less than 2000 mg/L, which is within the limits set by BIS standards 10500:2012. The quality of reject water depends on the quality of the feed water. The TDS of reject water was about 1.5 to 3 times higher than that of feed water. Another difference between industrial and home RO systems is the pressure, recovery, and contaminants that are removed from reject water. In industrial RO plants, there were large amounts of contaminants and less reject water. In domestic RO systems, on the other hand, there was a lot of reject water and less contaminants because of low back pressure. The current study on water analysis in Jaipur indicates that RO-rejected water is adequate for non-potable applications and can be repurposed to alleviate future water scarcity challenges.

Keywords: Feed water, RO Reject Water, Domestic and Industrial RO System, TDS, Water reuse

INTRODUCTION

Water is important for all living things and for the health of our planet. Water is necessary for every cell in the body to do its metabolic processes, photosynthesis, cellular respiration, and growth. It is a basic human right and a major global problem to make sure everyone has access to safe drinking water (WHO 2017). Because of things people do, like dumping dirty dishwater, laundry waste, urine and faeces, sewage, and direct industrial effluent, the quality of water has gotten worse. Iron, fluoride, arsenic (geogenic), heavy metals, and phosphates are common pollutants that come from a variety of human activities, such as pesticides used in farming, sewage from homes, and industrial waste.

Water purification technologies, especially reverse osmosis (RO), have become important for solving global problems with water quality and scarcity. They can get rid of odors, salts, heavy metals, organic impurities, microorganisms, and other contaminants, and they can also make the water taste better. Household reverse osmosis (RO) systems have gained popularity in India due to escalating concerns regarding the quality of tap water (Gani *et al.*, 2023). During the 2019–2020 financial year, more than 10 million RO units were sold in India. The market is expected to grow at a compound annual growth rate (CAGR) of 9% between 2020 and 2026 (Gani *et al.*, 2023). RO systems can be used in homes and factories,

especially in Rajasthan, which has a lot of problems with water quality and relies on groundwater. RO systems make clean water, but they also make reject water, which is a problem because it makes up 30% to 70% of the feed water and is full of iron, salts, and other potentially harmful substances. The quality of RO reject water depends on where the feed water comes from (surface water, groundwater, or a municipal supply) and how the system is set up (for home use or for business use). The chemical properties of RO reject depend on things like pH, hardness, alkalinity, anions, cations, and impurities like heavy metals. If there are harmful contaminants in the feed water, the reject water is likely to have trace metals like nickel, iron, chromium, and molybdenum (Vaishnav *et al.*, 2023). If reject water is not properly disposed of, it can pollute groundwater and soil, which can harm the environment. The quality of the rejected water also depends on other things, such as the type of membrane used, the washing solutions, the system's recovery, the pressure applied, and the use of anti-scalant, corrosion products, or other chemicals used in the pre-treatment (Tayeh 2024). In areas where water is scarce, like Rajasthan, where RO systems are common, it is important to compare feed and reject water. This is because looking into ways to reuse water sustainably can help the environment and we can use comparative analysis to predict problems that could harm water bodies and soil.

RO systems are good for places where the groundwater has a lot of TDS, salinity, and hardness. To safely and sustainably reuse water, it is important to screen plant responses to reject water's salinity and ionic loads. This study aims to assess the economic, technical, and environmental challenges related to RO reject water (brine) and to explore strategies for its management and reuse.

The current study mainly concentrated on a comparative evaluation of the water quality of feed and reverse osmosis (RO) reject water obtained from domestic and industrial packaged drinking water facilities. It also looked at whether RO reject water could be used for irrigation or landscaping by comparing it to water quality indices. It looked at how it might affect plants, soil, and the environment, and it suggested a sustainable way to use it. The current study focused on brackish water treatment plants that treat ground, surface, and municipal water. Jaipur, the capital of Rajasthan, is a very crowded city with a TDS range of 100 to 10000 mg/L of water. Here, reverse osmosis (RO) is commonly used to lower the TDS of drinking water. For the past 40 years, Reverse Osmosis has been the most popular water purification method based on semipermeable membranes, with a huge 44% share of the global market. There are more than 15,000 desalination plants in the world today, and about half of them use reverse osmosis technology. On November 13, 2024, the ministry sent the states operational guidelines for community water purification plants. The states have successfully set up 7368 RO plants, as shown by review meetings, video calls, talks between state officials, and the integrated management information system (IMIS). According to an order, 850 RO plants have been set up in Rajasthan (in response to Lok Sabha Unstarred Question No. 330, which was due for reply on 25/02/2016 (Digital Sansad)).

Groundwater is the source of brackish groundwater. This water can be naturally salty or made salty by seawater intrusion or human activities. One of the biggest problems with the RO system is that it rejects water that is made as a by-product. Water samples were taken and tested to look at the data on the quality of the feed and reject water.

Heritage City is the study area. Jaipur is in the semi-arid western part of India, on the eastern edge of the Thar Desert. Groundwater is very important for meeting water needs there. Jaipur is the tenth most populous city in India and is always growing. There were 6,626,178 people living in Jaipur district, with 3,471,847 living in cities and 26.91% living in rural areas (2001–2011). Maurya *et al.* (2022) conducted a study that confirmed the built-up area of Jaipur will double by 2050 (CGWB, NAQUIM 2.0, 2024), which will put a lot of stress on water resources. Groundwater depletion is at a very dangerous level and will soon become a big problem, especially with climate change. This is important for the Heritage city of Jaipur. A lack of water would hurt Jaipur's economy and tourism. So, it's important to take action right away to protect the environment and encourage conservation efforts.

Antoine Nollet first talked about reverse osmosis in 1748 (Zewdie *et al.*, 2021). Since the middle of the 1970s, reverse osmosis (RO) systems have been widely used to make brackish and seawater safe to drink

and to make clean water for industrial, medical, and household uses. Reverse osmosis is a physical process that separates salts from water using a semi-permeable membrane that is pushed through by pressure. The feed water flows through the membrane, separating two streams of water, one with a lot of salt and the other with little salt. When the pressure applied is greater than the osmotic pressure, water moves through the membrane, and the solvent starts to move toward the side with less concentration (Figure 1). The concentration and other properties of the feed water are very important when designing a RO system. The main problems with the RO system are that it doesn't recover enough water, it makes too much brine, and it has environmental problems when it comes to getting rid of the brine. More concentrated brine raises osmotic pressure, uses more energy, makes recovery harder, and raises the risk of membrane scaling.

