CONCENTRATED SOLAR RADIATION AS A METHOD OF DESALINATION

Aryan Mittal[1], Dhruv Khera[2], Dr. J.P. Kesari[3]

[1] *Student, Dept. of Information Technology, Delhi Technological University, New Delhi, India*
[2] *Student, Dept. of Information Technology, Delhi Technological University, New Delhi, India*
[3] *Associate Professor, Dept. of Mechanical Engineering, Delhi Technological University, New Delhi, India*

---***---

Abstract - In the era of climate change and depleting freshwater resources, the water from oceans and sea provides a viable source. But the salinity of seawater, which makes the resource unfit for direct consumption. In order to separate salt from seawater we go through the process of Desalination.
Desalination is the process of removing salt and minerals from seawater, to the point where the water is fit for human consumption and irrigation. This can be done by either reverse osmosis method or thermal method. Using thermal decomposition, the saline water is heated till it evaporates and henceforth the evaporated water is let to condensate in a different chamber. The salt/minerals(brine) can be separated from water, thus it is made fit for consumption.

***Key Words*:** optics, photonics, light, lasers, templates, journals

1.INTRODUCTION *(Size 11, Times New roman)*

All Middle East and North African (MENA) countries have an outstanding potential for solar energy. Making use of concentrating solar thermal power (CSP) plants to power seawater desalination either by electricity or in combined generation with process steam to solve the water scarcity problem in MENA is a rather obvious approach. The AQUA-CSP project which was sponsored by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) quantifies the potential of this technology in MENA and the socio-economic and environmental impacts implied by a large-scale dissemination in order to provide a well-founded database for decision and policy makers in the water sector and to facilitate the inclusion of this approach in national development plans. Some preliminary results of this project are presented here. Advancement of population and economy, increasing urbanization and industrialization, and the rather limited natural resources of potable water in MENA are leading to severe deficits of freshwater in many parts of MENA. Present day infrastructure for water distribution, enhanced efficiency of use and better water management are to be established as soon as possible. How- ever, even the change to best practice would leave ample deficits, which are poorly covered by over-exploiting groundwater resources. Large use of desalted seawater is therefore unavoidable in order to maintain a reasonable level of water supply. The desalination of seawater based on fossil fuels is neither sustainable nor economically viable in a long-term perspective, as fuels are increasingly becoming expensive and scarce. Concentrating solar power (CSP) offers a sustainable substitute to fossil fuels for large scale seawater desalination. The problem can be solved by CSP, but market introduction must start immediately in order to achieve the necessary freshwater production rates in time.

Classical CSP technologies were used by ancient Greek and Chinese as they used mirrors or glasses to make fire. In the 20th century amid the oil crises in the 1970s, the interest in solar energy began to increase to outstand fossil fuel resources. There are four main technologies for yielding the concentrated solar power: parabolic trough, linear Fresnel reflector (IFR), central receiver, and parabolic dish. All types of CSP works with the same principle (reflector and receiver) which depends upon the solar radiation.

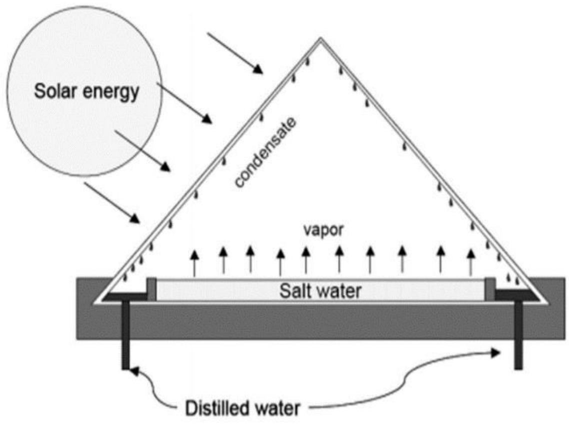
2. METHODOLOGY

CONCENTRATED RADIATION FOR THERMAL DESALINATION

Introduction to solar energy

The sun was adored by many ancient civilizations as a powerful God and solar energy is the ancient energy source used by humans. The first known practical use was in drying for food preservation. Scientists have long looked at solar radiation as a source of energy, by trying to convert it into a useful form for direct utilization. Archimedes, the Greek mathematician and philosopher (287–212 BC), used the sun's reflected
heat to burn the Roman fleet in the Bay of Syracuse. In the eighteenth century, the French naturalist Boufon experimented with different solar energy devices which he called 'hot mirrors burning at long distance'. Most forms of energy are actually solar in origin. Oil, coal, natural gas and wood were originally made by photosynthetic processes. Even wind and tide energy also have a solar origin, as they are being caused by differences in temperature in different regions of the earth. The enormous advantages of solar energy, compared with other forms of energy, are that it is clean, sustainable and can be used without causing any environmental pollution.
Solar energy is used to heat and cool buildings, to heat water for domestic and industrial uses, to heat swimming pools, to power refrigerators, to run engines and pumps, to desalinate water for drinking purposes, to produce electricity, in chemistry applications and for many more functions. The determination of which source of energy to use should be made on the basis of economic, environmental and safety considerations. Because of its desirable environmental and safety advantages, it is widely believed that, where possible, solar energy should be utilized instead of energy developed from fossil fuels, even when the costs involved are slightly higher. This section highlights the desalination of saline water by using solar energy.

