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DESIGN AND OPTIMIZATION OF THE CONCENTRATOR

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ABSTRACT: The majority of desalination systems are energy demanding, requiring high-grade energy sources such as natural gas, electricity, oil, and fossil fuels. These processes result in carbon footprints, which contribute to the loss of the ozone layer as well as the development of health risks for humans. It also contributes to global warming, which is a hot subject these days and poses a danger to the sustainability of human life. When it comes to heat-to-heat conversion, the possibility of harvesting solar energy is the most efficient and effective. Thermal desalination is a low-temperature application procedure that requires just a one-time investment yet produces water for a long period of time (up to 10 to 15 years). Various sun thermal desalination technologies, including direct and indirect ones, have been described in this work. When water comes to medium and large-scale desalination systems, indirect methods are preferred, but direct methods, such as those utilising solar stills, are better suited for small and medium-sized systems. With a few simple modifications, the performance of low-cost solar stills may be significantly increased by including a variety of readily available materials. In order to supply the daily need for fresh drinking water, these low-cost stills may be readily and inexpensively constructed. They are sufficient for the needs of tiny homes and communities living on islands and in coastal areas that have limited financial resources. It may also be used for the distillation of brackish water for the benefit of the local inhabitants that live along river banks. A system like this is also suited for areas impacted by fluoride since it removes fluoride from the water. Using low-cost solar stills, arsenic, mercury, cadmium, coliform bacteria, viruses, and bacteria may be removed from water without sacrificing quality.

Keywords: *Solar energy, Desalination methods, Fresh water, Low-cost solar stills.*

INTRODUCTION

Salt water covers 97.5 percent of the earth's surface, and the world's enormous population lives in a state of scarcity of water owing to a restricted supply of fresh water, despite the fact that fresh water is readily available nearby. Desalination of salt water from the ocean, sea, rivers, and lakes is the most efficient method of supplying fresh water to a rising population [1]. Many desalination facilities are already in operation, but they are both expensive and energy consuming, making them uneconomical. In order to solve this deficiency, a study of current improvements in technology and system design had been conducted, which helped to lower the cost of the desalination system while simultaneously increasing its efficiency. A reversible thermodynamic process is the most energy efficient procedure for any desalination system, regardless of the processes or system being employed to achieve this goal [2].

In the typical thermal desalination process, hazardous and poisonous gases are released into the environment, harming the ecosystem. In turn, this leads to an increase in global temperature, which eventually results in global warming. Even a 1 degree Celsius increase in temperature causes the melting of the polar ice cap and rising sea level, which may cause islands, coastal regions, and river banks to be submerged. This has a significant impact on the tiny world population who live on islands and in coastal locations because this is the only supply of food, water, and income for them. They are also living in terror of global warming since this is the only source of food, water, and income for them. As a result, it is our obligation to reduce fear in them through the use of solar energy. Excess fluoride consumption (above 1.5 mg/l of water, as defined by the World Health Organization's guideline value for fluoride in water) results in dental effects and bone problems and consumption in large quantities for an extended period of time results in highly severe potential skeletal issues. This is a serious problem that can result in partial disability in a human person, and it affects many countries of the world because of the excessive quantity of fluoride present in the water in Asia.

In India, there are 18,000 distant villages where people are forced to live in the dark since there isn't even a single electric pole for the distribution of energy. Some isolated areas experience regular power outages lasting up to 16–20 hours each day, or there is no electric power supply at all. However, because these places are gifted with an abundance of solar energy, it is necessary to capture solar energy for heat and light applications to satisfy the daily demands of the local population. At the COP21 climate meeting in Paris, India announced the formation of a worldwide solar alliance involving 121 nations, with the alliance's headquarters situated at NISE Delhi. These nations, including India, are endowed with an abundance of solar heat, which makes them a desirable place to live. These countries are using solar energy to satisfy energy demand in a sustainable, economical, safe, and convenient manner while also reducing greenhouse gas emissions. It is absolutely necessary to employ clean and renewable energy for the benefit of the environment and the generation of energy for the future. The sun elemental provides us with life and energy, which is especially important in our search for newer, cleaner, renewable forms of energy. Almost all of India's areas receive more than enough solar radiation, and the country receives solar radiation for at least 300 days each year or more than 3000 hours of sunshine per year. India is endowed with a vast amount of solar energy. In terms of yearly average direct normal irradiance, it is 5.4188 kW hours per square metre per day and 1156.39 W/m2. The yearly average of direct normal irradiation varies from region to region within the nation, with some areas of Rajasthan, Karnataka, and Tamilnadu receiving the highest annual average of DNI. Some of the nations that receive the most solar energy include Australia, South Africa, Chile, Mexico, Algeria, Libya, Egypt, Namibia, Botswana, and Zimbabwe, just to name a few. According to the regional average, the South Asian area comes in second place after the Middle East and North Africa region (MENA), while the territories between the tropics of cancer and the tropics of Capricorn region get the greatest amount of solar energy isolation.

