A REVIEW ON RESEARCH TRENDS IN SINGLE SLOPE SOLAR STILL SYSTEM FOR INCREASING ITS EFFICIENCY

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ABSTRACT

Solar distillation is a technique through which brackish water is converted into potable water by using solar power. Since fossil fuels are costly and continuously depleting and distillation process needs a large amount of fuel for getting drinking water from saline water. For this solar still system is a quite better option. Basically solar still system classified in two ways, and active solar distillation system and passive solar distillation system. For enhancing performance of solar distillation system many researches are made in various arrangements is made on solar still. The basic aim of this review paper is to review single slope solar still system based on reducing the loss of solar energy by using phase change materials like paraffin wax, silica as an energy storage materials, wick type solar distillation system and study about the erosion and corrosion of solar still basin material which affects directly or indirectly of solar still performance. It is found using these arrangements increase the performance and energy efficiency of the solar distillation system by 60%. Also some other parameters like solar radiation, air flow velocity, dust and cloudy condition, inclination angle of glass reflector and depth of saline in basin etc. affects its performance.

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1. INTRODUCTION

In present era, whole world facing a remarkable challenges of energy and water scarcity, which affect the fruitful progress of each country. Mostly populations of different countries lived in water shortage countries by 2025 [1]. It is well known that approximately 97 per cent of water is present in the form of sea water this is highly saline water and this highly salty water is not good for human utilization. Around 2%, out of total available water, at hand in the form of ice in glaciers. Only 1% of potable water is available into the lakes, pond and underground [2, 3]. But this potable water is not for drinking purpose because of containing

harmful pathogenic bacteria, viruses and parasites. According to World Health Organization (WHO), By using this infected water around 3 million people die due to diseases like cholera, diarrhea etc. every year in the world [4, 5]. So for purifying this contaminated water, various types of Reverse Osmosis (RO) are used. Due to high maintenance, high energy consumption and expensive cost this RO system is not affordable for most of the persons. For this purpose most of the person is made potable by boiling which consumes around 0.71 kWh of heat for producing $1m^3$distillate water [6]. Due to continuous increasing the price and CO2 gas emission of fossil fuels, distillation by boiling is not suitable for producing drinking water. Hence there is a requirement of such method which is affordable for common person in society and also ecofriendly [7]. According to studies, solar power from the sun is the energy that is derived to thermal or electrical energy. It is an eco-friendly method of energy production. Solar power is the best method for distillation of brackish water which fulfills the availability of potable water requirement and reduces carbon emission on the environment [8]. By solar distillation system the brackish water is converted into potable water. It works same as raining process by the natural hydrological cycle Fig. 1 [9]. According to hydrological cycle, when the sun rays incident on water from sea, lakes or ponds, water heats up and evaporates. When these vapours in the atmosphere condense to tiny droplets of water by attaining dew point temperature. These water droplets collected in clouds and falls like rain. Similarly brackish water present in the solar still basin evaporates due to direct incident of sun rays. The evaporated water vapours collected on glass cover similar to cloud. When dew point temperature attains, vapours condensed and water droplets slide down and collected in the collection pot of solar still system. As per drinking water standard potable water must have TDS less than 500 ppm [10].

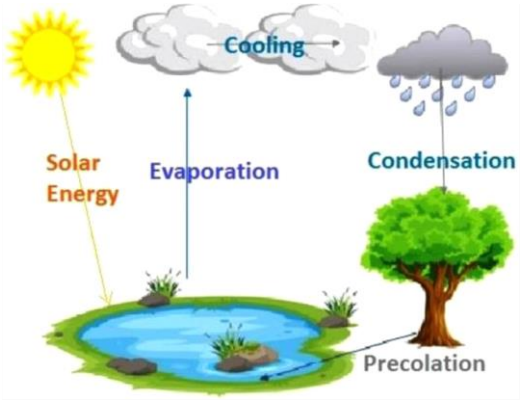

Fig.1[9]. Natural Hydrological Cycle

2. Solar Distillation System (Solar Still)

Solar distillation system is basically based on cost-effective technology which is used for reducing the water shortage problem. For this issue a large number of designs and technological innovations have been introduced. Basically conventional solar still has a basin and covered by transparent glass or plastic on its top. Inner surface of basin is black paint coated as well as covered with acrylic sheet to prevent the heat loss of incident sun rays. When sun rays falls on the glass cover, water heats up which causes evaporation and condensation process underside the top cover [11-12].

