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RO Reject Water Characteristics, Environmental Impacts and Management

*Jyoti Vaishnav[a], Prama Esther Soloman[a], Chhagan Lal[b] & Pankaj Kumar Jain[a]**

[a]*Department of Environmental Science, Indira Gandhi Centre for Human Ecology, Environmental and Population Studies, University of Rajasthan, Jaipur, India*
[b]*Department of Physics, University of Rajasthan, Jaipur, India*

**Corresponding author: pankajbio2001@gmail.com*

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ABSTRACT

Supply of potable water to every citizen is the prime challenge to many countries. Water purification is done by so many methods but reverse osmosis (RO) process using membrane is extensively used throughout the world. This technology is widely applied to meet potable water quality standard. In this process ground or surface water is used as feed water and pure water and Reverse Osmosis Concentrate (ROC) are formed as product and by product respectively. ROC is discharged in this reverse osmosis process and it contains dissolved inorganic and organic pollutants. RO system permits the separation of water molecules and salts through a semi-permeable membrane by pressure gradient. In household, reverse osmosis unit uses a lot of water as a feed water due to low back pressure system, as a result recovery is less and a lot of water go as waste, which has no further use. RO process discharge water is almost 50% of feed water and it is one of the major drawbacks of this process. The concentration of contaminants in RO reject is influenced by the nature of feed water as well as the kind of membrane being used in RO system along with applied pressure and recovery rate of the system. RO brine is a significant component of desalination plant because there are management issues related to its proper treatment and disposal of the ROC is an important part of sustainable water treatment practice. RO waste water may have catastrophic consequences for water stressed regions and mega cities and it is the biggest task in present time. This review highlights the RO process and reverse osmosis concentrate or rejected water together with their physicochemical parameters, potential risk by using RO concentrate disposal methods and environmental benefits of reusing brine water which can resolve the problem of water scarcity. The study revealed that RO waste water disposal problem can be minimized by reclaiming the RO brine and using it for fish farming, irrigation, producing salt and in brick formation. Hence this manuscript proposes an environmentally friendly approach for sustainable management of RO brine water.

Keywords: Reverse Osmosis Concentrate (ROC); Environmental problems; Reverse Osmosis process; Brine water; Water purification techniques

INTRODUCTION

Fresh water is an essential element to sustain all forms of life on the earth. Only less than one percent of earth's water is fresh water, which is easily assessable to meet our necessity. Most of the fresh water remains inaccessible and located in the Arctic, Antarctica or Greenland. We can find freshwater in the form of surface and groundwater. These resources are renewable but in limited quantity (Zia et al. 2013).

Freshwater availability is declining across the world. Frequent episodes of drought, little rainfall and low snowfall have greatly declined the availability of clean and freshwater on the earth. Rapidly growing population has made it difficult to fulfill the collective need of water in agricultural, industrial sectors and for human consumption. Thus, the existing resources of water are getting exhausted at a fast pace and quality of freshwater has been degrading also (Datar and Vashistha 1992). So, conservation of water is mandatory and it can be achieved by integrated water resource management (Yusofa and Saadb, 2022). Reuse or recycling of water is utmost vital method for the sustainable conservation of water (Hanafiaha et al. 2022).

Water sources for human consumption are classified on the basis of their importance. The most vital source of fresh water is surface water, subsequently groundwater, then comes rainfall, followed by dissolved seawater and reclaimed wastewater (Valdes et al. 2021). Distribution of water is uneven throughout the world. India contributes 16% of the world's population whereas the resources of water are only 4%. Groundwater resources are under constant stress in India as a result of anthropogenic activities and geogenic factors. Water quality is also a problem in India due to inland salinity, fluoride, arsenic, nitrate, iron and costal salinity (Gedam 2012).

Quality of water is important for drinking purpose. Impurities present in water such as suspended solids and other impurities make it non-potable. In India about 80% of water pollution is caused due to mixing of domestic wastes in water bodies (Tiwari 2017). The availability of potable water is a worldwide concern. Consumption of contaminated water could have direct as well as indirect effects on human health. It may cause several diseases such as typhoid, fever, diarrhea and cholera (Ali et al. 2015) in human beings. Therefore, water needs to be treated or disinfected before it reached to the households. There are many approaches to get rid of impurities from water, i.e. chemical treatment, advanced oxidation, filtration and membrane separation technique etc. (Gedam 2012).

