EFFICIENT DESALINATION BY LAYERED HEATING OF SALINE WATER: A REVIEW

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Abstract- Thin layer heating technology for desalination is one of the topics that is catching eye of many researchers recently. The sun is a very good renewable energy source that can solve many human being's problems such as water scarcity. Solar energy can be utilized for water desalination. Nowadays, parabolic trough collector and dish reflector and other optical concentrators are used to concentrate the solar radiation to get more power. They are complex and costly. Efficiency of basin type solar still and other conventional solar still is decreases as we increase water quantity, due to the heat loss to water. Due to this reason need of solar desalination devices that use localized heating of a thin layer of water. In the past few years, significant research is done for the developing thin layer heating desalination. In this review, basin type solar still is discussed, properties of wood and titanium dioxide materials for substrate and absorber have been discussed. Recently developed desalination devices are studied and how desalination is carried out by using absorber and substrate is discussed.

Keywords: Desalination, Basin type solar still, Titanium dioxide, Wood.

1. INTRODUCTION

In future, we need to fulfil the increasing demand for fresh water because of the increasing world population [1]. There are many freshwater resources available but these will not be enough. Desalination is considered as very useful to fulfil water demand. There are two methods which are used for desalination of saline water is thermal desalination and reverse osmosis technology. Solar water desalination uses a renewable energy source. It has less impact on the environment. So, this method can be used to reach water demand. Therefore, we need to develop low-cost desalination devices for getting fresh water. In past years it is seen increasing fast advances for the development of layered heating of water type desalination devices.

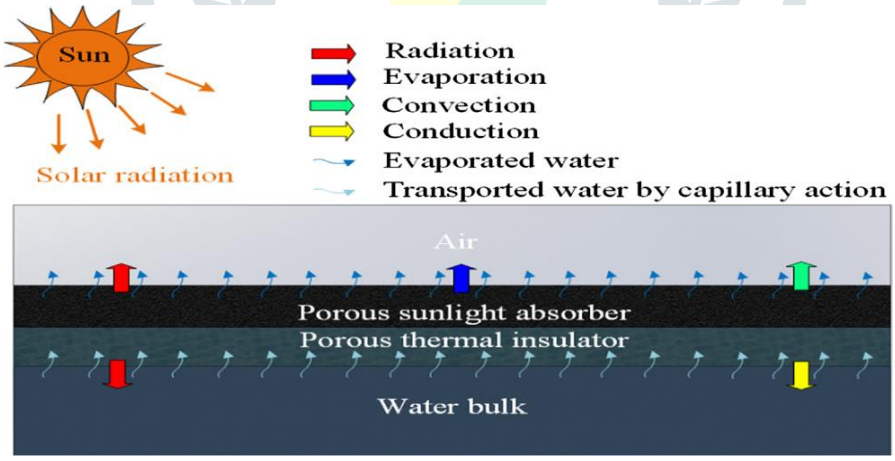

Fig. 1 Mechanism of conversion of water into vapour [2]

Bi-layered desalination device is made up of substrate material which is thermal insulator a thin layer of absorber material is deposited onto it as shown in fig. 1. The solar radiation is energy input given to the system. This input is used to evaporation of water. The energy which is absorbed by absorber material is used to heat the thin water layer. The total enthalpy of heat required to change the phase of water from liquid to vapour is reached, the water layer starts to evaporate. Evaporation of water takes place in the absorber layer by water wicked in the micro-pores of substrate material, by the capillary action. If a thin layer of water is heated locally for desalination, water bulk is not heated but the only thin layer is heated. If we heat water bulk there is more heat loss occurs [2].

To get efficient desalination using this device the following features are required:
The absorber material should have good sunlight absorption to convert sunlight energy into heat.
Thermal conductivity of substrate material should be very low.
Whole bi-layered desalination device should float on water.

Here, we give a brief overview of efficient solar desalination, conventional solar desalination devices, materials used for substrate and absorbers, new solar desalination device which has titanium dioxide deposited on wood.

