Portable Water Dispenser for Desalination Using Solar Energy

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One of the very important things to keep living things alive is 'water'. It is very important to use water wisely. Nowadays, it is very difficult to get consumable water easily because of the nature imbalance due to many mistakes of human beings. At present, there are many desalination methods, but they are either costly or not working efficiently. So, a portable desalination equipment, which is useful in both summer and winter seasons and does not need any electricity, has been devised. Solar energy is used to desalinate the water. The model is portable and can be used in oceans, polluted lakes and ponds to obtain unusable water and make it usable for human consumption.

Keywords: Water, Desalination, Conservation, Consumable water, Drinking water, Solar energy, Wind energy

Introduction

Desalination is a process that extracts minerals from saline water. It is a process in which salt is removed from water to make it consumable. Desalination focuses on cost-effective provision of freshwater for human use. Along with reused wastewater, desalination is one of the few rainfall independent water resources.

Desalination still proves to be a costly method for acquiring freshwater. When it comes to desalinating the saltwater, two of the main possibilities are thermal distillation and reverse osmosis. Thermal distillation involves boiling the water and collecting the resulting freshwater condensation, which is applied in the proposed model.

With growing demand for good water and all other water resources draining, the desalination division has been improving at an increased rate. The proposed portable water dispenser functions completely on solar power and utilizes no other source of energy. Solar power is made highly effective by the use of Fresnel lenses fitted, which concentrate the solar radiation on the water and make the water boil and thus evaporate

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at a faster rate. The vapor is then collected through a connected outing pipe and condensed in a storage.

Depending on solar radiation, the evaporation and condensation rate will vary. This model is particularly effective during sunny days. But considering the fact that the world is currently running short of energy resources, this model resourcefully supplies us with fresh potable water.

2. Literature Review

Damini *et al.* (2016) explained how energy and water are the main resources that need to be conserved in the first place all over the world. The use of energy rose rapidly due to the consumption of fossil fuels. Degrading these fossil fuels leads to pollutant augmentation in ground water which is used for drinking purpose. This can be achieved through renewable energy sources like solar, wind, hydro and biomass. The renewable energy is clean and green energy and the most promising alternative technology. The energy of solar is abundant all over the world, especially in India. The solar energy must be utilized in an efficient way so that the electric consumption can be gradually minimized. In this paper, Evacuated Tube Collector (ETC) type solar water heater is integrated with the desalination unit; subsequently, that leads to heating and purification of water with minimum heat losses in the respective hybrid system. The ETC type solar water heater stores water at high temperature, whereas it requires heated water for increased evaporation as well as yield. Using this integrated system ensures thermal efficiency, sustainability, social and economic development in the societies.

Amrit *et al.* (2016) investigated the performance of honeycomb-structured PVC used as packing material inside humidifier in Humidification-Dehumidification Desalination Plant. The affecting operational parameters like mass flow rate of water and air on the performance parameters of humidifier such as range, effectiveness, efficiency, water evaporation rate, heat and mass transfer rate are studied. The inlet hot water to the humidifier is kept around 35-60 °C. The result is analyzed at different flow effectiveness of humidifiers and is found to be maximum of 0.75.

Adel *et al.* (2015) evaluated the effect of solar irradiation on the permeate flow rate produced by vacuum membrane distillation installation. The used membrane module, in our case, is composed of two hollow fiber membrane wound in helically coiled shape. These fibers were placed in parabolic through concentrator absorber. The relatively hot solution (brine) in the absorber was used as a feed for our fibers. After the establishment of the model governing equations, a resolution was done with the finite element method. The sensitivity of the permeate flow rate to the solar irradiation and feed salt concentration were investigated.

Membrane Distillation (MD) is a thermal process based on highly porous and hydrophobic membrane. It can be classified into four different configurations according to the nature of the cold side of the membrane. These configurations are Direct Contact Membrane Distillation (DCMD), Air Gap Membrane Distillation (AGMD), Sweeping Gas Membrane Distillation (SGMD) and vacuum membrane distillation.

