Solar Desalinator

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Abstract - *The project aims to supply fresh drinkable water by using solar energy which is abundantly available. It focuses on effective use of solar thermal energy by using CSP (Concentrated Solar Power) technology through parabolic mirrors that will concentrate solar energy on the water container. A parabolic dish will enable to raise the temperature of water to leading to evaporation of water and deactivation or killing of micro-organisms.*

Key Words: Parabolic Mirror, Concentrated Solar Power, Carbon filtration, Solar Insolation, Floor Area.

1. INTRODUCTION

Water makes up about 71% of the Earth's surface. In this, 97.5% is salt water from its oceans and only 2.5% is fresh water. Of that 2.5%, approximately 69% is frozen in glaciers and ice caps, leaving less than 30% in fresh groundwater (swamps account for another 1 %)[1]. The saline water is unfit for purposes like industrial processes, irrigation, drinking and many other domestic purposes.

Desalination (also called "desalinization" and "desalting") is the process of removing dissolved salts from water, thus producing fresh water from seawater or brackish water. Involvement of 'Solar' in the project involves use of the equipment that will help harness the solar thermal energy. Solar desalination includes two aspects; first aspect is sediment removal using carbon filter and then removal of dissolved salts and pathogen in the container due to heat generated by parabolic dish. Initial filtration is carried by a carbon filter. Carbon filtration is a method of filtering that uses a bed of activated carbon to remove contaminants and impurities using chemical adsorption. Carbon filters are very effective at removing chlorine, benzene, radon, solvents trihalomethane compounds, volatile organic chemicals such as pesticides and herbicides and hundreds of other man-made chemicals. In addition, filters remove bad tastes and odours from the water. After this initial filtration by carbon filter, water is then collected in a container.

The project focuses on effective utilization of solar energy by using CSP (Concentrated Solar Power) technology through Parabolic Dish or Parabolic Mirror. The Parabolic dish will be a complete mirror (not reflective sheets) and the sun rays will be focussed on the container in which the post-filtered (through carbon filters) water will be stored. The dish will enable to obtain higher temperatures (up to 100°C and more) to kill or deactivate all classes of pathogens including protozoan cysts that have shown resistance to chemical disinfection and viruses that are too small to be mechanically removed by microfiltration. As the water heats due to radiation from the sun, the increased temperature will kill or inactivate an important part of commonly waterborne pathogenic bacteria, viruses, helminths and protozoa at a temperature between 65°C and 75°C [2], thus making water drinkable.

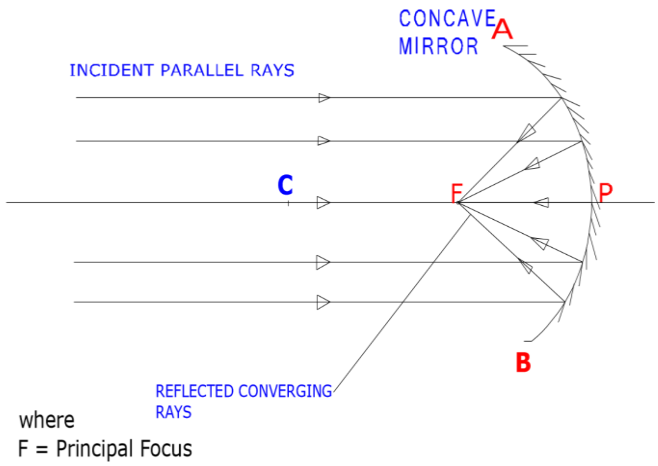

Fig -1: Working Principle of Parabolic Mirror

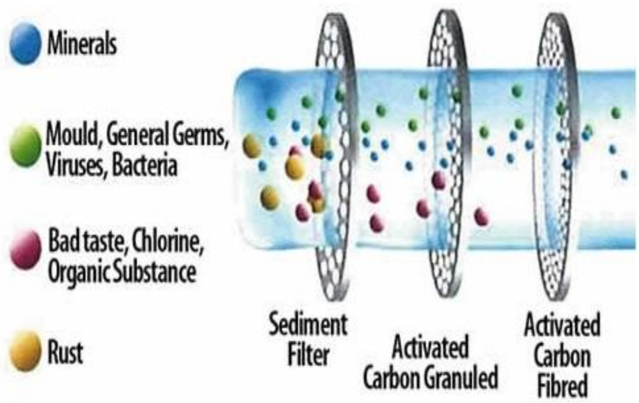

Fig -2: Carbon Filtration Process

2. DEVELOPMENT & DESIGN

The overview layout of the project along with the components, design calculations with its assumptions are shown below.

2.1 Components of the Solar Desalinator

1) **Carbon Filters:** It has three elements sediment filter, Pre carbon filter and post carbon filter. Collectively Carbon filter removes sediments of size 0.5-50 micrometers and also controls odour and taste of water.
2) **Parabolic Mirrors**: A parabolic dish is a type of solar thermal concentrator that is completely made of a mirror, curved as a parabola. The energy through the sunlight falls on the mirror is focused on to where objects are positioned that are intended to be heated.
3) **Trolley**: Trolley is a component where other apparatuses will be placed. The trolley will have a reservoir at the top, followed by the filters on the next level, the container and the water collector on the next level and salt bed at the bottom.
4) **Copper Container**: The copper container was bought out, which can hold a maximum 560 ml of water. A hole was drilled on the top which serves as an outlet for steam generated and another hole was drilled on the side which helps as an inlet for water. The pipes were attached to aid the movement of water and steam by the process of brazing. A detachable tight fitting was made so as to minimize leakage of water from the container.
5) **Volumetric Flask**: A volumetric flask which is made of glass, is used to collect fresh water by condensation of steam generated. The volume of this flask is 500 ml.