Solar energy may be captured effectively for use in solar-to-heat applications that are environmentally friendly and environmentally sustainable. In some cases, the thermal efficiency of solar-to-heat conversion can approach 100 percent or more. There is no true limit, but there is a limit when it comes to converting it to work, but there is no limit when it comes to turning heat to heat. Pure drinking water is a necessity for the survival and long-term viability of all living things. The growing need for water for drinking purposes can be satisfied by large-scale desalination of seawater, which removes fluoride, salt, and impurities from the water and distributes it to the trusting population [3]. Solar energy is a clean and sustainable source of energy that is abundantly accessible on the planet and may be used for desalination at a low cost using a flexible method. Solar energy can be gathered more effectively for use in solar-to-heat conversion systems. Because of the failure of the monsoon rains and the vast number of deep bore wells utilised for the extraction of drinking water, our planet is facing a crisis in terms of the availability of pure drinking water. Consequently, in some regions of the world, reducing the level of groundwater access and raising the depth of borewell leads to rises in fluoride content, which in turn causes the most serious orthopaedic problems to manifest themselves. As a result, it is preferable to use surface water from the sea, rivers, polluted water, and rain gathered water for desalination rather than groundwater. It is now an absolute imperative to ensure that everyone has access to safe drinking water in every region of the globe [4].

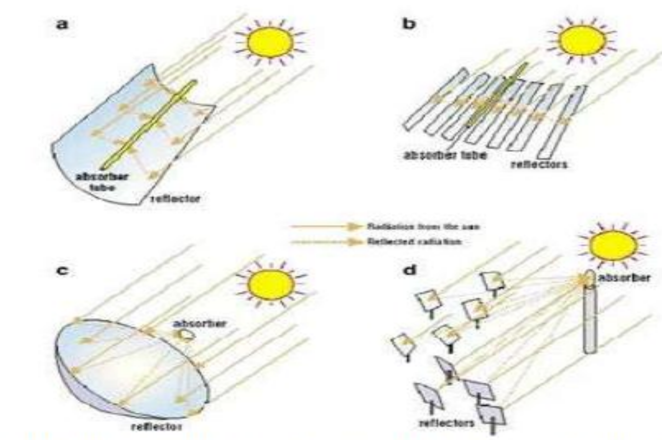
The demand for water is rising at a faster rate than the sustainable level, and desalination is the most effective technique of supplying the shortage in water [5]. "In 2015, 400 million people drank desalinated water, and it is predicted that by 2025, 14 percent of the world's population would be compelled to drink sea water," Dr. Md. Eaqub Ali stated in a statement. By 2030, global water consumption is expected to reach 16,900 billion m3 (Bnm3), with 2400 Bnm3 of available water shortage. Desalination processes are used to make up for this deficit in water supply. Desalination is a low-temperature application and a critical issue and thrust area related to cutting-edge research in solar thermal energy, as identified by the Ministry of New and Renewable Energy (MNRE) of the government of India. Desalination is a low-temperature application and a critical issue and thrust area related to cutting-edge research in solar thermal energy [6]. The Ministry of Natural Resources and Environment encourages scholars to do research and development in this field by giving national solar science fellowship programming. Reverse osmosis, vacuum distillation, or a combination of these processes are used in existing desalination facilities, however these methods are energy intensive (using a lot of electricity, gas etc). The solar thermal water desalination process may be divided into two basic categories: direct systems and indirect systems. Direct systems are the most common type of solar thermal water desalination system [7].

Selection of Solar Collector:

You need a high enough temperature to keep your absorber to evaporate a significant volume of water quickly. The thermal efficiency of non-concentrating solar collectors, such as a Flat Plate Collector, may reach 600C to 800C with 20% to 25% efficiency. A significant amount of solar energy is lost due to reflection on the pot and reflection outside the pot in panel or curved surface collectors. As a result, the concentrator's form is not quite parabolic. Concentrating collectors maximise the use of solar energy, and the absorber can provide the necessary heat quickly [8]. Using parabolic concentrators, it is possible to attain temperatures of up to 2500C with a 30% to 35% efficiency.