Reverse osmosis (RO) is a well-known procedure to gain clean water. It is well known and preferred desalination technique since it is safe, uses less energy and low space requirement at reduced cost to treat the water (Morton et al. 1997; Purnama et al. 2003; Schiffler, 2004). The osmosis process, involves separation of solutions of variable concentrations by a semi-permeable membrane and there is movement of solvent from low solute concentration to a higher concentration of solute, till solutions on either side of the semi-permeable membrane become equal in strengths (David et al. 2004; Crittenden et al. 2005; Bhatia, 2008). Pressure is applied in the RO process to counteract the usual osmotic pressure, and a semi-permeable membrane is employed to remove suspended particles, molecules, ions and bigger particles also including bacteria. It is useful to get fresh water for domestic and industrial purpose. RO process is very effective process to treat water, however after treatment, the solute particles are retained on the pressurized portion of the semi-permeable membrane. Several studies have indicated that the generation of brine (also referred as Reverse Osmosis Concentrate or ROC) as a by-product of the RO process is one of its key limitations (Pramanik et al. 2017; Giwa et al. 2017; Elsaid et al. 2020; Ghernaout, 2020). Several liters of water are rejected in reverse osmosis process. This reject water carries contaminants which are rich in persistent organic pollutants, dissolved organic and inorganic impurities etc. A desalination unit may generate about 20 to 90 gallons (or 75-340L) of ROC water each day to deliver only five gallons (19L) of fresh water which may be disastrous for mega cities.

The improper discharge of RO wastewater into water bodies causes several environmental impacts (Chandra et al. 2011). High concentration of salts and anti-scalant present in brine water causes serious environmental problems of phosphate pollution and then need high-cost treatment (Darre and Toor, 2018). Brine water quality is greatly influenced by the characteristics of the feed water. Reject water contains high concentration of inorganic salts, anti-scale additives, barium, silica, sulphate, calcium chloride and sodium etc. High TDS causes scaling due to the high concentration of calcium carbonate ($CaCO_3$), calcium sulphate ($CaSO_4$) and barium sulphate ($BaSO_4$). These salts are present in saturated form or exceed to their solubility limit. These salts decrease the permeate recovery of RO process (Lee et al. 2009; Subramani et al. 2012). So, this process has led many researchers to contemplate that reutilization of the RO reject water for crop production or irrigation, mixing water in cement for brick production, fish farming and spirulina cultivation can be helpful in ceasing the release of brine in natural environment (Ganesh et al. 2019).

Therefore, the ROC effluent discharged from RO process develops interest for its reuse (Valdés et al. 2021). The goal of this study is to produce a comprehensive profile of RO feed water and ROC characteristics, major environmental concerns / impacts and management of ROC. Generated brine water could be utilized for application to land as nutrient supplement and biomass production, which can minimize environmental deterioration and help to resolve food security problems. These have an economic worth also, as they may be used for generation of fodder for consumption of cattle and other livestock. This study also directs to change our attitude towards reject brine water and to make desalination process both sustainable and eco-friendly, thus reducing negative impact on the environment.

CONCEPT AND MECHANISM OF MEMBRANE PROCESS

In 1748, French physicist Jean-Antoine Nollet defined the concept of the RO process for the first time (Zewdie et al. 2021). RO process is widely utilized to purify two classes of water i.e., brackish water (slightly saline) and sea water. In reverse osmosis process brackish water or source water is passed across a special semi-permeable membrane at applied high pressure which allows only water molecules to pass further excluding dissolved solids (Zewdie et al. 2021). So, in this process to obtain purified water, it is allowed to flow from high concentration solution to dilute solution, across a semi permeable membrane. It is advised that the feed water must undergo prior treatment to ensure elimination of inorganic salts and suspended particulates, followed by application of high-pressure pump that allows the feed water to pass across a semi-permeable membrane (Garud et al. 2011).

The RO system uses a selective semi-permeable membrane which usually discards 99% contaminants of feed water and produce pure water. The water left behind that carries impurities and contaminants is discarded in drain as reject. The recovery rate of 15% to 60% is usually achieved by RO process.

The percentage recovery rate is calculated using the following relation (Sharma and Joshi, 2014).