3. Solar Still Classification

Solar stills are primarily categorized as passive and active solar still. Passive solar still is also known as conventional solar still due to its basic design. Therefore having poor efficiency around (30–40%) and small quantity of distillate water approximately 3-4 liters/m^2per day [13].

3.1 Passive Solar distillation system: It consists of a basin and a single slope. It does not involve the use of any mechanical and electrical devices. Fig.2 [14] shows passive solar still system.

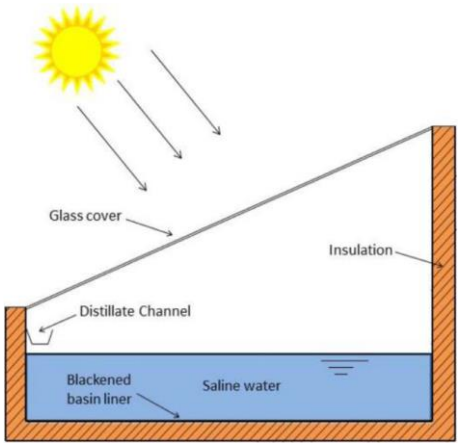

Fig.2 [14] Passive solar still system

It occurs due to a large amount of incident solar energy lost through walls and surface of basin. Around 61.60% heat is lost from solar still and out of this 25.70% lost from sidewalls, 35.70% is lost from glass cover and basin surface. It is noted that only 38.40% heat is used for distillation purpose.
It is clearly shown in fig.3 [15], the total energy utilization in this solar still. That is the reason for its lower efficiency.

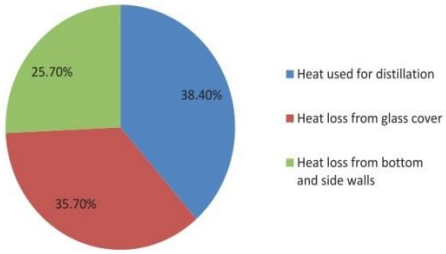

fig.3 [15] Graphical representation of heat lost in solar still

3.2 Active Solar Still: It consists of auxiliary equipments like blowers, pumps and other type of energy resources to collect store and covert solar energy. Fig.4 [16] shows active solar still system.

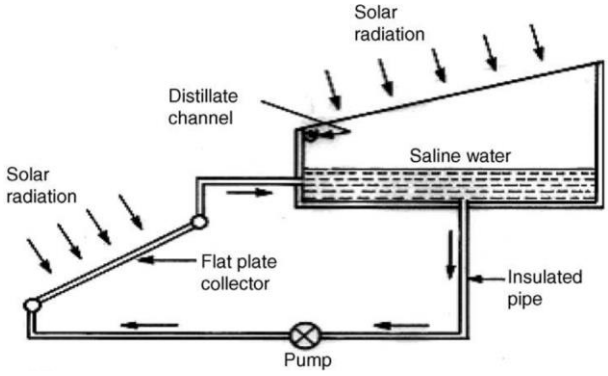

Fig. 4[16] Active solar still system

4. Methodology

This research work is done on the recent advancement in solar distillation system to maximize its efficiency and performance are studied to find out right energy storage materials, phase change materials, effect of height of brackish water into the basin, operating parameters and it's corrosion study. Recently wick type solar stills are using for enhancing the freshwater productivity. Due to using this type solar distiller

improves its efficiency around 60% as compare to the simple passive solar still. A lot of papers are collected for this review paper from various journals of national and international which are graphically represented in Fig.5 [17].

