Evolution of solar still : A review

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KEYWORDS

Nano-Fluids,
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Heat Transfer,
Evolution,
Thermal Efficiency.

ABSTRACT

Solar still is a device which gives distilled water as a yield using solar thermal energy on a distillation of brackish water and seawater. This study discusses the results of previous efforts ratify that insulation thickness has a significant impact on the performance of the device. Also, the basin material has an ample effect on the production of distillate. Use of solar storage material in the basin increases productivity. Previous researches show that nano-fluids are widely used to enhance the evaporation rate, which increases distillate production. The results intimate that basin water level plays a significant role in the performance of still. Some modifications like installation of solar mirrors, fins, shallow solar pond, mini solar pond are done on still, which shows an increase in productivity of the device. This review paper gives an overview of the basics of solar still working, performance, and developments to enhance its efficiency.

1. Introduction

Water is an important constituent for human life. Now a time water is a fundamental human need for domestic and industrial use. As earth is covered from 71% of water, of which 97.5% being salt water and 2.5% is fresh water and only 1% is easily accessible, most of it trapped in glaciers and snowfield, only 0.007% of the whole water is available for use and to fulfil human fresh water demands. Now a time water scarcity is a global issue and due to urbanisation and industrialisation, human population had increased so demand for fresh water is also increasing day by day.

To solve this problem, Solar still water desalination technique was developed. Solar desalination is an alternative method to provide fresh water from saline sea water, brackish water. Solar stills can serve ultimate solution for providing potable water in those areas where availability of solar energy is in abundance but water quality is not up to standards. It uses solar radiation to evaporate water vapour from brackish water (waste water) which is then condensed and collected to give distilled water to be served as potable water.

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Along with fresh water as global need, energy demand is also a major issue, 80% of global energy demands are fulfilled by fossil fuel [3] which are non-renewable sources of energy, which create carbon emission issues , which leads to unexpected climate change, global warming such environmental issues rises due to use of non-renewable resources to meet global demand. Total worldwide renewable energy desalination installation amount to capacities less than 1% of that of conventional fossil fuel desalination plants. This revive us to make renewable energy as an alternate source for clean, efficient energy [4] source and so comes the solar still water desalination technique which provide fresh potable water. Solar distillation uses solar energy as a renewable source of energy which makes it eco-friendly and feasible for clean energy crises. Also, the construction material required is easily available and subtly fabricated.

Solar still has advantages like its simplicity, low installation cost, great advantage in remote areas, easy maintenance, uses zero cost solar energy, pH and other water qualities of distillate are claimed to acceptable and are under standards [1],[2]. Although the major disadvantages with solar still is its lower productivity (distillation output), time inefficient, efficient only in sunny areas. As there are many sources of fresh water like rivers, lakes, rain water, etc but in many remote areas no such sources are available, if they are available then many a time not potable, they are polluted due to direct contamination of industrial waste rivers, oceans and for rain water now called as acid rain due to air pollution. So solar distillation plant can become easy mode to provide fresh water because it is easy to setup where needed, only needed is the good amount of sunlight. Rain water harvesting can also be the one solution fresh water demand but the problem arises is of storage of water for long time, also it is not possible for individual to store rain water. So, here solar still has advantage, as it can be easily setup and have easy maintenance.

2. Historical Review

Water distillation technique has been performed for a long time to provide fresh water from saline, brackish water. Water desalination technique comes very earlier in 4th century B.C., Aristotle stated a mode in which simply water evaporates and condensed water was collected for drinking purpose water. Earliest documented work on solar distillation was done by Arab alchemist during 16th century (1551) using glass vessels. Intense heat of solar rays were used to evaporate water using wide earthen pots to collect water drop by drop in it, this experiment was performed by Della Porta, one of the exigent Scientist in solar distillation field named Giovani Batista Della Porta (1535-1615), he wrote 3 editions on desalination system, he mentioned about solar desalination in his 19th volume of second edition issued in 1589. He had described importantly about solar distillation equipment in 19th volume which gives fresh water as output from brackish water [6].

