A Review on various solar still designs

Manoj Kumar Gautam[1], Bhupendra Gupta[2], Jyoti Bhalavi[3]

[1]Research Scholar, M.E. (Heat Power Engineering)
[2]Assistant Professor, Department of Mechanical Engineering
[3]Assistant Professor, Department of Industrial and production Engineering
Jabalpur Engineering College, Gokalpur, Jabalpur (M.P.) - 482011, India

***Abstract*: At present pure and usable water decreasing day by day because of increasing population. A large percentage of human health is affected due to impure and saline water. Indeed, even today, immature nations and creating nations confront a gigantic water shortage in view of instrument and contamination made by manmade exercises. Without influencing the biological content we need to clean the water. Solar still is basic concept of purifying the water from impure water, in our planet solar energy is a best form of renewable energy, that utilization of sun based warm vitality, which is openly and inexhaustibly accessible. In 21stcentury we are using advance and advanced technology in every field but some territories are still remote and undeveloped where even the essential necessity of electric force is either rare or absolutely missing till date. To make clean water and provide usable water we have best alternative source of energy is a solar energy. Normally sunlight based still having low efficiency and effectiveness so that we are going to increase the con-dancing water capacity and increase the solar still efficiency in the further research**

***Keywords*: Solar still, single slope, solar still productivity, efficiency, effectiveness.**

1. INTRODUCTION

Nearly 1.1 billion individuals in this world have lacking access to safe drinking water. There are 26 nations do not have enough water to keep up agriculture and financial advancements. Rivers, lakes and groundwater reservoirs for fresh water requirement are going to be depleted. Most of the diseases are due to brackish water [1]. According to a survey, 79% of the water available on the surface of earth is salty and in the form of sea water. 20% of the water available is brackish and only one percent of water is available as the fresh and drinkable water [2]. Distillation is a technique to convert brackish or impure water into fresh and drinkable water. Some of the conventional distillation processes such as Multi-effect evaporation, thin film distillation, Multi-stage flash evaporation, reverse osmosis and electrolysis are the most feasible solution for large water requirements [3]. Solar still is an easy technique for distilling water which utilizes the low cost available solar energy. It is widely used to produce potable water [4].
The aim of this paper here is to reveal the various past works over enhancement in productivity of a single slope single basin solar still. In this paper, most of the parameters affecting the performance of solar still are discussed with their results for future work.

2. TYPES OF SOLAR STILLS

Solar still is possibly the oldest method of desalination of water. Its principle of operation is the greenhouse effect; the radiation from the sun evaporates water inside a closed glass covered chamber at a temperature higher than the ambient.

2.1 Passive Solar Stills

In a passive still the distillation takes place purely by direct sun light. The Figures bellow depicts various types of passive solar stills. The single slope and double slope solar stills are the conventional low temperature solar stills, operating at a temperature below 60oC. Of the above two, single slope solar still is more versatile and efficient.

2.2 Active Solar Stills

In an active solar still, an extra thermal energy is fed to the water in the basin to create a faster rate of evaporation. To increase the evaporation rate in an active mode the extra thermal energy is fed into the basin. To increase the productivity of solar still, the various active methods are being carried out by many researchers. Most of the works were based on the flat plate collector and concentrating collector. A broad classification of the solar stills is depicted in the table: Further the active solar stills are classified as:

- High temperature distillation solar stills: hot water is fed into the basin from a solar collector panel.
- Pre-heated water application solar stills: hot water is fed into the basin at a constant flow rate.
- Nocturnal production solar stills: hot water is fed into the basin once in a day.

2.3 Vertical solar stills with a flat plate solar collector: The distillation unit consists of 'n' parallel vertical plates. The first plate is insulated on its front side and the last plate is exposed to ambient. Each plate in the enclosure is covered with wetted cloth on one side. The cloth is extended into a feed through along the upper edge of each plate. Feed water in the through is then drawn onto the plate surface by capillary. Excess water moves down the plate and is conducted out of the still. The last plate is cooled by air or water.

2.4 Solar still integrated with mini solar pond: Solar pond is an artificially constructed pond in which significant temperature rises are caused to occur in the lower regions by preventing convection. Solar ponds are used for collection and storage of solar energy and it is used for various thermal applications like green house heating, process heat in dairy plants, power production and desalination. A mini solar pond connected to the stills to enhance the productivity and tested individually. The results show that, maximum productivity of 100% was obtained when the fin type solar still was integrated with pebble and sponge.

