A SHORT REVIEW ON SOLAR WATER DISTILLATION FOR GETTING FRESH WATER IN RURAL AREA

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Abstract

Water is very essential for human life as it is a god like thing. Due to high growth of population and industrial developments especially from the early 20th century, people living in rural areas and remote villages suffer with shortage of drinking water. People living in urban and rural areas depend on surface and ground water sources, where these sources are majorly polluted by industrial waste. The use of reverse osmosis technique and other conventional technique appears to be costlier technologies and requires a very large land mass. An economical method of converting the saline water to potable water is by using solar energy. Solar still desalination is one method of converting saline water into potable water by evaporation and condensation. Many researchers carried out extensive studies on the solar still desalination technique and this paper communicates a detailed review about the existing desalination technique by solar energy.

Keywords: Desalination, still. Wick, Phase Change Material

1. Introduction

Energy and water are very important for life on Earth and sustain the modern world. In many parts of the developed world, the control and utilization of water and energy has driven economic development and progress. In the developing world, many regions suffer from shortages of fresh drinking water and energy supplies. The United Nations Environment Program (UNEP) stated that one third of the world's population live in countries with insufficient fresh drinking water to support the population. Consequently by 2025, two thirds of the world population will face water scarcity.

Drinking water of acceptable quality has become a scarce commodity. The World Health Organization estimates that over a billion people lack access to purified drinking water and the vast majority of these people are living in rural areas where the low population density and remote locations make it difficult to install traditional clean water solutions [1]. In India two third of population live in rural areas and fresh water crisis is already evident in many rural parts of India. The fresh drinking water crisis is not the result of natural factors, but has been caused by human actions for satisfying the need. India's rapidly increasing population and changing lifestyles, also satisfy the need for fresh water. Intense competition among competing user's agriculture, industry and domestic sector is driving the ground water table deeper and deeper. Some 45 million people are affected by water quality problems caused by pollution, by excess level of mercury, fluoride, arsenic, iron or by the saltiness of water. Millions of people do not have adequate quantities of safe water. In rural areas, women and girls still have to walk long distances and spend up to many hours every single day to provide the household with water. Scarcity of fresh water problems are facing many arid zones of Gujarat and Rajasthan, while these places are getting more amount of solar energy, apart Gujarat and Rajasthan that in western India, which face water shortage and have huge underground saline water sources, certain regions in Haryana state and Maharastra states also have underground saline water in spite of high rain fall [2].

Distillation process is widely used for purification of water. Different methods of distillation have been used in several countries to resolve the crisis of drinking water. A variety of distillation technologies has been developed over the years on the basis of thermal distillation, membrane separation, freezing, electrodialysis, etc. The conventional water distillation processes consume larger amount of energy to separate a portion of pure water from the saline water. The physical change in the state of water as well as filtering via membrane processes, such as Multi Stage Flash (MSF) distillation, Multiple Effect Distillation (MED), Vapor Compression (VC) distillation, Reverse Osmosis (RO), and Electro-dialysis (ED) are most often used to treat saline water. Some of these processes are complex, requiring skilled operation and maintenance, and not considered to be energy efficient and economical.

Solar desalination is a very promising alternative that can partially support the human needs for fresh water with an environment-friendly energy source. It exhibits a considerable economic advantage over other desalination processes due to cost-free resource and reduced operation and maintenance cost. Solar desalination is a process where solar energy is used to produce fresh water from saline or brackish water for drinking, domestic and other purposes. The simple and independent operation of solar distillation unit is highly suitable for small scale and remote applications. It provides an opportunity for rural communities to prepare their own potable water at considerably lower prices. Solar water distillation has begun over a century ago. In 1872, a solar plant with capacity around 4000 m^2 has been built in Chile and successfully ran for many years. In addition, the small plastic solar stills have been employed to provide potable water for life rafts floating in the ocean during World War II. Thus, the use of solar energy with water distillers has a long history and the technology is well improved and field tested throughout the world. The classification of solar desalination is shown in fig. 1