WORKING:
In this system the heat gaining and desalination processes take place naturally in the same device. The basin solar still represents its simplest application, the still working as a trap for solar radiation that passes through
a transparent cover.
Solar still: Solar still distillation serves as a natural hydrologic cycle on a small scale. The basic design of a solar still, which is similar to a greenhouse, is shown in the figure. Solar energy enters the device through
a sloping transparent glass or plastic panel and heats a basin of salt water. The basin is frequently black to absorb energy more efficiently. The heated water is evaporated and then made to condense on the cooler glass panels. The condensed droplets run down the panels and are accumulated for being used as fresh water. Experience proves that ~1 m2 of ground will produce 3–4 l/day of freshwater. Because of low production, it is important to diminish capital costs by using very inexpensive construction materials. Efforts are being made by various researchers to raise the efficiency of solar stills by changing its design, by using additional effects such as multi-stage evacuated stills and by adding wicking material, etc., these modifications have raised the production per unit area. In the simple solar still, the latent heat of condensation is dissipated to the environment. However, the latent heat of condensation can be utilized to preheat the feed water, and this obviously leads to an improvement in the still efficiency.



ADVANTAGES OF SOLAR STILL METHOD:
Solar still technology requires a large area for solar collection so it is not feasible for large-scale production, especially near a city where land is scarce and expensive. The approximate installation costs tend to be considerably higher than those for other systems. They are also susceptible to damage by weather. Labor costs are likely to be high for routine maintenance to prevent scale formation and to repair vapor leaks and damage to the still's glass. However, they can be economically viable for small-scale production for households and many small communities, especially where solar energy and low-cost labor is abundant.at

3. TYPES OF DESALINATION
Desalination is a man-made process that converts saline water (usually sea water) to fresh water. Distillation and reverse osmosis are the most popular desalination methods. There are some choices. Each has its own set of benefits and drawbacks, yet they are all beneficial. Membrane-based (e.g., reverse osmosis) and thermal-based (e.g., multistage flash distillation) approaches can be distinguished. Distillation, or boiling and
re-condensation of seawater to remove salt and contaminants, is the classic method of desalination.

Evaporation
The salt water is left to evaporate under natural conditions, and henceforth the steam is directed to a condensation chamber. This separates the water from brine, where freshwater is collected in the condensation chamber and brine in the collection chamber. Evaporation is a very slow process, hence this procedure for desalination is highly inefficient. But because evaporation is a natural and reversible process, hence it is highly cost effective.

Reverse osmosis
In terms of installed capacity and annual growth, reverse osmosis is the most used desalination method (RO). Semipermeable membranes and applied pressure (on the membrane feed side) are used in RO membrane processes to preferentially boost water penetration through the membrane while rejecting salts. Thermal desalination technologies often consume more energy than reverse osmosis plant membrane systems.
The cost of energy in desalination operations varies greatly depending on the salinity of the water, the size of the plant, and the kind of treatment. The cost of desalinating salt water is still unknown. The reverse osmosis process is not maintenance free and various factors interfere with its efficiency.

Thermal Distillation
The thermal desalination technique uses energy to evaporate water and subsequently condense it again. When there is waste heat or sufficient electricity accessible, as is usually the case with refineries and power plants, thermal desalination is an efficient and viable solution. The two major types of thermal distillation processes are;
-MED is known for its high thermal efficiency and dependability.
It is based on a multi-effect process in which a spray of seawater is evaporated and then condensed repeatedly. This extremely efficient technique increases the amount of pure water that can be generated with a given amount of energy, lowering the cost significantly.
-MVC is a cost-effective, reliable desalination solution for refineries, process industries, power plants, and remote development sites — ideal when electricity is the only source of some power. The MVC has been used as an inexpensive, low-maintenance workhorse desalination solution by dozens of businesses with a vital requirement for stable and reliable supply of process and boiler feed water.

3. CURRENT GLOBAL SCENARIO
There are over 16,000 operating desalination plants in 177 countries, generating an estimated 95 million m3/day of freshwater. Desalination currently accounts for around 1% of the world's drinking water. Desalination is notably common in Middle Eastern and North African countries like Saudi Arabia, the United Arab Emirates, and Kuwait. Kuwait

generates more water through desalination than any other country in the world. In small island developing governments, desalination is also a significant source of water.