For instance, in RO system that is operating at a recovery rate of 60%, 100L source water is feed, then 60L of purified water will be delivered for every 100L of feed water, by that RO system. So, 40L water will be reject as waste water, in order to obtain 60L of purified water (Sharma and Joshi, 2010).

Reverse osmosis process consists of feed, permeate and reject water stream (Figure 1). Its performance depends on the kind of membrane, pressure, membrane pore size, temperature and quality of water entering in the system.

$$\text{Recovery (\%)} = \frac{\text{Flow rate of Permeate (Purified Water)}}{\text{Flow rate of feed water}} \times 100$$

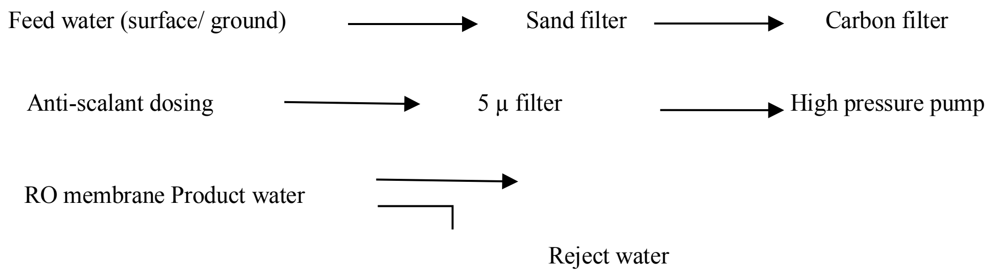

FIGURE 1. Steps involved in RO process

WORKING MECHANISM OF RO PLANT

RO plant consists of four systems which are as follows (Table 1):

1. Pretreatment system: All suspended solids are removed during the pretreatment process and this helps to discourage the growth of microbes or precipitation of salts on the membrane. Pretreatment can be done by flocculation, coagulation, sedimentation, sand filtration or membrane process (Garud et al. 2011).
2. High pressure pump: The required pressure for purification of brackish water may range from 17 to 27 bars and for seawater it varies from 52 to 69 bars, depending on the membrane chosen and water being treated. As the raw water moves across the membrane, the remaining feed water and reject solution becomes more concentrated. The source side has high water pressure that is needed to reverse the natural osmotic process to allow the movement of water through the semi-permeable membrane while discarding the contaminants. So, RO is pressure driven membrane-based separation technique, that causes removal of ions, dissolved salts, suspended particulate and organic matter from source water with the help of a semi-permeable membrane to produce potable fresh water (Zewdie et al. 2021).
3. Membrane system: RO plants are the most effective method to treat ground or surface water for drinking purpose. Due to high rejection rates of RO membranes, RO system can remove much smaller salts, particles and ions. The principal of desalination is application of pressure that is greater than natural osmotic pressure on raw water that causes infiltration of water in the reverse direction and forces the water molecules of feed water to other side of the membrane leading to removal of impurities from the raw water (Fig. 2). Cellulose triacetate, cellulose acetate, aromatic polyamide, hydrozide resin, and polyoxadiazole etc. are the used to prepare RO membranes (Ahuchaogu et al. 2018).
4. Post treatment: Recovery of pure water in RO process ranges from 35% to 85% and depends upon pretreatment, characteristics of feed water, concentrate disposal options, suitable energy design configuration etc. Amplified feed pressure and permeate flux results in increased recovery rates (Wilf and Klinko 2001).

TABLE 1. Advantages and disadvantages of RO Process

S. No.	Advantages	Disadvantages
1.	This is a very advanced, safe and energy saving separation technology for treatment of water.	RO process is a membrane-based technique, its fine membrane structure allows it not only to remove harmful impurities, but also essential nutrients from feed water (Ahuchaogu et al. 2018).
2.	Small space is required for equipment and its operation is simple (Pervov 2014). RO systems can remove both organic and inorganic impurities.	RO system greatly used in household which also generate a lot of reject water and it is discarded in drainage without any usage. In this system we use low back pressure and form only 5 to 15% fresh water of total feed water. So, it may lead to scarcity of water thus having harmful consequence for large populated cities (Ahuchaogu et al. 2018).
3.	It works at room temperature without phase change, which decreases the scale development and corrosion.	One of the main disadvantages of the RO process is discharge of a lot of brine water or concentrate. This concentrate causes several environmental problems due to the presence of high amount of various salts, which require high economic cost for the treatment (Darre and Toor, 2018).

