Water & health security in western Rajasthan and their remedial measures through solar energy: A case study

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Abstract: - High TDS in the drinking water has adverse effects on the health as per the drinking water standards (IS:10500). The permissible value of TDS for safe drinking of water is below 500 mg/l. In the survey, it has been found that in the western Rajasthan, the TDS in the groundwater at most of the places varies between 1100 to 6700 mg/l, which is unfit for drinking. Under the NRDWP (2009) scheme of Government of India, the habitation comes under "critical habitation" and there is a need to supply potable water through tankers or through Regional Water Supply Schemes by the PHED, Government of Rajasthan for drinking purposes. Recently Jal Jeevan Mission (JJM) by Government of India initiatives emphasizes to provide pipe water supply till 2024 to all households. In order to utilize the High TDS water which is available in the groundwater through Tube wells, Open well, there is need for its treatment through RO-Plant. During the RO-Treatment process, 20~50% of water comes as RO-Rejects having much higher TDS value which is currently discharged on the open land, nearby water bodies or infiltrate to the groundwater further leading to spoiling of soil and groundwater quality in the region simultaneously affecting the health of human being and fertility of agricultural field signaling reduction in crop yield and change in crop pattern. The evaporation of RO-Reject through solar at decentralized as well as centralized location has been found feasible due to availability of ample sunshine radiation in the western part of Rajasthan.

Keyword: TDS, RO Plant, CETP, Solar Concentrator

1. Introduction

Water being a basic necessity for sustenance of life, needs to be made available to every individual. In order to provide drinking water to each and every household, a number of schemes have been initiated by the Central and State Governments. The performance of schemes depends upon many factors such as groundwater availability, levels of coverage and consumption, water quality and institutional arrangements for operation & maintenance. [1]. The Department of Drinking Water, Ministry of Rural Development, Government of India has formulated a policy under National Rural Drinking Water Programme (NRDWP) and guidelines have been framed to meet the challenge of providing drinking water security to every household in the rural areas [2].

Water in rural areas of Rajasthan is mostly being supplied free of charge. Currently, there is an acute shortage of drinking water in the entire Rajasthan state, particularly in rural areas. This situation worsens during the summer season and the Government has to supply water through tankers and at many places by railway wagons. Due to the geographic nature and climatic conditions of the state, maintaining the water supply is an uphill task for the Government.

Water is determined fit for drinking purposes through various water quality parameters. Out of those parameters TDS plays a vital role particularly for the major western regions of Rajasthan meeting water quality standards stipulated by BIS in IS:10500. Total Dissolved Solids (Salts) is a concentration of positively charged and negatively charged ions in water. It originates from natural sources, sewage, urban run-off, industrial wastewater and chemicals used in the water treatment process. Referring to IS:10500 standard[6] of drinking water quality the Total Dissolved Solid (TDS) in water should not be more than 500 mg/l. Water is unfit for human consumption, if the TDS level is more than 1000 mg/l. Several diseases like nausea, lung irritation, rashes, vomiting, dizziness etc occur, if the drinking water is having high TDS. TDS for longer periods will lead to chronic health conditions like cancer, kidney failures, nervous system disorders, liver problems, weaken immunity and may also cause birth defects in the newborn [3].

Even for plantation and agriculture purposes, its value should not exceed 2100 mg/l. However, due to natural and man-made reasons, the quality of the water w.r.t. TDS in the Rajasthan districts of Jodhpur and Bikaner exceed these permissible values of TDS for drinking as well as agriculture purposes. People inhabiting the area are bound to use high TDS water for drinking as well as agriculture purposes resulting in the health hazards as well as drastic change in the yield of agriculture crops. Moreover, the crop pattern has also changed in the last three to four decades. The Public Health Engineering Department (PHED), Rajasthan had conducted several studies to identify the quality of the water used by their people and came up with the initiative to supply minimum drinking water through "Regional Water Supply Scheme (2009. Under the NRDWP of Government of India, efforts have been made by the Government of Rajasthan to identify the critical habitation, where the quantity and/or quality of water for drinking purpose is inadequate. The efforts are being made to treat the water at the centralized as well as decentralized level for the supply of safe water. The objective was to "Enable all households to have access to and use safe & adequate drinking water within premises to the extent possible **(Source: NRDWP Guidelines 2013)**. Scenario is yet to improve. Still the people have to travel long distances to fetch comparatively good water for their survival. Rain water harvesting through construction of "underground tanks" or "*tanka*" have been found, but it is limited to the economically sound people. The goal of JJM (Jal Jeevan Mission)[1] is to provide functional household tap connection to every household with service level at the rate of 55 litres per capita per day (lpcd). It is a huge task not only financially but also in terms of consumption of time and work involved in its implementation. Under the JJM, there is provision for technological intervention for treatment to make water potable (where water quality is an issue, but quality is sufficient) [1,2].

