Study and design of a PORTABLE SEAWATER DESALINATION UNIT and analyse the purified water quality for any further improvement

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DOI: 10.29322/IJSRP.13.07.2023.p13939
http://dx.doi.org/10.29322/IJSRP.13.07.2023.p13939

Paper Received Date: 13th June 2023
Paper Acceptance Date: 18th July 2023
Paper Publication Date: 30th July 2023

Abstract

In this investigation, we are using the various methos of desalination for removing salts or other minerals and contaminants from seawater to obtain fresh water for human consumption and for domestic/industrial utilization.

We have worked on a project focusing on demonstrating a field-deployable desalination system with multistage membrane filtration processes, composed of two-stage ion concentration polarization, to convert seawater to drinkable water. The portable system desalinates seawater (2.5–45 g/L) into drinkable water (defined by WHO guideline), with the energy consumptions of 15.6–26.6 W h/L (seawater).

The process can reduce suspended solids by at least a factor of 10 from the source water, resulting in crystal clear water (<1 NTU) even from the source water with turbidity higher than 30 NTU (i.e., cloudy seawater by the tide). Also, the water resulting color (5), Order (Agreeable)and Taste (Agreeable) within the acceptable limit, which is required for an ideal drinking water.

We built a fully integrated prototype (controller, pumps, and battery) packaged into a portable unit (42 × 33.5 × 19 cm3, 9.25kg, and 20.61 L/h production rate) controlled by turbidity meter and IR unit. The out-flow time is 175 sec/2.91 minute per liter of water discharge, which is equal to 20.61 liter per Hour.

Due to the unprecedented in size, efficiency, and operational flexibility the demonstrated portable desalination system, could address unique water challenges in remote, limited resource regions.

Keywords: Desalination; Freshwater production; waste energy; Reverse Osmosis, Energy Recovery.

1. Introduction

Desalination Plants in India are an additional source of water for human use. Desalination of Seawater can help in meeting the freshwater demand of human and environment of a given area. Natural desalination has been occurring on earth since the creation of the seas. Water evaporates from the sea and then condenses to form pure rain water. Desalination has been practiced by man in the form of distillation for over 2000 years.

Desalination Plants in India are an additional source of water for human use. Desalination of Seawater can help in meeting the freshwater demand of human and environment of a given area. Although there are a number of ways to convert seawater to fresh water, a common overall process applies to all schemes. Actual nature of each step would depend on the desalination method used.

In this project we are following Membrane Technology of desalination, that will provide more accurate result by the use of minimum source of filtration.

When pressure is applied to the solution with the higher salt concentration solution, the water will flow in a reverse direction through the semi-permeable membrane, leaving the salt behind. This is known as the Reverse Osmosis process or RO process.

An RO desalination plant essentially consists of four major systems: a) Pretreatment system, b) High-pressure pumps, c) Membrane systems, d) post-treatment. And we are dealing with the same process is addition of different apparatus and the analyzing the outcome thereafter.

2. Design and description of the Set up:

The RO desalination process is energy intensive. This is due to the low recovery ratio (25 % to 40 %) and the high operating pressure (60 bar to 80 bar).

The various stages of designing based upon the following steps:

- Pre-treatment is very important in RO because the membrane surfaces must remain clean. Therefore, all suspended solids must be first removed, and the water pre-treated so that salt precipitation or microbial growth does not occur on the membranes.
- The choice of a particular pre-treatment process is based on a number of factors such as feed water quality characteristics, space availability, RO membrane requirements, etc. High pressure pumps supply the pressure needed to enable the water to pass through the membrane and have the salt rejected. A portion of the feed water is discharged without passing through the membrane. Without this discharge, the pressurized feed water would continue to increase in salinity content, causing super-saturation of salts. The amount of feed water that is discharged as concentrate, ranges from about 20 percent for brackish water to about 50 percent for seawater.
- Post-Treatment consists of stabilizing the water and preparing it for distribution. The post treatment might consist of adjusting the pH and disinfection. If the desalinated water is being combined with other sources of water supply, it is very important to ensure similar water quality characteristics in both water sources.
- Initialization of essential tools for balancing water flow (by use of S Valve & TDS controller) & Energy recovery devices by supplying electricity through adopter, the efficient durable performance of the whole system can be ensured.
- Improvements in membranes and energy recovery devices used for seawater RO (SWRO) have improved the overall process efficiency thereby lowering the costs associated with treatment.