- Solar energy harvesting devices

In terms of solar power, there are two primary categories. PV systems convert solar energy directly into electricity, whereas solar thermal systems turn solar radiation into heat that may be used. Solar collectors are used in solar thermal systems to gather energy from the sun. As the name suggests, the solar collector works by absorbing heat from the sun and transforming it into usable electricity. The gathered heat energy may be put to use in a variety of ways, including the production of electricity, heating food, and desalination of water. Concentrated and non-concentrating solar concentrators are the two main types of solar collectors. Reflectors are used in concentrating solar collectors to direct the sun's rays toward an absorber. Non-concentrating solar collectors, on the other hand, employ flat surface absorbers to collect solar energy rather than concentrating it [9]. When compared with concentrating solar collectors, the efficiency of non-concentrating collectors is lower. Concentrator collectors include parabolic troughs, linear fresnels, dish collectors, and heliostats. Different forms of parabolic concentrators are seen in Figure 1.



(a) Parabolic trough (b) Linear Fresnel (c) Dish collectors (d) Heliostats

Figure 4.1 Types of Solar Collectors

Figure 1: To illustrate a variety of parabolic concentrator designs.

- **Parabolic trough:** It is a form of solar concentrator collector that utilises the mirror surface of the a linear parabola concentrator to guide solar energy toward an absorber tube that runs along a line connecting the foci of the parabolics. Troughs in the shape of the letter "u" are called parabolic. An optical receiver tube is placed along the focal line of the troughs to receive the concentrated sunlight.
- **Linear fresnel:** Parallel arrays of linear mirrors are used to focus light onto the stationary receiver at the top of a linear tower in the linear fresnel collector The Fresnel lens concept underpins the design. However, it isn't a parabolic trough like the one you might expect. The receiver is a linear tube positioned on a tower not very high just above collector, which is comparable to the heliostat system.
- **Dish collector:** The sun's rays converge on a receiver at the dish's focal point in a parabolic dish collector. In order to reflect all incident rays that are parallel to its axis, a point known as the focal point is used. The thermal receiver must be perfectly aligned with the dish construction to receive the beam. The receiver takes in the sun's rays and transforms them into heat. Mirror-like reflectors, as well as an absorber at the focal point, distinguish the parabolic dish collector from a typical satellite dish.
- **Heliostats field:** An array of heliostats known as field collectors surrounds a central receiver, known as the

power tower, in the solar thermal plant. Flat mirrors, called heliostats, follow the sun's path and reflect its rays onto a central receiver. Energy is converted to a fluid, such as water or molten salt, which is subsequently pumped to the intended purpose.

Scheffler's collectors and parabolic dish concentrators are two types of dish collectors. Figure 2 depicts Scheffler's method, which utilises a segment of a parabolic curve with the focus point located distant from the dish.

Using a parabolic dish system with automatic tracking, the sun's rays are concentrated at the focal point in front of the dish, where they may be received. Heat engines like Sterling engines can be used to produce electricity in some systems. In a small-power capacity range, parabolic dish systems may attain a receiver temperature of 10000C and achieve excellent efficiency in converting solar energy into electricity.

The heating pot in a solar concentrator is situated in a limited region that is reflected solar energy. The heating pot is referred to as an absorber, while the area where the pot is maintained is referred to as the focus region.

A platform with support for the cooker is used to hold the parabolic concentrator. The parabolic concentrator should constantly face the sun, as indicated in figure 4.3, and the sun's rays should be incident completely normal to the concentrator for optimum collection on the cooker. If there is no automated tracking system, the concentrator must be manually aligned to the sun every 10-15 minutes.

Because of the high initial and ongoing expenditures, Scheffler's or the trough method is not suitable for many applications. For a household, especially in rural locations, a parabolic dish concentrator with manual tracking appears to be the best option. It has thus been decided that the heating source for the desalination system should be a parabolic concentrator.

Energy requirement:

The system is being built to meet the daily water needs of a rural household. The volume of water needed and the amount of heat energy needed to evaporate that amount of water are critical considerations.

Review and analysis have shown that a person needs no less than 2 litres of water every day to survive (Courtesy- World Health Organization and Renal and Urology News). A household of four needs a system that can evaporate 8 litres of water. In addition, solar energy is accessible for about 24 hours a day, which means that At least 7 hours should be necessary for water to evaporate from this system. The amount of energy required to evaporate 8 kilogrammes of water in seven hours is determined.

$$Q = \frac{8 \times 4187 \times (100-27) + 8 \times 2257 \times (1000)}{7 \times 3600} = 815 \text{ W}$$

Water has a specific heat of 4187 J/kg K and a latent heat of 2257 kJ/kg at a temperature of 270C. A solar concentrator is used to collect the quantity of energy needed to heat the water. Reflected and focussed at the focal point, the solar radiation falling on the concentration region will be reflected. They travel thru the medium also and lose heat at the absorber as they move from the reflecting surface. In Watts, Qs is the amount of solar energy that falls on the ground as a result of the equation.

$$Q_s = I \times A_c \text{ W}$$

where,

I = the total solar radiations in W/m2, and

Ac = the area of the concentrator.