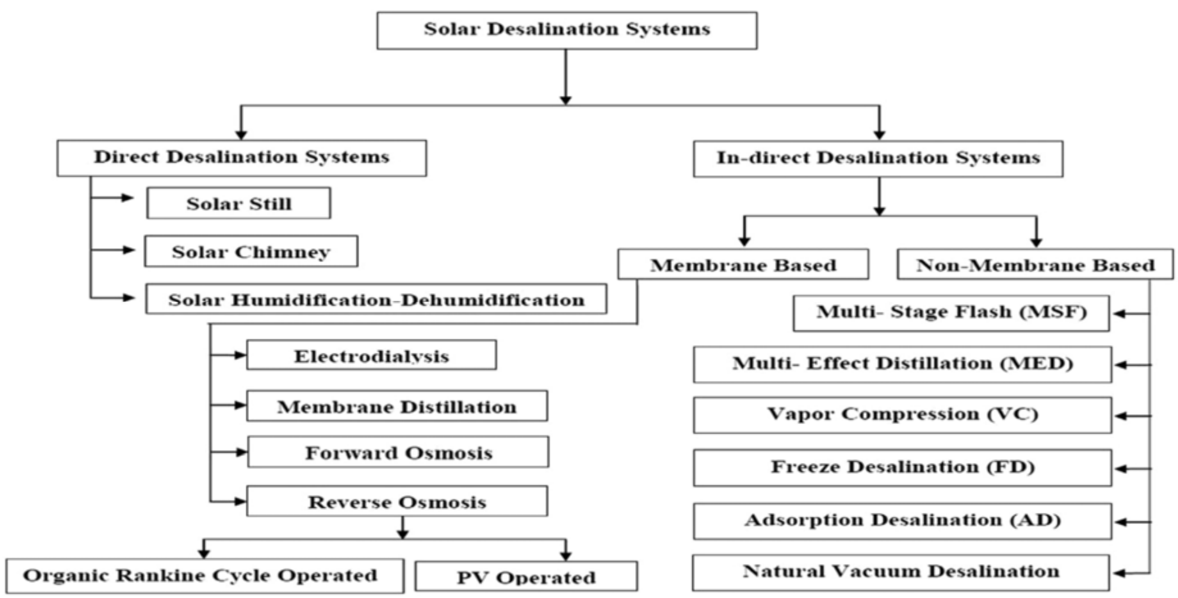

Fig. 1. Classification of solar desalination systems [3].

2. Solar Still

A solar still is a very simple device by which can be converted saline, brackish water into drinking water. Solar stills work exactly the same processes which in nature generate rainfall, namely evaporation and condensation. Its working is very simple; a transparent cover (glass/plastic) encloses a pan or box of saline water and latter store solar energy within the enclosure. This heats up the water causing evaporation and condensation on the inner face of the sloping transparent cover. This distilled water is generally drinkable; the quality of the distillate water is very high because all the salts, inorganic and organic components and microbes are left behind in the pan. A schematic diagram of simple solar still is shown in Fig. 2.