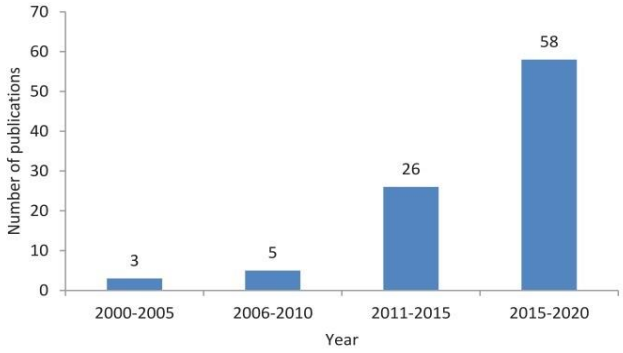

Fig.5 [17] Number of publication reviewed

4.1 Phase Change Materials (PCM)

The main problem of solar still system for its lower efficiency is loss of energy. So for its better performance different types of phase change materials (PCM) are used. These materials work continue for distillation even at sun set. In this paper study is made to find out the best phase change material for distillation. At the time of study paraffin wax amongst other phase change material like lauric acid, bitumen etc. is the most important phase change material (PCM) for solar still system. This material enhances performance and efficiency of solar distillation by 180%, and 67.20%, respectively [18-19].

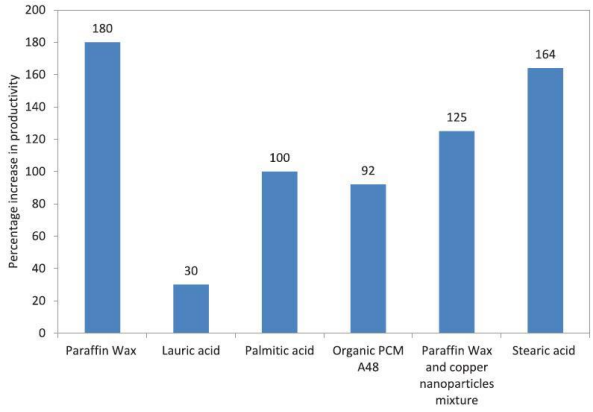

Fig.6 [20] Productivity with PCM.

The productivity of active solar still is obtained around 307.54% when it is messed with paraffin wax [21]. The various types of PCM is given below in chart [22].

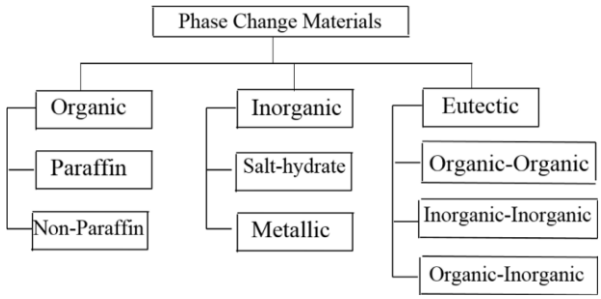

Fig 7 Classification of PCM [22]

4.2 Energy Storage Material

Energy can be stored by some kind of material like sand particle by heating process and whenever there is requirement of energy for heating or cooling process, this storage material release its stored energy later. Basically, energy storage material classified as thermal and chemical as shown in Fig.8 [23]. Economically thermal energy storage type material is mostly in solar distillation process. Furthermore thermal energy storage material also classified as sensible heat and latent heat. Since sensible heat storage materials are heavy and require large space [24]. Therefore Latent heat storage materials are mostly used in solar distillation because it stores heat more than 5 to 14 times [25].

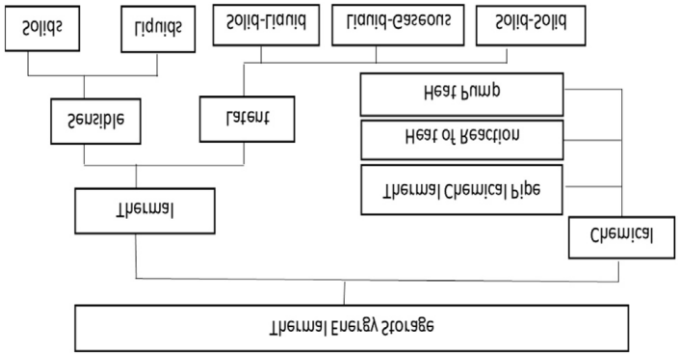

Fig. 8 Classification of Energy Storage Material [23].