Around 21,000 desalination facilities are currently in use around the world. The UAE, Saudi Arabia, and Israel are the three countries with the most. With a capacity of 1,401,000 cubic meters per day, the world's largest desalination facility is in Saudi Arabia.

Desalination is currently more expensive than most other water sources, and it only covers a small portion of total human use. In arid areas, it is usually only economically viable for high-valued uses. However, desalination for agricultural use is on the rise in densely populated areas like Singapore and California. The most widespread application is in Persian Gulf.

While acknowledging that costs are lowering and that the technique is typically favorable for rich areas near seas, a 2004 research concluded that "Desalinated water may be a solution for some water-stress zones, but not for poor, deep in the core of a continent, or at high elevation." Unfortunately, this includes some of the most water-stressed areas." and "Indeed, to acquire transport expenses equivalent to desalination prices, one must raise the water by 2000 meters or transport it across a distance of more than 1600 kilometers.

As a result, it may be more cost-effective to transfer fresh water from another location rather than desalinate it. Transport expenses could mirror desalination prices in cities far from the sea, such as New Delhi, or in high places, such as Mexico City. Desalinated water is especially expensive in areas like Riyadh and Harare, which are both far from the sea and high in elevation. Other places, such as Beijing, Bangkok, Zaragoza, Phoenix, and, of course, coastline cities like Tripoli, have substantially lower transportation costs." Water is pumped 320 kilometers inland to Riyadh after desalination in Jubail, Saudi Arabia. Desalination is becoming a more competitive option for coastal towns.

5. ADVANTAGES OF SOLAR RADIATION FOR THERMAL DESALINATION OVER TRADITIONAL METHOD

According to Masdar, an Abu Dhabi sustainability effort, desalination facilities emit a total of 76 million tonnes of CO_2 per year, with emissions expected to rise to about 218 million tonnes by 2040 if no action is done. However, the salty water that is pushed back into the sea poses a special threat to marine life, according to Leticia Reis de Carvalho, coordinator of the UN Environment Programmer’s Water Management Branch.

Desalination waste brine can limit marine creature growth, raise seawater temperature, and diminish dissolved oxygen levels, all of which impair aquatic life, according to Carvalho.

On the other hand, solar radiation desalination is highly renewable, cost effective and eco-friendly.

Solar energy desalination is a method by which the sun’s energy is used to desalinate brackish or seawater to produce healthy and water fit for drinking. There are two methods for using solar energy: straight by heating and evaporating the brackish or seawater in a solar still (this method is known as solar distillation) and indirectly by capturing solar energy using one of the techniques that transform solar radiation into thermal or electrical energy to drive a conventional desalination method (the indirect method is called solar-assisted or solar-driven desalination). Indirect thermal solar desalination methods are the multistage-flash thermal distillation method, the multiple-effect thermal distillation method, and the thermal vapour compression method. The last years two innovative solar driven methods of small -to medium size, found practical application although are still under development and optimization not yet totally commercialized: the humidification-dehumidification and the membrane distillation methods.

Electrical power generated from the sun’s energy is used to drive reverse osmosis, electrodialysis, or mechanical vapour compression desalination methods. Theoretically, solar energy can replace any other energy source, but from a practical standpoint this is not yet technically feasible, especially for large- capacity solar desalination plants. This is due to the spreading and very low concentration of solar radiation falling on the earth’s surface and variations in solar incident radiation. Solar energy depends on local insolation rates, which vary depending on location, the hour of the day, the day of the month, and the month of the year. These conditions result in an unsteady state diurnal operation. On the other hand, because solar radiation is very diluted, large surface areas are needed to capture the necessary amount of energy. Storage of heat or electricity could be a solution for smooth 24-h operation, but it adds to the capital cost, which in many cases is prohibited. Thus, solar desalination installations are of small- or medium-size capacity, ranging from a few to 100 m3/day, and in some cases up to 300 m3/day (26420–79260 gallons per day) for indirect methods. They can supply fresh water to remote, arid, or semiarid regions that have high intensity solar radiation.

Hence doing a comparative study of the two methods we can conclusively say that, Solar distillation systems are convenient for remote, arid, semiarid or remote regions, for poor small communities. Simple designs are preferred because they are cost-effective and easier to operate and maintain by unskilled local personnel. Low-cost, locally accessible materials can be used, taking into consideration the safety and lifetime of the installation. Although some solar distillation plants with capacities of 1–40 m3/day (in Greece, India, the Caribbean islands, and other places) were or some still are in operation, the interest currently has turned to solar-driven systems for medium capacities or to humidification-dehumidification and membrane distillation techniques of mall to medium capacities. Solar-driven desalination is a system suitable in regions having high solar radiation and large installation surface area but still have high cost capital and operational systems. As these systems combine together, different technologies must be carefully selected and coupled to achieve high efficiencies, simple operation, and easy maintenance. Most of the plants are pilot plants used to study and improve design, operation, and cost. They don't exceed about 0.1% of the capacity of desalination plants driven by conventional energy sources and require further study to improve technologies and lower cost.