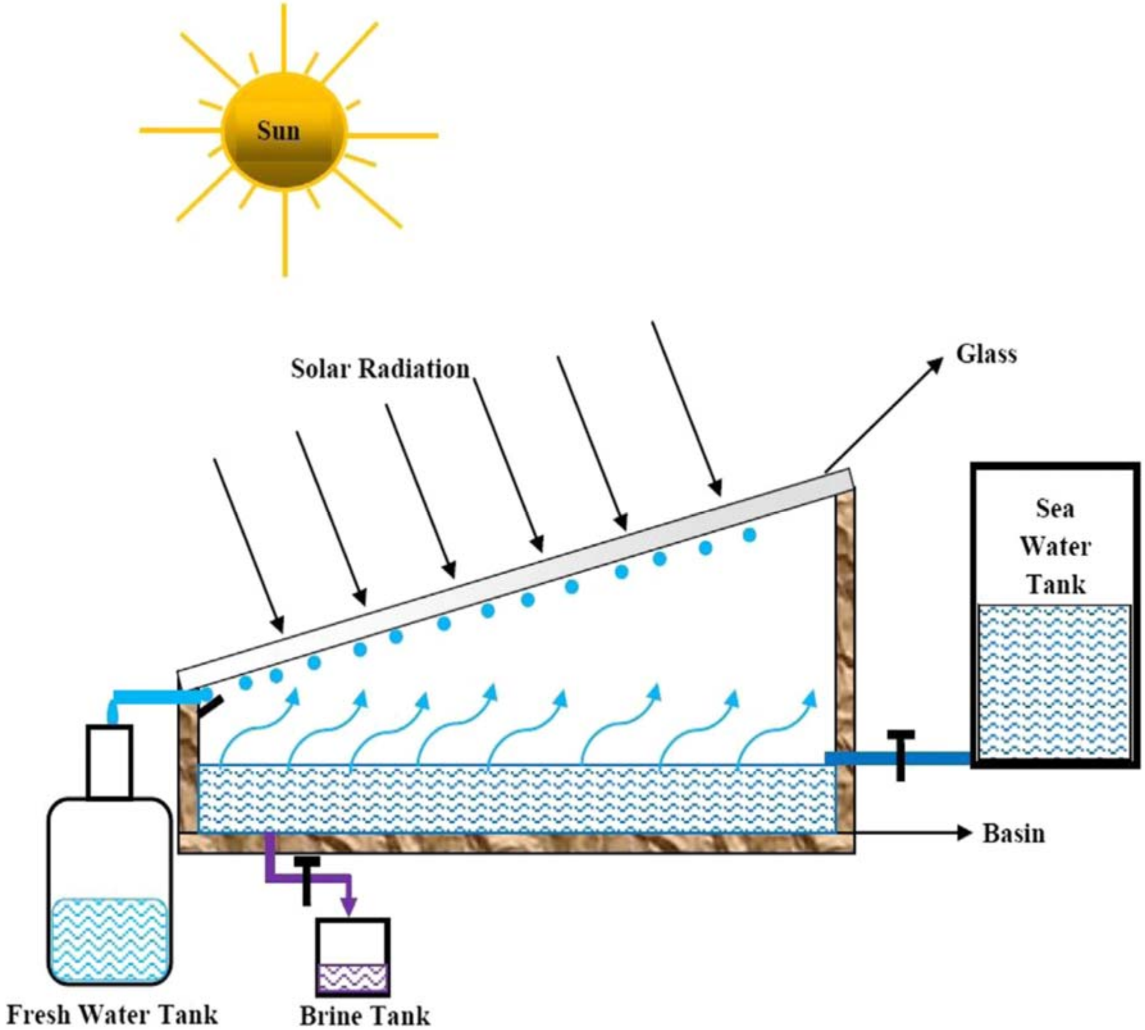

Fig. 2. Simple solar still [4].

3. Classification of Solar Stills

Solar stills are classified into two categories mainly single effect solar stills and multi-effect solar stills. Single effect solar stills are further classified into two groups: Passive solar stills and Active solar stills. The schematic representation of single effect solar stills is shown in Fig. 3. Passive solar stills utilize the internal heat trapped inside the still for the evaporation process, while active stills make use of external sources, such as solar collectors or waste heat from industries.