Further, net heat energy leaving the surface, QL is given by

$$Q_L = Q_s \times \rho \quad \text{W}$$

where,

ρ = The concentrator's reflectivity.

Net heat energy accessible at the focal point Qn is provided by when "X" amount of heat falls on the surface and only 30 to 35 percent of that heat is available at the focal point

$$Q_n = 0.3 \times Q_L \quad \text{W}$$

Alternatively, it may be expressed as follows:.

$$Q_n = (I \times A_c \times \rho) \times 0.3 \text{ W}$$

The solar radiation, the area of the concentrator, and the reflectivity of the material all influence the amount of thermal energy that can be harvested from the absorber. The strength of radiations varies from location to place and is dependent on the meteorological conditions. As a result, the reflectivity of the material and the absorber's size or area are used to guide concentrator design and optimization. Cost is crucial because the system will be employed in rural regions. Concentrators with a diameter ranging from 1.8 m to 10 m may be found on the market. The concentrator's power output should be 815 watts or more. The concentrator's diameter may be determined based on the intensity and reflectivity of the radiations.

Reflective Material Selection:

More solar energy is reflected by good reflecting material, and tracking time is reduced as a result. In order to provide a long life for solar concentrators, the material used must have high reflectivity and spectrum physical qualities Dust and contaminant buildup, reflective coating stability, environmental consequences, cleaning requirements and costs all need to be taken into account. Due to their high infrared reflectivity, metals that follow the Drude model are ideal for solar thermal applications.

A weighted hemispherical reflectance of roughly 86% and 92% for silver and aluminium, respectively, are the best drude metals for solar reflectance. As a result, the collector's high solar reflectance must be maintained during the collector's lifespan, which is around 20 to 30 years. Glass mirrors are the standard reflector material for solar, thermal, and electric purposes. Specular reflectance, longevity, and field durability are all advantages of using glass mirrors. Glass has a number of drawbacks, such as its weight, fragility, and cost. Polymer mirrors are more flexible, lighter, and less costly than glass mirrors, but they are also less durable and have a shorter lifespan.

The most common non-ferrous metal is aluminium. It is inexpensive, has a high reflectivity, and can be moulded. It is necessary to coat aluminium in order to preserve its optical integrity. Low-cost anodized aluminium reflectors are an option for this project's reflector needs. At current market pricing, aluminium-coated optical mirrors cost between Rs. 2475 and Rs. 5380 per square metre and cannot be installed on the proposed frame because of their weight and poor malleability (Ouannene, 2009). The system was created with the home user in mind. In order for reflective material to be ideal, it must be inexpensive, easy to maintain, and long-lasting. Reflective materials that can be employed in solar applications have been thoroughly researched. Experimentation with four anodized aluminium materials with qualities that fit the bill has begun.

Reflectivity testing

Reflectivity testing was conducted with the goal of finding a material that provides a good balance between cost and reflectivity. Among the anodized aluminium materials A, B, C, and D, the tensile strength ranged from 160 to 200 MPa and the yield strength ranging from 140 to 160 MPa. Reflective materials are shown in detail in Table 1.

Aluminium alloys of various grades were purchased from a German manufacturer of Material A. This sample cost Rs.1720/- per square metre. An aluminium goods producer in the United States sent samples B and C. This material was priced at Rs.2260/- per square metre. One of India's major integrated primary producers of aluminium, Sample C, was sourced from this business. This sample cost Rs.1830/-per square metre. It was a simple aluminium sheet acquired from an Indian producer of aluminium sheets that was used for this experiment. This sample cost Rs.1210/- per square metre.

Company/Supplier	Product	Alloy Al (%)	Hardness	Tensile Strength (MPa)	Symbols
Alanod-westlake(Germany)	MIRO 27	99.85	Hard	160 - 200	A
Alcoa aluminium (USA)	5XXX	93	Hard	160 - 200	B
Hindalco aluminium(India)	Hammered tone	99.85	Hard	140	C
Local Supplier (India)	Aluminium sheets	-	-	-	D

Table 1: Details of Reflective Materials

Reflectivity tests were performed on these four materials at the university level. Use of JASCO UV-Vis-NIR in the % reflectivity mode was used in the range of 400 to 2000 nanometers. To remove any surface deposits, the samples were carefully washed with soap and water. Chemical solvents were not utilised, and precautions were made to avoid scratching the surface. Figure 2 shows the testing findings.

