Minimization of Soluble Impurities of Ground Water by Reverse Osmosis

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Abstract— Groundwater dissolves much of the impurities that it percolates through. Generally it is harder than surface water. Prime water impurities include soluble dissolved salts, hardness, alkalinity and many toxic elements. The total dissolved solids, hardness and alkalinity have significant impact on the quality of water. The amount of physico-chemical parameters affects the water for most of its uses, whether for drinking, agricultural, or industrial use. The problem of impurities arises when its concentration exceeds the permissible limit prescribed by WHO and BIS standards. It has been found that RO is the most widely used technology to minimise the soluble impurities present in water. The performance of R.Os having thin film composite membranes of hollow fiber shape and made up of polyamide but operating at different pressures has been evaluated for TDS, TH, and TA minimization.

Key words: Reverse Osmosis, Minimization of Soluble Impurities of Ground Water

I. Introduction

Ground water is a renewable source of water supply for human beings and almost one third of the world's population use ground water for domestic purpose [1]. The quality of water degraded day by day due to various reasons including the ever-growing population, urbanization, industrialization and unskilled utilization of water resources. Various ecological factors like natural and anthropogenic, have impact on the ground water, whereas it is getting degraded because of deep percolation from intensively cultivated fields, disposal of hazardous wastes, liquid and solid wastes from industries, sewage disposal, surface impoundments etc. [2], [3], [4], [5].

The prime aim of the Guidelines for Drinking Water Quality is the protection of public health. The GDWQ offers an assessment of the health risk presented by micro-organisms and impurities present in drinking water. This assessment can then be applied to the development and execution of national standards for drinking water quality. Further, in response to demands from Member States, the Guidelines have always included guidance material concerning specific problems related to small community supplies [6].

Minerals can cause hardness (calcium or magnesium salts). Minerals and impurities are generally present in very small concentrations, and are measured in parts per million (ppm) (how many parts of impurities in a million parts of water) or milligrams per litre (mg/L).

Alkalinity is the capability of natural water to neutralize the acidic salts present in the water. Alkalinity in water is due to the presence of those salts present in water which produces hydroxide ion in water. Alkalinity is also measured in mg/L.

pH is a measure of the hydrogen ion concentration in water. pH is measured on a scale ranging from 0 to 14, on which seven is considered neutral. At a pH below 7, the water is acidic; at a pH above 7, the water is alkaline. Lower the pH, greater the acidity; higher the pH, greater the alkalinity. A change of one (1) pH means a ten-fold decrease or increase in the hydrogen ion concentration. The normal range of pH for drinking water is 6.5 to 8.5 [7].

The permissible limit of TDS in drinking water prescribed by WHO and BIS is 500 ppm and 500-1500 ppm respectively. The permissible limit of total hardness in drinking water prescribed by WHO and BIS is 500 ppm and 200-600 ppm respectively. The permissible limits of Ca^{2+} and Mg^{2+} contents in drinking water prescribed by WHO and BIS are 500 ppm , 200-1000 ppm and 50 ppm, 200-400 ppm respectively. The permissible limit of TA and pH in drinking water prescribed by WHO and BIS are 500 ppm, 200-600 ppm and 6.5-9.2 and 7-9.2 respectively. These physico-chemical parameters when present above their permissible limits serve as impurities. The problem of impurities arises when its concentration exceeds the permissible limit. One of the promising methods to minimize these impurities is reverse osmosis (R.O.) process.

RO is a physical process in which contaminants are removed by applying pressure on the feed water to direct it through a semi permeable membrane. RO membrane rejects ions based on size and electrical charge. Efficiency of the process is governed by different factors such as raw water characteristics, pressure, temperature and regular maintenance [184]. Reverse osmosis is a process that uses semi permeable spiral wound membrane. Feed water is delivered under pressure through the membrane, where water permeates the minutes pores of the membrane and is delivered as purified water called permeate water. Impurities in the water are concentrated in the reject stream and flushed to the drain is called reject water. These membranes are semi permeable and reject the salt ions while letting the water molecules pass. The materials used for RO membranes are made of cellulose acetate, polyamides and other polymers [9].

II. Materials and Methods

A. Material Selection

The performance of R.Os having thin film composite membranes of hollow fiber shape and made up of polyamide but operating at different pressures has been taken for minimization of TDS, TH, and TA. Descriptions of the different ROs are given in table 1.

S. No	Pressure on membrane (Bar)	Permeate water quantity in liter per hour (lt/hr)	Size of membrane in inch (diameter, length)
1	3.4	8	1.75×11.75
2	16	250	1.8×26
3	25	2000	8×80

Table 1: Parameters of different R.Os

Note: R.O. operating at pressure 3.4 bar is named as R.O.1, R.O. operating at pressure 16 bar is named R.O.2 and R.O. operating at pressure 25 bar is named R.O.3.

1) Study Area

Hisar district occupies an area of 3,983 square kilometres (1,980 sq mi). It is located at 2905'5'' north latitude and 75045'55''east longitudes. The district falls in a hot and semi-arid south western zone of Haryana State (India).