2. Solar Water Treatment Process

With the evolution of advanced water treatment technology, it is possible to bring down the High TDS water to the potable level through the membrane / Reverse Osmosis (RO) technology. Different grades of RO-Membrane are available to bring down the TDS from 1,000 mg/l~20,000 mg/l to the level of permissible TDS value of less than 500 mg/l for drinking purposes. Even the sea-water can also be converted to the TDS level of drinking water quality through Sea-water membrane. But it is a huge challenge to handle generation of RO-Rejects, which varies from 20~50% of input quantity of water to the RO-system of water treatment. The level of TDS in the RO-Reject water varies from 2000 mg/l to 20,000 mg/l based on the input TDS of impure water and number of stages of RO-treatment in the regions (Bikaner & Jodhpur). This level of High TDS RO-Reject is detrimental to the soil as well as ground water, if not discharged in a scientific manner after proper treatment [4]. There is a need to evaporate the RO-Reject water and convert the salt present in them in the dried form for its reuse or disposal in the secured Hazardous Waste Treatment, Storage & Disposal Facility (TSDF), if it meets the criteria stipulated in the Hazardous Waste & Other Wastes (Management & Transboundary) Rules, 2016. The solar water treatment process stepwise is shown in figure 1.

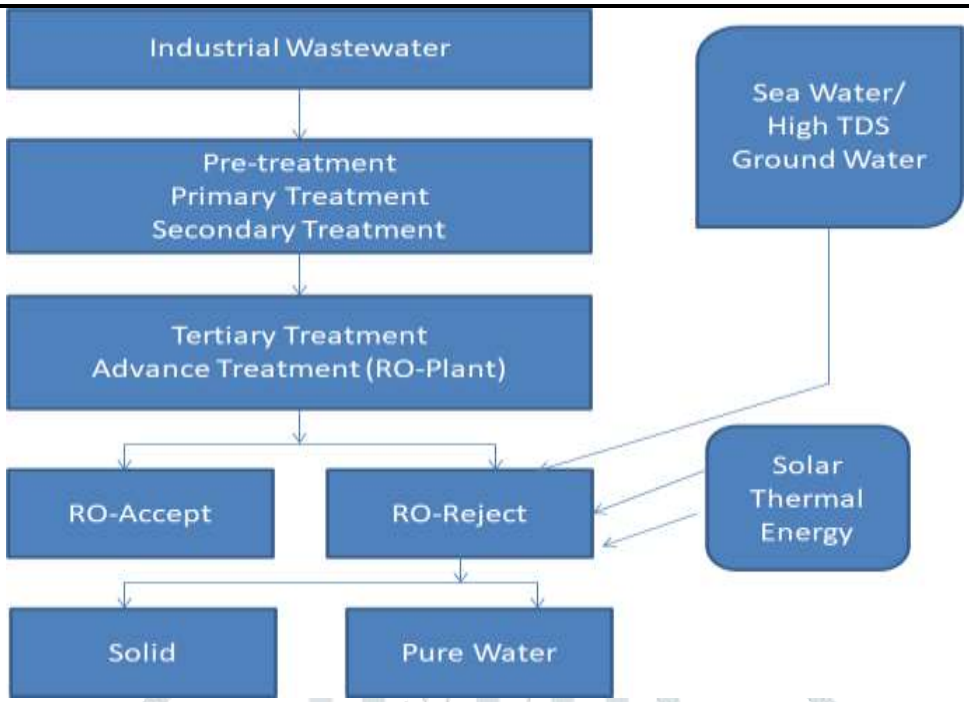

Figure 1: Water treatment process using solar

With the increasing trends of utilization of RO plants, a number of Package Drinking Water Plants have come up in the last two to three decades. People are utilizing the Packaged Drinking Water with great pride and status. In the urban area, everyone in 10 houses have their own RO-Drinking Water Plant which is being integrated in the piped water supply line to get more low TDS water. Sometimes, the Packaged Drinking Water plant forgets to maintain the minimum mineral level in the Packaged Drinking Water which leads to adverse impact on health of the users. Therefore, it is essential to maintain the minimum level of mineral before supply to the users for the drinking purpose [4,5].

Hence, there is need of selection of membrane which reduces the TDS level of input water in the RO-Plant to the permissible TDS level for drinking water by means of addition of requisite minerals after complete extraction of salts present in the input water, if the source of salts present in the input water is not meeting the requirement of good health.

The major environmental concern observed in the RO-Plant is indiscriminate disposal of RO-Reject on the land or ground water and other water bodies. Its repercussions are more strenuous in future for sustainability.

Nature has not given only the scarce and high TDS water to the districts of Rajasthan. But also flooded with the more than 300~330 Sunshine days and hot climate, which could be converted to boon by utilizing Solar Radiation for the evaporation of RO-reject water instead of going for steam/electricity-based evaporators/Multi-Effect Evaporator to convert the RO-Reject water into distilled water and dried salts for the safe handling.