This paper is arranged as follows: Section 2 presents a study of conventional solar desalination. Section 3 presents various substrate materials and why wood is used. Section 4 presents various absorber materials and why titanium dioxide is used. Section 5 presents previous work related to efficient desalination.

2. Conventional solar desalination

Desalination process is defined as the mineral components are take away from saline water to get fresh water by condensation of evaporated water. Conventional solar water desalination is done by using parabolic trough collector, Dish reflector, Fresnel lens, Basin type solar stills etc.

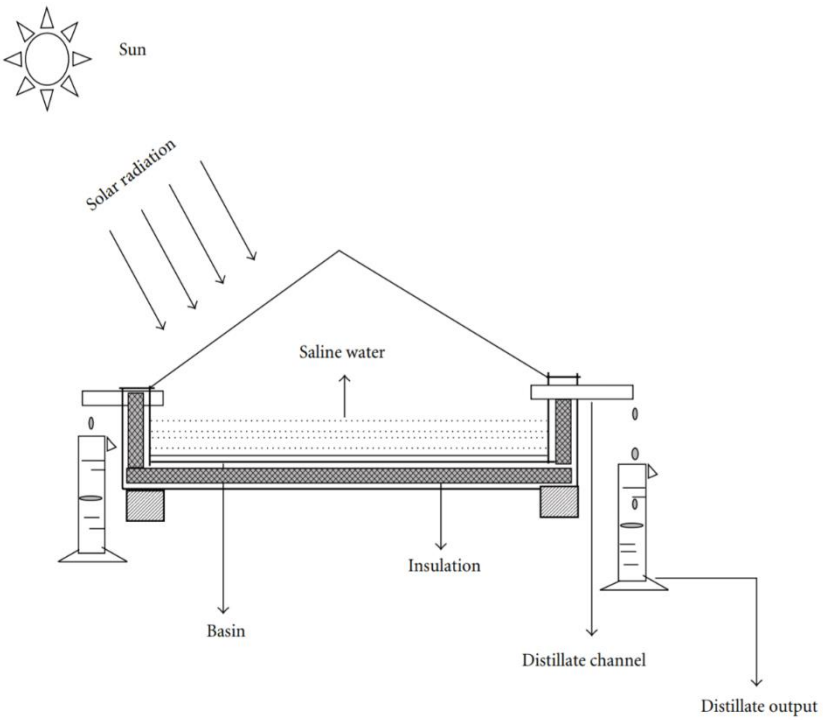

Fig. 2 Basin type solar still [3]

Basin type solar stills are used for desalination of water. At the bottom and side of basin thermal insulation is used, so that heat not transferred from side and bottom. Inside the basin at bottom and side thermal absorber placed. When solar radiation falls on saline water, water gets evaporated due to heating of water which is collected on glass placed above the basin. The evaporated water condenses on the glass and collected in distillate output [3]. Variation of single slope solar still efficiency is 21.22 % to 34.2% and for double slope solar stills efficiency varies from 23.14 % to 36.4 % [4]. The efficiency of basin type solar stills is increased by modifying solar stills by using multiple fins, spreading coal at the bottom of the still and radiation is increased by fitting a reflecting mirror at the bottom of the still [15].

This conventional solar stills are less efficient and involve more cost [19]. Parabolic trough collector and dish reflector and other optical concentrators are used to concentrate the solar radiation to get more power. They are more complex and costly. Efficiency of basin type solar still and other conventional solar still is decreases as we increase water quantity, due to the heat loss to water [3]. To increase efficiency, additional methods required. Due to these reasons, we can do more research on methods to increase the efficiency of solar stills and we can get low cost and more efficient solar desalination. For this a solar still is proposed which is made up of a thin layer acts as an absorber of sunlight, which is deposited layer by layer onto a substrate material acting as a thermal insulator between water and the absorbing material. Whole bi-layered desalination device should float on water and the substrate should consist of porous structure so water wick up to the absorber surface by using capillary action and absorber absorbs the sunlight. The energy which is absorbed by absorber material is used to heat the thin water layer. The total enthalpy of heat required to change the phase of water from liquid to vapour is reached, the water layer starts to evaporate. Because of layered heating of water, heat loss is reduced and we get more efficient solar still [2].