After study on basic fundamental and physical laws on solar distillation, inventors designed many apparatuses on solar desalination. First apparatus on conventional type was designed in 1872 at North Chile Las Salinas by Swedish engineer Charlos Wilson (Hay, 1973). Saline water from near saltpeter mine was used to convert it in potable water, the distillation plant was of Total Land area 7896m^2 and covered with sheets of sloping glass covers.

This plant was actuated for 40 years which gives 22.7m^3 yield of fresh water per day for

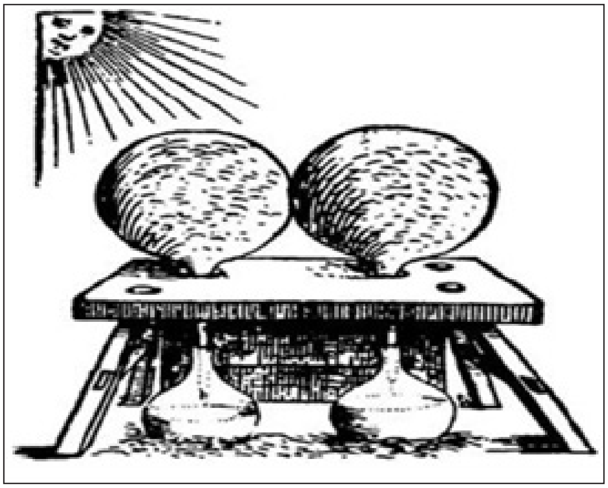

Fig. 1. The Della Porta solar distillation apparatus, as presented in his book ''Magiae Naturalis'' (Nebbia and Nebbia- Menozzi, 1966)[6].

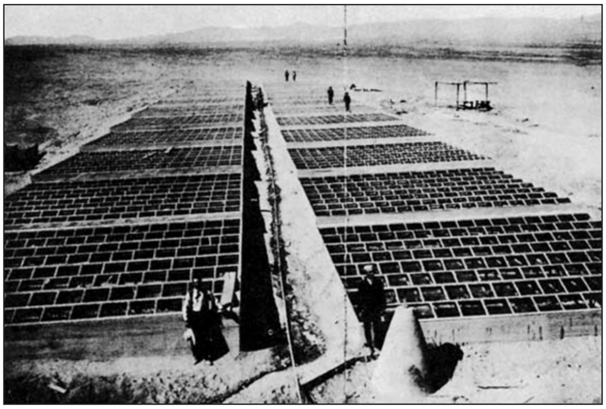

Fig. 2. The world-wide first solar distillation plant at Las Salinas [6].

the workers of mine. During 1950's, curiosity in solar distillation again revitalise to work on large centralized distillation plants. In California, the aim was to develop plants of producing capacity one million gallons of water per day. After 10 years of researchers around the world, scientists concluded that large solar distillation plants were too expensive to compete with fuel-fired ones. After that, for advancement in solar distillation, researches oriented towards small solar distillation plants. 38 plants in 14 countries of capacities ranging from a few hundred litres to around 30,000 litres of water per day were constructed in between 1960 and 1970.

3. Evolution in Solar Distillation

To enhance the productivity of solar still, time to time many researches has been performed and analysed thoroughly. In this review such developments in solar still will be illuminated.