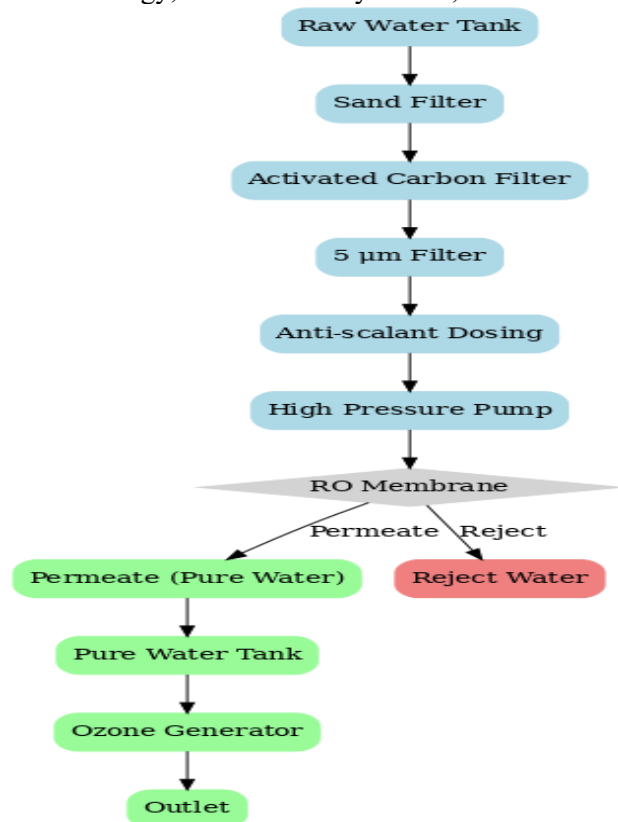


Figure 1: Reverse Osmosis (RO) process

Characteristics of Feed and RO Rejected water

TDS has a small amount of organic matter and dissolved inorganic ions like calcium, magnesium, carbonate, bicarbonate, sodium, potassium, chloride, sulfate, and nitrate. Natural freshwater usually has a TDS level between 20 and 1000 mg/L, while brackish water usually has a TDS level between 100 and 10000 mg/L. The TDS of RO rejected water also depends on the source water, how well the system works, the type of membrane used, the pressure applied, the anti-scalant dosing, the washing solutions, and the other chemicals used in the pre-treatment process. Because household RO systems only recover 5-15% of freshwater, they make a lot of reject water. This low recovery rate can make water shortages worse in cities with a lot of people (Ahuchaogu *et al.*, 2018). In industrial plants, on the other hand, recovery can be anywhere from 15% to 60% because high pressure is used during treatment.

The characteristics of RO reject water are also affected by how well the RO membrane works. The hydrodynamic conditions of a RO system, such as flow rate, pressure, pump efficiency, and membrane fouling, affect the permeate flux and recovery. Research has investigated the influence of operational

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parameters (pressure, temperature, and feed water quality) on critical performance indicators such as permeate flux and recovery rate. RO's effectiveness also depends on the amount of pollution and the conditions in the area. Adding pressure improves the quality of permeate flux, which means that the TDS goes down because the RO membrane pushes the solutes (unwanted components) onto the membrane. When the operating pressure is high, the percent rejection usually goes down. When the operating time goes up, the permeate flux and TDS content go down. As the operation time goes up, the permeate flux and TDS content tend to go down, while the solid buildup on the membrane's surface goes up, which makes concentration polarization stronger. This causes the membrane to get dirty, which makes it less able to hold back contaminants or unwanted parts and lets solutes and iron through, which raises the TDS of the permeate (Budiyono and Buchori, 2008).

Pre-treatment chemicals like acids, biocides, scale inhibitors, and chlorine neutralizing agents can change the physio-chemical properties of RO concentrate and the amount of contaminants in it. The temperature and ionic strength of the feed water are two environmental factors that affect the composition and levels of contaminants in the ROC. The RO membrane can also get rid of bacteria, viruses, chemicals, salts, and other impurities. The main problem with this system is the by-product brine, which is about 1.5 to 3 times more concentrated than the feed water. The RO membranes reject more than 99% of TDS, so metals and other pollutants are found in the water that is rejected. RO systems get rid of 90–98% of TDS, 99% of organics, and 99% of bacteria. According to Krishnan *et al.*, (2007), high-performance membranes can remove up to 99% of minerals in one pass.

The performance of a RO membrane is very sensitive to things like temperature, pressure, and pH. When the temperature rises, it raises the permeate flow rate, recovery ratio, fluoride concentration, permeate flux, and solute solubility. It can also speed up the rate at which solutes pass through membranes, but it lowers the rate at which salt is rejected. A higher temperature lowers viscosity, which speeds up the flow of water through membranes (Gedam *et al.*, 2012).

RO works well to get rid of fluoride and other inorganic pollutants as well. When the feed pressure is high, the percent recovery and percent salt rejection go up, but the fluoride concentration and TDS of the permeate go down. More pressure increases the driving force, which overcomes osmotic pressure and lets more water pass through the membrane at a faster rate. The percentage of contaminants that are rejected depends on the pressure that is applied, the strength of the contaminants in the raw water, and the temperature of the system (Gedam 2012; Ali *et al.*, 2015).

The percentage of salt rejection and recovery goes down as the pH goes up, but the concentration of permeate goes up. It Less permeate fluoride, salt rejection, and flux. pH has a big effect on the fluoride rejection ratio, so it's important to keep the pH level just right. Effective permeability goes up when the pH goes from 3 to 9.5. The pH of the feed water affects how much fluoride is in the permeate. As the pH goes from 3 to 7, the amount of fluoride in the permeate goes up. As the pH goes from 7 to 9.5, the amount of fluoride goes down. The amount of fluoride in permeate goes down at acidic pH because fluoride forms strong hydrogen bonds in acidic solutions (Gedam *et al.*, 2012). The best pH range for feed water to run a RO system is between 6.5 and 8.5. At this pH range, scaling of membranes (from hydroxides, carbonates, and silicates) and corrosion of system parts are less likely to happen. Extreme pH can shorten the life of thin-film composite (TFC) RO membranes, so they are sensitive to it. Corrosion and metal fouling happen when the pH is below 6.5, and membrane stress and scaling happen when the pH is above 8.5. To keep the pH and membrane life and stop calcium carbonate scaling, you can use standard pre-treatment methods like acid dosing, lime softening, and anti-scalants. These methods can keep this range. The amount of water that RO plants throw away depends on three things: the TDS of the feed water, the TDS of the permeate or treated water, and the size or capacity of the plant. The bigger the difference in TDS between raw and treated water, the more rejected water will come from RO plants. Also, bigger plants tend to make less reject water than smaller plants do.