Maheswari *et al.* (2014) utilized the heat energy wasted in exhaust gas of an IC engine of low capacity for distillation desalination using a submerged horizontal tube straight pass evaporator and a condensing unit, without the aid of any external energy for pumping system. In this work, a horizontal tube straight pass evaporator was designed and fabricated, and experiments were conducted. The performance of the Submerged Horizontal Tube Evaporator (SHTE) was analyzed under various load conditions. The work proved that 1.8 L/h of saline water can be desalinated from the 5 HP Engine Exhaust gas without affecting the performance of the engine. By utilizing the heat energy, in addition to increase in overall efficiency, the thermal pollution is also reduced considerably.

Alwaer and Gryzagoridis (2014) presented the results that were obtained while monitoring the thermal performance of a solar water desalination system. The system consists of a solar collector equipped with evacuated heat pipes which supply heat from the sun to a circulating fluid in a collective manifold. A solar simulator consisting of an array of halogen floodlights was used to heat the evacuated heat pipes, which in turn transferred the heat to the circulating fluid feeding a heat exchanger in the system's geyser. The irradiance from the solar simulator that could be controlled by means of variable transformers controlling the voltage to the halogen lamps was measured over the surface of the evacuated heat pipe collector. The procedure allowed for exposure of the collector to the solar simulator for 7 h daily and thereafter normal cooling of the system. Preliminary results so far have shown that it is possible to use modern domestic water heating systems to produce steam which when condensed becomes potable water.

Hanen and Slimen (2014) investigated humidification process by air passing through seawater. The objective was to determine the humid air behavior through the humidification process. A test setup was designed and constructed to carry out and optimize this technique. The process consists of air bubbles passing through seawater situated on a simple basin. The experimental results obtained were used to put stress and correlate the influence of different operating conditions on the air behavior in the humidification process.

According to Mariem and Lotfi (2014), the power of desalination system by Renewable Energy Sources (RES) systems has been going through an upward trend, especially since the last decade. This paper concerns the modeling and the control of a desalination unit by reverse osmosis-based solar energy. The system includes photovoltaic panels, electrical converters, batteries and a desalination unit which presents the load. Dynamic modeling of various components of this isolated system is presented. To ensure the balance between consumption and production and to guarantee the proper operating of the unit, control loops are developed. The simulation results showed that the proposed hybrid power system equipped with control loops operates efficiently under load power demand variations.

3. Objectives

The study has the following objectives:

- Utilizing the inherently available solar energy to obtain consumable water from oceans and polluted lakes where the water is unfit to drink.
- Desalination of water using solar energy at the seashores which helps people to get consumable water. Also, mineralize the water using proper attachments.
- Getting freshwater to the needy.
- Developing an affordable portable water system.

4. Methodology

There are so many models available in the market which purify the salty or polluted water to potable water, but all available methods are either costly or need external power source. Hence, this is one critical factor that not everyone can afford such equipment. Also, there are some regions where the power source is not at all available, so the main objective of the paper is to provide potable water at low cost to all communities at all regions where sunlight is inherently available.

Some of the methods used to desalinate water are:

- Rainman Desalinator: It is a portable electric desalinator for cruising sailors with petrol powered system driven by Honda 50cc 4 stroke motor. They create three standard high output reverse osmosis options, two of which are packaged in a handy briefcase format.
- Desolenator (Small-Scale Solar Desalinator): By combining solar PV, solar, thermal, and a heat exchanger, desalinator has developed a portable water purifier and desalination device powered by renewable energy
- Portable Solar Powered Desalinator: This system is encased in a military grade, shock-resistant, noncorrosive case and powered by any 24 V DC source; also this system is so efficient that it can be run from a vehicle's electrical system, portable solar panels or portable solar power system.

- Solar Cucumber: It is a giant curved solar panel top. Inside the floating units, saltwater is collected and evaporated in an airtight vacuum circulated by solar power.