3. Substrate materials

Absorber which is deposited onto a substrate material acting as a thermal insulator between absorber and water. The substrate should have a low thermal conductivity, it should have good hydrophilicity characteristics for transport water from the water basin to surface. The substrate should consist of porous structure so water wick up to the absorber surface by using capillary action and absorber absorbs the sunlight. The whole structure should have low density and it can float on the water. Various substrate materials

which are easily available are paper, gauze, wool, carbon fabric, cotton fabric, wood, aerogel etc. These materials are porous and possess low density [2].

Paper cannot be used in the real-world application in desalination, because it has very less life in water and its mechanical properties are poor. Carbon fabric and cotton fabric also have less life against water and thermal conductivity of these materials also more [5]. For substrate material, wood and aerogels are more promising materials as they have more life in water, have more strength, good machinability, hydrophilicity, low thermal conductivity [13]. So, these materials can be used as a substrate. Aerogel is more costly than other materials [6]. Wood has the benefit of abundancy and more availability and has low cost [7].

4. Absorber material

An absorber is deposited onto a substrate. Absorber should good absorber of sunlight to get better conversion of sunlight to heat. Absorber should give chemical stability and non-toxicity. Absorber should have high light to heat conversion capacity. Absorber should be porous material. So, it can easily evaporate water. Various absorber materials which are available are Aluminium, gold, silver, polypyrrole, graphite, graphene oxide, cermet, titanium dioxide, ferroferric oxide etc [2].

Coating of aluminium nanoparticles on the substrate is difficult [8]. Gold and silver have superior optical properties but the cost is high. Materials which are made up of carbon like graphite and graphene oxide are easily available at low cost. High sunlight absorption with the good conversion of light into heat, titanium dioxide and other metal oxides are a good choice. Titanium dioxide has low cost, Non-toxic and good chemical stability. For this reason, titanium dioxide preferred against other absorber materials [9]. Titanium dioxide exists naturally in three crystalline forms anatase, brookite and rutile. Rutile has more light to heat conversion rate [17].

5. Recent work related to efficient desalination

Keng-Ku Liu [10] and others were done work related to efficient desalination. Graphene oxide act as absorber material is deposited on wood which gives good sunlight absorption and good conversion to heat which results in an increase in the temperature of the surface of the absorber.

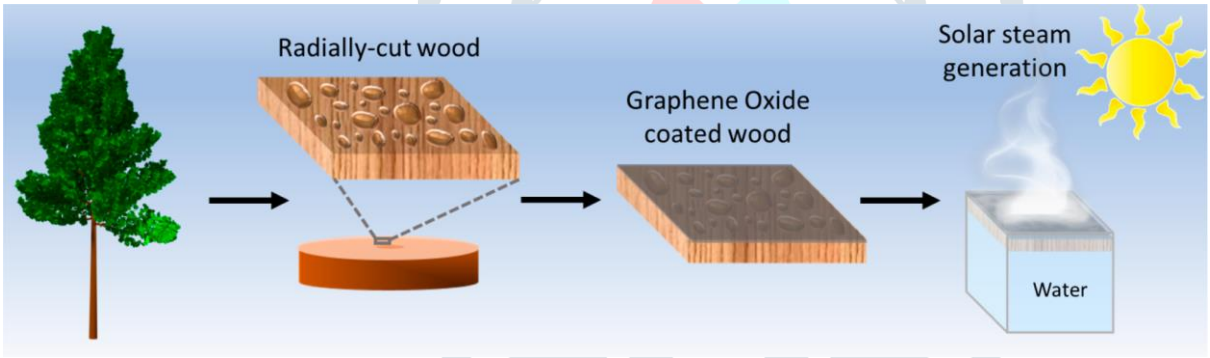

Figure 3. Illustration of Graphene Oxide deposited on wood for efficient desalination using bilayered structure.