2.5 Basin type solar still: Such solar stills have been operated for farm and community use in several countries. It consists of a blackened basin containing saline water at a shallow depth, over which is a transparent air tight cover that encloses completely the space above the basin. It has a roof-like shape. Impure water in the basin or tray is heated and the vapor produced is condensed to purified water on the cooler interior of the roof. The cover which is usually glass, may be of plastic is sloped towards a collection trough. Solar radiation passes through the cover and is absorbed and converted into heat in the black surface.

3. MINIMUM WORK OF SEPARATION

From the viewpoint of thermodynamics, desalination is a work-driven process that undoes the irreversible mixing of salts into water. This separation process requires the least amount SOLAR DESALINATION 285 of work when it can be done reversibly and uses greater amounts of work when the separation process generates entropy through thermal or mechanical irreversibility. A benchmark in the design or assessment of any desalination process is therefore to determine the least, or reversible, work that will be required to remove some percentage of the water from a saline source.

4. DESIGN PARAMETERS

4.1 Single- and double-sloped solar stills

An extra basin was added to the established single-basin for the purpose of increasing the performance of the double-sloped solar still. It was discovered that this addition prompted a productivity increase of almost 85% as compared to its single basin counterpart operating under similar circumstances.

4.2. Water depth

The results positively showed output decrease as the depth of water in the basin increases. In the case of an active solar distillation system, more outputs were obtained compared to the passive solar still, due to the high temperature difference between the water and the internal glass cover temperatures in the active mode.

4.3 Effect of Angle of Cover Inclination on the Yield of a Single Basin Solar Still

Having observed the performance of stills with different angles of inclination, it can be partially established that the optimal still cover inclination for Makurdi location is higher than 150 as indicated by the characteristic volume/efficiency versus inclination of cover trend lines. It is a partial conclusion because a more rigorous work with larger angles of inclination. The trend lines also indicate that for 00 angle of inclination, the still can have an efficiency of about 0.461 with an output of 48.4 cm^3.

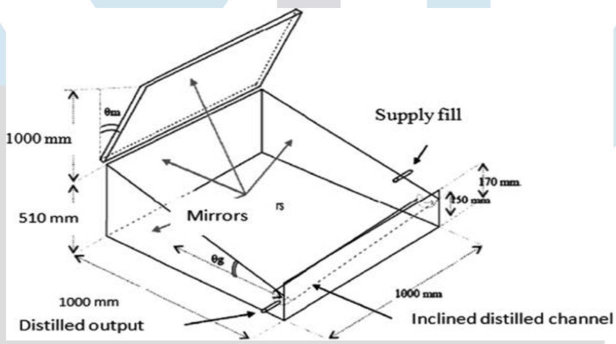

Fig.1 .Schematic diagram of the basin-type solar still.

The parameters that affect the yield of fresh water and efficiency are:

- Tilt angle of cover plate
- Depth of water
- Feed water flow rate
- Cover plate temperature
- Convective heat transfer from cover plate and side walls
- Design of structures and shapes
- Solar tracking
- Coating
- External enhancement like heat pipe, coolers

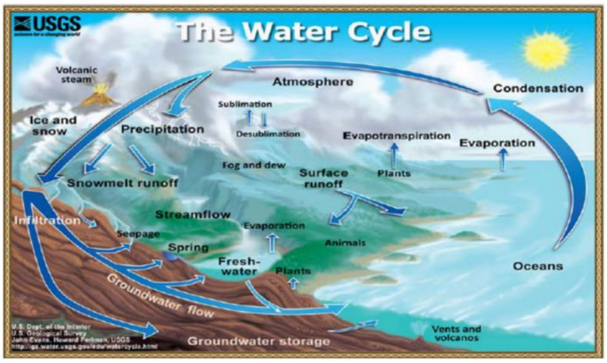

Fig. 2 Principle of hydrological cycle (http://water.usgs.gov/edu/watercycle.html)