4.1 Concept Scoring and Screening

The purpose of concept screening (Table 1) is to sift through many new product ideas quickly and inexpensively early in the new product development process to identify the most promising concepts. The concept screening has been done based upon several criteria related to the models. The concept screen works simply by comparison against a benchmark base option (Rainman desalinator). A base option is then chosen, against which all other options will be compared. This is a very supportive process, as it is much easier to associate two choices than allocate a standalone score to a single option. The base option may be a competitor product, an industry benchmark or other standard. The team then examines each concept and compares it against each criterion to give it a relative score. The scoring scheme for this may simply be +1, 0 and –1 to show 'better, same, worse' or may have values to indicate how much better or worse it is. Thus the concept screening helps to decide the pros and cons of available models. After comparison with 4 models, the portable water dispenser proved to be a much better model.

Table 1: Concept Screening

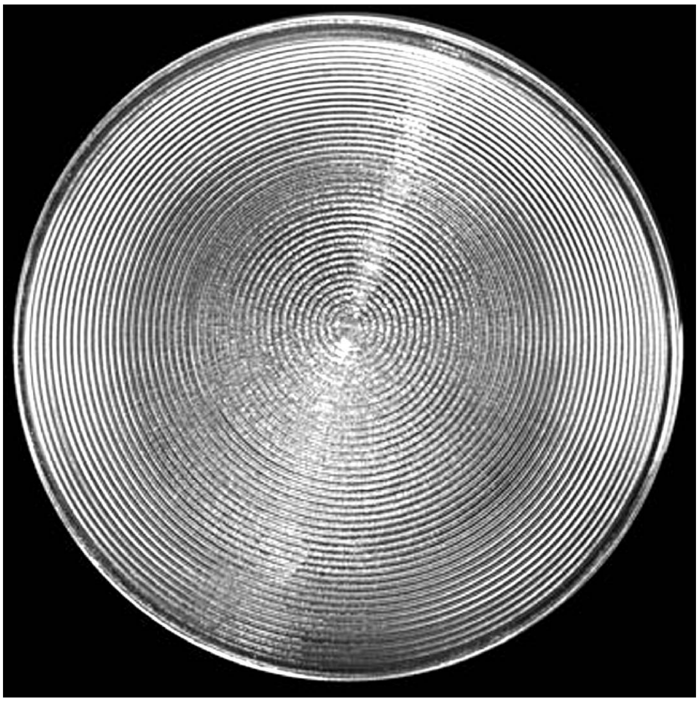
Criteria	Rainman Desalinator	Desolenator (Small-Scale Solar Desalinator)	Portable Solar Powered Desalinator	Solar Cucumber	Portable Water Dispenser
Universality	0	–	–	–	+
Ease of Use	0	+	0	–	+
Durability	0	0	0	+	+
Efficiency	0	–	+	0	+
Portability	0	+	+	–	+
Performance	0	–	–	–	0
Sum of +'s	0	2	2	1	5
Sum of 0's	2	2	2	1	1
Sum of –'s	0	3	2	3	1
Total Score	**0**	**–1**	**0**	**–2**	**6**

4.2 Design Details

The portable water dispenser is built using the following materials:

- Aluminum Hollow Frame: The hollow aluminum frame has been chosen to make the model lightweight.
- Fresnel Lens: The lens (Figure 1) is used to concentrate the sunrays at a distance. The focal point of this Fresnel lens is 11.9 inches.
- Rectangular Glass Container: The glass container is used to enclose the heat and the pressure formed during heating. The frame has been enclosed to keep the temperature from decreasing and to keep the pressure inside. The volume of polluted water it can contain at a time is 2.5 L.
- Angular Hinges: The angular hinges have been fixed in the portable water dispenser to make sure that the side lenses can be moved at various angles depending on the sunlight.