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4.	In this process we use anti-scalant which reduces membrane cost (Ahuchaogu et al. 2018).	Due to its high cost, brine disposal is a problem for desalination plants.
5.	RO operation relies on pressure as a driving force. RO systems are simple to operate and design is modular in nature. The membrane of RO is easily replaced within a few minutes. These are cheap cost wise and require low maintenance. Expansion of the system is also easy. So, this technique is very popular in high TDS water regions.	In RO system, pre-filters of RO membranes require replacement regularly. These used pre-filters cannot be used again so they are discarded after every use, this imposes additional stress on the environment by increasing the cost related with the solid waste generation (Sharma and Joshi2010).

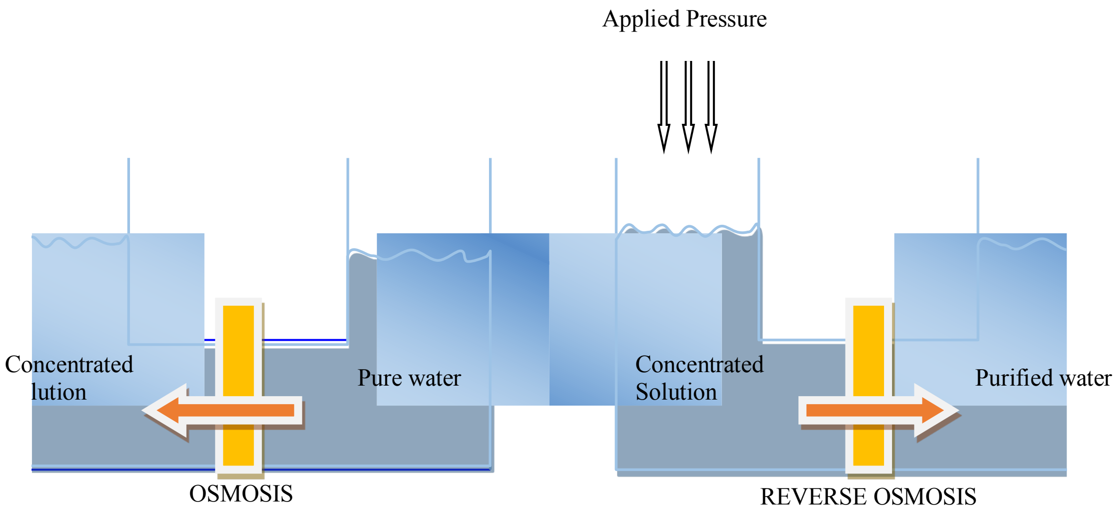

FIGURE 2. Working mechanism of Reverse Osmosis Process

CHARACTERISTICS OF BRINE WATER

The ROC is also known as brine or reject water (Luukkonen et al. 2020; Maheshwari and Agrawal, 2020). RO concentrate is the byproduct of purification of feed water that comprises of raw water along with the chemicals added during pretreatment process of the raw water. So, the composition of discharged brine water is also varied (Table 2).

ROC contains organic phosphonates (used as anti-scalant) in different quantities and other complexing agents, that are usually disposed of in water bodies, this intensifies the problem of eutrophication (Valdés et al. 2021). The characteristics of ROC depends on various factors, like quality of feed water, type of membrane, process conditions (concentration and recovery features), percentage recovery and chemicals needed for the pretreatment of water (Elsaid et al. 2020). These chemicals are sodium hypochlorite, aluminum chloride, ferric chloride, sodium hexameta phosphate and acids etc. (El-Naas 2011) (Table 3). Brine water quality is also influenced by the pore size of membrane used in the RO method (Torres-Carrión et al. 2018).

Environmental conditions (pH, temperature and ionic strength) may also affect the concentration of impurities found in ROC (Joo and Tansel, 2015). Chemical characteristics of RO brine are primarily dependent on pH value, alkalinity, hardness, cations, anions and other impurities such as heavy metals. If harmful contaminants are present in the feed water, then ROC is likely to have heavy metals, such as nickel, iron, molybdenum and chromium. With the increment in temperature, percent recovery, permeate concentration, TDS and fluoride are also increased but percentage of salt rejection is decreased. If we increase the pressure on the feed water, then it leads to increase in the percent recovery but the concentration of permeate TDS and fluoride is decreased on the other hand if the temperature of the feed water is increased than it results in an increase in salinity and fluoride concentrations (Gedam 2012).