Table 1: Comparison of generation of reject water by Industrial RO plants and Domestic RO system

Parameter	RO Plant- Case 1		RO Plant- Case 2	
	A	B	A	B
Capacity of RO Plant	10 LPH	10 LPH	10 LPH	100 LPH
TDS (Input Water)	1500 ppm	1500 ppm	1500 ppm	1500 ppm
TDS (Treated water)	100 ppm	50 ppm	100 ppm	100 ppm

LPH (Litre per Hour)

In above table there are two RO plants -

1. Plant B will produce a larger amount of effluent than plant A, since there is more salts to remove and the difference of TDS is greater between feed and treated water in Plant B.
2. Smaller plants like A (10 LPH) will produce more reject water proportionally than larger plants like B (100 LPH). The TDS of rejected water can be calculated based on the rejection rate. 30% to 90% water can be rejected (Table 1).

For example- for a 50% rejection rate, TDS=1500 mg/L, to 500 mg/L, the reject water TDS would be $1500 + (1500-500) = 2500$ mg/L (Krishnan *et al.*, 2007).

MATERIALS AND METHODS

Present study evaluated and compared the feed water (ground or surface water quality) and its reject water generated through RO systems from two distinct sources.

Collection of water samples:

Industrial RO Plants used in the manufacturing of packaged drinking water.

Domestic RO systems installed in households.

A total of 40 water samples (20 raw water/feed water and 20 reject water samples) from domestic RO units and industrial packaged water plants were collected from different selected locations of Jaipur city. Sampling was based on water source type, scale of operation and accessibility. Samples were collected in a cleaned HDPE bottle directly from the source of the feed inlet and rejected outlet.

Water samples were analyzed for physico-chemical parameters like temprature, pH (digital pH meter model no. Systronics 802/1254), EC (Conductivity-TDS meter model no. Systronic 307/639), TDS and TSS (evaporating method), alkalinity, chloride, total hardness, calcium, magnesium (titration method), sodium and potassium (Flame photometer model no. Systronics 128 µc/2983).

RESULTS

The analytical results of groundwater are given in the table (Table 2). The quality of groundwater samples was compared with ISO: 10500 standards and Indian Irrigation Standards IS 11624:1986.

Groundwater Quality Data

The analysis of results indicates that the pH of the feed water ranged from 6.9 to 7.7. Electrical conductivity was observed in the range of 550–4900 µS/cm, while TSS varied from 1.66 to 3.71 mg/L. TDS values ranged between 290 and 2550 mg/L. Other parameters were as follows: Total Alkalinity, 130–375.16 mg/L; Chloride (as Cl⁻), 66.01–799.7 mg/L; Total Hardness, 140–560 mg/L; Calcium (as Ca²⁺), 28.86–128.26 mg/L; Magnesium (as Mg²⁺), 16.56–63.86 mg/L; Sodium (as Na⁺), 35–420 mg/L; Potassium (as K⁺), 2.5–4.67 mg/L; Sulphate (as SO₄²⁻), 11.55–80.45 mg/L; Fluoride (as F⁻), 0.28–1.0 mg/L; and Nitrate (as NO₃⁻), 1.7–140 mg/L.

Reverse Osmosis Reject Water Quality Data

The analysis of RO reject water showed that pH ranged from 7.1 to 7.8. Electrical conductivity varied between 750 and 7600 $\mu\text{S}/\text{cm}$, while TDS ranged from 360 to 3350 mg/L and TSS from 3.0 to 6.7 mg/L. Total Alkalinity was observed in the range of 166.4–1170 mg/L; Chloride (as Cl^-), 88.64–1040 mg/L; Total Hardness, 160–1140 mg/L; Calcium (as Ca^{2+}), 35.27–176.70 mg/L; Magnesium (as Mg^{2+}), 17.53–119.6 mg/L; Sodium (as Na^+), 42.5–585 mg/L; Potassium (as K^+), 4.25–8.63 mg/L; Sulphate (as SO_4^{2-}), 20.48–127.63 mg/L; Fluoride (as F^-), 0.19–1.2 mg/L; and Nitrate (as NO_3^-), 3.5–182 mg/L.

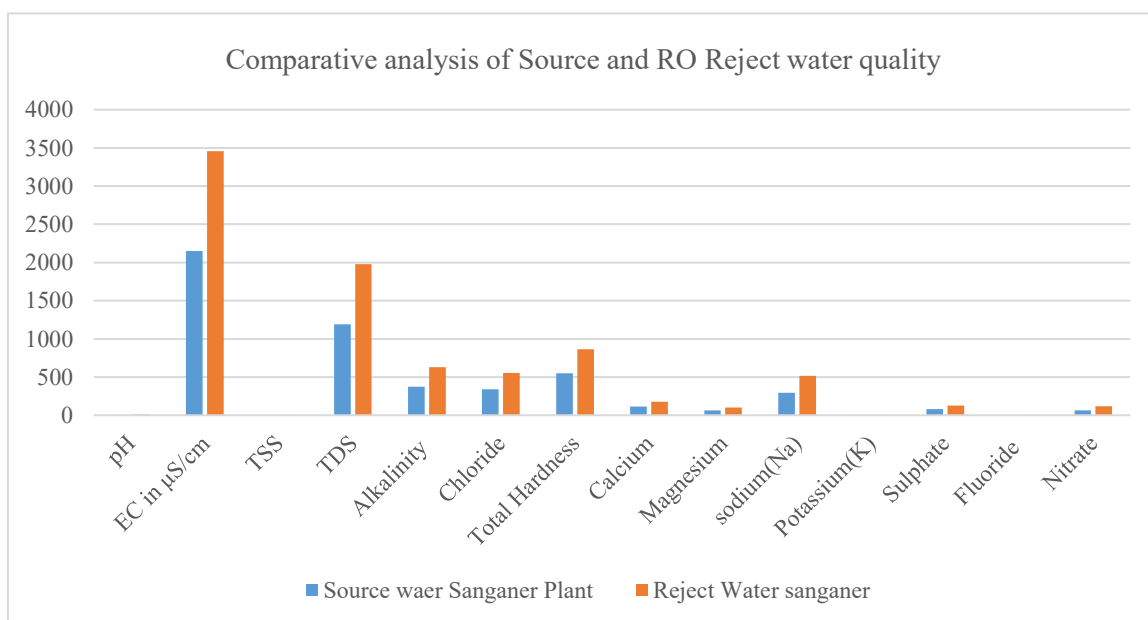
Comparative Analysis of feed and RO Reject Water