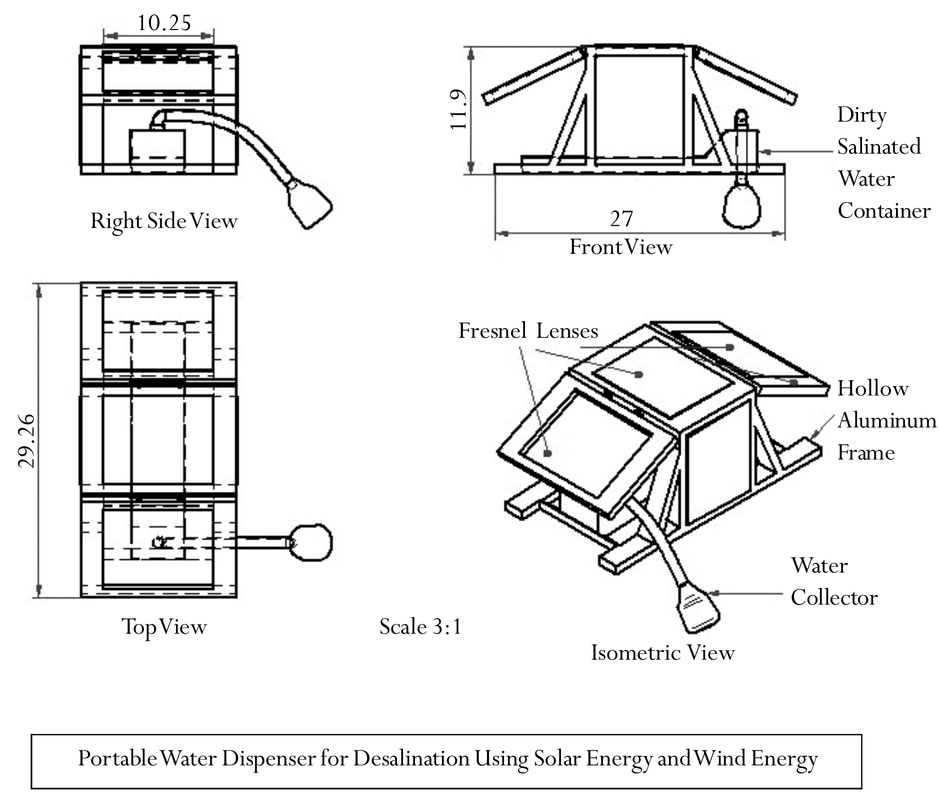
Figure 1: Fresnel Lens



4.3 Mechanism

The model (Figure 2) works upon the simple physical principle of evaporation and condensation. The undrinkable water in the enclosed glass container gets heated and then evaporated by the heat produced from the Fresnel lens which concentrates the sunrays. After half an hour, the water starts to get evaporated and water vapor is formed in the enclosed glass frame. The formation of water vapor is condensed and collected in water collector. The water collected is clean drinkable water.

Figure 2: 2D Drawing Details of Model



5. Results and Discussion

Portable water desalination is a great way to have drinking water in any outdoor emergency situation. The main objective is to provide clean drinkable water at less cost without using any external power source. Thus, this model (Figures 3 and 4) is successful in giving the necessary amount of water for survival.

- The input volume of undrinkable water in the model was 1.5 L and this level was maintained throughout.