They get thermal efficiency 83% at power 12 KW/m^2. Deposition of Graphene Oxide on wood is prepared by drop-casting aqueous Graphene Oxide solution on the surface of the radially cut wood and make Graphene Oxide solution to dry naturally. They used wood because of abundancy and natural vessel-like structure.

Dandan Hao [11] does the work related to efficient desalination in which they deposit titanium dioxide on cotton fabric, cotton fabric/ Polydopamine and cotton fabric/ Polydopamine/ Polypyrrole. Efficiency they get is 26 %, 80 % and 98% respectively at power density 1 KW/m^2. Efficiency is found by using formula $m*h_{lv}/Ei$. Where,
m is water evaporation rate, h_{lv} is enthalpy, Ei is total light power incident on the surface of the device.

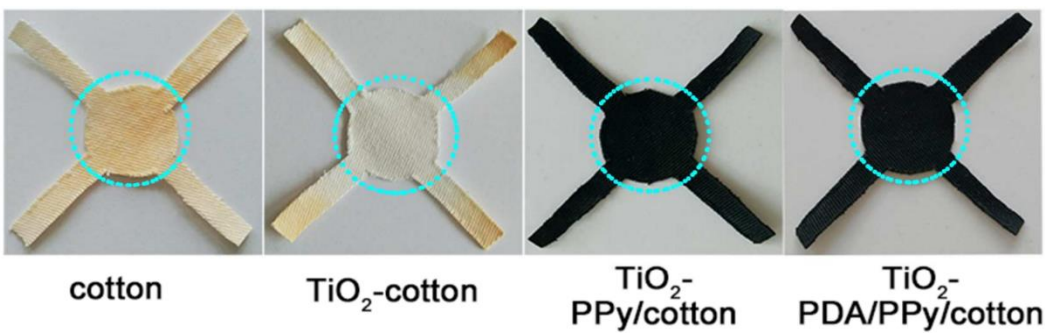

Fig. 4 Deposition of titanium dioxide on cotton [11].

Higgins [12] deposits Titanium nanorods on Carbon Fabric for getting solar desalination based freshwater. It shows 60.2% efficiency when deposited on carbon fabric.

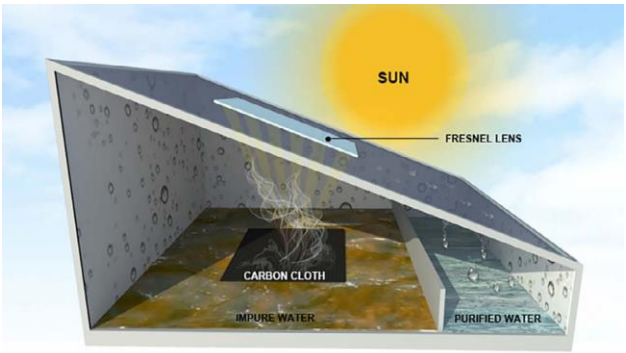

Fig. 5. Image of the carbon cloth used to get purified water [12].

Fig. 6 Formation of the hot zone and vapour generation [12]

In fig. 5 water desalination by deposition of titanium dioxide on carbon fabric, by using Fresnel lens is shown. In fig. 6 images of the formation of vapour generation and hot zone formation process is shown.

Lin Zhou [8] make an efficient aluminium is used as absorbing material at high absorption of sunlight, aluminium nanoparticles are 3D porous membrane. The resulted structure is consists of aluminium nanoparticles deposited onto porous anodic aluminium oxide substrate on surface and sides. Efficiency achieved is 60% at power density 1 KW/m^2.