Table 2: Comparative Analysis of Feed and RO Reject Water quality

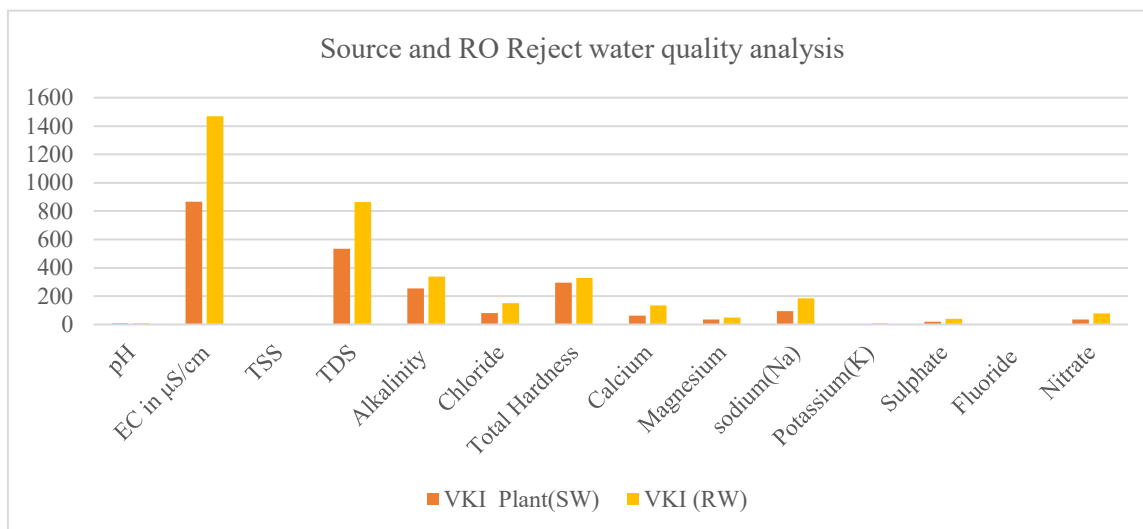
S.No	Parameter	Sample Name	RO Plant Sanagner	RO Plant VKI	RO Plant Jhotwara	RO Plant Niwaru Road	Malviya nagar Bisalpur supply Domestic	Sitapura Domestic	Katewa Nagar Domestic
1.	Temprature	SW	25°	25°	25°	25°	25°	25°	25°
		RW	25°	25°	25°	25°	25°	25°	25°
2.	pH	SW	7.3	7.41	7.3	7.1	7.7	7.6	6.9
		RW	7.4	7.56	7.4	7.2	7.8	7.8	7.1
3.	Conductivity umho/cm	SW	2150	866.66	1215	855	550	4900	1180
		RW	3458	1468.3	3500	1430	750	7600	1650
4.	EC ms/cm	SW	2.15	0.87	1.22	0.86	0.55	4.9	1.18
		RW	3.45	1.62	3.5	1.43	0.75	7.6	1.65
5.	TSS mg/L	SW	3.71	1.66	3.5	2.5	2	4	2
		RW	6.57	4.33	6.5	4.5	3	6	4
6.	TDS mg/L	SW	1192	535	880	485	290	2550	650
		RW	1977	863.3	2375	805	360	3350	910
7.	Alkalinity mg/L	SW	375.16	254.4	197.6	304.2	130	900	182
		RW	631.4	337.4	663	504.4	166.4	1170	234
8.	Chloride mg/L	SW	342	81.24	171.62	83.54	66.01	799.7	155.95
		RW	554.7	149.45	476.2	125.3	88.64	1040	252.42
9.	Total Hardness mg/L	SW	550	295.66	334	150	140	520	560
		RW	864	329	1140	281	160	676	780
10.	Calcium mg/L	SW	115.14	62.07	77.5	30.46	28.86	56	128.26
		RW	176.7	134	153.9	72.15	35.27	72.8	176.35
11.	Magnesium mg/L	SW	63.85	34.35	34.09	18.02	16.56	92	58.44
		RW	102.8	49.16	99.83	24.61	17.53	119.6	82.79
12.	Sodium	SW	293.7	94	119.75	90.25	35	420	106

	mg/L	RW	515.4	184.63	290.75	140.5	42.5	585	136
13.	Potassium mg/L	SW	4.67	3.87	4.55	2.5	4.4	4.6	3.7
		RW	6.95	8.63	12.75	4.25	6.3	6.2	4.4
14.	Sulphate mg/L	SW	80.45	19.95	28.97	11.55	31.64	80	32.24
		RW	127.63	39.83	75.12	20.48	44.98	104	53.32
15.	Fluoride mg/L	SW	0.38	0.125	0.28	0.65	0.4	1	0.272
		RW	0.59	0.19	0.45	1.2	0.6	1.6	0.35
16.	Nitrate mg/L	SW	63.26	36.13	40.8	79.11	1.7	140	42.21
		RW	117.5	79.17	115.6	114.55	3.5	182	70.6