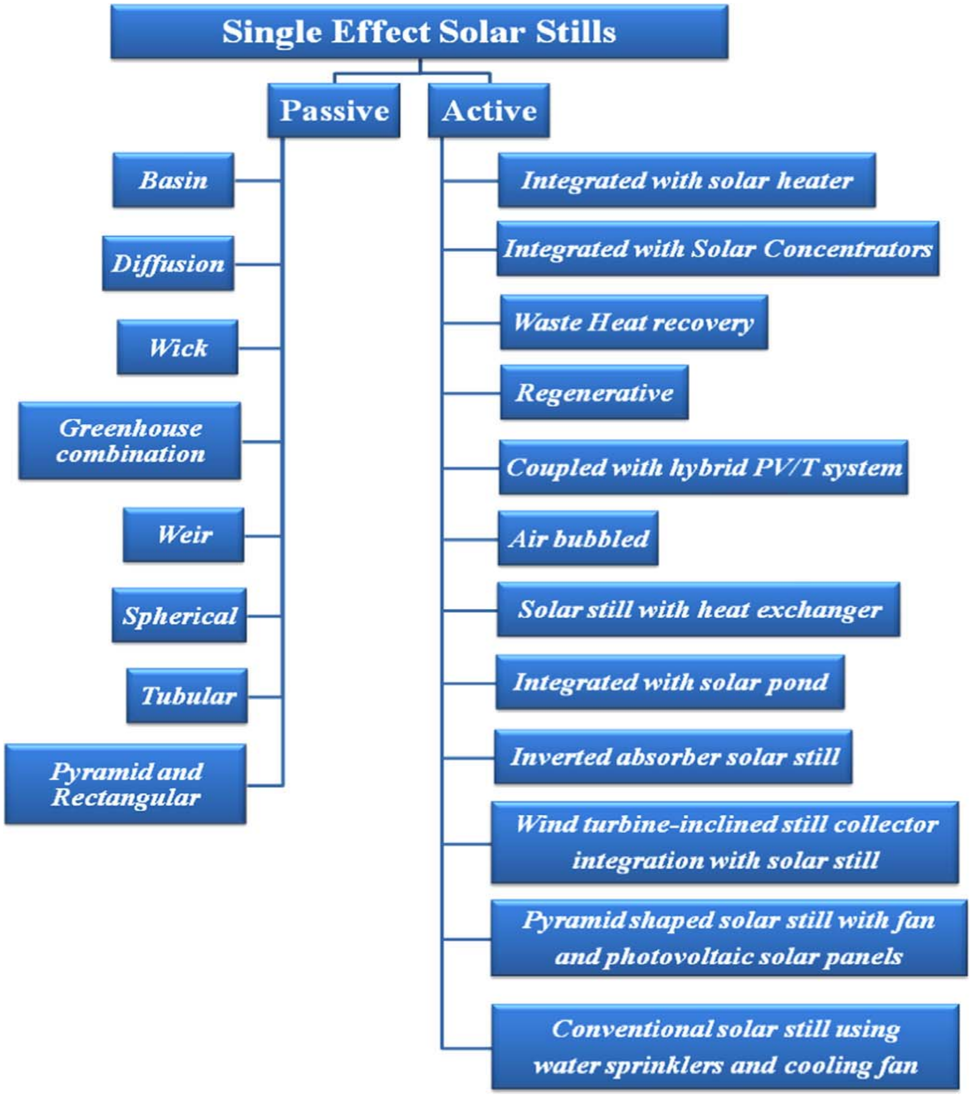

Fig. 3. Various designs of single effect passive and active solar stills[5]

3.1 Passive type solar stills

3.1.1. Single basin single slope solar still

In which solar energy collected by bottom elements (basin liner) itself for evaporation of brackish water. The simple single slope solar still is shown in Fig. 4. The sun's energy in the form of short electromagnetic waves passes through a clear glazing surface such as glass. Upon striking a darkened surface, this light changes wavelength, becoming long waves of heat, which is added to the water in a shallow basin below the glazing. As the water heats up, it begins to evaporate. The warmed vapor rises to a cooler area. Almost all impurities are left behind on the basin. The vapor condenses on to the underside of the cooler glazing and accumulates in to water droplets or sheets of water. The combination of gravity and the tilted glazing surfaces allows the water to run down the cover and into a collection trough, where it is channeled in to storage. The performance of a basin type single slope solar still system was investigated by Abdallah et al. [6]. In this system, the performance of the solar still is improved by increasing the production rate of distilled water The experimental result shows that the use of internal mirrors improved the system thermal performance upto30%.

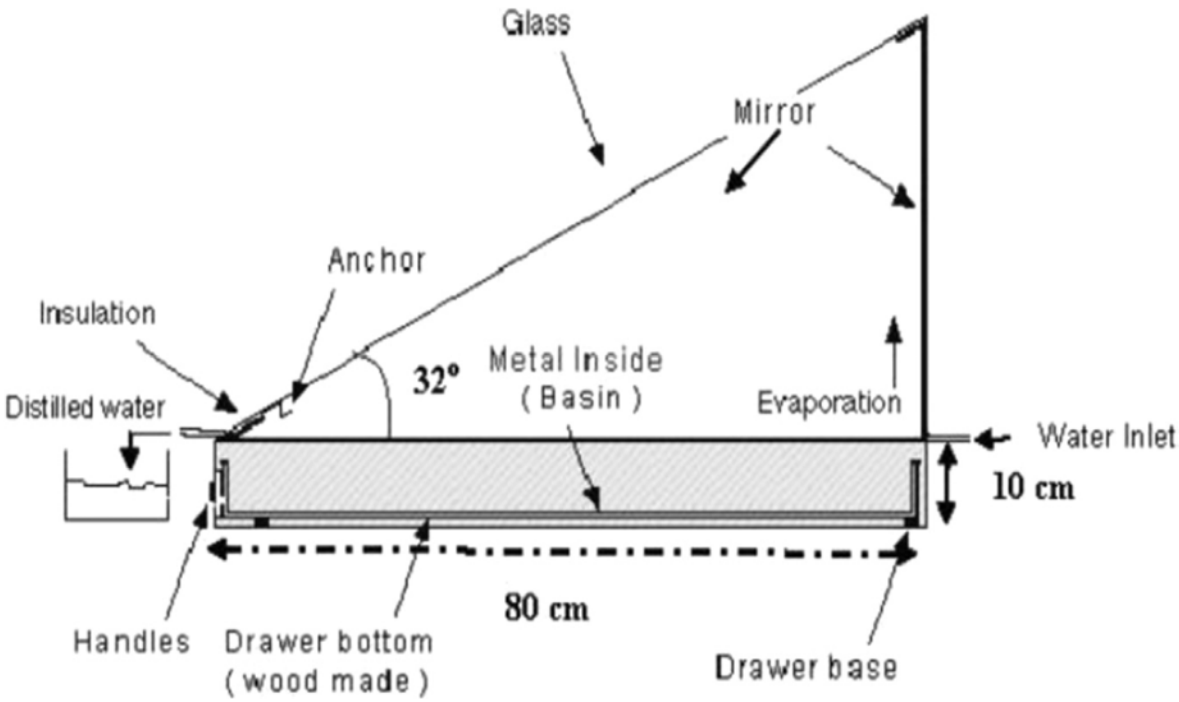

Fig. 4. Schematic diagram of a single slope solar still [6].