Flow Diagram:

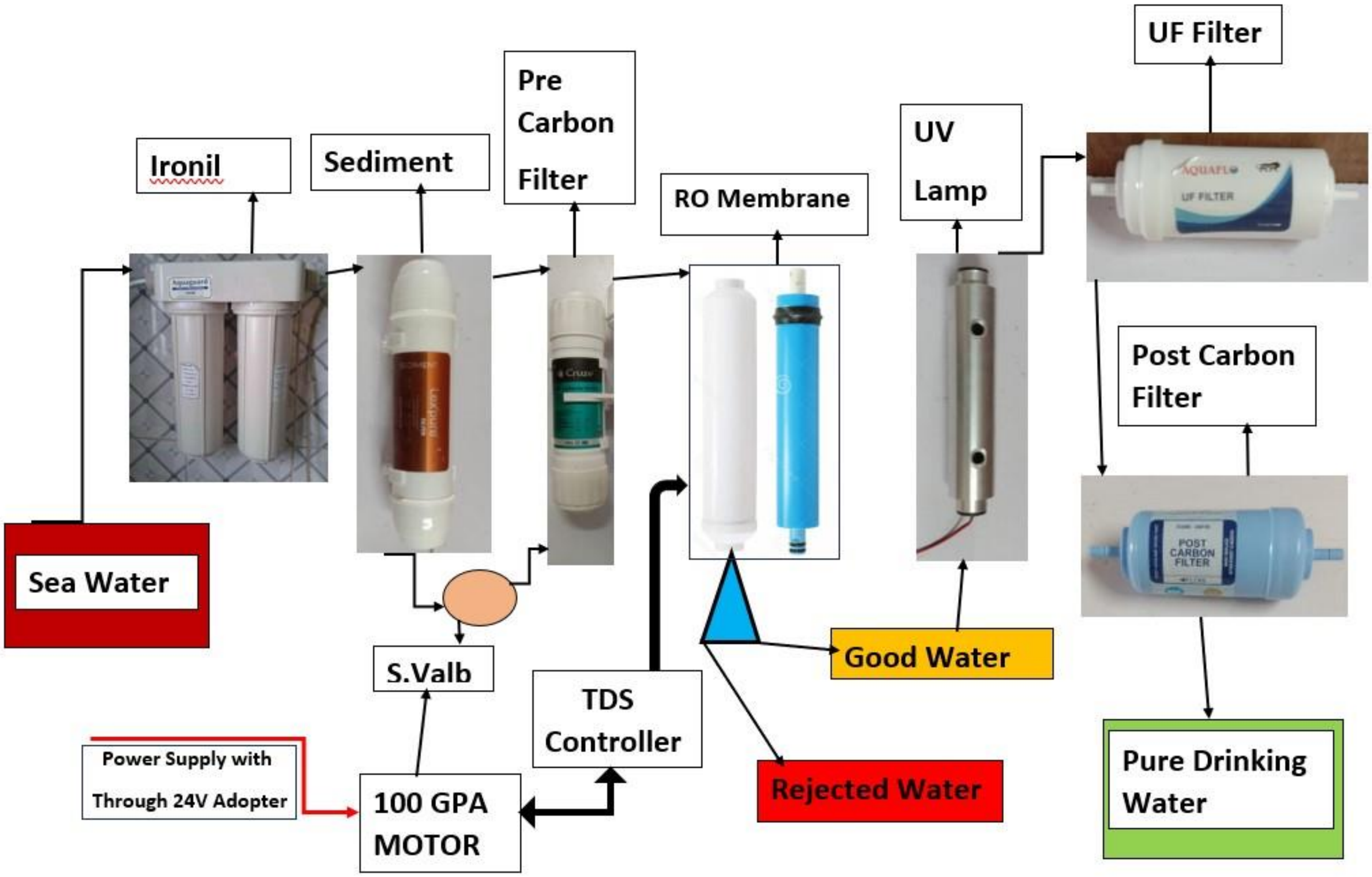


Figure 1 Schematic Layout of the desalination unit

3. Pre-Treatment of Saline Water and its Effects:

In pretreatment process the prefilter (Ironil, sediment, pre carbon filter) traps large particles such as dust, oil, and iron (from the compressor), and pipe scale and rust (from the pipework) and thus protects the sterilizing filter and increases its lifetime.
Filters sediment, dirt, particulates, sand, and silt. Binders free, antistatic free, lubricants free or other additives free. Good Quality Products for All Domestic RO Water Purifiers that provides safe & healthy water and makes Your Purifiers Life Longer

Naturally, water contains very small suspended particles (approximately 0.1 micron, defined as colloidal). The surface to mass ratio is huge compared to visible particles which cause them to deposit in unlimited patterns and therefore add up and thicken where they deposit. This accumulation and deposition of