Performance Study of Community Scale Reverse Osmosis Plant, Vidhani Jaipur

Saurabh Singh, Akash Johari, Ajay Kumar Gautam
Department of Civil Engineering, Swami Keshvanand Institute of Technology, Management and Gramothan, Jaipur-302017 (INDIA)
Email- 2016pce5409@mnit.ac.in, akashjohari4@gmail.com, ajay1990veer@gmail.com
Received 02.03.2019 received in revised form 06.04.2019, accepted 20.04.2019.

Abstract: Water is most available and consumed resources but even though it is abundant there is a worldwide crisis for fresh water. People are not getting enough fresh water for drinking and sanitation need. In Rajasthan a state with ground water sources with high salt content the most favourable treatment is using Reverse osmosis technology which is one of the most important and widely recognized technologies for production of fresh water from brackish groundwater.
The present study shows the results of a performance analysis of small community scale reverse osmosis units located in Jaipur, producing drinking water from brackish groundwater. Vidhani treatment plant of capacity of 1000 litres/ hour (LPH) at different geographical locations and having varying Total dissolved solids (TDS) in rural areas of Jaipur was selected and analysed for several parameters related to chemical quality of water and energy input with an objective to assess the performance of these units. The study has thrown open many reasons that explain relatively accelerated fouling observed in these membranes due to scaling by hardness causing substances than that found in other areas of the country. This results in a significant loss of useful life of the membranes and hence calls for special techniques to be adopted for their cleaning to improve the overall performance.

Keywords: Reverse Osmosis (RO), Total dissolved solids (TDS), litres/ hour (LPH).

1. NEED OF THE STUDY

Water is an essential natural resource for sustaining life and environment that we have always thought to be available in abundance and free gift of nature. However, chemical composition of surface or subsurface is one of the prime factors on which the suitability of water for domestic, industrial or agricultural purpose depends. Freshwater occurs as surface water and groundwater. Though groundwater contributes only 0.6% of the total water resources on earth, it is the major and the preferred source of drinking water in rural as well as urban areas, particularly in the developing countries like India because treatment of the same, including disinfection is often not required. It caters to 80% of the total drinking water requirement and 50% of the agricultural requirement in rural India. But in the era of economical growth, groundwater is getting polluted due to urbanization and industrialization. Presence of various hazardous contaminants like fluoride, arsenic, nitrate, sulphate, pesticides, other heavy metals etc. in underground water has been reported from different parts of India.

2. INTRODUCTION

More than 1 billion people worldwide lack access to potable water, and almost 2 million children die each year due to inadequate access to clean water and adequate sanitation. Worldwide, consumption of water for municipal, industrial and agricultural uses is expected to increase substantially and aggravate this already gloomy situation [1]. The global water crisis is felt, due to several factors, among which are population growth, increase in per capita water consumption, depleting fresh water resources, population of surface water and groundwater, as well as long-term variations in the hydrological cycle due to climate change [2].

Creating new sources of high-quality water through reclaiming, recycling, and reusing water remains the only way to address these challenges. Reverse osmosis (RO) based desalination is one of the most important and widely recognized technologies for production of fresh water from sea water, brackish groundwater or wastewater. Since its conception and initiation, a significant development has been witnessed in membrane technology with respect to material, synthesis techniques, modification and modules over the last few decades [3].

More than 50% desalination plants in world are based on reverse osmosis technology according to a recently published report [4], India's water desalination market is all set to grow at Compound annual growth rate (CAGR) of 225 for next five years.

Government of India, in its recent "National rural Drinking Water Program Guidelines", has stated that it is the responsibility of state governments to supply a minimum of 8 litres of water per capita per day (LPCD) for drinking and cooking that conforms to BIS: 10500 [5]. A state wide survey of all village/habitations was carried out by public Health Engineering Department (PHED) Rajasthan and water quality data were compiled in 2001-2004. A total of 75266 water samples from different sources, including tube wells, open wells and hand pumps were analysed. 42352 samples (56.27% of the total sample population) were found to contain total dissolved solids, fluoride and nitrate in excess of the respective prescribed limits of 1500, 1.5 and 45mg/l. These data underscore the gravity of the situation in Rajasthan state of as far as the chemical quantity of water is concerned [6].

As reverse osmosis system is easy and quick to install operate and maintain, these have become the prime choice of Rajasthan government to cater to the aforementioned requirement especially under multiple chemical quality problems this plants can be integrated in rural and interior parts of villages to solar energy driven system also. The Government of Rajasthan has installed about 2000 RO plants with capacity varying from 500-2000 LPH during last five years in rural communities and 2000 more plants of 1000-2000 LPH capacity planned for the next two years besides around 3000 RO plants of capacity varying from 250-1000 LPH are already being operated in hostels, education institute, industries under corporate responsibilities (CSR) and private water suppliers.

