The Pharma Innovation Journal 2023; SP-12(11): 465-468

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(11): 465-468

www.thepharmajournal.com
Received: 05-08-2023
Accepted: 10-09-2023

Design and development of cost-effective seawater filter

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Abstract
The different approaches across the globe for purification/filtration of sea water were used. These approaches are based on either thermal multi stage flash, reverse osmosis technology. But they are too expensive. In present study three approaches were used for purification of sea water. This includes media filtration, chemical treatment, and biological methods. The individual media were studied Sand, Coco peat, Bricks, Sawdust, Sugarcane Residue, Sawdust, Ceramics, Roof Tile, Clay Pot, Chalk, Coconut shell Charcoal, Rice husk Charcoal, and Zeolite etc. The best performing media and their sequence is decided. The particle density of sand (1.18-2 mm), bricks (>3.35 mm), rice husk, rice husk charcoal, cocopeat, sugarcane residues, sawdust was found that 2043.13, 1861.42, 445.25, 598.90, 318.79, 3333.33,375.73 kg/m³ respectively, the bulk density was found that 1371.57, 812.75, 106.11, 105.16, 286.21, 51.59, 421.61 kg/m³ respectively and maximum water holding capacity was found that 29, 39.3,354.5,403.2, 737.2,783.8% respectively. The sequence of sea water filter media was arranged on the basis of performance of media. The physiochemical analysis was carried out. The seawater was analyzed before and after filtration.
Seawater passed through the designed seawater filter and result found that the average % reduction in EC was 41% and average% reduction in pH was found 17.62%. The seawater was passed from the designed filter and the time was recorded to reach the water at outlet. It was observed that on an average the flow rate of seawater filter was 8.73 lit/hr. The total cost of developed sea water filter was found to be Rs. 1629.

Keywords: Filtration, media, seawater filter, physiochemical analysis

Introduction
Worldwide about 2.7 billion people experience water scarcity every year (Anonymous, 2012) [3]. Around 1.2 billion people, i.e., Almost one-fifth of the world's population, live in areas of physical scarcity, with another 500 million people approaching this situation (Sharma & Bharat 2009) [21]. Another 1.6 billion people, or almost one-fourth of the world's population, face economic water shortage (i.e., where countries lack the necessary infrastructure to take water from rivers and aquifers). Per capita water supply per year in India in 2011 was 1545 m³/Year and in 2025 it will be reduced 1341 m³/Year. (Anonymous, 2010) [2].
Desalination of seawater is the procedure of removal of salts from the seawater. Desalination of seawater could unlock the vast resources and provide sustainable source of water to water stressed area of the country. Desalination is implemented in more than 100 countries around the world, including the United Arab Emirates, Oman, Malta, Portugal, Greece, Italy, India, China, Spain, Cyprus, Saudi Arabia, Japan, and Australia. Worldwide, the desalination plant produces over 3.5 billion gallons per day i.e., 1, 32, 48, 941 m³ of potable water. Seawater desalination technology, reachable for decades, made remarkable strides in many arid areas of the world such as the Middle East, the Mediterranean, and the Caribbean. The potential of an RO desalination plant has increased from 1990 to 2020. There are currently around 21,123 total desalination plants installed worldwide spanning across 150 countries, with a total global cumulative desalination contracted capacity of around 126.57 million m³/d in 2019. Over 300 million people globally are now reportedly relying on water from desalination plants for diverse needs (Anonymous 2019) [4]. Multi-stage flash distillation (MSF) and reverse osmosis (RO) desalination processes account for about 80% of the world's desalination water production capacity. In the Middle East (particularly Arabian Gulf countries), MSF units are widely used and represent over 40% of the world's desalinated water production capacity (Amin *et al*. 2020) [1].
Other methods of desalination also used by various researchers like Electro dialysis (ED), Membrane Distillation (MD), Co – generation, Vapor compression evaporation (VC), Freezing, Ion Exchange, Nano filtration (NF), Solar energy-based methods.

Most of these plants rely on a multi-step process based on reverse osmosis, which requires expensive infrastructure and large amounts of electricity. Since the freshwater resources are very limited to serve the major population needs and salt water is unsuitable for many applications, desalination of salt water (seawater) emerges as a boon to most of the population to serve their needs. The standard desalination techniques like multistage flash distillation multi effect vapour compression and reverse osmosis are only reliable for large capacity ranges of 100- 50,000 m^3/Day of freshwater production. Large scale thermal desalination requires large amount of energy and special infrastructure that makes it fairly expensive.

Current physio -chemical desalination technology is not only energy intensive and expensive process but also gives severe environmental impact from brine and greenhouse gases emission. Therefore, it is neither environmentally – friendly nor feasible to countries with limited resources. Industrial scale desalination process also faces several challenges such as intake, pretreatment, pressure pumping, membrane cleaning and separation, brine and sludge deposition. A highly corrosive resistance pipe is another economic factor and requires specialized equipment’s.