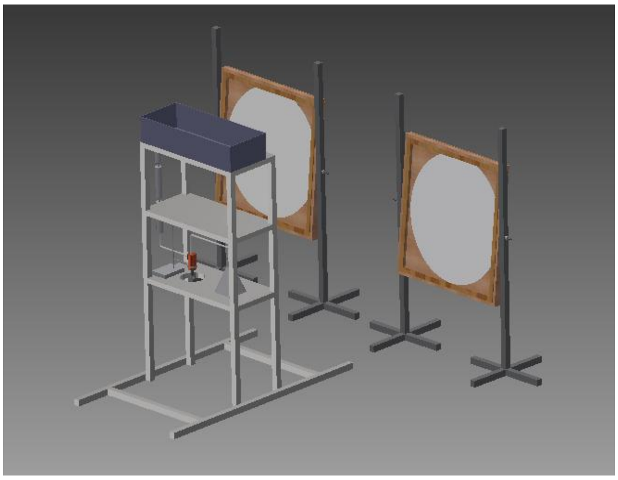

Fig -3: Layout of the Project

Table -1: Components Summary

Component	Dimensions		Quantity
Parabolic Mirrors	Diameter	0.99 m	2
	Depth	0.05 m	
Trolley	Height	2.00 m	1
	Width	1.25 m	
Copper Container	Internal Diameter	6.80 cm	1
	External Diameter	7.00 cm	
	Height	15 cm	
	Volume	560 ml	
Volumetric Flask	Volume	500 ml	1

2.2 Design Procedure

The volume was decided i.e. within the range 500-600 ml to make the process of desalination continuous. The standard values for internal diameter, external diameter and the height were readily available.

The values of thermal conductivity of copper [3], velocity of air [4] were obtained

Convective heat transfer coefficient of outside air, h_a is given by:

$$h_a = 10.45 - v + 10\sqrt{v}$$ [4]

where, v is the velocity of wind.

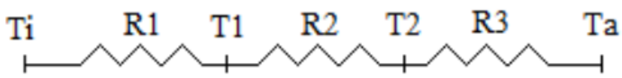

Fig -4: Thermal Resistance Circuit

Where,

R_1 = Convective Resistance due to water inside

R_2 = Conductive Resistance of Copper Container

R_3 = Convective Resistance of outside air

$$R_{total} = R_1 + R_2 + R_3$$

Heat losses are given by:

$$Q_{loss} = \frac{T_1 - Ta}{R_{total}}$$

Losses due to radiation are given by:

$$Q_{rad} = \sigma * A * \varepsilon (T_2^4 - T_a^4)$$

Heat required is given by

$$Q_{req.} = Q_{tank} + \text{Latent Heat of Vaporization}$$

Total Heat Required

$$Q_{total} = Q_{req} + Q_{loss} + Q_{rad}$$

The incident radiation was calculated. The value of Solar Insolation [4] which depends on the location and time was attained. The value obtained is in the form of number of mirrors (n).

$$Q_{available} = Q_{incident} \text{ x Reflectivity x n x } A_{total} \text{ x } \eta \text{ x C.R.}$$

Where, A_{total} is the area of the mirror

Concentration Ratio (C.R.) is given by:

$$C.R. = \frac{\text{Aperture area of dish}}{\text{Area of Receiving surface } (2\pi rh)}$$

Equating Q_{total} with $Q_{available}$ will give us the number of mirrors to be used.

The project involved usage of 2 mirrors.

The software *Parabolic Calculator 2.0* helped in simulating the various dimensions of the potential mirrors. The standard dimension as available were used and the values were thus calculated and obtained.

2.3 Fabrication of Components

1) **Mirror Casing**: The wooden casing was made to fit in the parabolic mirrors. The wood and plywood were procured from a timber shop. For the surface levelling of the wood obtained, Surface Planar Machine was used whereas the cutting wood and plywood was done by Rotor Cutting Machine. The casing is supported with plywood at the rear end of the casing.

2) **Trolley**: Due to smaller height of the rack, the height is raised to a total of 2 m, by a structure made up of Mild Steel with 5 x 5 cm cross section. The material was obtained from the workshop and was cut into desired lengths by Abrasive Cutting Machine. The pieces were fabricated in the workshop along with 4 Caster wheels, welded at the bottom to promote easy motion of the trolley.

Fig -5: Trolley

Fig -6: Final Setup of Solar Desalinator

3. TESTING & RESULTS

During the initial testing of the mirrors on 11th and 12th January between 10:00 am to 1:00 pm, it was observed that the temperature attained on the external surface of the copper container, was in the range of 150°C to 230°C

The water that will be collected and sent for checking of drinkability of the water under IS: 10500-2012 certification, to certified authority

Table -1: Results

Sr. No.	Test Parameter	Units	Results	Acceptable Limits
1.	Colour	Hazen	< 5.0	5 Max
2.	Odour	-	Agreeable	Agreeable
3.	pH	-	7.4	6.5 to 8.5
4.	Taste	-	NA	Agreeable
5.	Turbidity	NTU	0.326	1 Max
6.	Total Dissolved Salts (TDS)	mg/L	108	500
7.	E. Coli	MPN/100 ml	Absent	Should be Absent

4. CONCLUSION AND FUTURE WORK

The setup of Solar Desalinator was fabricated according to the design calculations within the prescribed time period. The water sample obtained post the process, will be sent to a certified authority to check the salinity and drinkability of the water. A majority of desalination set-ups make use of parabolic troughs or power towers on a large scale. On smaller scales and less investments, parabolic dish can serve as a viable option as it involves use of parabolic dish that can help in achieving higher temperatures.

Incorporation of Solar Tracker can greatly reduce the human effort in moving of the mirrors in obtaining a sharp concentration of the sun rays on the container.

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