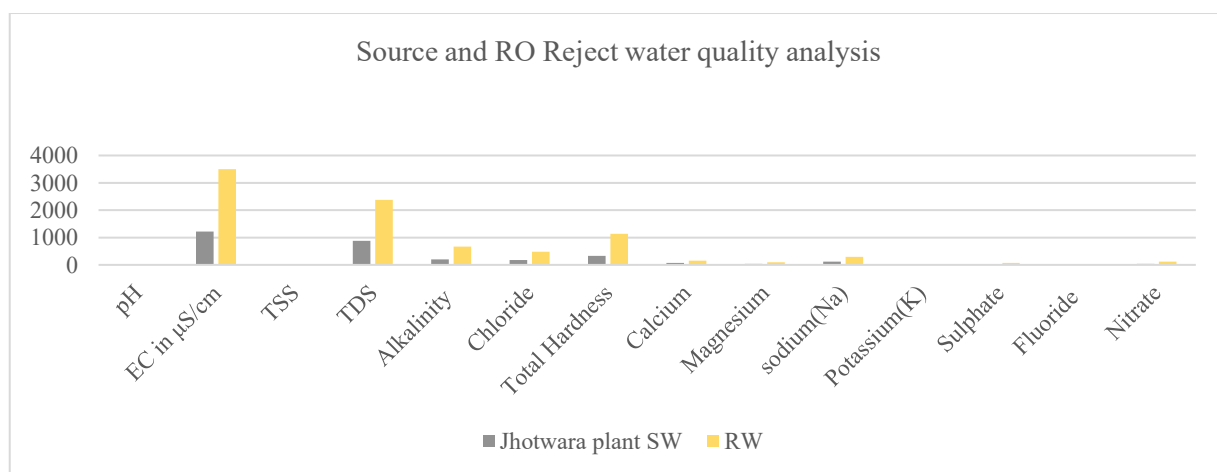
Graph 1-7 show that the reject water TDS in industrial RO plants was 1.6 to 2.7 times higher than feed water, while in domestic systems it was 1.2 to 1.4 times higher, attributable to pressure.



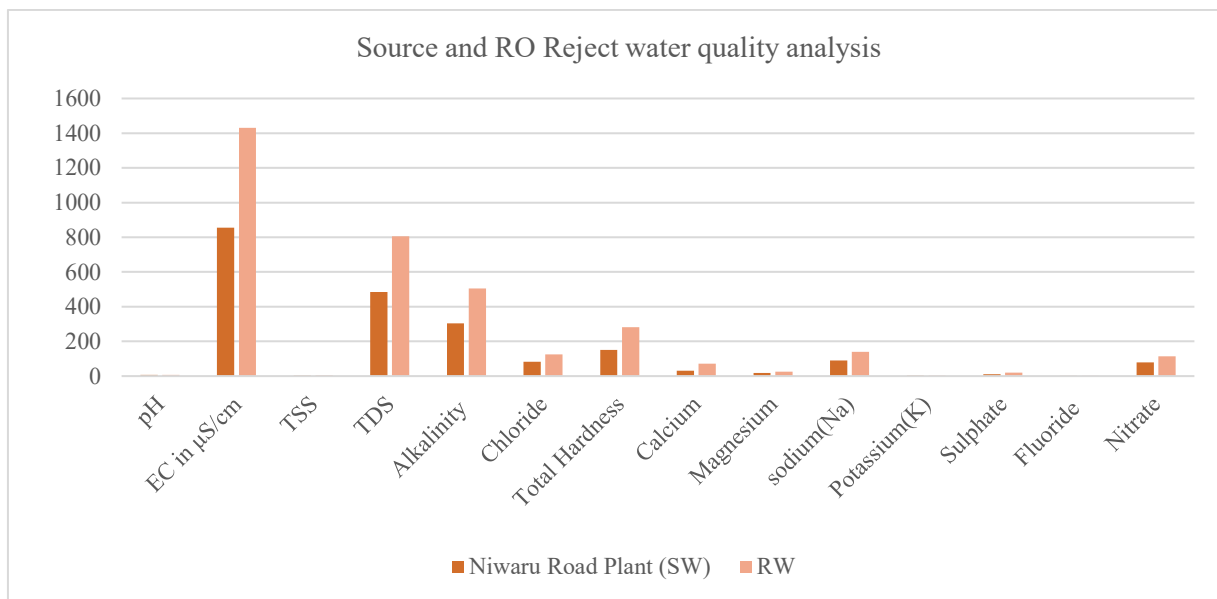
Graph 1: Comparative analysis of Source and RO Reject water quality of Sanganer (Packaged drinking water plant)



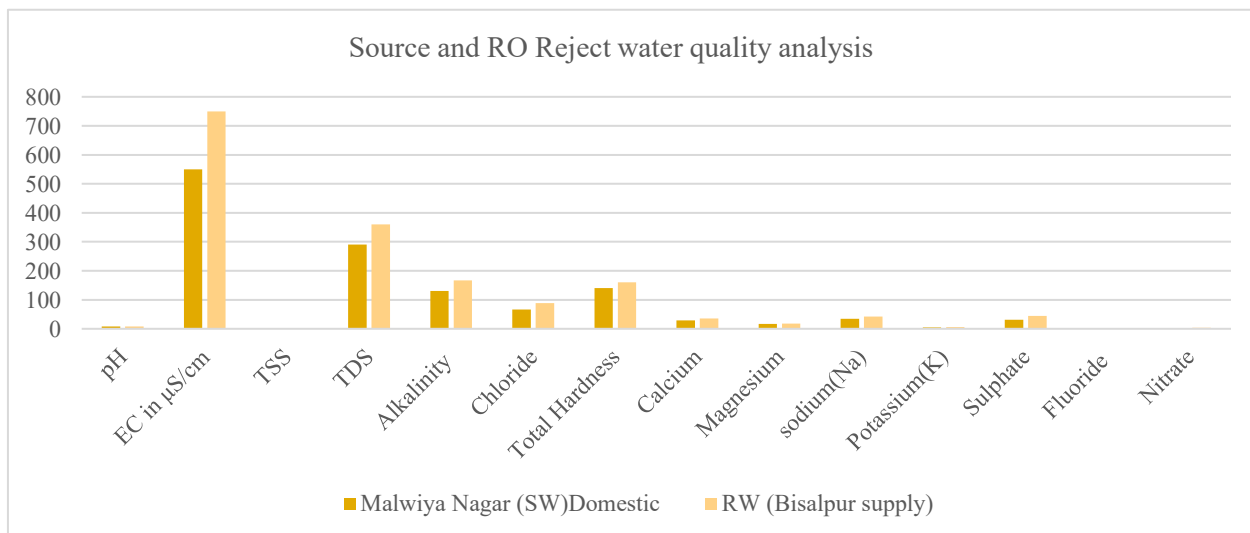
Graph 2: Comparative analysis of Source and RO Reject water quality of VKI (Packaged drinking water plant)



