COMPARATIVE STUDY OF MEMBRANE CAPACITIVE DEIONIZATION TECHNOLOGY AND REVERSE OSMOSIS FOR TOTAL DISSOLVED SOLIDS FROM WATER

[1]Pragya Bohra,[2]Lalita Solanki, [3]Dr. Anil Vyas, [4]Dr. S.K. Singh
[1]M.E. Scholar, [2]Additional Chief Engineer, [3]Associate Professor, [4]Professor
[1]Department of civil Engineering, M.B.M. Engineering College, J.N.V. University, Jodhpur, Rajasthan, India
[2]Public Health and Engineering Department, Jodhpur, Rajasthan, India
[3]Department of Chemical Engineering, M.B.M. Engineering College, J.N.V. University, Jodhpur, Rajasthan, India
[4]Department of civil Engineering, M.B.M. Engineering College, J.N.V. University, Jodhpur, Rajasthan, India

Abstract*—Growing human population, severe neglect and over-exploitation of water resources has made water, a scarce commodity. The whole world is concerned for the availability of clean and potable water. Most of the available water is saline and is not potable. Water supplies are running out of the actual water needs of the society. We are now in need of finding cost competitive newer technologies for reclaiming this valuable life-sustaining liquid. Membrane capacitive deionization is one of those prominent technologies which assure to be more efficient with higher water recovery and less power consumption. This comparative study was done to evaluate the salt removal efficiency of Membrane Capacitive Deionization over reverse osmosis. The pilot plant (CapDI) manufactured by Voltea (Netherland) was provided by InNow India Pvt. Ltd for carrying out this study. It was found that Capacitive deionization technique is very efficient in removal of low salinity feed water sources. Energy consumption is quite low approximately only 20 to 30% of energy utilized by reverse osmosis. And flow recovery rate of CapDI plant is also high than reverse osmosis plant.

***Index Terms*—Electric Conductivity, Membrane Capacitive Deionization, Trace Metals**

I. INTRODUCTION

The desalination of seawater and brackish groundwater to provide fresh drinking water is an established and thriving industry. Desalinisation refers to any of several processes that removes amount of salt and any other minerals present in the saline water. Salt water is desalinated in order to produce fresh water that is suitable for human consumption or irrigation. The most commonly used technologies at present for the desalination process are Thermal Distillation and Reverse Osmosis (RO) filtration.

Rajasthan is the largest state of India, it shares only 1/10 of the average share of water than rest of the country [1]. Water supplies in most of the Indian cities including cities of Rajasthan are not matching the actual water need of the society. Groundwater is the major source of drinking water in some part of the Rajasthan. Presence of higher amount of salts in underground water sources in the western Rajasthan is enhancing the less availability of potable water to the population. This study was done to evaluate removal of salts from membrane capacitive deionization.

By definition, Membrane Capacitive Deionization is a combination of conventional Capacitive Deionization with ion-exchange membranes (IEMs) placed in front of the electrodes. Ion exchange membranes can be positioned in front of one or both electrodes. Ion-exchange membranes have a high internal charge due to covalently bound groups such as sulfonate or quaternary amines, which allows easy access for one type of ion (the counter ion) and block access for the ion of equal charge sign (the co-ion). Addition of Ion-exchange membranes significantly improves desalination performance of the Capacitive Deionization process, in terms of salt adsorption, charge efficiency and energy consumption. The membranes can be included as stand-alone films of thicknesses between 50 and 200 μm, or can be coated directly on the electrode with a typical coating thickness of 20 μm[2].

MCDI Working

Desalination by MCDI is done by applying constant current with varying voltage , so method is known as constant current(CC).

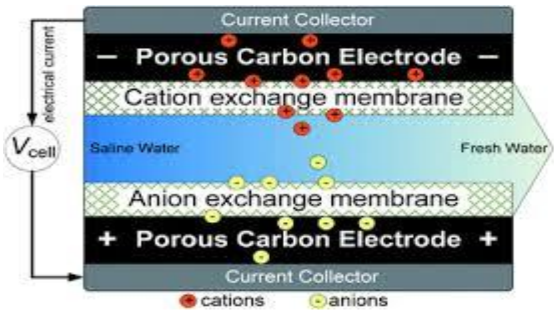

Figure 1 membrane capacitive deionization.