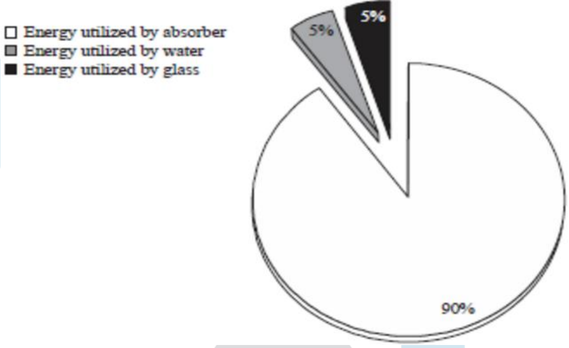

Fig. 3 Energy utilization of solar still (Sathya murthy et al., 2015a)

Many researchers have conducted solar still performance evaluation based on the above said parameters and these results are discussed in the following sections.

Single Basin Solar Still Concave Wick Solar Still: Kabeel (2009) investigated experimentally on the performance of a concave wick type solar still where the basin is made in the shape of concave structure with cover on four sides, which can be seen in Fig. 4. Steel frame support the pyramidal glass surface and a black cloth in kept inside the surface for better evaporation of saline water. Experimental studies concluded that the water temperature is less than the wick temperature, which the wicks absorbing emissive power creating a driving force on evaporation of water. Solar still efficiency improved by 50% than conventional single slope solar still, where the condensing and evaporation area of present model is more than basin area. Typically the total yield from the solar still was found as 4.1 kg m–2. More over the spacious area and insulation thickness is reduced by 50% in case of concave basin of solar still.

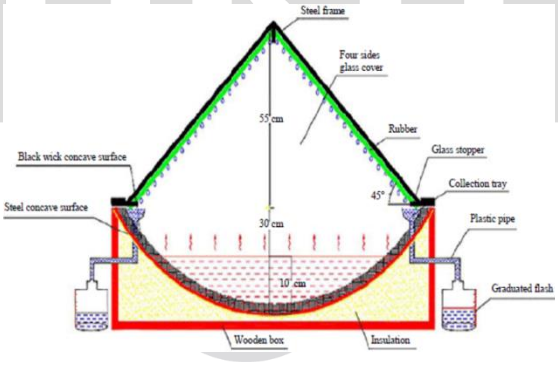

Fig. 4.Schematic diagram of a concave wick solar still (Kabeel, 2009)

Hemispherical solar still: Figure 5 shows the schematic diagram of a hemispherical dome cover solar still. Driving force is the important phenomenon on fresh water yield as it is a parameter of temperature difference between water and glass. The yield of solar still not only depends on glass water temperature difference, also it depends on wind velocity, ambient temperature and cover temperature. Arun Kumar et al. (2012) investigated a hemispherical cover solar still with and without cooling medium. From their study the effect of cooling the surface of cover improved the efficiency from 34-42% with a fixed flow rate of water as cooling medium at 10 ML min–1 on the entire surface. Also, the effect shows that the yield improved by 1.25 times than without cooling.

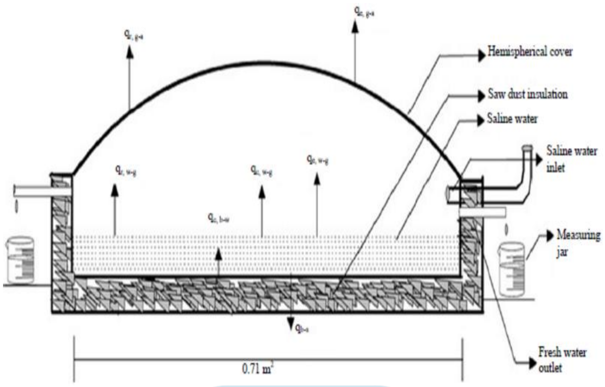

Fig.5 Schematic diagram of hemispherical solar still (Arunkumar et al., 2012)

The average output with and without cooling is found as 4.2 and 3.5 L m–2 day–1, respectively. The improvement in yield is due to dome shaped cover instead of flat plate cover. Also, the area of aperture area is more for incident radiation, whereas from conventional still shadow effect is more.

Inverted absorber solar still: Figure 6 shows a single basin inverted absorber solar still. In either way heat input to the solar still can be given which was proposed by G.N. Tiwari. Tiwari and Suneja (1998) and Dev et al. (2011) experimentally investigated the effect of reflecting the solar radiation through the bottom of the absorber. The yield of inverted absorber increases by two times than conventional solar still yield.