2) Water Sampling

A total of five groundwater samples were collected from district Hisar, Haryana, India. The source of these samples was hand-pump. The water samples were collected in pre-cleaned polyethylene bottles. The water was left to run from the sampling source for 5-6 minutes to pump out the volume of water standing in the casting before taking the final sample. The samples were then taken in the pre cleaned bottles and were analysed just after the sampling [10].The description of sites and the physico-chemical characteristics of the water sample are given in table 2.

Sample No.	Name of Site	TDS (ppm)	TH (ppm)	Ca^{2+} content (ppm)	Mg^{2+} content (ppm)	TA (ppm)
Sample 1	Village Burak Hisar	1250	520.7	104.8	62.8	20
Sample 2	Middle school Dayal singh colony (Hansi)	1690	596.6	120	72	72
Sample 3	Sisaipull (Hansi) Hisar	1050	406.0	80	50	52
Sample 4	Village Sadalpur Sub Division Adampur Hisar	780	338.1	68	40.8	28
Sample 5	Water works Chikanwas Hisar	566.0	497.2	100.0	60.0	12.0

Table 2: Experimental sites of raw water samples with Physico-chemical characteristics

All parameters are expressed in ppm (mg/L)

Each of the five water samples was passed through different ROs to minimise the soluble impurities and to check the performance of different models of ROs.

B. *Methodology*

Total dissolved solid was measured by gravimetric method. Total hardness of water was determined by using EDTA titration method. Calcium content of water samples was estimated by using the complexometric titration method (EDTA). Magnesium content of the water samples was calculated indirectly using Ca^{2+} and TH content of water samples by following formula:

$$Mg^{2+} \text{ (mg/L)} = [\text{Total hardness} - (Ca^{2+} \times 2.5)] \times 0.243$$

Total alkalinity of the water sample was estimated by titrimetric method using N/50 H_2SO_4.

The pH of samples was analysed by using a 'EUTECTIC CYBERNETICS Model pH Scan Meter' [11-12].

Each of the five water samples was passed through different ROs one by one to minimise the soluble impurities and to check the performance of different models of ROs operating at different pressures.

III. RESULTS AND DISCUSSION

One by one all the raw water samples were passed through each of the R.Os operating at different pressures, amount of residual physico-chemical parameters in permeate water then analysed by the standard methods. Performance of different ROs to minimize the soluble impurities of the raw water samples are shown in table 3 to 7.

S. No.	Physico-chemical parameters	Concentration of Physico-chemical parameters in raw water	% Removal		
			RO1	RO2	RO3
1	TDS	1250.0	94.3	95.1	96.0
2	TH	520.7	96.1	96.9	97.9
3	Ca^{2+}	104.8	95.8	96.5	97.5
4	Mg^{2+}	62.8	96.3	97.3	98.3
5	TA	20.0	97.5	98.4	99.0

Table 3: Minimization of soluble impurities of raw water sample 1 after passing through RO 1, RO 2 and RO 3

All parameters are expressed in ppm (mg/L)

S. No.	Physico-chemical parameters	Concentration of Physico-chemical parameters in raw water	% Removal		
			RO1	RO2	RO3
1	TDS	1690.0	93.7	94.6	95.2
2	TH	596.6	95.9	96.7	97.6
3	Ca^{2+}	120.0	95.7	96.3	97.2
4	Mg^{2+}	72.0	96.1	97.0	98.1
5	TA	72.0	95.0	96.5	97.0

Table 4: Minimization of soluble impurities of raw water sample 2 after passing through RO 1, RO 2 and RO 3

All parameters are expressed in ppm (mg/L)

S. No.	Physico-chemical parameters	Concentration of Physico-chemical parameters in raw water	% Removal		
			RO1	RO2	RO3
1	TDS	1050.0	94.5	95.7	96.7
2	TH	406.0	96.5	97.9	98.5
3	Ca^{2+}	80.0	95.9	97.6	98.0
4	Mg^{2+}	50.0	97.0	98.3	99.0
5	TA	52.0	96.2	97.1	97.5

Table 5: Minimization of soluble impurities of raw water sample 3 after passing through RO 1, RO 2 and RO 3

All parameters are expressed in ppm (mg/L)

S. No.	Physico-chemical parameters	Concentration of Physico-chemical parameters in raw water	% Removal		
			RO1	RO2	RO3
1	TDS	780.0	94.9	96.2	97.5
2	TH	338.1	96.9	98.3	99.3
3	Ca^{2+}	68.0	96.2	98.1	98.9
4	Mg^{2+}	40.8	97.5	98.5	99.5
5	TA	28.0	97.0	98.0	98.7

Table 6: Minimization of soluble impurities of raw water sample 4 after passing through RO 1, RO 2 and RO 3

All parameters are expressed in ppm (mg/L)

S. No.	Physico-chemical	Concentration of Physico-	% Removal		
			RO1	RO2	RO3

	parameters	chemical parameters in raw water			
1	TDS	566.0	95.1	96.5	97.7
2	TH	497.2	96.5	97.8	98.6
3	Ca^{2+}	100.0	96.2	97.5	98.4
4	Mg^{2+}	60.0	96.8	98.1	98.8
5	TA	12.0	98.0	98.8	99.2

Table 7: Minimization of soluble impurities of raw water sample 5 after passing through RO 1, RO 2 and RO 3

All parameters are expressed in ppm (mg/L)

From the above tables it can be clearly seen that the quality of permeate water increases as the pressure on membrane increases.