particles on membrane surfaces results in what are known as amorphous gels. Such membrane fouling agents are complex mixtures and are difficult, sometimes impossible, to clean. Through pre-treatment, fouling is significantly reduced, if not prevented. There is also a possible reduction in the damage to reverse osmosis membranes. The pre-treatment method to be used depends on the extremes of the characteristics of the raw water

The benefits of the pre- treatment will be product flow optimization, salt rejection optimization and product recovery, reduction of operating costs, and reduction or decrease in cleaning frequency and membrane replacement costs. A pre-filter's purpose is to capture larger particles like dust and hair, preventing them from clogging the HEPA filter. Of course, HEPA filters have no problem capturing these large particles, so the pre-filter will NOT increase the effectiveness of the purifier.

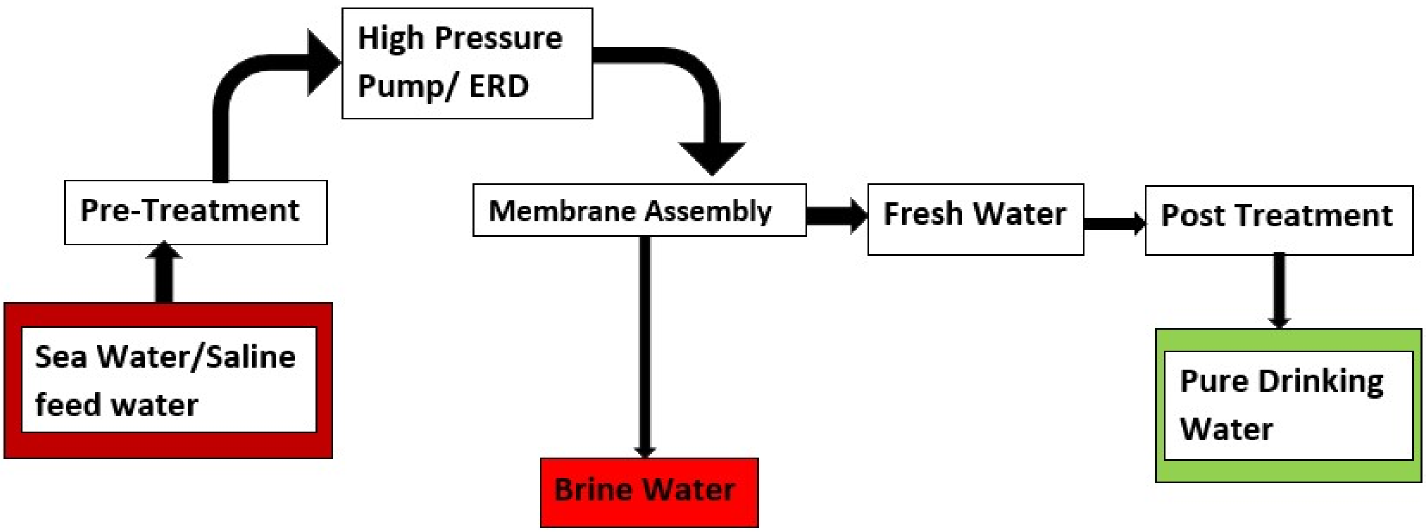
4. Characteristics:

Energy Recovery in RO Systems, is the economic and efficient feature during desalination. A crucial condition for the layout of an RO system is the specific energy consumption, which should be kept as low as possible.

This, therefore, means that the recovery ratio must be as high as possible and the associated feed water pressure be kept as low as possible without compromising the standards of the quality of water produced.

This process is energy intensive due to the low recovery ratio (25 % to 40 %) and the high operating pressure (60 bar to 80 bar). Based upon the current made potable size instrument we achieve a quite good output (by using 9.65 bar motor to achieve 20.61 l/h out flow of good water).

The TDS value obtained in TDS meter is reduced from **791 to 215**, which is a good result in single time flow.



Basic component of membrane treatment process

The resulting figures showing desalination contains of sea water, which was performed in a single flow of filtration. Those can be acceptable and could be used in further study & experiments.

Below table showing the following parameters those are achieved (based upon the test result), during desalination process in a single flow:

TEST RESULT

Result based on IS Code- 10500: 2000-For drinking water — SAMPLE QTY- 1 LITER

Sl no	Test Parameter	Units	Sea Water Charecters	Result (After Process)	Acceptable limit (As per IS/ Standard)	Permissible limit in absence of alternate source(As per IS/ Standard)	Test method
1	Temprature	C	___	25.3	___	___	APHA 2310 Ed. 2017-2550 B
2	PH	ph Unit	Avvg 7.75	7.82	6.5 to 8.5	No relaxation	APHA 23'd Ed.4500-H. B (Electrometric Method)
3	Turbidity	NTU	70-142 NTU	0.43	1	5	APHA 23'O Ed.2130 B (Nephelometric Method)
4	Color	Hazen Unit		5	5	15	Visual Comparison Method (APHA 23'd Ed 2120 _ B)
5	Order	___		Aggreable	Aggreable	Aggreable	Threshold Odour Test (APHA 23rd Ed 2150 _ B)
6	Taste	___		Aggreable	Aggreable	Aggreable	___
7	E Coil	CFU/100ml	upto 400 CFU/100ml	0	Shall not be detected in any 100ml sample		MFT Method
1	Elect. Conductivity	umho/ cm	upto 50000	7500	___	___	APHA 23ro Ed.2510 B (Laboratorv Method)
2	Cloride	mg/l	Min 18000 mg/l	2240	250	1000	APHA 23'd Ed.4500 Ct- B (Aroentometric Method)
3	Total Hardness (As Caco3)	mg/l	Upto 6630 mg/l	850	200	600	APHA 23rd Ed. 2340 C (EDTA Titration Method)
4	Total Alkalinity (As Caco3)	mg/l	upto 200 mg/l	96	200	600	APHA 23.d Ed. 2320 B (Titration Method)
5	Fluoride(as F)	mg/l	upto 1.4 mg/l	0.655	1	1.5	APHA 23'd Ed. 4500 F -C (Ion -Selective Electrode Method
6	Iron	mg/l	upto 3 mg/l	0.158	1	No relaxation	APHA 23'o Ed. 3500 Fe B; (Phenanthroline Method)
7	Nitrate(NO3-)	mg/l	0 to 45 mg/l	5.16	45	No relaxation	APHA 23'd Ed. 4500 NOs- D (Nitrate Electrode Method)
8	Total disolved solid(TDS)	mg/l	>35000 mg/l	4875	500	2000	Calculation Method
9	Residual Chlorine	mg/l	upto 0.42 mg/l	Not detected	0.2	1	Visual Comparison Methoo (O T Method)
10	Total Coliform	CFU/100ml	upto 400 CFU/100ml	>200.5	Shall not be detected in any 100ml sample		MFT Method