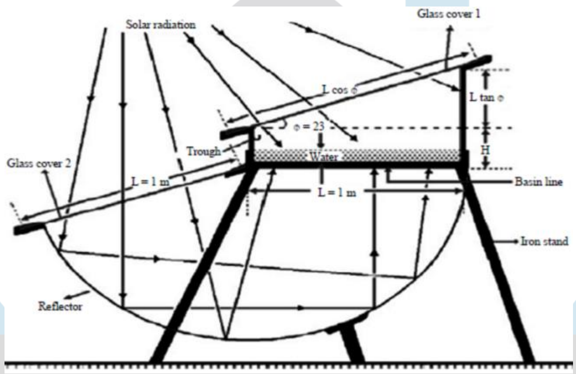

Fig. 6.Schematic diagram of an inverted absorber solar still (Dev and Tiwari, 2011)

Other parameters such as multiple basins, water depth and effect of wind velocity are also discussed. While analyzing different water mass the evaporative heat transfer is higher at minimum water mass. Due to the higher water depth inside the basin, water could not able to heat up to a higher temperature. The yield of solar still drops from 5.2-3.5 kg m–2day–1 for 0.01-0.1 m, respectively. Dev and Tiwari (2011) theoretically and experimentally derived the characteristics of an inverted absorber and single slope conventional solar still. The results showed that the instantaneous gain and loss in efficiency and distillate are similar to the previous model while the depth of water maintained at 0.01 m.
Tiwari and Suneja (1998) investigated the performance of solar still and arrived to a conclusion that there is an increase in temperature of water in the absorber due to the reduction of heat loss from absorber and increased value of absorptivity. The depth of water is an important parameter for the water temperature and it is increased by decreasing the water depth in the basin which simultaneously increases the evaporative heat transfer. As the water depth increase from 0.08-0.1 m there was no significant improvement in the convective and radiative heat transfer coefficient.

Pyramid single basin solar still: Taamneh (2012) experimentally studied a pyramid solar still under forced and natural convection. Experiments are carried out in Tafila city (Jordan) and performance of solar still with and without fan show that the reduced temperature of glass increases the condensation with larger temperature difference. The solar still yield during mid-noon on experimental day with and without fan found to be 0.4 and 0.35 kg m–2h–1, respectively and the maximum efficiency of the solar still was increased from 40-50% with fan as cooling. Hence, with the help of a solar PV assisted fan cools the surface areas of the glass for better condensation of vapor.

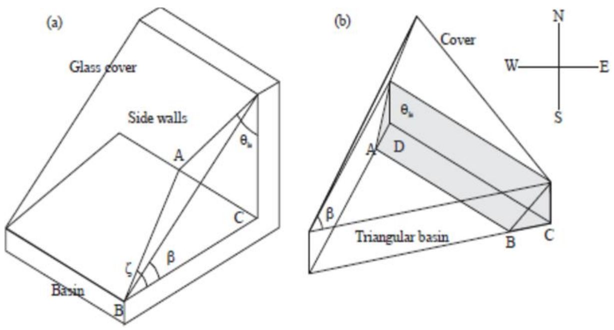

Fig. 7.Schematic diagram of a triangular pyramid solar still (Sathyamurthy et al., 2014c)

Nagarajan et al. (2014b) conducted a detailed review about the solar collectors using nano fluids in solar thermal applications. Nagarajan et.al.(2014a) and Sathyamurthy et al. (2014a) investigated the performance of a triangular pyramid solar still as shown in Fig. 7. The results showed that the yield from solar still is higher and for a least water mass of dw = 2 cm it was found as 4.2 kg m–2 day–1.The convective and evaporative heat transfer from the solar still is equal to the Duckle's prediction and the solar radiation follows the similar curve of water temperature. This proves that the water temperature is directly proportional to solar radiation. The water temperature throughout the basin is equally maintained and this is due to the reduction of shadow of side walls falling in the solar still. On the economic and space constraints the new model is more efficient for 75 and 50%, respectively than a conventional solar still.