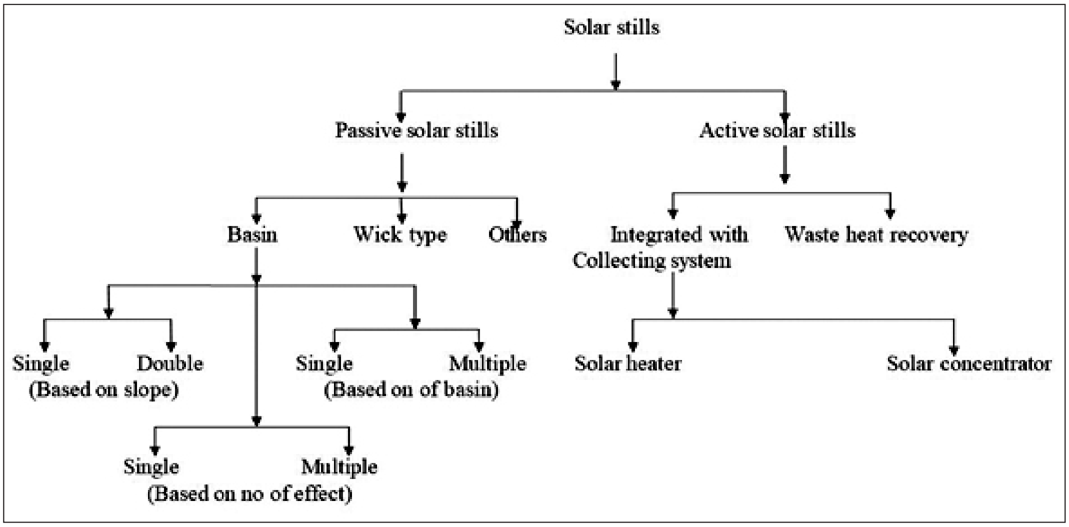

Fig. 3. Classifications of solar distillation system.

Basically, there are two types of solar stills. First one is passive solar stills and another one is active solar stills. Passive solar still has three types Basin type, wick type and others. Basin type has two type one is single Basin and another one is multiple Basin type solar stills. Active solar still has also two types one is integrated with collecting system and another one is waste heat recovery type. Integrated with collecting system has two types of still that is solar heater and solar Concentrator.

Passive solar stills are that stills which usage the direct available solar energy from for desalination of water and store it in solar stills itself while the active solar stills that type of solar stills which usage external solar energy from solar panel, solar storage etc.

3.1 Passive solar still

This simple Basin type passive solar stills are widely used in the world which is shown in figure 4.

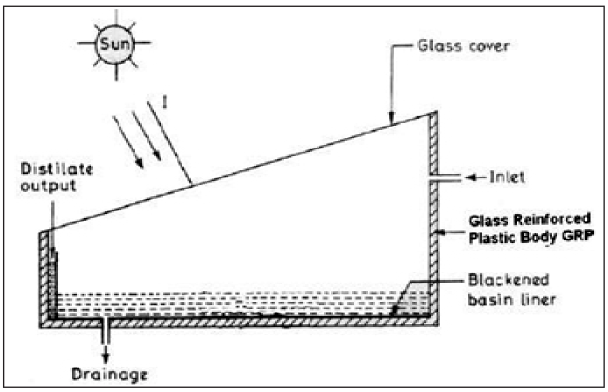

Fig. 4. Single slope single basin solar still.

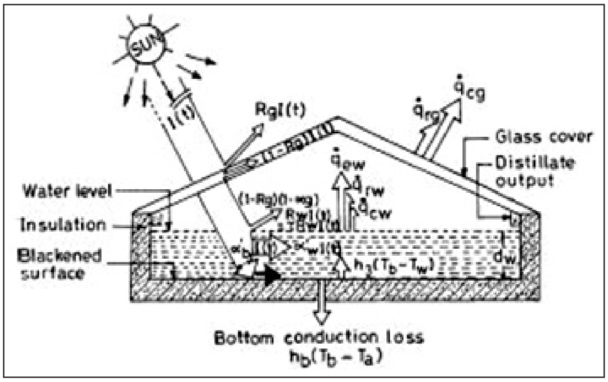

Fig. 5. Double slope single basin solar still.

These are most economical solar stills for domestic use. Design of single slop solar stills is very easy and simple. These have more longer life than others. Its maintenance cost and running cost is very less. Active solar stills are used for commercial purposes.