As observed in Figure 3, quantity of reject water generation is more at lower recovery rate, and about the same pollution level as the source water, while concentration of the pollutants is higher with the increase in the recovery. However, at high recovery rates (>60%) the contaminant concentration of the reject water becomes more than double as compared to lower recovery rates (Sharma and Joshi, 2014). The data indicates that RO system with high recovery rate, the quantity of reject water is reduced. Though, the concentration of contaminants shows an upsurge with the increase in recovery rates (Figure 3).

TABLE 2. Chemical composition of Feed and RO brine water from various desalination plants

S. No.	Parameter	pH	EC (µs/cm)	TDS (mg/L)	Alkalinity (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	References
1.	Raw water	6.8	-	635	360	73.5	76	27.6	131	Pervov, 2014
	Brine water	7.6	-	1629	762	147	190	78	312.8	
2.	Raw water	7.3	1030	585	-	-	-	-	-	Najar et al. 2017
	Brine water	7.7	1280	728	-	-	-	-	-	
3.	Raw water	7.4	4000	-	-	698.6	408	202	334.8	Kankarla et al. 2021
	Brine water	7.4	8000	-	-	893.5	699	367.7	689.0	

TABLE 3. Chemicals used and their role in RO process

S. No.	Name of Chemicals/ Substances	Uses
1.	Sodium hypochlorite (NaOCl)	For chlorination of water to prevent bacterial growth in desalination process.
2.	Aluminum chloride ($AlCl_3$) and ferric chloride ($FeCl_3$)	Flocculants for suspended particle removal from the water.
3.	Sodium hexameta phosphate ($NaPO_3$)	Anti-scale additives which prevent scale formation on the membranes and pipes.
4.	Acids	To adjust the pH of water.

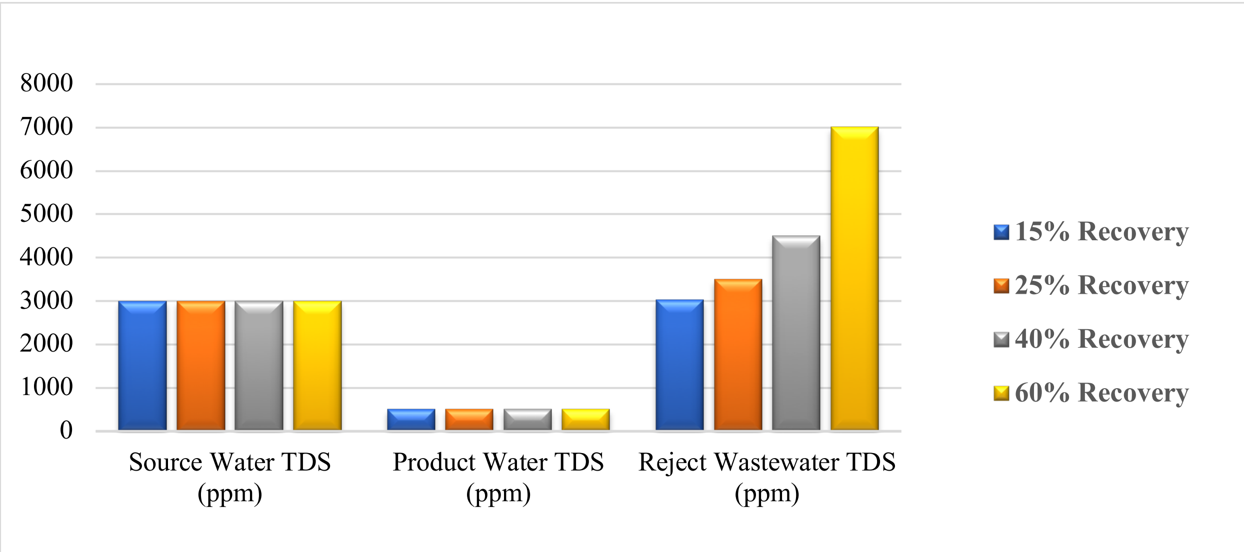

FIGURE 3. Amount of TDS (in ppm) at different recovery rates
Source: Sharma and Joshi (2014)

POSSIBLE IMPACTS OF RO REJECT WATER ON ENVIRONMENT

With growing interest towards RO desalination process, concern about its probable environmental impacts has also caught our attention. Large quantities of feed water is utilized by RO desalination plants and it releases concentrated brine in the environment (Tiwari, 2015). It is commonly recommended that brine concentrate coming out of the desalination plants results in harmful effects on physical, chemical, and ecological aspects of receiving environments (Ali et al. 2015). Several studies revealed that disposal of RO reject water has significant environmental issue.