Spherical solar still: A schematic diagram of a spherical solar still is shown in Fig. 9. Saline water from the storage tank is fed into the absorber which is placed inside the spherical shaped cover through which the solar radiation is transmitted to evaporate the saline water. The major advantage of the solar still is from all the direction the radiation is transmitted and the thermal equilibrium of water is maintained for evaporation. Dhiman (1988) analysed a spherical solar still on the thermal performance and results have showed that the efficiency of solar still is increased by 30% than the conventional solar still.

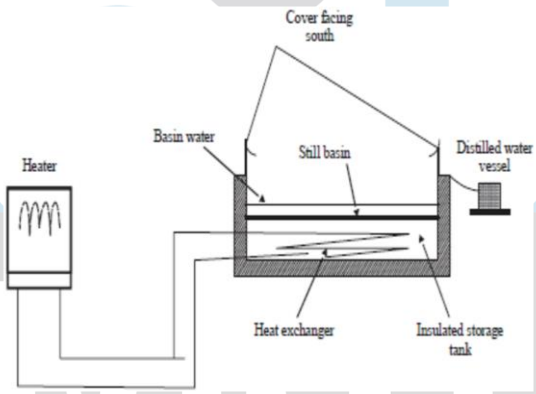

Fig. 8.Schematic diagram of solar still integrated with a heater (Voropoulos et al., 2003b)

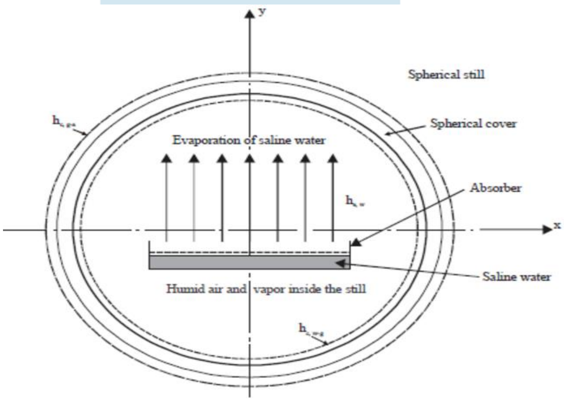

Fig. 9.Schematic diagram of spherical solar still

Transportable hemispherical solar still: Ismail (2009) reported that a transportable hemispherical solar still typically produces between 2.8-5.7 L m–2 day. The average efficiency of solar still reached a maximum of 33%, further there is a efficiency decreased by 8% when the depth of water increased by 50%. Figure 10 shows a simple transportable hemispherical solar still. Also, the daily efficiency decreased linearly as the depth of water increased.

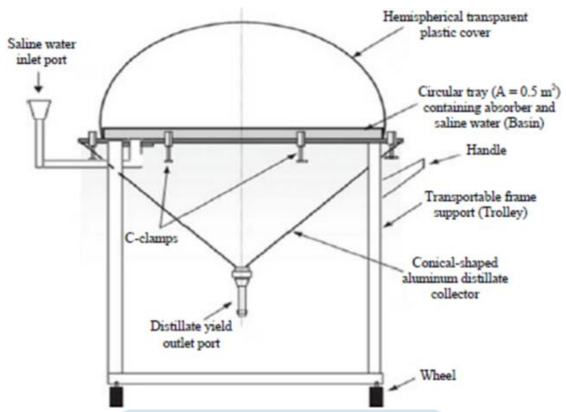

Fig. 10.Schematic diagram of transportable hemispherical solar still (Ismail, 2009)

Tubular solar still: A simple mechanism of a tubular solar still is shown in the Fig. 11, where it usually consisting of transparent cylindrical tube in which a rectangular absorber is placed. The solar intensity is transmitted through the cover reaching the absorber and heat up the water. The water evaporated in the inner surface forming a thin film and rejects its latent heat for condensing. Due to gravity, the condensed water slides through the inner surface of cover and get accumulated in the calibrated flask.