3.2 Multi basin solar stills

Multi Basin solar stills has more thermal efficiency in terms of daily production per square meter due to use of latent heat. A figure of multi Basin solar still is shown below.

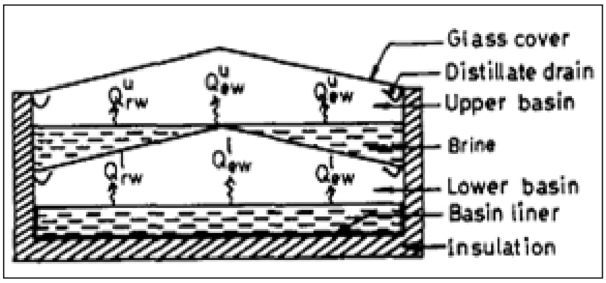

Fig. 6. Schematic of a double slope - double basin solar still.

As shown in the figure another glass sheet is fixed between the Basin liner and the glass cover. Glass sheet provides base of an extra basin for the brackish water, and whole equipment behaves as two simple Basin solar still placed one above other. Upper basin utilises the waste heat from the lower Basin.

4. Working of Solar Still

Working principle of solar still is quite simple, as like rain formation in environment. Brackish water in basin evaporates due to solar radiation, water vapours formed are then condensed on a slant glass cover, from where it drips down to side and collected in a storage tank. The salts and minerals do not evaporate with the water. The apparatus is sealed packed to minimize water leakage. Wooden frame encloses the apparatus which provides support and insulation. Inner walls of basin are painted black to absorb maximum sunlight which increases water temp. Solar still works on heating, evaporation, and condensation, therefore if solar radiation decreases, heating of water mass decreases which further reduces the evaporation rate and output of solar still. Increase in solar radiation increases the distillate output. Fig 3 shows the schematic diagram of single basin solar still. This technique can particularly use to turn seawater, brackish or contaminated water into clean safe water for drinking. Different-different modifications are done, which shows increase in productivity.

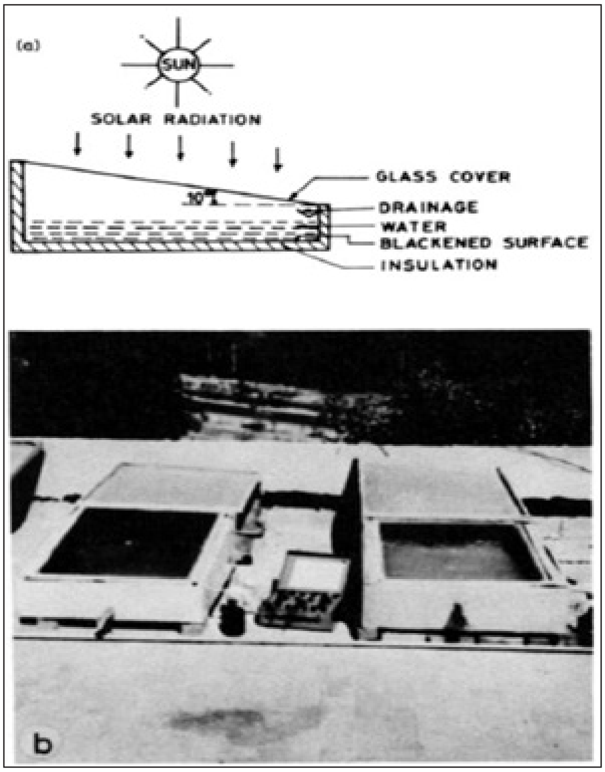

Fig. 7. (a) Schematic sketch of single basin solar stall (b) Photograph of a solar still used for the experiment [8].