In RO desalination process two types of products are formed (i) Product water (ii) Reject water /brine/ROC. The reject water contains salts in addition to chemicals used in pretreatment process (Elsaid et al. 2012). In desalination process, the RO plant generates high volume of brine, which is twice saline than the source water. Improper disposal of the reject water leads to mixing of this high TDS water with the groundwater resources hence, posing a great risk to living beings. It also has deep effect on subsurface soil properties, when it is discharged on land (Mohamed et al. 2005).

The matrix of RO reject water is influenced by various factors, like the feed water sources, pretreatment and chemicals used during the process. Acids, biocides and anti-scalant have a direct impact on the characteristics of brine (Ersever 2007). The presence of corrosive metals, that are used during pretreatment of feed water are also significant concern because disposal of these metals is not an easy task (Katal et al. 2020). High salt content present in brine water with elevated amount of sodium, boron and chloride can deteriorate the soil quality, affect plant productivity and also pose an increased risk of soil salinization (Mass, 1990). Brine disposal on land can change the electrical conductivity of soil thus affecting plant productivity. SAR (Sodium Absorption Ratio) calculates the relative levels of sodium, magnesium, and calcium (Mohamed and Antia, 1998). Higher value of SAR can lower the soil permeability (Rhoades, 1990). Alteration in the sodium content of soil affects the structure of soil and interferes with the permeation of water thus interfering with development of plant. Although this does not lead to decline in the water uptake by the plants (Hoffman 1990; Maas 1990). Brine water disposal can result in poor aeration of soil, as a result of decreased soil permeability. There is also reduction in the salt leaching from root zone. Heavy metals and other inorganic components present in brine may induce chronic health problems (Mohamed et al. 2005).

DISPOSAL OF BRINE

Presently, brine disposal is a major issue of RO process. It should be disposed in the environment after essential investigations. Many studies have been conducted to reduce the concentrate stream, to decrease the cost of consequent disposal. This can be done by using suitable desalination process, properly pretreatment of feed water and strengthen the system recovery. Though, the disposal method also depends on the salinity and quality of brine (Table 4).

The choice of disposal method depends on the following key factors:

1. Reduction in the quantity of concentrate
2. Elements present in the concentrate
3. Physical and geographical considerations of disposal site
4. Accessibility of disposal site
5. Option selected must be permissible
6. Must have public acceptance

The cost of brine or concentrate disposal is affected by the above factors. It may vary from 5-33% of the entire cost involved in the process of desalination (Ahmed et al. 2001; Elsaid et al. 2012).

However, brine generated from an inland brackish desalination plant is very difficult to manage. Desalination is a significant problem because desalination plants are located at a distance from the coastal area. Brine coming from desalination plants that are located away from the coastal areas, can be disposed of by some conventional methods that include (i) direct disposal in surface water bodies (ii) dumping in municipal sewer system (iii) evaporation ponds (iv) using for irrigation of high salinity tolerant plants(Ahuja and Howe, 2005) (v) injecting in subterranean saline aquifers (aquifers with non-drinking water) (vi) conventional crystallization (vii) deep well injection (viii) disposing through pipeline into the sea (Katal et al. 2020) etc.

Several studies indicate that the best solution for brine disposal is the use of evaporation ponds. These ponds are considered to be the most feasible method, which has minimum negative impacts on the environment, however these require large space (Nadi et al. 2014)

There is a need to develop an action plan to reduce the ROC discharge impacts on environment. Action plan will be helpful in (i) Establishing standards to reduce or prevent environmental problems (ii) evaluating the potential recovery of ROC (iii) applying treatment technologies (iv) delineate mitigation and control strategies (Valdés et al. 2021).