Direct Normal Irradiation of Bikarner & Jodhpur Rajasthan ranges between 5~7 $kWhm^2$, which is suitable for the installation of high efficiency Solar Concentrator for the evaporation of RO-Reject water [6].

The Thermal utilization of Solar Radiation can be made through various Thermal based Solar devices like Solar Concentrator Parabolic disc and its modified or advance form to utilize absorbed solar head directly or indirectly for the evaporation of High TDS RO-Reject on small scale and large scale of evaporation respectively. At the

habitation/village level, the decentralized direct solar based evaporation system would be more feasible whereas for the centralized and large scale treatment, the indirect solar thermal based technology would be feasible in which first the solar radiation will be captured through the Thermic Fluid Heater which can build up the temperature to about 300 deg C and the same Thermic Fluid Heater would be utilized for generation of steam at high pressure for evaporation of large quantum of High TDS water through Indirect heating/jacketed coiled heat transfer. During the whole treatment process, there are two major outputs- (i) Dried Salts and (ii) Distilled water, if the vapor would be condensed.

The quality of dried salts would vary based on the source of water. Normally, the salts present in the natural way in the groundwater can be recycled and reused for the different industrial purposes, after analysis of all the constituents present in it. It would be the source of natural resources. Moreover, the salts do not come under the purview of Hazardous waste category and hence it can be disposed of on Municipal Waste Sanitary Landfill. If the source of High TDS water is from the industrial application i.e. after advanced treatment of Industrial Effluent, then the salts present in the treated wastewater would be mostly heterogeneous in nature and not suitable for recycle/reuse and there is chance to come under the category of Hazardous Waste. Then it has to be disposed of in the Hazardous Waste TSDF [7].

By adopting solar radiation, the high TDS water in the region can be converted into potable drinking water at decentralized as well as centralized level and the availability of water can be increased and the issue of Water & Health Security can be overcome.

The replenishment of ground water through Rainwater Harvesting will further improve the quality of the ground water and there would be a shift in the high TDS groundwater to gradually low TDS groundwater and thus the agriculture crop yield and pattern will also be improvised.

3. Solar Based Zero Liquid Discharge System

The following stage are used for water treatment using solar based liquid discharge system

(a) Pre-Treatment of wastewater before RO
(b) Multi Stage RO system to concentrate RO 2-3 times.
(c) Thermal Driven Process- 3 stage MEE or Membrane Distillation (MD)
(d) Through MD Process concentration of TDS can achieve upto 200,000 ppm. This can be dried in an open pond under the sun/spray drying.

The Figure 2 is showing various stages to treat the hog TDS water using solar energy.