3.1.2. Basin stills with internal and external reflectors

A basin still with internal and external reflectors was designed by Tanaka [7] as shown in Fig. 5. The still consists of a basin liner, internal reflectors in two sides and back walls, a glass cover, and a vertical external reflector. Because of the usage of reflectors, more solar radiation is introduced into the still compared to conventional solar stills and thus is was reported that there was an increment in the daily productivity by 70–100% on winter days. Tanaka and Nakatake [8] presented a theoretical analysis and they observed that year round average increase in the daily productivity was 48%.

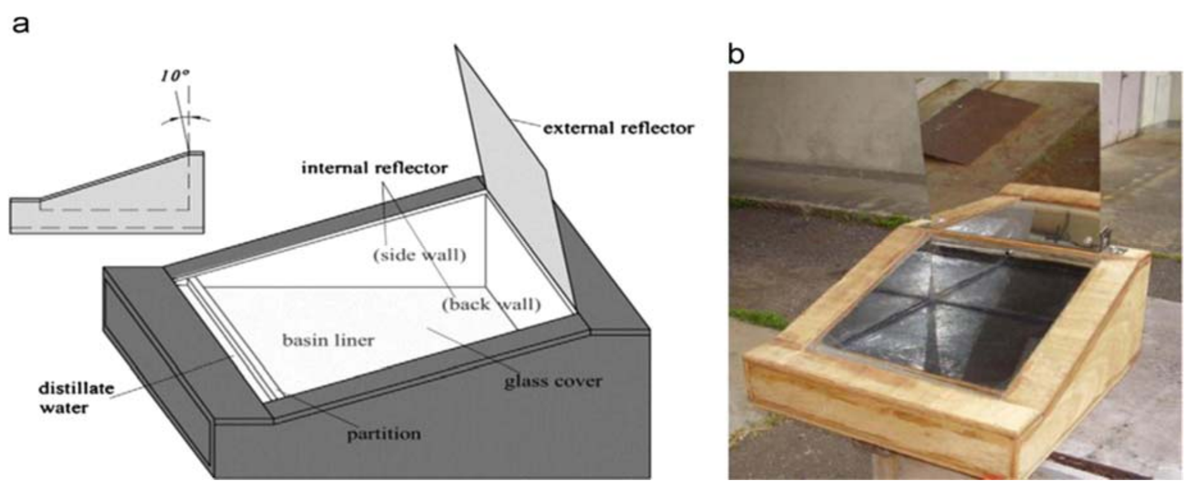

Fig. 5. Single slope still with internal and external reflectors; (a) schematic (b) experimental setup [7].

3.1.3. Solar still with sponge cubes

Sponge cubes in the brackish water was used by Abu-Hijleh and Rababa'h [9] to improve the rate of evaporation. The schematic diagram is shown in Fig. 6. The effects of sponge cube size, percent volume of sponge, water depth, water salinity and the use of black coal and black steel cubes were also investigated. They had proved that the distillate productivity increased by 18–273% compared to an identical conventional still without sponge cubes under the same conditions.

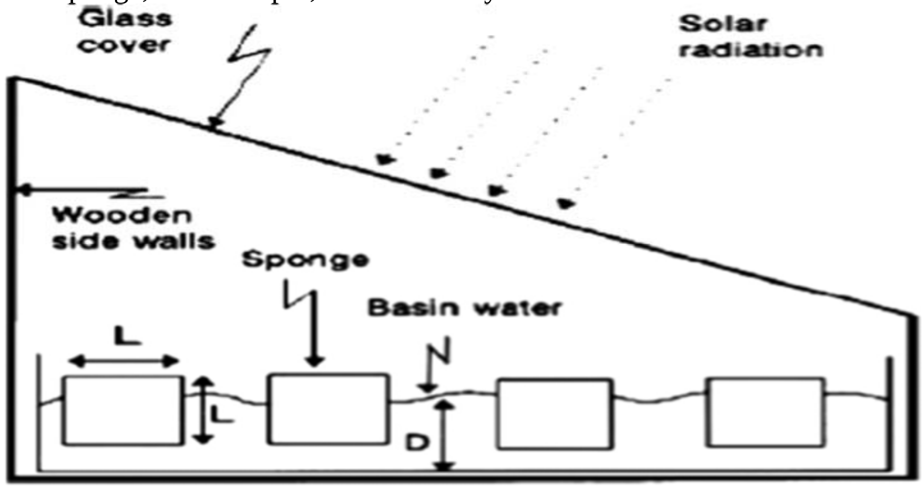

Fig.6. Single slope still with sponge cubes [9].