Test Conducted in the Govt Laboratory Bhubaneswar, Odisha

Conclusion:

By increasing number of RO membranes more salinity from the feed water can be removed. The membranes should be placed in series arrangement. By using filter efficient sediment filters, carbon filters, alkaline cartage etc, TDS filter we can obtain water which is much free from other impurities.

In India around 63 million people living in coastal areas. The coastal areas have lowest per capita water availability in country. But in such regions, the sea water is available perennially, so the sea water desalination is a better option in future.

Research and development of energy and cost-effective desalination technologies has been, and still is, an ongoing process as sources of fresh water continue to diminish at an alarming rate whereas population growth is increasing dramatically.

Based on the achieved data (shown in below table) it can be treated as a successful innovative design for a portable RO and could be recommended for further modification.

Performance Comparison

Sl. No	Description	Present market Available RO	Our Assembled Portable RO	Remark

1	Equipment	RO + UV + UF + Minerals with TDS Controller	1- IRONIL 2- 100 GPD- 24 VOLTAGE 140PSI Pump 3- S. VALVE 4- RO MEMBRANE 5- PRE CARBON-FILTER 6- UV LAMP 7- SEDIMENT 8- UF FILTER 9- POST CARBON FILTER 10- TDS CONTROLLER	More equipment increases the accuracy level
2	Initialization Price(Rs)	17000	12000	Cheaper
3	Out put Max	15L/ Hr	20.61 L/Hr	Higher
4	Purification	Normal Water	Sea Water & Normal water	Any source it could be used
5	Size	40L x 23W x 54H Cm3	42 × 33.5 × 19 Cm3	Both portable in size, can be handled properly
6	Electricity Consume	25 W to 40 Watt	24W-25W	Due to ERD elec. Consume low, with better output.
7	Possibility of Modification for low cost to High performance	No	Yes	Modification for better performance with low cost can be made
8	Durability	6000 Liter	Approx more than 8000 litres	Perform better, due to much filtration process

If technology continuous to produce new method & better solution to the issues that exit today, there would be a whole new water resources for more & more countries that are facing drought, completion for water and overpopulation. Now a days, sea water desalination is not widely used in India but as per seen the population, industrialization for next 30 years, desalination process is essential.

References:

1- Sadhwani, J. and Veza, J. Desalination and Energy Consumption in Canary Islands. Desalination, 221, 2008, pp. 143-150. https://doi.org/10.1016/j.desal.2007.02.051

2- Al-Karaghouli, A. and Kazmerski, L.L. Energy Consumption and Water Production Cost of Conventional and Renewable-Energy-Powered Desalination Processes. Renewable and Sustainable Energy Reviews, 2013, pp. 343-356. https://doi.org/10.1016/j.rser.2012.12.064

3- Buros, O.K., “The ABCs of Desalting”, International Desalination Association, 2000.

4- Krishna, H. J., Virgin islands Water Resources Conference, Proc. Editor, University of the Virgin Islands and U.S. Geological Survey, 1989.

5- U.S. Department of the Interior, Bureau of Reclamation, “Desalting Handbook for Planners”, 3rd Edition, 2003.

6- Global Water Intelligence. 2010. DeSalData.com. Oxford, England.

7- Mallevialle, J., P.E. Odendaal, and M.R. Wiesner. 1996. Water Treatment Membrane Processes. Denver, Colo.: AWWA and AWWA Research Foundation

8- Wad1e, N.M. 2001. Distillation plant development and cost update. Desalination 136:3–12.