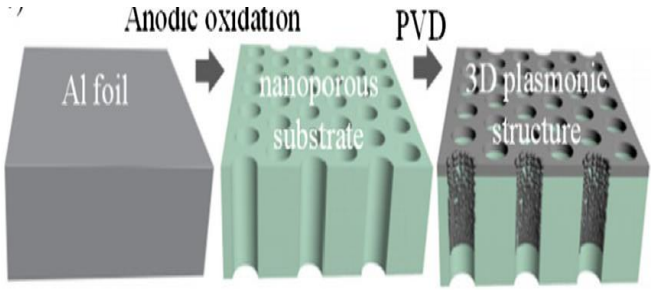

Fig. 7 The aluminium nanoparticles/AAM structure formed after the nanoparticles deposition [8]

Tian Li design [14] A solar desalination device that uses cross-plane water carried in wood via a nano-porous channel. Graphite deposited on wood by using a spray.

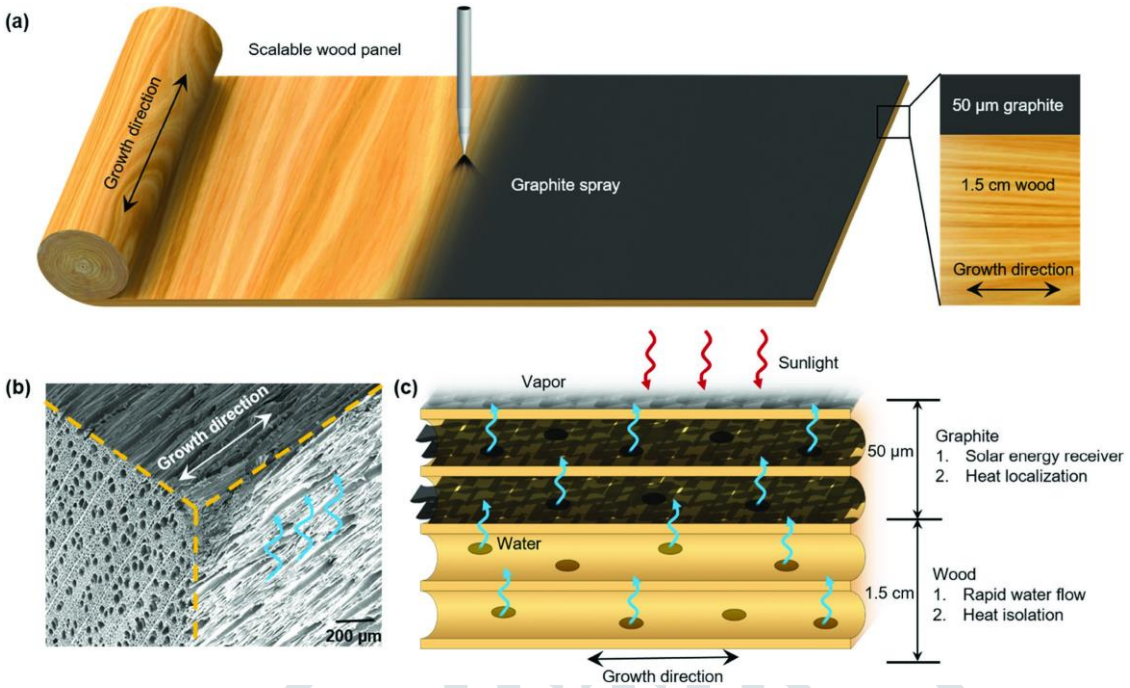

Fig. 8 a) Schematic of fabrication. b) SEM image that shows wood porosity c) Schematic diagram showing the desalination mechanism when the graphite is deposited on wood [14].

Efficiency achieved was 80 % at 1 KW/m^2. Fig. 8(a) shows deposition of graphite on wood. Fig. 8 (b) SEM image shows the wood lumens in line with the direction of growth, water transportation is best directed across the lumens to get efficient solar desalination. Fig. 8(c) shows the mechanism of vapour generation by rapid water flow to the absorber surface.

Xiuqiang Li [18] develop a desalination device made up of graphene oxide, absorber material is 4 µm thick and it is deposited on a very thin layer of cellulose of 50 µm, cellulose used to get water from water basin to the absorber by capillary action and covered on the polystyrene foam of 1.6 cm thick. This foam is acting as a thermal insulator and give support to the absorbing material.