3.1.4. Solar still with multiple low thermal inertia porous absorbers (blackened jute cloth)

An experimental and theoretical work was proposed by Srivastava and Agrawal [10] to enhance the performance of conventional single slop basin type solar still by incorporating multiple low thermal inertia porous absorbers (blackened jute cloth), floating adjacent to each other on the basin water with the help of thermocol insulation .the schematic diagram is shown in Fig. 7.

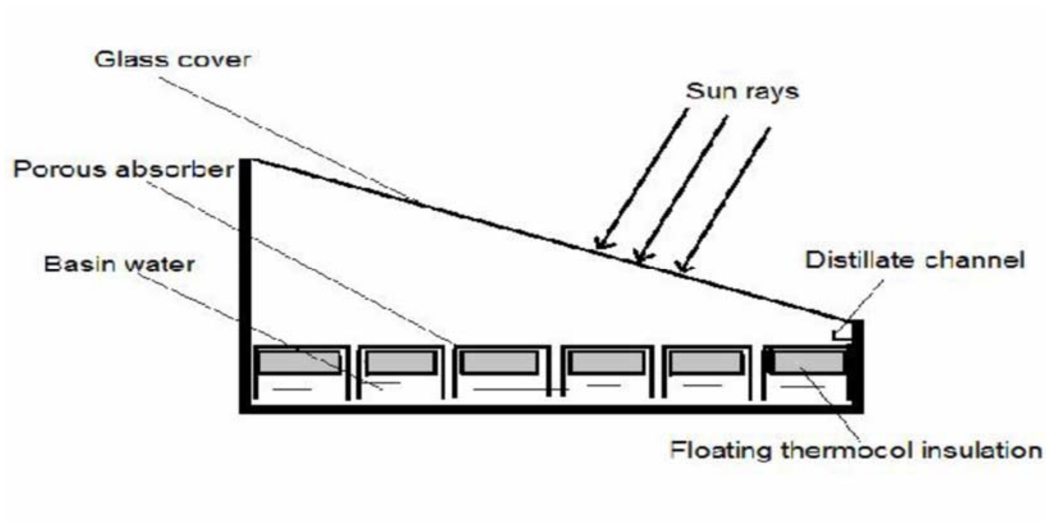

Fig. 7. Single slope still with porous absorber on the thermocol insulation [10]

In the modified solar still, nine such absorber pieces were floated side by side length wise on the basin water so that the water surface was completely covered by the absorber with required clearance from the basin walls. The edges of the jute cloth were dipped in the basin water, so that it remained wet due to capillary action. The performance of the modified still was compared with the perfectly synchronized conventional basin type solar still of identical dimensions and found an increase of 68% and 35% in the distillate yield on clear and cloudy days. The effect of basin water depth and the improvement in productivity by the use of twin reflector booster were also experimentally investigated and found an increase in the yield by 79%.

3.1.5. Solar still with rotating shaft

Abdel-Rehima and Lasheen [11] worked on improving the performance of solar desalination systems with a modification of using a rotating shaft installed close to the basin water surface. The schematic diagram is shown in Fig. 8. The results showed that an enhancement of distillate yield by 2.5% at May, 5% at June, and 5.5% at July respectively.