In the present study the performance of community based RO units installed in Jaipur (Rajasthan) having capacity of 1000 LPH and geographical expanse was evaluated. The objective of the study was to understand the behaviour of small size RO plant, with brackish ground water feed under varying condition. The special emphasis was on development of a chemical cleaning schedule of membranes in order to reduce the specific power consumption (SPC).

3. METHODOLOGY

Vidhani treatment plant is installed in areas where ground water is not fit for drinking purpose due to high value of chemical parameters.

3.1 Sample Collection and Sample Testing

Water samples of raw, filtered and reject water were collected from Vidhani RO units. Flow and pressure readings were taken from instrument installed at these plants. Water samples were tested in Environmental Lab (SKIT, JAIPUR) for parameters like pH, alkalinity, TDS, Hardness, sulphate, nitrate, chloride and fluoride following methods prescribed in APHA [5]. Some data for Vidhani plant were collected from the operator's records, which were maintained at the plant site. FIG. 1 shows vidhani RO treatment plant and flow chart of vidhani treatment plant is shown in figure 2.

Figure 1: Vidhani RO treatment plant

Figure 2: Flow Chart of vidhani treatment plant

4. RESULTS AND DISSCUSSION

After collecting the sample from vidhani treatment plant, Ph and TDS test perform at different point such as raw, product and reject water and result are shown as table 1 and 2 at different date.

Table 3 shows the flow rate of product and reject water and also shows the head required for antiscalant quantity for dosing tank.

Table 1: Ph and TDS (mg/l) Readings of Vidhani Treatment Plant

Ph value			**TDS (mg/l)**			**Date of Readings**
Raw	**Product**	**Reject**	**Raw**	**Product**	**Reject**	
7.7	7.6	7.8	1474	149	3184	01/11/2018
8.5	7.1	7.4	1365	151	2200	11/11/2018
8.0	8.1	8.3	1253	98	2287	21/11/2018
8.2	8.4	8.6	1156	190	2185	28/11/2018
7.9	7.8	8.1	1502	127	3192	01/12/2018
7.6	7.8	7.9	1400	145	2200	14/12/2018
7.9	8.0	8.3	1212	103	2213	28/12/2018
7.7	8.4	8.7	1628	106	2419	14/01/2019
7.9	7.8	8.0	1166	130	2170	21/01/2019

Table 2 : Pressure Readings (kg/cm^2) of Vidhani Treatment Plant

Membrane-I (kg/cm^2)		**Membrane-II (kg/cm^2)**		**Membrane-II (kg/cm^2)**		**Date of Readings**
IN	OUT	IN	OUT	IN	OUT	
10	8	6.5	6.5	7.8	7.4	01/11/2018
8.7	7.8	6.5	6.5	7.8	7.4	11/11/2018
8.7	7.8	6.5	6.5	7.8	7.4	21/11/2018
8.7	7.8	6.5	6.5	7.8	7.4	28/11/2018
10	8	6.5	6.5	7.8	7.4	01/12/2018
8.7	7.8	6.5	6.5	7.8	7.4	14/12/2018
8.7	7.8	6.5	6.5	7.8	7.4	28/12/2018
8.7	7.8	6.5	6.5	7.8	7.4	14/01/2019
8.7	8.7	6.5	6.5	7.8	7.4	21/01/2019

Table 3 : Flow rate, wash time and antiscalant quantity of Vidhani Treatment Plant

Product Flow Rate (in litre)	Reject Flow Rate (in litre)	Head required For Antiscalant quantity for dosing tank (in cm)	Multi grade filter back wash time (inmin.)
1000	800	150	15

Fig.4 depicts the removal efficiencies of various chemicals present in the raw water, which indicates that the TDS of the raw water reduced from an average of 2000 to 116 mg/L representing a removal efficiency of 94%. The reject had a TDS around 4000mg/L indicating about 50% recovery of water in the system. Hardness removal was about 97% while chloride showed a removal of about 91% indicating a higher rejection of divalent ions over mono-valent ion.

Among other major anions, sulphate and fluoride both indicate a removal equivalent to that of hardness as these are attached to calcium and magnesium in water. Usually RO process is more expensive compared to other options for fluoride removal, as it requires high functioning pressure; fluoride being a smaller molecule than chloride, its rejection is relatively lower than that of chloride. The residual fluoride after a routine RO process may not be able to satisfy the drinking water requirement and sometimes an additional reaction for enhancing the size of fluoride bearing molecule has to be introduced to improve the efficiency of fluoride removal [7-9].