MANAGEMENT OF RO REJECT WATER

Nowadays, Number of groundwater desalination plants have been increasing. RO process produces freshwater at the large expense of natural water and leave behind a lot of highly concentrated brine (ROC) as a waste product. Reject RO water has serious threat to our ecosystems. However, the RO reject water may also have certain beneficial constituents that may be put to some useful practice. By utilization of these wastes, we can turn environmental problem in to economic benefit. Studies conducted by many scientists revealed that RO brine water can be reutilized if proper characterization and analysis performed with the main objective of initiating possible usage for management of reject brine. There are following possible ways by which we can manage the brine:

FISH FARMING

The brine water can be utilized for fish farming. Many studies have shown that RO reject water can be used for farming of Tilapia (*Oreochromis niloticus*) fish. These species are well adapted and can survive in high salinity of the RO reject water. The production system for Tilapia, using RO reject water has been developed in the semi-arid region of Brazil. Experiments revealed that when the electrical conductivity of brine water ranged from 9.82 to 13.38 mS/cm, Tilapia fish yield ranged between1.78 to 1.96 kg with 80-94.7% survival (Sanchez et al. 2015). Several other studies have proved that the RO reject water can be easily used for rearing Tilapia as the average body weight was found to be similar to that of those growing in less saline water (Souza et al. 2022). Other species of fish like European sea bass (*Dicentrachus labrax*) can also be grown in brine water but dilution is needed. Since, $CaCO_3$ precipitation happens in fish organs, so regulation of $CaCO_3$ saturation level is also essential (Klas and Peretz, 2020). So, we can utilize this brine for the cultivation of salt resistant fish species.

SPIRULINA CULTIVATION

Spirulina is an obligate photoautotroph, multi-cellular, filamentous, cyanobacteria (blue green algae) which can be consumed by living beings. It is used as a food supplement. It is a powerful antioxidant, anti-inflammatory, anticancer and helps to reduce blood pressure. It grows at a pH range from 8.3-11 (alkaline condition) and a temperature around 300C. Cyanobacterium has a distinctive quality to neutralize poisonous substances and heavy metals. It can also remove the salts and calcium from saline water (Okamura and Aoyama,1994; Sandeep et al. 2013). Certain species of Cyanobacteria, for example, *Spirulina maxima* and *Spirulina platensis* are capable of coping with high salt concentrations. Even when the salt per liter of water ranged from 20 and 70g and electrical conductivity between 32 to 112 mS/cm, *S. platensis* had shown appropriate growth. Spirulina makes use of lesser quantity of water per kg of protein as compared to any other crop.

Spirulina provides valuable nutrients to Tilapia sp. Therefore, it can be used as an alternative or supportive nutrient (Paulino et al. 2006). Results demonstrated that the valorization of RO reject management through *S. plantesis* farming can be considered as a step ahead for reducing use of freshwater and conventional nutrients for algal mass cultivation.

CROP IRRIGATION WITH RO REJECT WATER

Numerous studies have been performed to find out the tolerable limits and impacts of salinity on different plant species. Identification of salinity tolerant plant varieties is also essential. So, there is prerequisite for detailed assessment of chemical nature of the concentrate obtained from the desalination plant to find out its reusing suitability for irrigation.

RO brine water can also be used as a fertilizer but after dilution using fresh water or with animal urine, to crops. Halophytic plants can be irrigated with brine reject stream because these plants are able to tolerate appreciable levels of NaCl in their tissues (Gómez-Bellot et al. 2021). Others crops yield reduced due to higher salinity in brine water. There is need to explore the effects of different sodium and calcium ion concentrations on plant physiology, growth and yields to improve the salt tolerance of crops. Table 5shows the permissible limits for different categories of irrigation water in Texas, USA with respect to TDS.

BRINE WATER IRRIGATION IN ATRIPLEX NUMMULARIA PLANT

Halophyte forage shrubs Atriplex spp. is found in Brazil, Chile and Argentina. It is an extremely versatile plant that can survive in semi-arid and arid regions. It can be used as a high protein food for humans and fodder for livestock. This plant can be cultivated in saline soil and in drought weather conditions. Atriplex has a good capacity to salt absorption and protection of the soil. Brine water when combined with organic matter of agricultural waste, can be utilized to water the Atriplex field (Sánchez et al. 2015).