Engineers are challenged to develop cheaper, cleaner, easy and more energy efficient way of desalinating seawater for drinking, crop irrigation and commercial use for regions of the world that suffer from water shortages. Water purification is the collective name for a group of processes that make water more suitable for drinking, medical use, industrial use and so on. Water purification processes is designed to remove or reduce existing water contaminants to the point where the water is fit for use. In water treatment filtration plays an important role in multi barrier approach for reduction of salinity. It is one of the core processes. The high performance in removal of particles achieved by granular filtration. Sand is one of the major filter media; alternative media have been developed and used in this study.

This project envisages the utilization of locally available material for filtration of seawater to remove salt content. Three individual approaches were used in this study media filtration, chemical treatment, biological methods. The best results obtained method was used for seawater filter design.

Material and Methods

The present study entitled, “Design and development of cost-effective technology for the purification of sea/ salty water into irrigable water.” was carried out at Laboratory and Instructional farm of Department of Irrigation and Drainage Engineering, College of Agricultural Engineering and Technology, Dapoli.

Water sampling and analysis

Seawater was collected from Murud Beach and Karde Beach, which are the nearest source for seawater. The raw seawater analyzed for EC and pH each time before and after conducting trials.

Media preparation

1) Media Selection 2) Media cleaning 3) Media Crushing 4) Grouping of media according to particle size 5) Filtered seawater analysis for EC and pH.

Media selection

The physical and chemical properties of all media such as particle density, bulk density, porocity, maximum water holding capacity, EC and pH were determined. The filtration test of individual media Sand, Coco peat, Bricks, Sawdust, Sugarcane Residue, Ceramics, Roof Tile, Clay Pot, Chalk, Coconut shell Charcoal, Rice husk Charcoal, and Zeolite for various thicknesses was performed. Depending upon the performance of the Sand (1.18-2 mm), bricks (>3.35 mm), rice husk, rice husk charcoal, cocopeat sugarcane residues, cocopeat media were selected for study.

Calculations

Calculation of weight of media required

1) Volume of container (V) = ∏ d2h/4

d = Diameter of container (m) = m

h = Layer of fitrer media (m) = m

Weight of filter media (Kg) = Density (Kg/m3) × volume (m3)

2) TDS (ppm) = Correction Factor × Electrical Conductivity (dS/m)

Value of correction factor = 640

3) Percentage Reduction in EC of sea water

$$\text{Percentage Reduction in EC} = \frac{\text{Initial EC} - \text{Final EC}}{\text{Initial pH}} \times 100$$

4) Percentage Reduction in pH of Sea water.

$$\text{Percentage Reduction in pH} = \frac{\text{Initial pH} - \text{Final pH}}{\text{Initial pH}} \times 100$$

Design and development of sea water filter: Construction of seawater filter

The filter was constructed in the following sequence:

The four 63 mm PVC pipes of 120 cm, one 110 mm PVC pipe of 120 cm were used. Polytubes of 16 mm size and total 4.5 m were used for filter design.

Table 1: Media Seqence and depth

Candles	Filter Media	Layer (cm)
First Candle	Sawdust	100
Second Candle	Sand	100
Third Candle	Bricks	60
	Coco peat	40
Fourth Candle	Sugarcane Reside	70
	Rice Husk Charcoal	20
	Rice Husk	10
Fifth candle	Storage Tank	120
Sixth Candle	Cartridge filter	-

1. Selection of suitable PVC pipes

The 4 PVC pipes of 63 mm diameter and 120 cm length were selected for filling the media. One PVC pipe of 120 cm length and 110 mm diameter were selected as storage tank. These pipes were marked 7 cm from each end and drilled the holes for grommet and take off insertion.

2. Length of pipe

The pipe length is decided according to media depth and considering additional 20% length.

3. Length of lateral

The lateral length from supply tank to first candle is decided on the basis of total head of all the candles.

4. Connection of two candles

Considering the EC and pH reduction % of media the candles are joined and flow of supply water from one candle to another candle is finalized.

5. Position of candles

After carrying vertical and horizontal trials for water passing. Horizontal position of candles finalized. Because it reduces the head loss and there is no more difference found in EC, pH reduction in vertical and horizontal position.