Results shows that that the quality of permeate water increases as the pressure on membrane increases i.e removal of dissolved impurities from raw water increases with increase of pressure applied on membranes.

It is found that R.O. 3 operating at a pressure of 25 bar removes the total dissolved solids from 95.2%-97.7%, R.O.2 operating at a pressure of 16 bar removes 94.6%-96.5% whereas removal capacity of R.O.1 operating at a pressure of 3.4 bar is 93.7% to 95.1%. Total hardness removal capacity of R.O.3 is from 97.6%-99.3%, R.O.2 removes from 96.7%-98.3% and R.O.1 removes 95.9% to 96.5%. Calcium content removal by R.O.3 is from 97.2%-98.9%, by R.O.2 is from 96.3%-98.1% and by R.O.1 is 95.7%-96.2%. Magnesium content removal capacity of R.O.3 is from 98.1%-99.5%, by R.O.2 is from 97.0%-98.5% and by R.O.1 is from 96.1%-97.5%. R.O.3 is able to remove alkalinity from 97%-99.2%, removal capacity of R.O.2 is from 96.5%-98.8% and of R.O.1 is from 95%-98%.

It has been reported that when the effective pressure of the feed water is increased, the dissolved solids content of the permeate water will decrease.

The above discussion can be concluded that salt passage is an inverse function of pressure i.e the salt passage decreases as applied pressure on membrane increases. This is because increased pressure increases permeate flow rate and hence dilution of salt.

A. *Advantages*

- The process provides an effective barrier for total dissolved solid, total hardness, calcium and magnesium content and total alkalinity.
- There is no requirement of adding chemicals.
- The process needs a very low operating cost.

B. *Limitations*

- Wastage of lot amount of water as reject water.
- The process requires the use of electricity. So, this is not a very useful process in those areas where electricity is not available.
- Maintenance or replacement of the membrane is required whenever necessary i.e. when the concentration of soluble impurities in permeate water rises above the standard norms.

IV. Conclusion

R.O. method is very efficient method for the minimization of soluble impurities present in ground water. But during operation of R.O. systems if the membrane material is exposed to very high pressure then it may result in an increase in the density of the membrane material i.e. causing compaction, which will decreases the rate of diffusion of water and dissolved impurities through the membrane.

Therefore, optimum pressure should maintained on R.O. membranes prescribed by the membrane manufactures given in the data sheet for the proper functioning and long life of membranes.

References

[1] United Nations Environment Program (UNEP) (1999). Global Environmental Outlook 2000. UK: Earth scan, 2000.
[2] Kass A., Yechieli Y., Vengosh A. and Starinsky A (2005). The Impact of Freshwater and Waste Water Irrigation on the Chemistry of Shallow Groundwater: A Case Study from the Israeli Coastal Aquifer. Journal of Hydrology, 300: 314-331.
[3] Amina C., Lhadi L.K., Younsi A., Murdy J. (2004). Environmental Impact of an Urban Landfill on a Coastalaquifer. Journal of African Earth Science, 39: 509-516.
[4] Oren O., Yechieli Y., Bohlke J.K. and Dody A. (2004). Contamination of Groundwater Under Cultivated Fields in an Arid Environmental, Central Arava Velley, Israel. Journal of Hydrology, 290: 312-328.
[5] Anwar F. (2003). Assessment and Analysis of Industrial Liquid Waste and Sludge Disposal at Unlined Landfill Sites in Arid Climate. Waste Management, 23: 817-824.
[6] Shrivastava R. and Choudhary B. (1997). Drinking Water Quality in an Average Indian City - a case study of Agra (UP). Pollution Research, 16: 63-65.
[7] Handa B.K. (1975). Geochemistry and Genesis of Fluoride Containing Groundwater in India. Groundwater, 13: 275-281.
[8] Babra D., Caputi P. and Cifoni D.S. (1997). Drinking water Supply in Itlay. Desalination, 113: 111-117.
[9] Garud R.M., Kore S.V. and Kulkarni G.S. (2011). A Short Review on Process and Applications of Reverse Osmosis. Universal Journal of Environmental Research and Technology, 1: 233-238.
[10] *Hem* J.D. (*1989*). Study and Interpretation of the Chemical Characteristics of Natural water. US Geological survey, Washington, D.C., Water Supply Paper 3: 263.
[11] Mirna H. S., Maja E.R. and Andrew F. (2014). A Review on Adsorption of Fluoride from Aqueous Solution. Materials, 7: 6317-6366.
[12] Tebutt T.H.Y (1983). Relationship between Natural Water Quality and Health. United Nations Educational, Scientific and Cultural Organization, Paris.