In CC-operation the effluent salt concentration level remains at a fairly constant value, namely at a constant low value during adsorption, and at a constant high value during desorption. Another advantage of CC operation is that one can precisely tune the effluent salt concentration level by adjusting the electrical current, or water flow rate, as control parameters. CC operation works only in MCDI and not in CDI. Instead, in CDI-CC the effluent salinity changes throughout the adsorption step, indicating that the salt adsorption rate is not constant, even though in CC-mode operation. This is due to the fact that in CDI the electrical current is partially compensated by counterion adsorption and for the other part by co-ion desorption. The co-ion desorption effect decreases at high voltages and then the current is directly proportional to water desalination rate, but this is not yet the case at low cell voltages. Thus the salt adsorption rate by the full cell pair changes as function of time and this is why in CDI-CC the effluent salinity does not quickly level off to the desired constant. For CC operation in combination with membranes (MCDI-CC), Constant levels of the effluent salt concentration are quickly reached after start of a new adsorption step, because the co-ions are kept within the electrode structure and only counter ions carry the ionic current[3]. The study is carried out keeping the current constant 240 ampere and voltage as a variable.

Study Area

Some places (RaikokiBasni, CharanokiDhani, NPH Chowki, PWD colony Jodhpur and Ghantiyali, Kuria, Kishangarh) of Jodhpur and Jaisalmer districts were taken as study places as in these districts underground water have high salt Concentrations. Both Districts do not receive adequate amount of rainfall, making ground water primary source of drinking water.

II. Methodology and Observations

The Pilot Plant (CapDI) was established at PWD colony of Jodhpur where tube well was the source of water. Other water samples were collected and transported in tankers from different selected underground sources. By keeping Water recovery, Current capacity (240 A), Number of cycles (3) as constants, all these samples were treated and reduction in TDS was assessed. Electric conductivity was taken as secondary parameter, as power consumption of the plant varies with variation in electric conductivity. The plant specifications were as given below.

Plant Specifications:

- Model: System IS 6 (Have 6 units of M(CDI) module)
- Instant Flow Rate: 0.5 – 6.1 m3/h
- Net Produced Flow: 2.4 – 3.5 m3/h
- Salt Removal: 25-98% (Adjustable)
- Water Recovery: 40-90% (Adjustable)
- System Power Requirement Single - Phase (4 kW)
- Water Feed Pressure: ≥ 6.0 m3/h , 3 bar
- Water Temperature 5 - 60 °C (40 - 140 °F)
- Number of cycles: 3 (Kept Constant)

In whole process current remains constant for a certain set percentage removal in both pure and waste cycle. When cycle changes from pure to waste, the current drops to zero and starts increasing to certain value. After reaching certain value it becomes constant for that cycle and voltage varies with increasing or decreasing percentage removal. By adjusting the desired set percentage removal in the plant will be reflected in the percentage change in electric conductivity. The removal of salts from MCDI with respect to reduction in salt concentration from RO was studied.

Table 1 Parameters of feed water TDS and removal by CapDI Plant of source NPH Chowki and RO Plant at Aau.

Treatment Process	Source	Plant Capacity (LPH)	TDS in feed water (mg/l)	TDS in treated water (mg/l)	TDS removal efficiency (%)	Power consumed (KWH)	Percentage Recovery
CapDI	NPH Chowki	1000	1472	204.8	86.09	0.81	69.50
RO	Aau	1000	1509	123	91.85	4	62.38

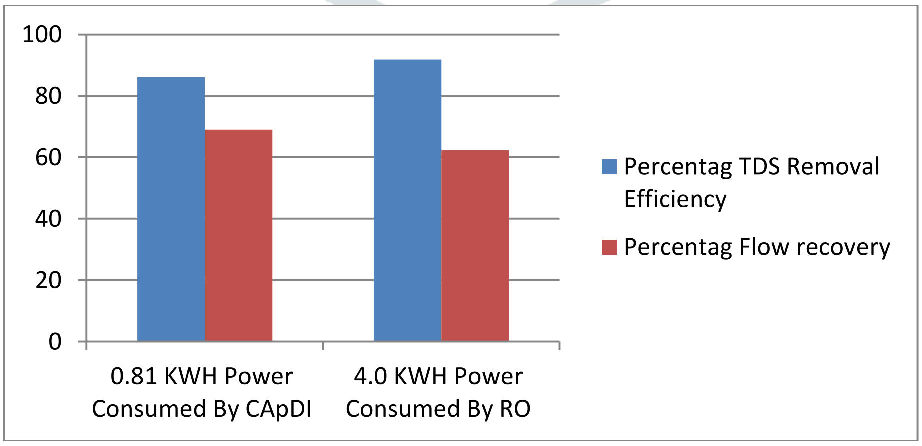

Figure 2 Efficiency V/S Power Consumption Chart of CapDI plant (Source NPH Chowki) and RO plant at Aau