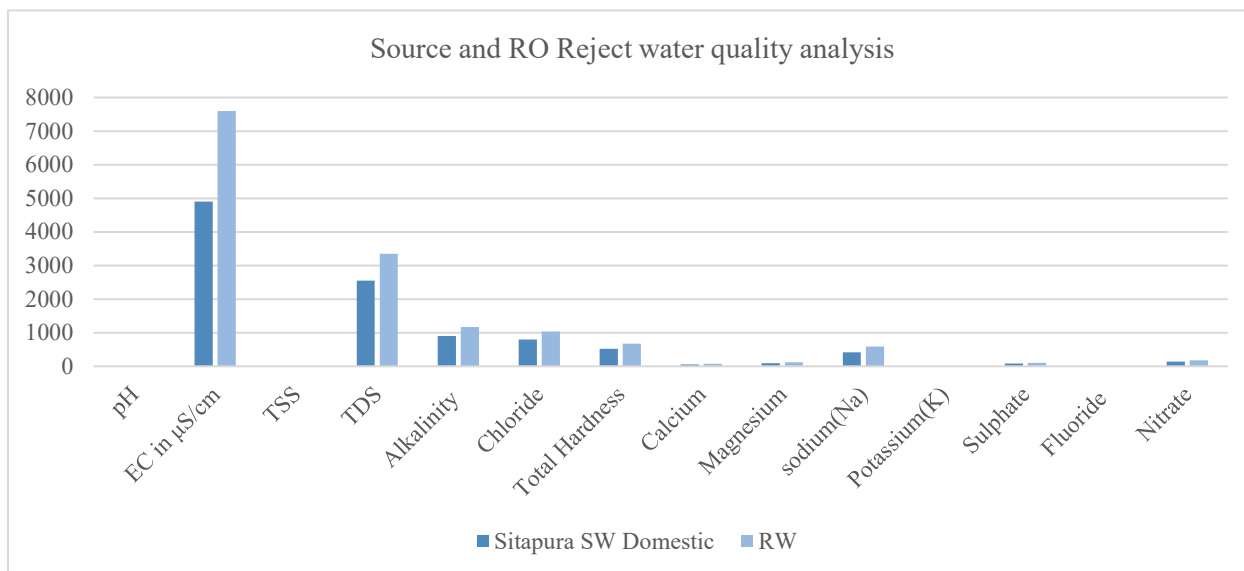
Graph 3: Comparative analysis of Source and RO Reject water quality of Jhotwara (Packaged drinking water plant)



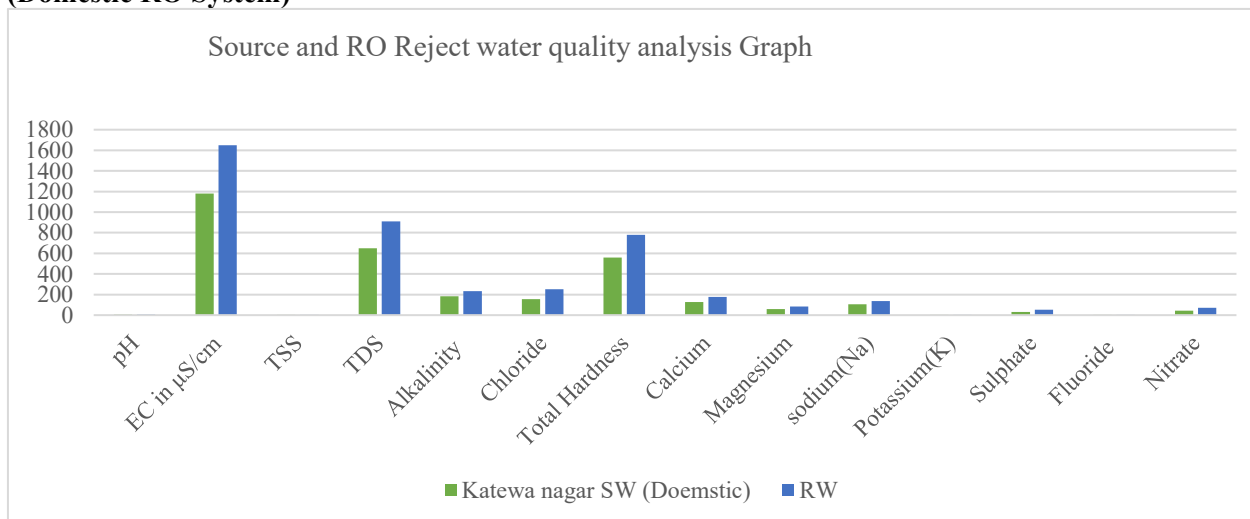
Graph 4: Comparative analysis of Source and RO Reject water quality of Niwaru (Packaged drinking water plant)



Graph 5: Comparative analysis of Source and RO Reject water quality of Malwiya nagar (Domestic RO System)



Graph 6: Comparative analysis of Source and RO Reject water quality of Sitapura, Baisalpur supply (Domestic RO System)



Graph 7: Comparative analysis of Source and RO Reject water quality of Katewa Nagar, Baisalpur supply (Domestic RO System)

DISCUSSION

The first step in making a brackish water system is to look at the makeup of the raw or brackish water, which changes depending on where it is. To get the best performance out of a BWRO system, you need to find the right balance between feed pressure, product quality, recovery, and membrane use (Alghoul *et al.*, 2009). The amount of product water, or RO permeate, depends on the pressure, the area of the membrane, the flow rate of the feed, and the quality of the feed water. As recovery goes up, the salt concentration in brine streams goes up as well. For example, at 75% recovery, the concentration factor goes up to 4 times, and at 90% recovery, it goes up to 10 times. The amount of salt in the reject stream doubles when 50% of the water is recovered and quadruples when 75% of the water is recovered. Plants work below their design recovery rate because higher recovery rates cause the salt concentration in the reject stream to rise, which could cause scaling on membranes (Singh 2009).