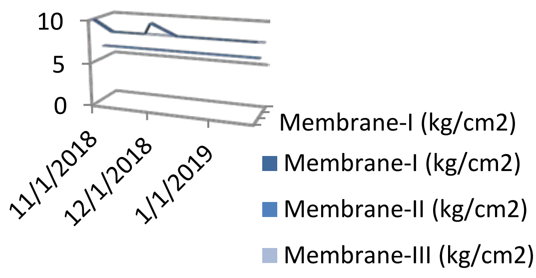

Figure 3: Ph test results of vidhani treatment plant

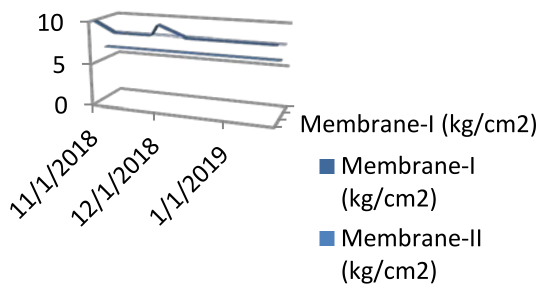

Figure 4:TDS test results of vidhani treatment plant

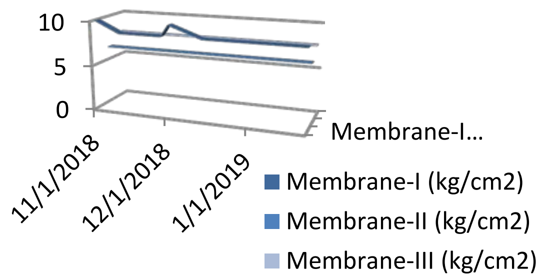

Figure 5: Pressure readings result of vidhani treatment plant

All parameters of water treated with the RO process were well within the limits prescribed by IS: 10500 [10] which is shown in table 4. These plants have been observed to remove hardness i.e. Ca and Mg salts, by over 95% efficiency, which are generally useful in human health. Based on the secondary data available for energy consumption from plant records, and the primary data collected during study, a curve is drawn, which shows relation between power consumption in KWh per kilolitre of filter water produced, also known as specific power consumption. Graphical results of vidhani treatment plant are shown in figure 3, 4 and 5.

Due to precipitation of foulants on membrane surface with time between two cleaning cycles, as per trend line, the specific power consumption increases by up to 13%.

After each membrane cleaning cycle, SPC reduces in a range of 12-13%. It is because, when foulants are removed during chemical cleaning, some amount of polyamide membrane material is etched by the chemical; hence the pore size of the membrane increases. This result is decreases in SPC.

Table 4 shows the comparison of standard limits of water to the vidhani treatment plant. After each chemicals wash, the salt rejection efficiency of membrane is reduced and membrane turns towards coarser pore sizes

The membranes, which are normally in series configuration in pressure vessels, should be rearranged in sequence after each wash to derive their maximum useful life. Membrane replacement is the major cost in these plants varying from Rs13500 to Rs20000 per module.

.

Table 4 : Comparison of Standard limits of Water to the Vidhani Treatment Plant(Source: Unit of Team Institute of Science and Technology Pvt. Ltd.)

Unit of Team Institute of Science and Technology Pvt. Ltd.					
S.No.	**Parameters**	**Observed Values**	**Testing Procedures**	**Requirments (acceptable limits) as per IS 10500:2012**	**Standard Permissible limit in the absence of alternate source as per IS 10500:2012**
1	Colour {Hazen}	Less than 5	IS 3025(part 4):1983 RA 2017	5.00	15.00
2.	Odour	Agreeable	IS 3025(part 5):1983 RA 2017	Agreeable	-
3.	Taste	Agreeable	IS 3025(part 7&8):1984 RA 2017	Agreeable	-
4.	Turbidity {NTU}	BDL(<0.1)	IS 3025(part 10):1984 RA 2017	1.00	5.00
5.	pH	6.50	IS 3025(part 11):1984 RA 2017	6.5 – 8.5	-
6.	Hardeness {mg/l}	16	IS 3025(part 21):1983 RA 2017	200	600
7.	Iron{mg/l}	BDL(<0.1)	IS 3025(part 53):2003 RA 2017	0.3	-
8.	Chloride	45.94	IS 3025(part 32):1988 RA 2017	250	1000
9.	Total dissolved solid{mg/l}	140	IS 3025(part 16):1984 RA 2017	500	2000

5. CONCLUSION

- There are many water treatment plants in Jaipur and one of them is Vidhani water treatment plant which is situated in Pratap Nagar near Poornima College.
- The special thing about this plant is it provide fresh consumable water at very cheap rate of 20 Litre for Rs 5.
- The plant is a self-service facility where a card is issued using which water can be purchased and the card can be recharged according to requirement.
- This case study provide useful data base to arrive at average operation cost of such community based plant
- These plant can be installed wherever water quality parameters are more than the permissible value
- The availability of good quality of water the consumption of water in villages typically average about 20 liters per day per family. This indicate that through a reasonable demand has been generated due to significant improvement in the taste of water, it is Presently use for drinking purpose and not for cooking as envisaged by the Government.