Table 2 Parameters of feed water TDS and removal by CapDI Plant of source Kuria and RO Plant at Shetrawa

Treatment Process	Source	Plant Capacity (LPH)	TDS in feed water (mg/l)	TDS in treated water (mg/l)	TDS removal efficiency (%)	Power consumed (KWH)	Percentage Recovery
CapDI	Kuria	1000	1492	45.62	96.94	0.84	63.90

RO	Shetrawa	1000	1520	290	80.92	4	61.45

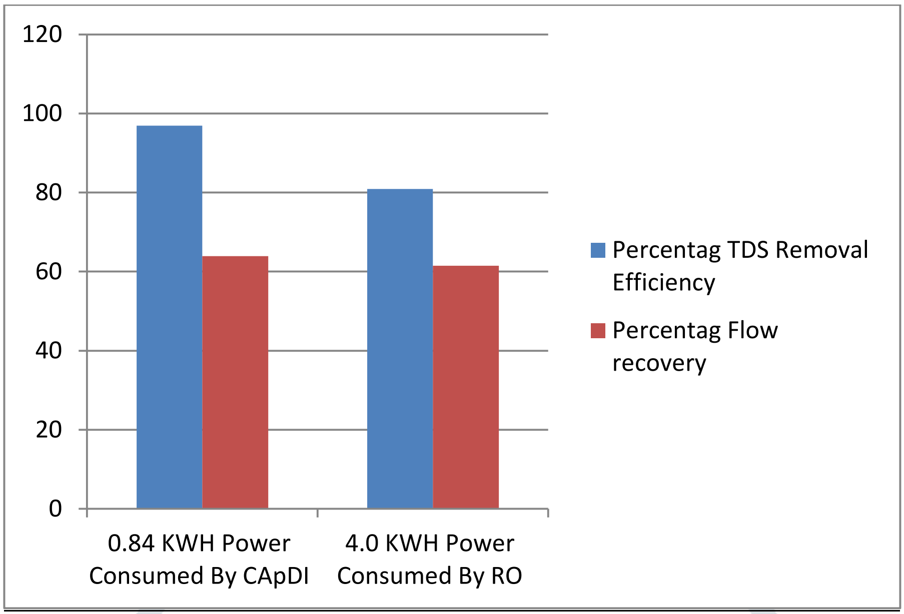

Figure 3 Efficiency V/S Power Consumption Chart of CapDI plant (Source Kuria) and RO plant at Shetrawa

Table 3 Parameters of feed water TDS and removal by CapDI Plant of source Kishangarh and RO Plant at Samaru

Treatment Process	Source	Plant Capacity (LPH)	TDS in feed water (mg/l)	TDS in treated water (mg/l)	TDS removal efficiency (%)	Power consumed (KWH)	Percentage Recovery
CapDI	Kishangarh	1000	1615	350	78.32	0.86	61.90
RO	Samaru	1000	1700	100	94.12	4	60.12

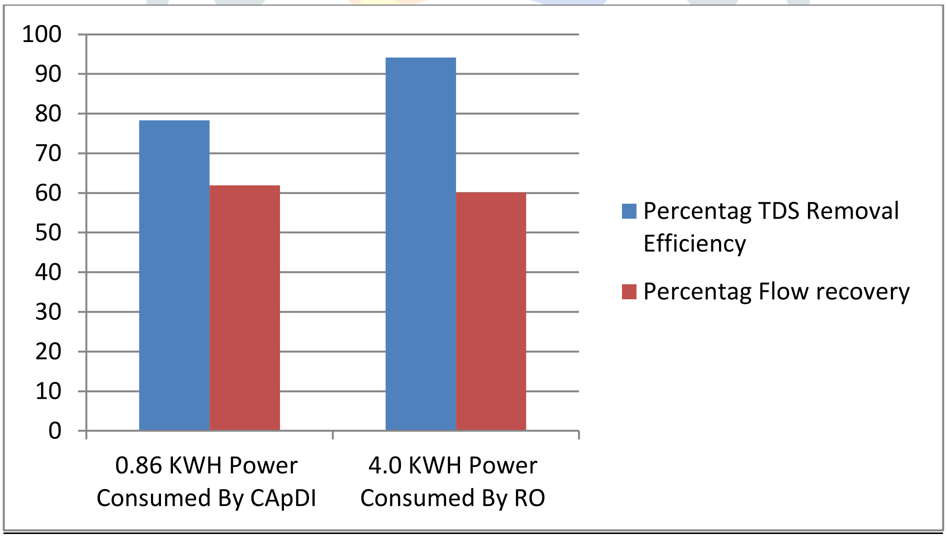

Figure 4 Efficiency V/S Power Consumption Chart of CapDI plant (Source Kishangarh) and RO plant at Samaru.