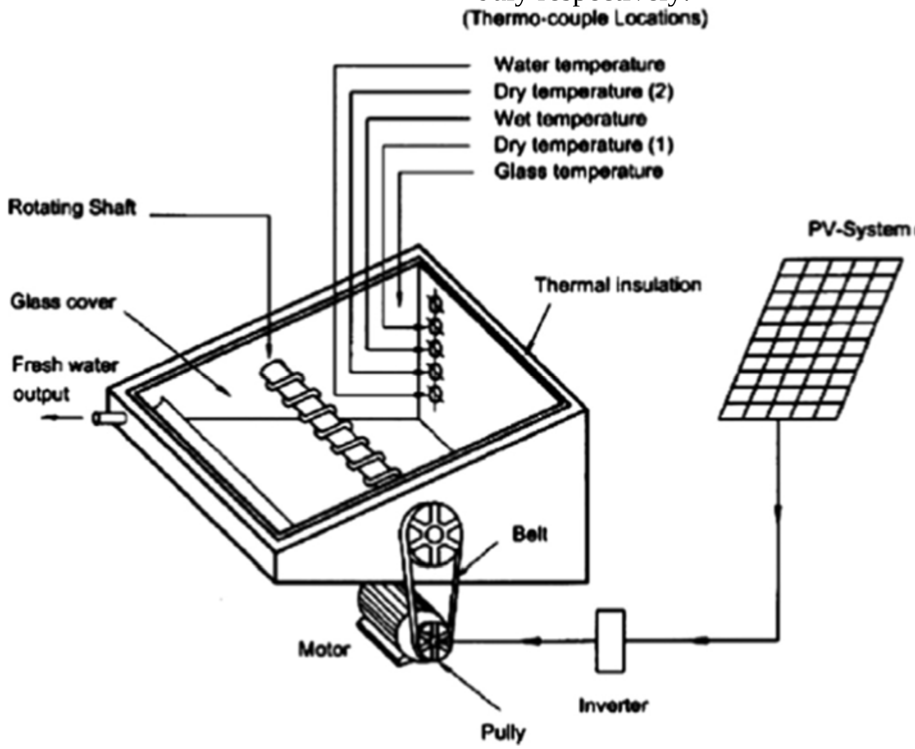

Fig. 8. Single slope still using rotating shaft [11].

3.1.6. solar still with phase change material

El-Sebaii et al. [12] proposed mathematical model for a single slope single basin solar still with and without phase change material (PCM) under the basin liner of the still. Numerical calculations were carried out using thin layer of stearic acid as a PCM on the beneath of the basin liner. It is shown in Fig, 9. The results of that study showed that, productivity daylight decreased as mass of the PCM increased; but productivity overnight and daily productivity were increased significantly with an increase of mass of the PCM due to the increased amount of the stored heat within the PCM. During discharging of the PCM, the convective heat transfer coefficient from the basin liner to basin water is doubled; thus, the evaporative heat transfer coefficient is increased by 27% on using 3.3 cm of stearic acid beneath the basin liner. Therefore, on a summer day, a value of daily productivity of 9.005 L/m2/day with a daily efficiency of 85.3% has been obtained compared to 4.998 L/m2/

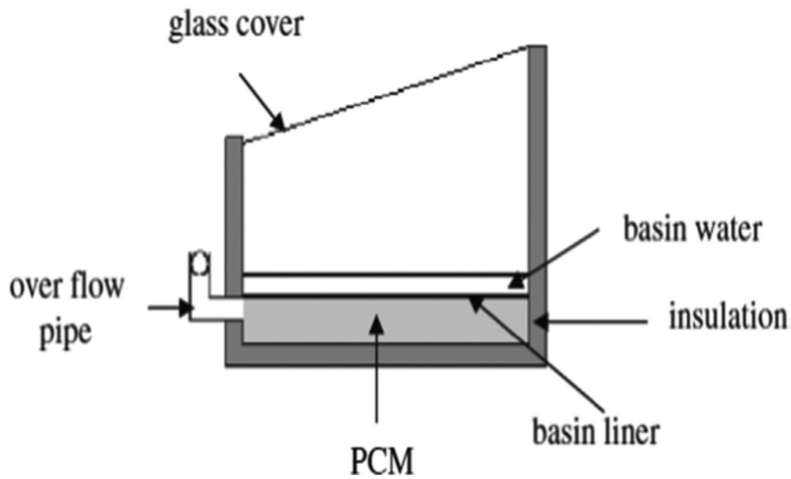

Fig. 9. Schematic diagram of the single slope-single basin solar still with PCM [12].

3.1.7. Wick type solar stills

Wick still mainly come under inclined type still. In a wick still, the feed water flows slowly through a porous, radiation-absorbing pad (the wick). A schematic diagram of multi-wick type solar still is shown in Fig. 10. In which blackened wet jute cloth forms the liquid surface which can be oriented to receive maximum solar radiation and a smaller mass of water will be heated to higher temperature and will evaporate rapidly. The wet surface is created by a series of jute cloth pieces of increasing length separated by thin polythene sheets, these pieces are arranged along an incline and the upper edges are dipped in a saline water tank. Suction by the capillary action of the cloth fiber, provides a surface of the liquid and the arrangement ensures that all the surface, irradiated by the sun is wet at all times; the portion of a piece of cloth, covered by the polythene sheet does not suffer evaporation and hence the exposed portion of the piece retains wetness. M.S. Sodha et al. [13] observed that, overall efficiency of multiple wick solar still is 4% higher than the basin type still. Their results also show that, the still cost less than half of the cost of a basin type still of same area and provide a higher yield of distillate.