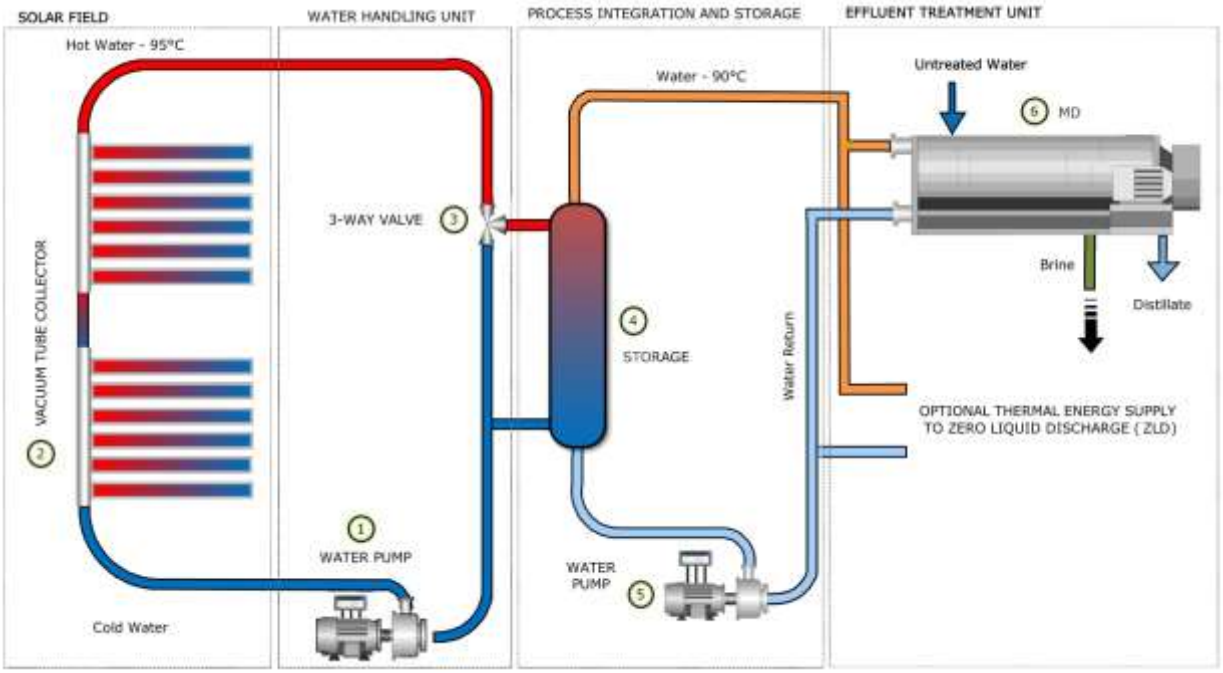

Figure 2: Water treatment using solar system

4. Water Quality in Western Rajasthan

As per census Jodhpur District had a population of 3,687,165 in 2011. Population of Jodhpur District in 2020/2021 is 4,140,093(estimates as per aadhar uidai.gov.in Feb 2019 data). The district has a total area of 22,850 sq km., 256 sq km is urban and 22594 sq km is rural. Out of the total population of 4,092,754 in the district, 1,264,614 are in urban areas and 2,422,551 are in rural areas. 234,790 households are in urban areas, 414,223 are in rural areas [7].

As per census, Bikaner District had a population of 2,363,937 in 2011. Population of Bikaner District in 2020/2021 is 2,654,321(estimates as per aadhar uidai.gov.in Feb 2019 data). The district has a total area of 30,239 sq km., 210 sq km is urban and 30029 sq km is rural. Out of the total population of 2,623,971 in the district, 800,384 are in urban areas and 1,563,553 are in rural areas. 139,973 households are in urban areas, 244,971 are in rural areas.

As per the statistic available on website of Jal Jeevan Mission, Government of India (Website: ejalshakti.gov.in), the status of contaminated water sources and affected number of habitations in the Bikaner & Jodhpur districts are depicted in table 1[7].