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Recovery Rate (%) = (Product flow rate / Feed flow rate) x 100

Rejection (%) = [(Feed solute concentration - Product solute concentration) / Feed solute concentration] x 100

The water is too alkaline, silica-rich, and hard for a high recovery rate to be possible. Dual RO systems must be used to get the best or most water recovery. (PRO+BRO) is less than 90%. PRO stands for Primary RO, and BRO stands for Brine Recovery RO (Singh 2009). A single-stage system doesn't recover much water, but a dual-stage system does and improves the quality of the product water (Alghoul *et al.*, 2009). Brackish water treatment plants make brine that is different depending on the source of the raw water, the salt concentrations, and the recovery rates. Changing the recovery rate of the RO system changes the properties of the concentrate. System recovery is the percentage of feed water volume that is turned into permeate or recovered.

Managing brine from reverse osmosis (RO) desalination carefully is important to reduce its effects on the environment. Land application, mixing with surface water, deep well injection into non-potable aquifers, evaporation ponds, discharge to wastewater treatment plants, engineered solar evaporation ponds, and marine discharge via pipelines are all common ways to get rid of waste (Mohammad *et al.*, 2005). Putting reject water on the ground can make the soil saltier and change its conductivity, which could make the soil less fertile and harm plants as well. The Sodium Absorption Ratio (SAR), which measures the relative amounts of sodium, calcium, and magnesium, is a key sign of whether soil is good for irrigation. Higher SAR values mean that the soil is less permeable (Mohamed and Antia, 1998; Rhoades 1990). Zero liquid discharge (ZLD) is the best way to stop brine discharge from small- to medium-capacity brackish water RO plants. But ZLD needs more treatment steps to manage the concentrate, which uses more energy and makes it harder to get rid of solid waste (Pearson *et al.*, 2021).

When RO brine is dumped into surface water, it can change the salinity of the water body that receives it. This can change the dissolved oxygen (DO) level in the water body, which can harm aquatic life. Because of this, RO reject should be handled and disposed of in a way that is good for the environment and meets general standards for effluent water. Reject water has pollutants in it that can hurt both people and crops, so the volume of the concentrate stream needs to be reduced. This can be done by fixing the RO plant, but it will also cost more (Pangarkar 2011).

This study further demonstrates that improper disposal of brine water negatively impacts surface and groundwater quality, in addition to soil health. Field observations in Jaipur indicated that the majority of industrial facilities in Sanganer discharge RO wastewater directly into Amanishah Nala, whereas a minority divert it into municipal sewer systems. Only a few facilities use evaporation ponds, reuse RO wastewater after softening, build separate tanks for brine storage, or treat it further through effluent treatment plants (ETPs). About 60% of people who use RO systems at home dump the water that comes out of them into sinks that are connected to the sewer system. The other 40% use it for flushing, cleaning floors, washing dishes, and watering plants.

In RO reject water, the total dissolved solids (TDS) are usually higher than in the feed water, sometimes by as much as twice as much. Water samples taken from different places in Jaipur showed that the concentration of the RO brine stream is between 1.3 and 3 times that of the feed water. This depends on things like the quality of the feed water, the recovery rate, the type and surface area of the membrane, the amount of anti-scalant used, and the pre-treatment processes. The present study conducted in Jaipur revealed that the total dissolved solids (TDS) in feed water ranged from 290 mg/L to 2550 mg/L, and in reject water, it varied from 360 mg/L to 3350 mg/L. This indicates that understanding the quality of feed water can assist in predicting the composition of brine and inform decisions regarding its reuse or disposal. In the Sitapura area of Jaipur, the TDS in reject water was as high as 3550 mg/L. In other areas, it stayed below 2375 mg/L. The Bureau of Indian Standards (BIS) says that the maximum amount of TDS in drinking water is 2000 mg/L, while the acceptable amount is 500 mg/L. In Jaipur, the quality of water in different areas is very different. IS 11624:1989 also sorts water into four groups based on its electrical conductivity (EC): Low (0–1500 $\mu\text{S/cm}$), Medium (1500–3000 $\mu\text{S/cm}$), High (3000–6000 $\mu\text{S/cm}$), and Very High

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(above 6000 $\mu\text{S/cm}$). To see if RO reject water could be reused or released, the measured TDS and EC values were compared to these regulatory standards.

The study showed that RO reject water is not safe to drink, but it can be used again for things like cleaning, flushing, and watering plants. We looked at water samples from different parts of Jaipur and found the following:

- VKI area: Raw water TDS: 535 mg/L, EC: 866.6 $\mu\text{S/cm}$; Reject water TDS: 863.3 mg/L, EC: 1468.3 $\mu\text{S/cm}$.
- Niwaru Road: Raw water TDS: 485 mg/L, EC: 855 $\mu\text{S/cm}$; Reject water TDS: 805 mg/L, EC: 1430 $\mu\text{S/cm}$.
- Malviya Nagar (Bisalpur supply): Raw water TDS: 290 mg/L, EC: 550 $\mu\text{S/cm}$; Reject water TDS: 750 mg/L.
- Katewa Nagar (Vivek Vihar): Raw water TDS: 650 mg/L, EC: 1180 $\mu\text{S/cm}$; Reject water TDS: 910 mg/L, EC: 1650 $\mu\text{S/cm}$.

According to IS 11624:1989 guidelines for irrigation water, all of these water samples fall within the medium salinity class ($<3000 \mu\text{S/cm}$). This means that reject water from these areas can be used directly for irrigation.

After treatment, Sanganer (Raw: TDS 1192 mg/L, EC 2150 $\mu\text{S/cm}$; Reject: EC 3458 $\mu\text{S/cm}$) and Jhotwara (Raw: TDS 880 mg/L, EC 1215 $\mu\text{S/cm}$; Reject: EC 3500 $\mu\text{S/cm}$) fall into the high salinity class (3000–6000 $\mu\text{S/cm}$). This means that they need to be diluted before they can be used for irrigation again. The salinity was highest in Sitapura, with raw water TDS 2550 mg/L, EC 4900 $\mu\text{S/cm}$, and reject water TDS 3350 mg/L, EC 7600 $\mu\text{S/cm}$. The reject water in Sitapura has a salinity level higher than 6000 $\mu\text{S/cm}$, which means it can't be used for direct irrigation without a lot of dilution.