4.3 Wick type solar stills

- Recently, a lot of research is made with a common aim to increase the performance of solar distillation devices. Hence, most effective type solar distillers come in to the light which is commonly known as wick type solar distillers. This review paper explores the current status of wick solar distillers. When wick type solar distiller is equipped with energy storage material, it gives drastically a large amount of potable water distillate [26-30]. Furthermore a large number of modifications are made on wick type solar distiller. Here, a rotating wick cloth type solar distiller is highly efficient around 66% and 84% [31-35]. If this solar still system is integrated with parabolic concentrator, its productivity can be increased by 676% [36-37]. A wick type solar distiller is shown in fig.9 [38].

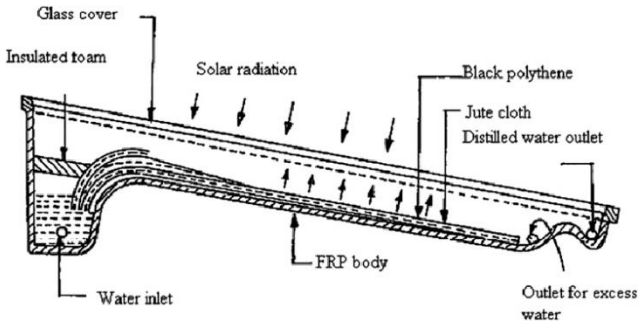

Fig.9 Wick type solar still [38]

4.4 Effect of Erosion and Corrosion of components

In solar distillation system, Nano fluid particles are present either in brackish water or energy storage materials. When heat transfer process takes place these Nano fluid particles causes the erosion and corrosion on a metal surface of solar distillers. This phenomenon is done in both chemical and physical ways. Since solar distillers are also used for purifying sea water and this water contains a large amount of chemical corrosion range, this will corrode metal surface so fast. Similarly on same time Nano fluid particle also causes erosion due to the collision between the metallic surface and particles in basin [39]. Hence to minimize erosion and corrosion activity, the Nano fluid should be tested before its use in the desalination process. Erosion and corrosion activity are also avoided by formation of a protective film on the metallic surface of basin [40-41]. Convenient system design and maintenance also avoid the effects of erosion and corrosion.

5. Desired Parameters of Solar Still

5.1. Climatic Conditions

- **Solar Radiation**

Solar still system is completely based on solar power. Therefore its productivity enhances when a large quantity of solar radiation falls over the distillers surface.

- **Wind Speed**

Wind velocity affects the outputs of active and passive solar stills and study shows that the output improves with increasing wind speed [42].

- **Dust and cloud cover**

Since solar distillers are completely depend on the solar radiations, therefore if environment is cloudy or dustful will decrease its performance.

5.2. Design Conditions

- **Single Slope or Double Slop**

Single-slope solar still receives more incident sun rays at various altitude as compare to double-slope solar still.

- **Inclination of glass reflector:**
- The distillate output can be increased up to 68.57% by using the reflective glass mirrors and if the reflective aluminum foil sheet is used output is increased by 48.57% [43].
- **Water Depth into Basin**

The distillate output will maximum when basin water depth is at 1 cm with phase change materials. The study investigates that increase in depth basin water decreases distillate output [44].

5. Conclusions

This review paper basically based on various research studies for increasing the performance and efficiency of solar still. This study concludes that

- Paraffin wax is the best phase change material which increases energy, productivity and exergy as 67.2%, 180%, and 40% respectively for single slope - single basin type passive solar distillers.
- Another advanced design solar distiller commonly known as wick type solar distiller which is highly efficient around 60% to 80%. If this solar distiller system is incorporated with parabolic concentrator, it increases its productivity by 676%.
- In solar distillers, basin is made with metal surfaces and due to continuous heat transfer process, Nano fluid particles present into the energy storage materials and brackish water causes the corrosion on these metal surfaces. Since the collision between the metal surface of basin and Nano particles causes erosion.
- This study investigates that increase in depth basin water decreases distillate output.
- By using reflective glass reflector, enhances distillate output by 68.57% and if reflective aluminum foil sheet is used in basin surface it also increases distillate water around 48.57%.

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