6. ECONOMICS OF SOLAR DISTILLATION

The desalination systems can be operated by the use of conventional and renewable energy sources and the huge majority of desalination plants over the world are currently managed by fossil fuel instead of renewable energy due to technical and economic barriers. It has been concluded that the cost of water produced from desalination systems by the means of conventional sources of energy is much lower than those powered by renewable energy sources. Generally, water desalination prices have decreased over the recent years due to technical improvements and research advancements in technologies. In conventional systems, the price for seawater desalination ranges from 0.35 Euro/m3 to more than 2.7 Euro/m3, while for brackish water desalination, the cost is almost half. On using renewable energy sources, the cost is much higher, and in some cases can reach even 10.32 Euro/m3, due to the most expensive energy supply systems. However, this cost is balanced by the environmental benefits. The table summarizes the cost of fresh water when the desalination system is powered by conventional and renewable energy sources.

Type of feed water	Type of energy	Water cost (Euro/m3)
Brackish water	Conventional fuel	0.21–1.06
	Photovoltaic cells	4.5–10.32
	Geothermal	2
Sea water	Conventional fuel	0.35–2.70
	Wind energy	1.0–5.0
	Photovoltaic cells	3.14–9.0
	Solar collectors	3.5–8.0

7. CONCLUSIONS

The desalination of brackish water and seawater is proving to be a reliable source of fresh water and it contributes in tackling the world's water shortage problems. This report has reviewed a number of thermal and membrane water desalination processes developed during recent decades. The advantages and disadvantages, for each desalination technology, including economics have also been covered. The use of renewable energies for desalination becomes a justifiable and technically mature alternative to the emerging and stressing energy situation and a sustainable solution for water shortage. Due to the dramatic increase in fossil fuel prices and the harmful impacts of burning fossil fuels, such as environmental pollution and climate change, coupling desalination plants with clean environment-friendly energy resources is a severe issue.

The scarcity of drinking water limits the socio-economic development of many areas, where solar resources are in huge numbers. Hence, the use of solar energy for water desalination in countries like Africa and the Middle East region which have plenty of solar energy is a promising issue for meeting water demand and would surely contribute both towards solving water scarcity problems and reducing carbon dioxide emissions by means of an ECO- friendly process.

ACKNOWLEDGEMENT

In performing our major project, we had to take the help and guidance of respected people, who deserve our greatest gratitude. The completion of this assignment gives us much pleasure. We would like to show our gratitude to Dr. J.P. Kesari, Mentor for a major project. Guiding us through numerous consultations. We would also like to extend our deepest gratitude to all those who have directly and indirectly guided us.

In addition, We would like to thank the Department of Mechanical Engineering, Delhi Technological University for giving us the support while working on this topic.

REFERENCES

[1] https://academic.oup.com/ijlct/article/9/1/1/663897#11559930
[2] Book- Principle of desalination second edition (Part-B) by A.K.D Laird
[3] https://www.sciencedirect.com/science/article/pii/B012176480X003211
[4] United Nations Environment Programme http://www.unep.org/themes/freshwater.html (10 April 2008)
[5] Al-Kharabsheh S.. Theoretical and experimental analysis of water desalination system using low grade solar heat, 2003 University of Florida PhD dissertation
[6] Colombo D, De Gerloni M, Reali M. An energy-efficient submarine desalination plant, Desalination, 1999, vol. 122 (pg. 171-6)
[7] Google Scholar
[8] Crossref
[9] WHO/EU drinking water standards comparative table Water treatment & Air purification and other supporting information
[10] http://www.lenntech.com/WHO-EU-water-standards.html 26 October 2007
[11] Tiwari GN, Singh HN, Tripathi R. Present status of solar distillation, Solar Energy, 2003, vol. 75 (pg. 367-73)
[12] Google Scholar
[13] Crossref
[14] Buros OK., The ABCs of Desalting, 20002nd ednInternational Desalination Association Pge. 30 ASIN: B0006S2DHY
[15] Google Scholar
[16] Buros OK. , The ABCs of Desalting, 1999 International Desalination Association Pge. 31
[17] Google Scholar
[18] European Desalination Society and Center for Research and Technology Hellas (CERTH), Sani Resort, Halkidiki, Greece, April 22–25, 2007.
[19] https://www.sciencedirect.com/science/article/pii/S1876610214032871