5. Literature Review

Many modifications are done on solar still to improve distillate productivity. Productivity of still depends on many factors like depth of water level in Basin, Muafag Suleiman K. Tarawneh [7] in their 6 months of study shows that increase in productivity can be achieved by lowering water depth level on basin-absorbing plate. [8] G.N. Tiwari and Madhuri done experiment based on water, conclusion comes out that daily yield increase with increase in water depth at initial high (>=45^{o}C) water temperature. Also, they show in experiment that dependence of yield on water depth is a strong function of initial temperature. [9] K. Shanmugasundaram, B. Janarthanan made an attempt to analyse the performance of dual purposes single basin double slope solar still, they found that productivity of still is higher when least water depth is maintained due thermal energy stored in basin. These all experiments show that water depth plays a crucial role in productivity of still, dependency of productivity with water depth is linked with thermal storage in basin water which increases evaporation rate and hence productivity [15]. [10] Anil Kr. Tiwari, G.N. Tiwari study the performance of still at different water levels in a single slope passive type solar still, they observed out that daily distillate production was higher for lower water depth in every month throughout the year. [11] Anil Kr. Tiwari, G.N. Tiwari convective heat transfer coefficient was studied in this experiment, conclusions come out that the convective and evaporative heat transfer coefficients are important for varying water depths.

Wind velocity is also another factor in performance of solar still, as wind speed increases productivity increases because due to wind glass temperature decreases, the glass water temperature difference increases and so the productivity [12].

Now a days nano particles are widely used in solar stills to increase productivity, they are placed in basin or mixed with basin wall paint which increases heat transfer rate which further increases evaporation rate, the productivity of still was higher than that of conventional type. Cuprous oxide is one of the example for nanoparticle [13][21].

Some modification in still were done to evaluate its performance [14], packed layer glass balls covered the basin which acts like thermal storage and second modification in this experiment was using rotating shaft near the basin water level to increase evaporation rate. On applying both modification overall efficiency of system was higher than the conventional type by 5-7%.

Mugisidi, D. et al., [16] performed experimental study on effect of using iron sand in basin, study shows that the solar still containing iron sand has 1.5% higher efficiency in lower solar radiation but has lower efficiency at higher solar radiation. Basically, iron sand work as absorber which increases surface and so the evaporation rate.

Effect of insulation was also analysed [17] by Abdul Jabbar N. Khalifa*, Ahmad M. Hamood, increase in insulation thickness increases the productivity by 80%.

Mathematical model was performed by M.A.S. Malik and Van Vi Tran [18] on nocturnal output of still, outcome appear that the distillate during night depends on several factors like wind speed, ambient air temperature, initial water temperature, water depth.

Recent work on effect surface cooling was performed Fin type solar still with mini solar pond were also analysed on the basis thermal purpose as heat transfer rate is affected on using fins in basin as radiation area increases in both modifications. For fin type solar still it was estimated that there can be 45% increase in productivity in comparison to conventional type and in case of fin type with mini solar pond productivity increase is 47.5%. Modification of flat plate absorber was done in solar still basin which increases the productivity by 25%, mica plate absorber was installed in the basin which works as thermal reservoir to increase distillate [19] [20].

6. Conclusion and Future Scope

- Historical review on solar still shows that smaller plants serving communities will be the right application of this technology, establishing and operating bigger plants is quite expensive.
- Amount of distillate output depends on the amount of water vapour generated which depends on temperature difference between brackish water and glass. Wind speed and amount of solar radiation are the factors which affect temperature difference of water and glass. Productivity increase as a result of increasing of the water temperature.
- Basin water depth level in solar still significantly changes the distillate yield it performs better at lower depth of water level. This effect is more distinguishable in winter than in summer due to lower solar intensity.
- Initial temperature of brackish water is also a considerable factor in productivity of still. Yield and water depth have high dependency on initial temperature of water.
- Using nanoparticles increases the performance by 25%. Nano particles augments the heat transfer which then increases water temperature and evaporation rate to make the productivity better than conventional type.

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