REUSE OF RO REJECT WATER FOR BRICK CONSTRUCTION

RO reject water can be used as mixing water in manufacture of CSA (Calcium Sulfoaluminate) cement bricks. When compared with purified water, RO reject water is more favorable in increasing brick strength and it fulfilled the Korean standards (KS) F 4004 (Lee et al. 2019). Studies recommend that RO reject water can be easily utilized as mixing water in production of CSA cement bricks but it cannot be used with concrete for embedding steel structure, since the high concentration of chloride may result in rusting (Lee et al. 2019).

RECOVERY OF MINERAL SALT BY ROC BRINE

RO rejects are usually dumped in water bodies thereby increasing the chemical load, leading to water pollution. The extraction of mineral salts from RO brine can produce valuable end products by decreasing water pollution. ROC is also responsible for increased level of salinity of the ground water (Ahmed et al. 2000). ROC of desalination plants has great potential for the production of salts and it cuts down the overall cost of desalination. Many studies proved that we can extract valuable products from ROC by using techniques like precipitation, evaporation, ion-exchange, adsorption, solvent extraction and membrane separation etc. (Kim, 2011; Pérez-González et al. 2012). Eisaman et al. (2012) described possible applications of ROC in industries and other fields. For example, Struvite is an isolated salt from ROC and it can act as low releasing fertilizer in agricultural sector without causing any harm to the plants. Struvite is produced by the reaction of phosphoric acid and ammonium hydroxide (Renita et al. 2016). Calcium oleate is an active ingredient of skin cream in cosmetic industries. It is also used as a food grease in food industries. It can be produced by using oleic acid of reject brine in a batch reactor with mechanical agitation.

TABLE 4. Disposal options for brine concentrate and their environmental concerns

S. No.	Disposal Methods	Environmental Concern
1.	Merger in Sewer system	Pollution of receiving water bodies
2.	Surface water	Pollution of receiving water bodies
3.	Land application	Pollution of soil and groundwater
4.	Evaporation ponds	Seepage from pond causes pollution of underlying higher quality aquifers
5.	Deep well injection	Seepage from well causes pollution of drinking water aquifers
6.	Zero liquid discharge	Seepage from landfill causes pollution of drinking water aquifers

Source: Mahi (2001)

TABLE 5. Irrigation water quality standard and salinity in Texas, USA

Categories of irrigation water		Concentration of Total dissolved solids	
		Electrical Conductivity (μmhos) at 25^{0}C	Gravimetric (ppm)
Category 1	Excellent	250	175
Category 2	Good	250-750	175-525
Category 3	Permissible	750-2000	525-1400
Category 4	Doubtful	2000-3000	1400-2100
Category5	Unsuitable	3000	2100

Source: Fipps (2003)

CONCLUSION

Availability of potable water to every person is a great challenge for most of the countries throughout the world. Many countries are utilizing desalination process that proves to be a feasible solution as it helps in fulfilling the growing demand of fresh water. The RO process is effective method in removing the dissolved salts, heavy metals, chlorine and harmful bacteria from raw water.

However, due to increasing popularity of RO desalination plants along with high consumption of feed water, our water resources are also in pressure. These RO plants draw out huge amount of water and generates a condensed brine concentrate which adds several pollutants in the environment. RO reject water when dumped in the environment greatly affects the physical, chemical and ecological aspects of the soil or water bodies. We can predict the risk of this reject water by finding of physicochemical characteristics of ROC (temperature, hardness, pH, salinity, and ions etc.).

There exist numerous methods to dispose brine. However, every disposal method possesses some advantages and disadvantages, and these should be given serious consideration. Countries need to minimize the environmental impacts of reject water discharge. Cost effective and environmentally conscious RO reject water treatment and management will stand a preference for the desalination industry.

This article indicates that mitigation actions, control strategies and management should be oriented toward ROC valorization. RO brine can be reused for energy recovery, brick production, metal recovery, crop irrigation of halophytic plants, fish farming, forage production by Atriplex for livestock feeding, oil from fish processing and Spirulina for proteins. Irrigation using RO brine water is suitable only for halophytic plant, if we apply it on other crops, it reduces the crop yield.

Further study is needed for sustainable management of RO brine water. There is a need to identify the plant and animal species which are more tolerant to brine water. We need to closely examine the effects of different concentrations of sodium and calcium on plant physiology.

It is realized that more extensive study is required to detect long term impacts of disposing RO reject water in natural environment. Additional investigation should also be conducted to device more eco-friendly alternatives technologies to RO filtration.

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DECLARATION OF COMPETING INTEREST

None

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