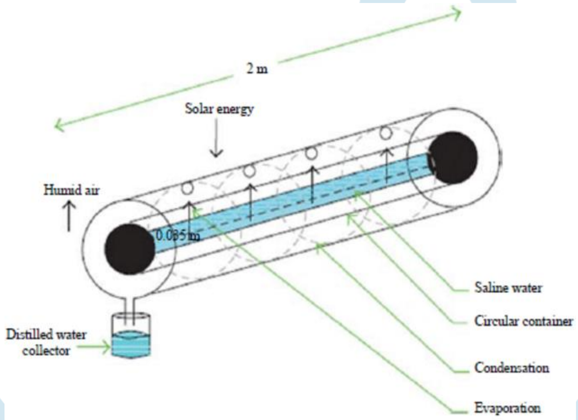

Fig. 11 Schematic diagram of tubular solar still

Double basin solar still: Figure 13 shows a schematic diagram of a double basin solar still. Cappelletti (2002) experimentally investigated a double basin solar still. In the shape of "V" the second basin is separated from the lower basin through which the horizontal trays are kept inside. The water evaporated in the lower part of the basin gets condensed in the "V" basin. The condensed water trickles down to the center were the distillate collector placed. Due to the lower temperature in the bottom basin the maximum efficiency of the still is found as 16%. Al-Hinai et al. (2002) experimentally investigated a shallow water solar basin with asphalt as coating material.

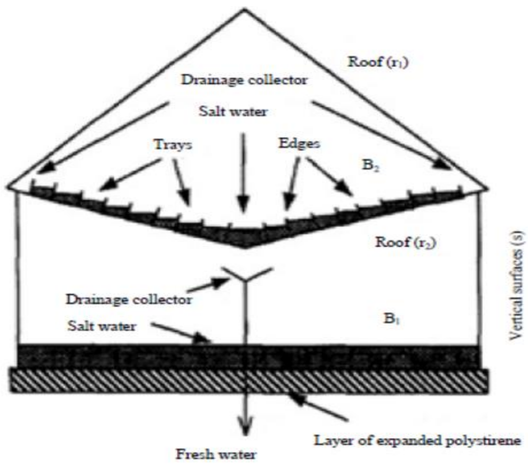

Fig. 13 Schematic diagram of double basin solar still (Cappelletti, 2002)

Inverted absorber double and triple basin solar still: The effect of number of basin and water depth in multi basin inverted absorber still (Fig. 14) was theoretically and experimentally determined by Suneja and Tiwari (1999a). The results agree that, the increase in water depth on the lower basin increase the daily yield of fresh water. Figure 15 shows the simple inverted absorber triple basin solar still. The daily yield of inverted absorber triple basin solar still is higher while comparing it with conventional still and increase in depth of water in the basin yield is lower. At a water depth of 0.02 m the yield was 11.5 kg m^{-2} and keeps on decreasing when the depth of water increased.

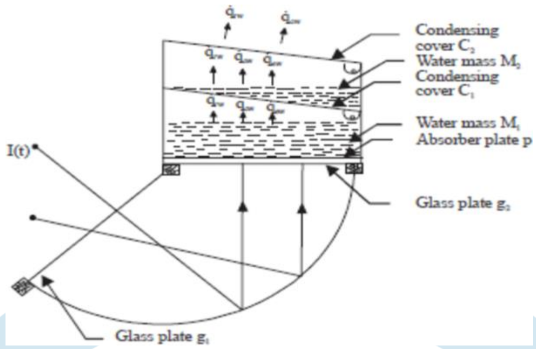

Fig. 14 Schematic diagram of inverted absorber double basin solar still (Suneja and Tiwari, 1999b)

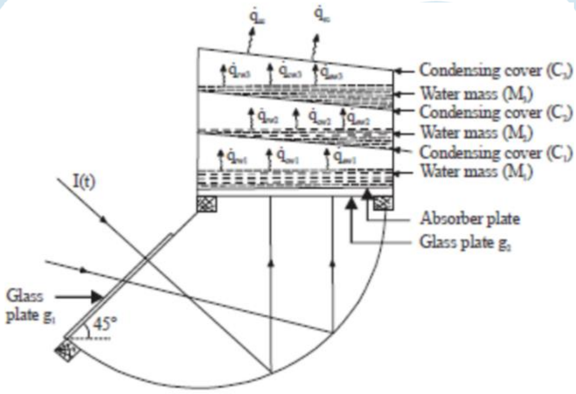

Fig. 15 Schematic diagram of inverted absorber triple basin solar still (Suneja and Tiwari, 1999a)

A comparative analysis has been carried out to analyse the performance of single and double effect. Results shows that an average yield of 4.15 and 6 kg m–1 day–1 for single effect and double effect solar still respectively.