Table 1: Status of contaminated water sources and affected number

Year	District	Number of sources as on 24/01/2021	Number of sources found contaminated (exceeding the permissible limit of IS:105000 w.r.t. TDS	Number of habitations affected
2018~19	Bikaner	20,649	459	253
2019~20	Bikaner	26,840	385	218
2018~19	Jodhpur	73,311	1015	1127
2019~20	Jodhpur	87,178	644	911

In order to survey the field conditions at the habitation levels, the water testing through the Digital TDS meter has been conducted during October to December 2019 in the districts of Bikaner and Jodhpur. The sample results have been tabulated below. From the Water quality test data it has been inferred there is wide variation in the TDS values in the different locations which ranges between 1100 to 6790 mg/l. These TDS values show that all have crossed the permissible value for drinking water. Hence there is a need to install the suitable water treatment plant. The conventional water treatment plant consists of treatment with lime & alum for the settling of suspended matter and other heavy metal constituents. Further it is treated in the softener for removing the hardness and then it passes through Multigrade filter and Activated Carbon Filter to remove color, odour. There is need of disinfection of water which is carried out through Ultra-violet plant (UV-Plant). After the above treatment of water, the TDS level does not reduce rather it increases due to addition of chemicals. Therefore, it has to pass through the Reverse Osmosis Plant (RO-Plant) which is membrane-based technology. The handling of RO-Reject would be done through solar evaporation method [5,7]. TDS ranges in Bikaner district are shown in table 2.

Table 2: TDS ranges in Bikaner and Jodhpur District

District	Block	Panchayat	Village	Habitation	TDS ranges (mg/l)
Bikaner	Bikaner	Badarsar	Badrasar	Badrasar	1270~3360
Bikaner	Bikaner	Badarsar	Mehrasar	Mehrasar	2850~6790
Bikaner	Bikaner	Jamsar	Jamsar	Jamsar	1270~3360
Bikaner	Bikaner	Kanasar	Kanasar	Kanasar Choti Dhani	1210~2800
Bikaner	Bikaner	Kharda	Kharda	Kharda	1420~3640
Bikaner	Bikaner	Lakhusar	Lakhusar	Lahusar	1870~4780
Jodhpur	Phalodi	Bamanu	Manavevar	Mananevar	2400~2500
Jodhpur	Phalodi	Baori Khurd	Baori Khurda	Bawari Khurd	2500~4212
Jodhpur	Phalodi	Bawari Kallan	Bawari Kallan	Bawari Kallan	3500~4700

Jodhpur	Phalodi	Daya Sagar	Matol Chak	Godaron Kd	1100~2502

There is a wide distance from one habitation to another, hence the decentralized RO plant at habitation level is the best solution. Wherever the water is available in plenty with comparatively low TDS value, it should be treated in centralized level and supplied through "Regional Water Supply Scheme" to the nearby more than one habitation.

The treatment of RO-rejects at decentralized level is done through small scale Solar parabolic Concentrator whereas big scale Concentrated Solar Power (CSP) is the best solution. The salt generated would be recycled/reused after proper testing else it should be disposed of in the Sanitary Landfill/ Secured Hazardous waste Treatment Storage Disposal Facility (TSDF) [8].

The study conducted by PHED, Rajasthan for the "Benchmarking of Rural Water Supply" in the year 2009~10 reveals that the TDS quality of the regions has crossed the permissible level in the regions. The water quality Maps for Bikaner and Jodhpur districts are given in Figure 3.