Heating may be done with infrared photons with a wavelength of 750 nm to 1000 nm. Material B showed the greatest reflectivity of the four materials in this wavelength range, reaching up to 90%. Because this material was priced at Rs.2260/- per square metre, it was more expensive than other options (Rs.1500/- per square metre). Sample A, on the other hand, had a reflectivity of 88% and cost Rs. 1722/- per square metre.

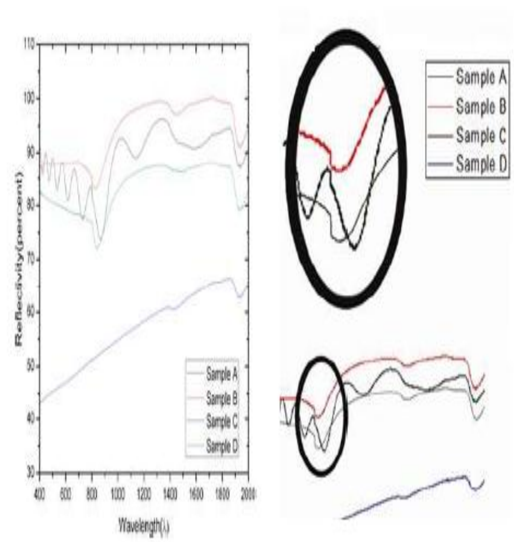


Figure 2: Testing for Reflectivity in a Graph

Listed in Table 4.4 are the costs and reflectivities of the sample materials. Sample A (MIRO 27) was chosen as a good reflector material because of its low cost and high reflectivity. Although its reflectivity (88 percent) was slightly lower than the best (91 percent), the cost was fairly reasonable.

Anodized Sample	Reflectivity (%)	Cost (Rs/m^2)	Area of concentrator (m^2)	Total Cost (Rs.)
MIRO 27(Sample A)	88	1720	4.11	7100
5XXX Plate (Sample B)	91	2260	3.97	9000
Hindalco (Sample C)	82	1830	4.42	8000
Basic Sheet (Sample D)	78	1210	4.63	5610

Table 2: Comparison of Total Cost and Reflectivity

A concentrator's minimum aperture area may be calculated when a material has been selected for use in its construction.

815 = 750 × Ac ×0.3 × 0.88

Ac = 4.11 m2

The concentrator's diameter was measured and recorded.

$$d = \sqrt{\frac{4}{\pi}}4.11=2.30 \text{ m}$$

As a result, a 2.3-meter-diameter concentrator was chosen to evaporate 8 kilogrammes of water. Eight litres of water can evaporate in less than 7 hours, or more than 8 litres of water can evaporate in the same amount of time as the radiation value increases.

Parabolic Concentrator and Absorber Thermal Performance Test:

The overall heat loss factor F'UL and the optical efficiency factor $F'\eta_o$ were evaluated by conducting heating and cooling experiments. A cooking pot with a predetermined amount of water was placed at the focal point of the parabolic concentrator in the first step (heating test). As a result of this, the parabolic concentrator was set up in such a way that a brilliant point of concentrated solar radiation fell directly on top of the cooking pot's bottom. Measurements were taken every 10 minutes or so until the water level reaches a temperature of 900C to 950C, at which point they were recorded.

As soon as the water temperature hit 950C, the concentrator was covered by an adequate-sized umbrella to assure absolute blocking of sun radiations. Five-minute intervals were used to obtain temperature readings until the water's temperature approached that of the surrounding air. It was computed at each time interval, and a plot with the this value on Y-axis and the time on X-axis was drawn for each set of data points. [ln (tw-ta)]. A least-squares linear regression equation was used to fit various locations on display. Cooling time constant is (-1/$\tau 0$), and the slope of the line is (-1/$\tau 0$). Substituting for well-known values of 0, the cooking pot's area (Aabs), and the pot's total thermal capacity (m cp), we were able to get the values of F'UL and $F'\eta_o$. Various amounts of water were tested on different days to see if there was a difference in the values of F'UL and $F'\eta_o$. Instantaneous efficiency was figured out and recorded.

CONCLUSION:

The heating capacity of the parabolic concentrator has been determined to be adequate. In the range of 2600C, the focused region achieved its maximum temperature. The average quantity of heat produced by the concentrator was 900 W while the sun was shining. Optical efficiency calculations revealed a 35 percent concentrator efficiency. The system's efficiency can be improved by carefully selecting the absorber, which needs less tracking.

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