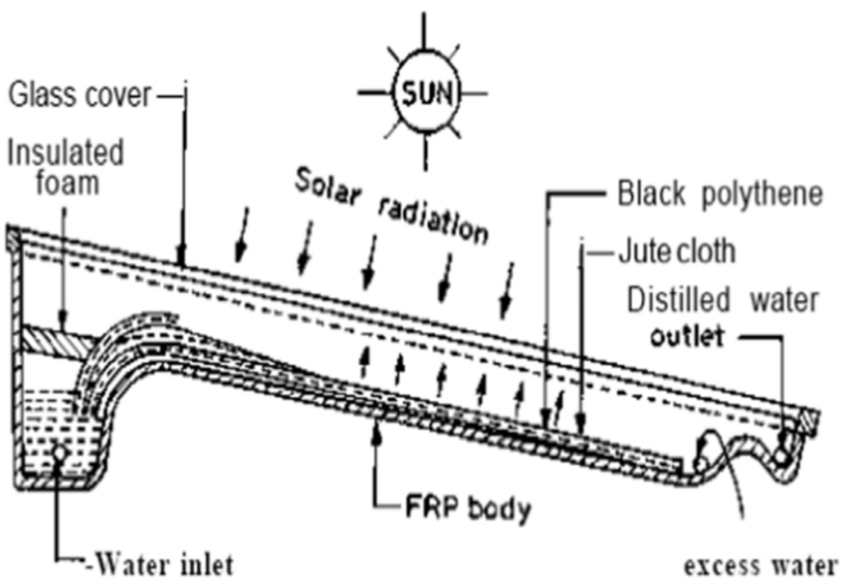

Fig. 10. Schematic representation of wick type solar still [13].

3.1.8. Concave surface type solar still

Concave wick type solar still is designed and made by Kabeel [14]; a concave shaped wick surface increases an evaporation rate because the water surface level is lower than the upper limit of the wick surface. It is shown in Fig. 11. Results show that average distillate productivity in day time was 4.1 L/m2 and the maximum instantaneous system efficiency was found to be 45% and the daily efficiency of the still was 30%. The maximum hourly yield was 0.5 L/h per m2 after solar noon.

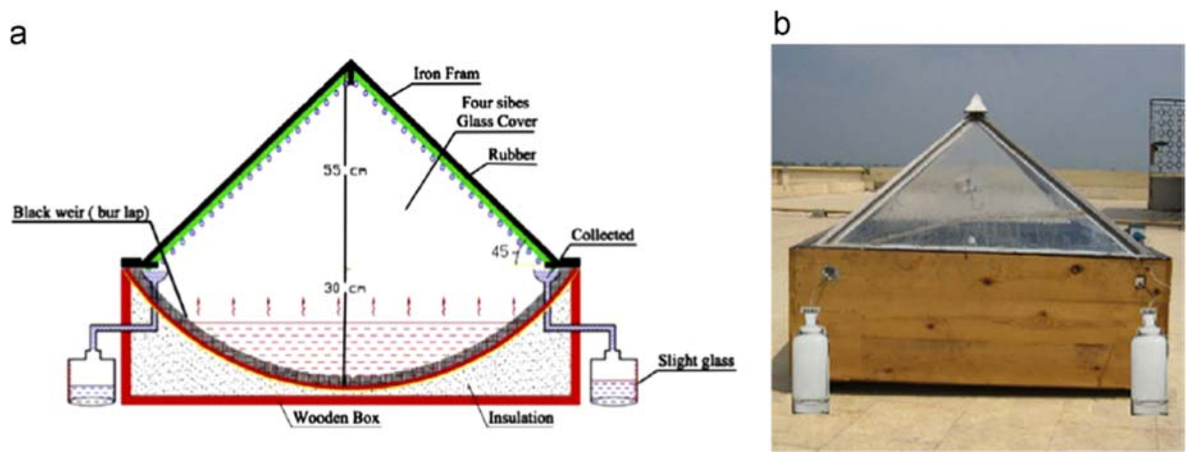

Fig. 11. Concave type solar still; (a) schematic diagram (b) experimental setup [14].

4. Conclusion

On the basis of survey of review in various solar stills, the following conclusion can be inferred.

(a) In the countries like India, where there are large parts of remote and rural areas with sufficiently high solar energy input. Solar distillation can be a feasible option for obtaining potable water.

(b) Solar distillation can be a very economical option as the cost of the solar still can be recovered within a year of operation.

(c) Solar energy is abundant, never lasting, available on site with free of cost and pollution free energy. (d) Solar stills have a good chance of success in India for lower capacities which are more than 20 km away from the source of fresh water and where the TDS of saline water is over 10,000 ppm.

(e) The floating absorber sheet improves the output of the still compared to an ordinary conventional

(f) The multiple wick solar still is the most economic and efficient among the existing solar stills.

(g) To decrease fresh water costs, efforts should be undertaken on the following research topics, storage studies, insulation studies, thermo-optical studies for the condensing covers, geometry and design studies.

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