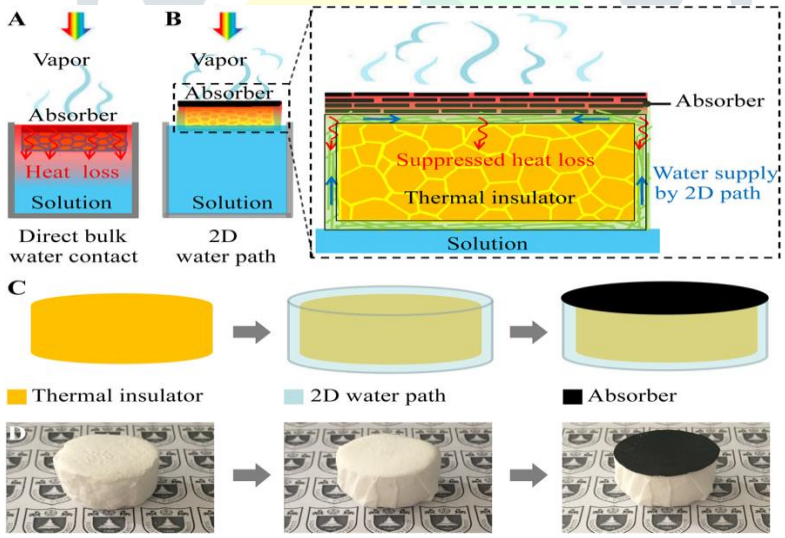

Fig. 9 (A) solar desalination with direct contact of water. (B) solar desalination devices with some heat loss. (C) The fabrication process of solar desalination device [18].

In fig. 9 (A) it is shown that due to direct water contact, heat loss to water is more. In fig. 9 (B) it is shown that due to 2D water supply heat loss is decreases. Fig. (C) shows Graphene oxide coating on polystyrene foam. The efficiency of still is 80% under one-sun illumination.

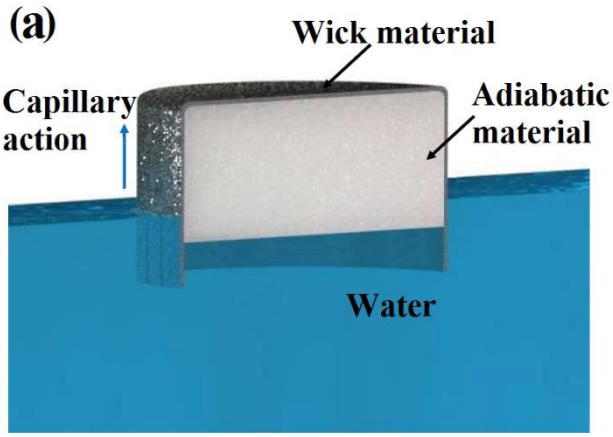

Fig. 10 (a) Diagram of evaporation [20].

Peng [20] uses some particles to get good heat transfer to surface water. Insulation material prevents the heat transfer between surface water and water in the basin. The efficiency of this solar desalination can go up to 78% when we use wick, graphite particles and polyethene.

6. CONCLUSION AND FUTURE PROSPECTS

This paper presents insights into conventional solar stills, different absorber and substrate materials used for efficient solar desalination, recently developed efficient solar desalination. Efficiency of basin type solar still and other conventional solar still is decreases as we increase water quantity, due to the heat loss to water. By localized heating of water, we can get more efficiency than conventional solar stills. By studying different desalination devices we can get an idea about heating water layer by layer and minimizes heat loss. By using titanium dioxide deposition on wood we can get more efficient and low-cost desalination device. For desalination, the structure is placed in a basin filled with water in sunlight. So, by heating of brackish water, we get water vapour which condensed on double slope glass and condensed vapour is collected. In recently developed solar stills, they did lab experiments. So, we have to apply it in the real world. Also, methods of deposition of absorber on the substrate should be investigated.

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