For the most part, reject water from VKI, Vivek Vihar, Niwaru Road, and Malviya Nagar can be used to water plants safely. However, reject water from Sitapura, Jhotwara, and Sanganer needs to be diluted before it can be used. In RO systems with lower recovery rates, reject water salinity stays moderate. This means that if you know enough about the quality of the raw water, you may still be able to reuse it. Tables 3, 4, and 5 show the specifications for drinking water, the Indian standards for irrigation water quality, and the standards for effluent discharge.

Table 3: BIS 10500:2012 Drinking Water Specification

S.No.	Parameter	Unit	Acceptable Limit	Permissible Limit
1.	pH	-	6.0-8.5	No Relaxation
2.	TDS (Total Dissolve Solids)	Mg/L	500	2000
3.	Total Hardness (as CaCO_3)	Mg/L	200	600
4.	Calcium (as Ca)	Mg/L	75	200
5.	Magnesium (as Mg)	Mg/L	30	100
6.	Alkalinity (as CaCO_3)	Mg/L	200	600
7.	Chloride	Mg/L	250	1000
8.	Sulphate	Mg/L	200	400
9.	Fluoride	Mg/L	1.0	1.5
10.	Nitrate	Mg/L	45	No relaxation
11.	Iron	Mg/L	0.3	No relaxation
12.	Zinc	Mg/L	5	15
13.	Copper	Mg/L	0.05	1.5
14.	Manganese	Mg/L	0.1	0.3
15.	Colour	Hazen	5	15

Table 4: Water quality rating based on the total salt concentration as per Indian Standard Guidelines for irrigation ISO 11624:1986

S.No.	Class	Range of EC (micromhos/cm)
1.	Low	Below 1500
2.	Medium	1500-3000
3.	High	3000-6000
4.	Very High	Above 6000

Table 5: Effluent standards for discharge

S.No.	Parameters	Inland Water	Surface	Public Sewer	Land for Irrigation	Marine coastal areas
1.	pH	5.5 to 9.0		5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
2.	Suspended Solids (mg/L)	100		200	600	(a) For process wastewater -100 (b) For cooling water effluent- 10 percent above total suspended matter of influent.
3.	Temperature	Shall not exceed 5°C above receiving water temperature		-	-	(c) Shall not exceed 5°C above receiving water temperature
4.	Fluoride mg/L	2		15	-	15
5.	Iron (Fe) (mg/L)	3		3	-	3
6.	Manganese (mg/L)	2		2	-	2
7.	Nitrate (mg/L)	10		-	-	20

Also, growing halophytes in dry areas with salty water is a long-term solution. These kinds of plants can be used as forage crops, fruit trees that people can eat, and oil-producing species. This helps protect limited freshwater resources. Global studies show that even water with a lot of salt, which was once thought to be bad for crops, can be used to grow crops if it is managed and diluted properly.

Controlled management has made it possible to use saline water for farming all over the world. For instance, for more than 30 years, 81,000 ha in the Pecos Valley of West Texas have been watered with groundwater that has a salinity of up to 6,000 mg/L (≈ 9.4 dS/m) (Moore and Hefner, 1977). In Israel, saline waters with salinity levels of up to 8 dS/m are frequently utilized in agriculture, and farmers in Tunisia, Egypt, and India possess considerable expertise in saline water irrigation (Ahmed *et al.*, 2002).

This study discovered significant distinctions between industrial and residential RO systems in Jaipur. In industrial RO plants, the TDS of reject water was 1.6 to 2.7 times that of the feed water. In domestic systems, it was only 1.2 to 1.4 times higher. This was mostly because the operating pressure was different. Domestic RO systems work at low pressure, which means they have lower recovery rates and produce a lot of reject water with low levels of contaminants. Over 60% of the feed water is usually wasted. You can use this

reject water with less salt for things like flushing, cleaning floors, watering plants, or washing dishes. You can also use it without diluting it.

Industrial RO systems, on the other hand, work at higher pressures, which means they get more water back and make better permeate with less reject water. But the reject water is very concentrated, especially after a long time of running, when the membrane flux goes down and the TDS in the permeate goes up. Industrial systems also use groundwater with varying quality as feed water, and they need pre-treatment and anti-scalant dosing to protect the membranes. This means that the recovery rates are higher, but the brine is more concentrated.

Municipal supply pre-treats the feed water for domestic RO systems, which lowers the amount of contaminants in both permeate and reject water. This makes the water more likely to be reused. But industrial systems rely a lot on the quality of the feed water, and reusing reject water needs to be done with care. By treating the first-stage reject through a second RO unit, dual-stage RO systems are better than single-stage systems. This improves overall recovery and lowers the amount of reject water.

CONCLUSION AND RECOMMENDATIONS

When the recovery rate is higher, the salt concentration in the RO reject stream goes up, which makes it more likely that the membrane will scale. Because of this, plants often run below their design recovery to avoid fouling. This method makes a lot of reject water, which shouldn't be thrown away if the feed water quality is good. Managing reject water well is very important because frequent membrane fouling or replacement raises operational costs.

As the demand for water rises and the supply of fresh water shrinks, it has become necessary to reuse RO reject water. In packaged drinking water plants, high-quality feed water makes sure that reject water is less concentrated and can be safely reused. This is because membranes need to be cleaned or replaced if they get dirty. Industrial RO systems can use extra treatments like microfiltration to get rid of suspended impurities while keeping salts concentrated. Reject water can be further treated with softening or ion-exchange processes so that it can be reused in places like fire hydrants and cooling towers. Open evaporation pits in zero liquid discharge (ZLD) systems let water evaporate, leaving salts behind that can be safely thrown away.

RO reject water with a TDS level below 2100 mg/L is usually safe to use again for things other than drinking, but water with a TDS level above this level could be dangerous. An NGT committee report from 30.04.2019 and a tribunal order from 20.05.2019 (O.A. No. 134/2015) say that RO can't be used for water with TDS below 500 mg/L because UV-UF treatment is enough. UV kills bacteria and viruses, and UF gets rid of microbial contaminants.

RO reject water could be used for many things, such as irrigation, growing halophytes, extracting salt and minerals, making cement, de-icing and keeping roads and mining sites free of dust, making cattle feed, the paper and plastic industries, construction, aquaculture and fish farming, and land application, depending on how well the plants can handle the saltiness. Also, RO reject water can help restore ecosystems by bringing back areas that have been damaged and making wetlands, which are good for bird-watching and hunting and are also important for protecting wildlife.

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