REFERENCES

[1] Imbrogno, J. et al., 2017. Critical aspects of RO desalination: A combination strategy. DES, 401, pp.68-87. Available at: http://dx.doi.org/10.1016/j.desal.2016.06.033.

[2] Munoz, I. & Fernandez-Alba, A.R. 2008. Reducing the environmental impacts of reverse osmosis desalination by using brackish groundwater resources. Water Research, 42(3), pp.801-811. Available at: http://www.ncbi.nlm.nih.gov/pubmed/17826817.

[3] Shenvi, S.S., Isloor, A.M. & Ismail, A.F., 2015. A review on RO membrane technology: Developments and challenges. DES, 368,pp.10-26. at:http://dx.doi.org/10.1016/j.desal.2014.12.042.

[4] Tech Sci Research, 2017 "Indian Water Desalination Plants Market Forecast & Opportunities, 2017.

[5] National Rural Drinking Water Program Guidelines [NRDWP], 2013.

[6] Dhindsa S.S. Water Quality Monitoring & Surveillance In Rajasthan Proc. Annual Convention of IWWA, Jaipur, January 6-8, 2006.

[7] Briao, V.B., Magoga, J., Hemkemeier, M., Briao, E.B., Girardelli, L., Sbeghen, L., & Favaretto, D.P.C. (2014). Reverse osmosis for desalination of water from the Guarani Aquifer System to produce drinking water in southern Brazil. Desalination, 344, 402-411.

[8] Gedam, V.V., Patil, J.L., Kagne, S., Sirsam, R.S., & Labhasetwar, P. (2012). Performance evaluation of polyamide reverse osmosis membrane for removal of contaminants in ground water collected from Chandrapur district. Journal of Membrane Science & Technology, 2012.

[9] Eswar, P., & Devaraj, C.G. (2011). Water defluoridation: Field studies in India. Indian Journal of Dental Advancements, 3(2), 526-33.

[10] BIS: 10500 (2012)

[11] A, V.G.G., 2011. Energy consumption and recovery in reverse osmosis. 36.

[12] Antony A., Jor H.L., Stephen Gray, Childress A.E., Pierre Le-Clech, Greg Leslie (2011), "Scale formation and control in high pressure membrane water treatment systems: Areview",Desalination,383,.doi.org/10.1016/j.memsci. 2011.08.054.

[13] Asadollahi M., Bastani D., Seyyed A.M. (2017), "Enhancement of surface properties and performance of reverse osmosis membranes after surface modification: A review" Desalination 420 (2017) 330–383, doi :10.1016//j.desal.2017.05.027

[14] A.F. (2017), "Membrane fouling in desalination and its mitigation strategies", Desalination 425 , 130–155, dx.doi.:10.1016/desal. 2017.10.018.

[15] Christian Z. K., Hater W. and Kempken N. (2012) "Cleaning of reverse osmosis membrane", Desalination and Water Treatment, 51(2012), pp. 343–351. doi: 10.1080/ 19443994 .2012.715424.

[16] Cob S. S., Hofs B., Maffezzoni C., Adamus J., Siegers W. G., Cornelissen E. R., Güner F. E. G. and Witkamp G. J. (2014) 'Silica removal to prevent silica scaling in reverse osmosis membranes', Desalination, 344, pp. 137–143. doi: 10.1016/j.desal.2014.03.020.

[17] El-Arnaouty M.B., A.M. Ghaffar A., Eid M., Aboulfotough M. E., N.H. Taher, El-Sayed S. (2018), "Nano-Modification of Polyamide thin film composite RO membranes by radiation grafting", Journal of Radiation Research and Applied Sciences." Doi.org/10.1016/j.rras.2018.01.005.

[18] Fath, H., Abbas, Z. & Khaled, A., 2011. Techno-economic assessment and environmental impacts of desalination technologies., 266, pp. 263-273.

[19] Gude, V.G., 2016. Geothermal source potential for water desalination- Current status and future perspective. Renewwable and Sustainable Energy Reviews, 57, pp.1038-1065. Available at: http://dx.doi.org/10.1016/j.rser.2015.12.186.

[20] Hafner Bob (2015)," Energy Dispersive Spectroscopy on the SEM: A Primer", Characterization Facility, University of Minnesota.