Schematic view of developed sea water filter and media taken is shown in fig.1

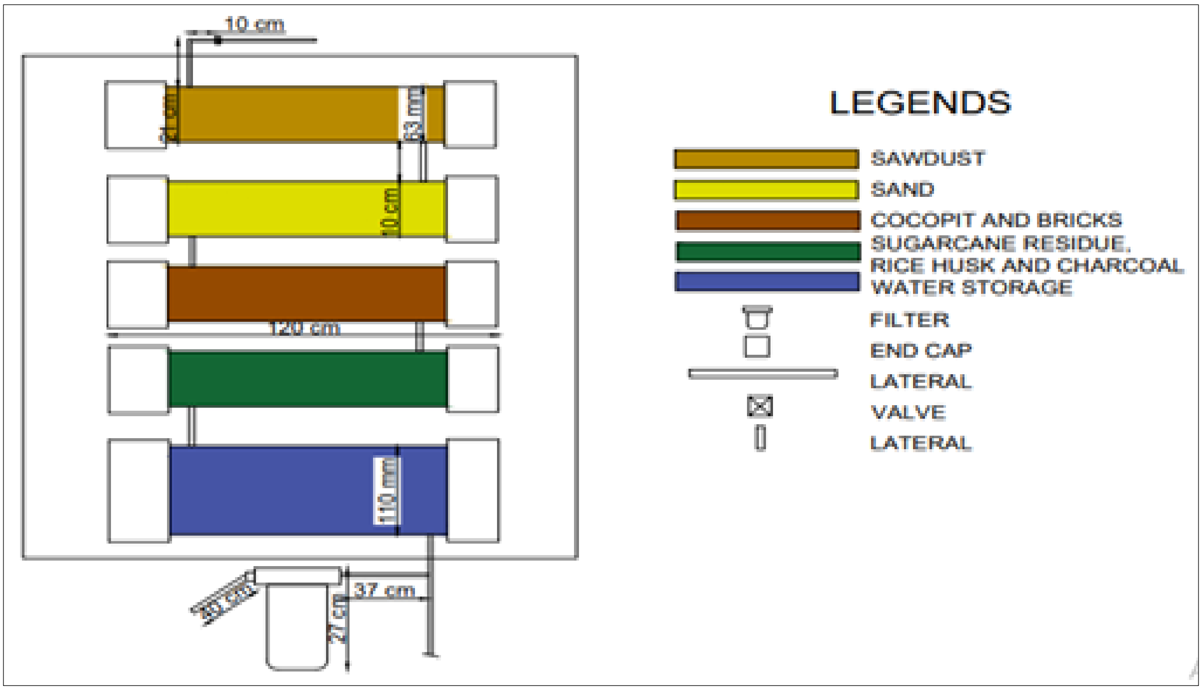

Fig 1: Schematic view of Seawater Filter

Working of Seawater filter

As shown in Fig.1.Filtering media is filled into four different candles of 63 mm diameter and 120 cm length. The 4 PVC pipes of 63 mm diameter and 120 cm length were selected for filling the media. One PVC pipe of 120 cm length and 110 mm diameter were selected as storage tank. These pipes were marked 7 cm from each end and drilled the holes for grommet and take off insertion. Selected depth of media i.e., 100 cm sawdust in first candle, 100 cm sand in second candle, 60 cm bricks plus 40 cm cocopeat in third candle and 70 cm sugarcane residue, 20 cm rice husk, 10 cm rice husk charcoal in fourth candle. Fifth candle is 110 mm storage tank. Below storage tank the cartridge filter kept vertically.

The supply tank is placed at 4 m height from inlet of first candle. Flow control valve, was used to control flow of sea water from supply tank. The seawater flows from supply tank to first candle by gravity. The flow from first candle to the second candle followed by third and fourth candle. Finally, water is collected into storage tank and supplied to inlet of cartridge filter. Outlet water is collected and its EC, pH and TDS measured. EC, pH and TDS of sweater before filtration and after filtration measured.

Result and discussion

The physical and chemical properties of selected media were shown in table No.2.

Table 2: Physical and chemical properties of selected media.

Properties Media	EC dS/m	pH	Bulk density Kg/m^3	Particle density Kg/m^3	Porosity %	Maximum water holding capacity%
Sand (1.18-2 mm)	0.310	7.06	1371.57	2043.13	32.87	29
Bricks (>3.35 mm)	0.278	6.03	812.75	1861.42	56.34	39.3
Cocopeat	0.594	6.5	286.21	318.79	10.22	737.2
Sugarcane residues	0.331	5.05	51.59	3333.33	98.45	783.8
Sawdust	0.450	5.81	421.61	375.73	-12.21	163.2
Rice Husk	0.586	6.33	106.11	445.25	76.17	354.5
Rice Husk charcoal	0.327	6.64	105.16	598.90	82.44	403.2

pH of seawater reduces from 8.1 to 6.7. Untrated seawater having EC of 53.16 dS/m which was reduced to 32.78 dS/m. Total dissolved solid of sea water sample decreased from 34022.4 ppm to 20979.2. The average % reduction in EC and pH was analysed before and after filtration.

Table 3: Flow rate of designed seawater filter

Sr. No	Time Taken (sec)	Time taken (hr)	Flow Rate (lit/hr)
1	11 litre	1 hr 16 minute	8.73

The cost analysis of the developed sea water filter was worked out as per the current rates of the material and media available in the market.

Summary

The best performing media i.e., Sawdust, sand, bricks, cocopeat, sugarcane residues, rice husk charcoal and rice husk were selected for final design. It was observed that the average pH reduction was 17.62%. The average % reduction of EC was 41%. The total cost of developed seawater filter was found to be Rs.1629. The flow rate of seawater filter is 8.74 lit/hr.

Conclusion

1. Developed technology is Eco – friendly.
2. Therefore, it is concluded from study media-based seawater filter is to reduce pH by 17.62% and EC by 41%. The treated water from developed sea water filter is to be used for further filtration line. The developed technology will reduce salt loads on further filtration line.

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