As shown in above observations TDS removal efficiency of CapDI plant is 15.8 % less than RO plant efficiency but power consumption is lower than RO plant, only approximate 21.50% of power consumed by CapDI plant as compare to RO plant.

Table 4Parameters of feed water TDS and removal by CapDI Plant of source Raiko Ki Basni and RO Plant at Hopardi

Treatment Process	Source	Plant Capacity (LPH)	TDS in feed water (mg/l)	TDS in treated water (mg/l)	TDS removal efficiency (%)	Power consumed (KWH)	Percentage Recovery
CapDI	Raiko Ki Basni	1000	3128	949	69.66	1.03	66.00
RO	Hopardi	1000	3250	246	92.43	4	60.05

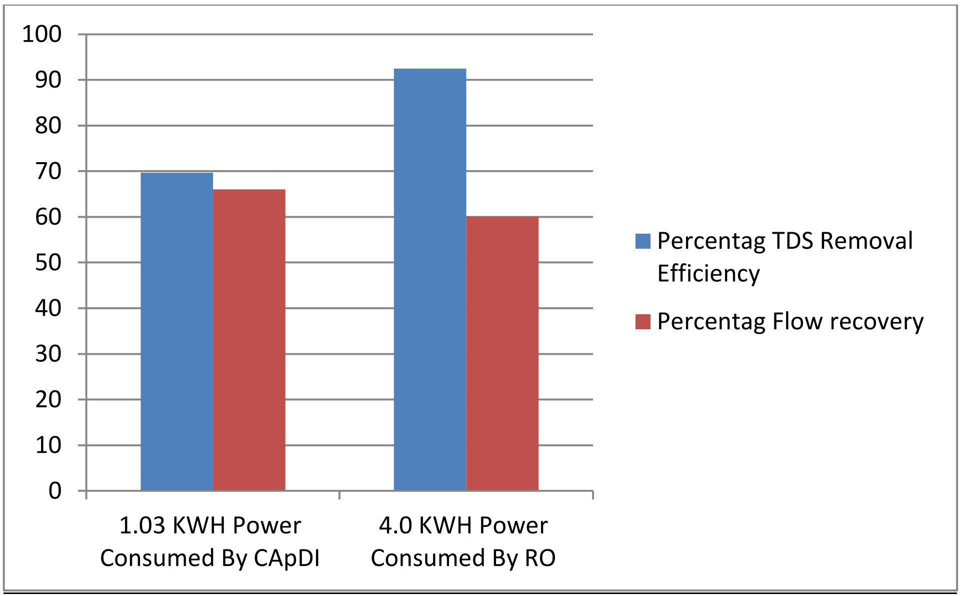

Figure 5 Efficiency V/S Power Consumption Chart of CapDI plant (Source Raiko Ki Basni) and RO plant at Hopardi.

As shown in above observations, TDS removal efficiency of CapDI plant is 22.77 %%, which is less than RO plant efficiency. But power consumption is much lower than RO plant only approximate 25.75% of power consumed by CapDI plant as compare to RO plant. And also percentage flow recovery of CapDI plant is more than RO plant.

III. Conclusions

Study was carried out on the raw water sample collected from the various location situated in Jodhpur and Jaisalmer district out of which three locations Ghantiyali, Kuria, and Kishangarh are situated at border area of Jaisalmer. And other locations of Jodhpur district are RaikokiBasni, CharanokiDhani, NPH Chowki, PWD colony. The water was directly feed to the capacitive deionization plant and treated for various preset percentage removal efficiency of salt and analyzed for TDS removal, power consumption and percentage flow recovery.

For a comparative study with RO plant, data of various location having similar TDS in raw water collected from web site of Public health engineering department, Rajasthan. It was found that Capacitive deionization technique is very efficient in removal of low salinity feed water sources (TDS < 3,000 mg/L). Energy consumption is quite low, approximately only 20 to 30%of energy utilized by RO Plant and flow recovery rate of CapDI plant is also higher than RO plant. CapDI plant have small footprint almost half the size of RO plant. There is no issue of fouling in CapDI plant which is usually seen in RO plant, fouling of hydrophobic membrane when the membrane is wetted.

Generally no pretreatment is required, and it offers Operational flexibility, as percentage reduction can be preset up to required level TDS in treated water as per its utilization purpose.

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