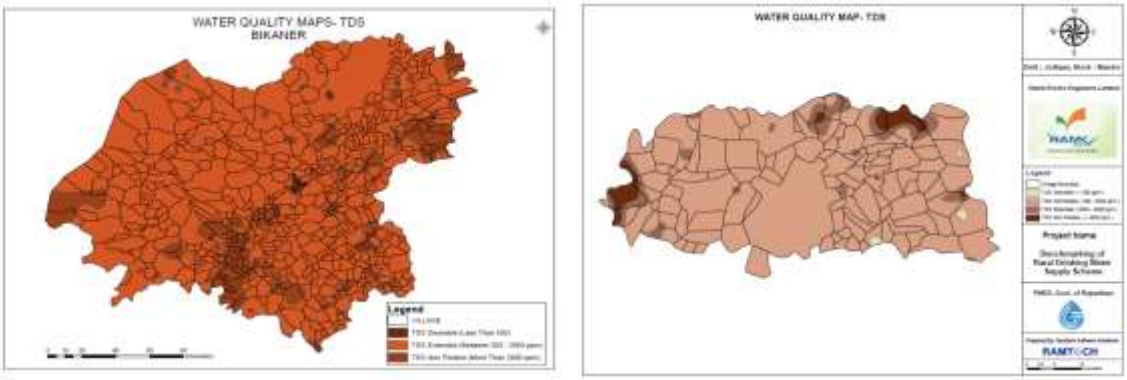

Figure 3: Source: Benchmarking of Rural Water Supply Scheme, PHED, Rajasthan (2011) [5]

Wastewater Treatment and Discharge through CETP

The impact of high TDS wastewater discharged through the Effluent Treatment Plant (ETP) and Common Effluent Treatment Plant (CETP) after partial treatment or no advance wastewater treatment and not handling the RO-rejects wastewater have created lots of damage to the receiving body (soil, surface water and groundwater). A study has been shown that due to improper treatment of textile effluent wastewater in the Common effluent Treatment Plant of Pali Industrial Area, Pali (Rajasthan), the TDS value of River Bandi are shown in table 3. The upstream water quality of Bandi River was TDS value of 470 mg/l whereas downstream value TDS level of 4008 to 6624 mg/l. The sample taken by Rajasthan State Pollution Control Board (RSPCB) on 11/11/2019 at different locations of river Bandi at the downstream side of CETP, Pali are placed below [4]

Table 3: TDS value of River Bandi

Location	TDS (mg/l)
Wastewater of Bandi River, Pali	11,838
Wastewater of Bandi River, Gadwara-Jaitpur Pulia, District Pali	3,688
Wastewater of Near Girdara to Jabariya Road Pulia, Tehsil Rohit, District-Pali	2,818
Water of Nehra Dam	2,578

It is evident from the above TDS value of river Bandi, all ground water sources at the bank of the river is severely contaminated resulting in deteriorated water quality for drinking and agriculture purposes. The health of the people as well as the yield of crops and change in crop pattern due to high salt content in the soil as well as groundwater/surface water of river Bandi used for the agriculture purpose is sorely affected. The high salt retaining plant species only would survive under such agricultural water quality.

As per the direction of NGT, the CETP management has to go for Zero Liquid Discharge (ZLD) i.e. they have to treat the wastewater in such a way to be reutilized for the industrial purpose. In order to achieve the ZLD, the CETP management has to go for advanced wastewater treatment and utilize the Reverse Osmosis technology to reduce the TDS for the acceptable range of industrial application. Further, the RO-reject, which has concentration in the range of 10,000 to 30,000 mg/l after two to three stages of RO-treatment to reduce the quantity of RO-Rejects for further evaporation. The CETP management can go for setting up of Solar based Thermal Concentrator / Concentrated Solar Power to absorb solar heat which would be stored in solar storage device and further transfer to the Thermal Fluid Heater to achieve temperature of more than 300 deg C to utilize for Steam generation for the Multi-effect Evaporator. This will save their operating cost toward use of conventional energy sources (Coal/Diesel). The salt generated from the process would be collected and stored in a safe manner and disposed of to the Hazardous Waste TSDF. The condensed water vapor from the multi-effect evaporator can be utilized as Distilled water for industrial application.

Conclusion:

With the field study conducted and analysis of water samples of groundwater in the regions of Bikaner and Jodhpur, it has found that the major pollutant in water is High Total Dissolved Solids (TDS). This makes the habitation critical with respect to quality of water. There is an adverse impact on the health of residents in those regions. Therefore, in order to make water potable and fit for drinking, the RO-Plant followed by provision of handling of highly contaminated RO-Reject through Solar is a feasible solution. Due to high Sun-shine days (300~330 days) and high solar irradiation (5~7 kWh/m^2), it is feasible to install solar thermal devices for evaporation of RO-Rejects which will help in achieving water security and for better health of the people and protecting the environment too for sustainability.

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