Figure 3: Actual Focal Points of Fresnel Lens

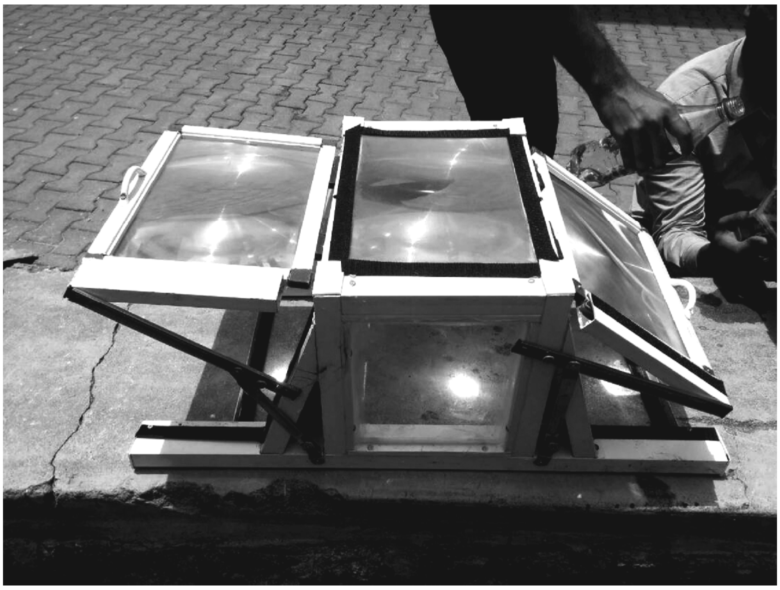


Figure 4: Actual Setup Arranged at 12 Noon

- The results obtained for the same amount of water are:
  - For 1 L input of salty water, the output obtained was around 700-800 mL of potable water in just more than an hour on a sunny day. It was also observed that the rate of evaporation and condensation was high during 11 a.m. to 2 p.m. This is the time when the rate of sunlight is very high, and all the three Fresnel lens are being put in use.
  - The portable water dispenser can discharge up to 4-5 L of pure water in a day.
  - The amount of freshwater obtained will vary depending upon the weather conditions and the level of salinity in the water.
  - Also, by rough cost estimation, this model is inexpensive and more effective, and requires low maintenance.

5.1 Cost Analysis

By comparing the cost of the portable water dispenser, i.e., the proposed model and the other water sources for one year, we got the following observations and results.

Suppose the model works only for 3 h a day considering worst sunlight condition. In that case, for even 1 h of heating, 600 mL of potable water will be obtained, and thus in 3 h, 1.8 L (approx. 2 L) of potable water will get collected. Even in the worst case, if taken only 25 days with optimum sunlight for the model to work in a month, the model will produce 50 L of potable water per month. And based on the results, it can be assured that for 1 year (excluding 3 months of rainy season when sunlight is not available sufficiently), the portable model will at least produce 400 L of freshwater even in the worst conditions. So, now considering the same for the mineral water bottle, i.e., 2 L of the same will cost around ₹30, and thus for 400 L, it will cost around ₹6,000. Now during the maximum working capacity of the portable water dispenser, it will give 6 L of water in a day and the costing will be recovered within a year. Thus, it can be concluded that the model is very cost-efficient and effective considering its high durability and low maintenance. From a broader approach, if we compare both types of water resource for 5 years, the cost of the mineral water will be around ₹30,000, i.e., around 4 times more than the portable water dispenser.

Conclusion

- In this paper, a systematic approach for the design, fabrication and testing of portable desalination equipment is presented.
- The main objective is to achieve clean drinkable water from dirt or salinized water, hence this desalination model made it possible using simple principle by condensation of steam to drinkable water.

- The clean drinkable water can be obtained around 70-80% from supplied dirt or salinized water without using any electricity.
- Hence analyzing the function versus cost with the presently available equipment in market, the portable desalination equipment is more efficient and less in cost.

Future Scope

- The plant can be setup near oceans to continuously generate drinking water. We can increase the desalination process faster with the help of larger Fresnel lens.
- Some attachments can also be used to add useful minerals before dispensing pure drinking water.
- It can also be used for high capacity purification by assembling number of portable water dispenser units.
- When the plant is big, the moist absorber can also be put into place to absorb as much water as it can. Although, the moisture absorber will not be very efficient compared to current desalination plant, but we need to take use of the available resources.
- This portable unit can also be used in life boats to obtain drinking water in case of emergencies.
- Also, the floating arrangement at shores of lakes and oceans will help to provide the drinking water for visitors.

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