Pyramid multi basin solar still: Figure 16 showing the schematic diagram of a triple basin pyramid solar still. Hamdan et al. (1999) experimentally carried out the performance of triple basin pyramid solar still. It was found that the yield of solar still is improved by 24% which is higher than that of single basin.

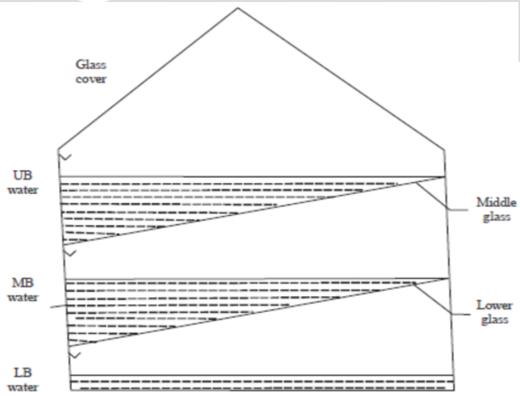

Fig. 16 Schematic diagram of pyramid triple basin solar still (Hamdan et al., 1999)

Furthermore, the solar still efficiency was 44% in the case of triple basin still and 42% in the case of double basin (Sodha et al., 1981), while it for a single basin is 32% (Murugavel et al., 2008).Pyramidal solar still are the next evolutionary solar still, which is discussed by Kabeel (2007). A multi shelve pyramidal solar still is shown in Fig. 17. Two identical solar still with distance between each shelves 30 cm are fabricated. Each solar still with bed material as saw wood and cloth material are placed in the shelves. The glass can be opened and during the night hours the moisture can be absorbed by the absorbing materials.

The results showed that the area of the upper basin is lesser than the lower consecutive shelves and hence the temperature from the upper layer is higher and gradually decreasing. Also, it reports that the use of cloth as absorbing material increases the productivity by 3.2% than wood saw and the maximum productivity during the mid-noon found to be 0.45 and 0.38 kg m–2 h–1 for cloth bed and saw wood respectively. This is due to that cloth material evaporates and absorbs the solution and porosity level is higher in the case than saw wood. Recommendations discuss that the better absorbing material and distance between each shelves improves the productivity of fresh water.
Tiwari et al. (1985) investigated a double effect single slope solar still as shown in Fig.It is concluded that the yield of fresh water depends on the lower basin water mass and the decrease in the water mass yield is more while during the absence of solar radiation the effect is reduced. For an higher water mass the yield is lower and during the absence of solar radiation the energy stored in the salt water is released and hence there is no discontinuous distillation,Continuous or intermittent flow of water on the glass surface is another method of improving the yield, which creates a larger driving force by taking away the heat from the vapor in the internal surface. The water takes away the heat from the surface by gaining the heat and water is restored in the basin by regenerating the heat. The results of Abu-Hijleh and Mousa (1997), Abu-Arabi et al. (2002) and Abu-Hijleh (1996) show that the flow of water over the cover increases the production rate by 20%. The utilization of flowing heat energy from the cover increases the productivity and produces an additional effect. Regenerative still with minimum water depth increase the productivity.

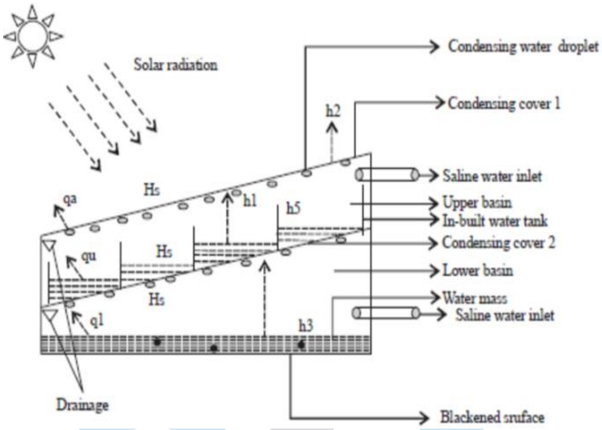

Fig. 17: Schematic diagram of single slope double basin solar still

Triple basin solar still: El-Sebaii (2005) analytically studied the thermal performance of triple basin solar still. Balancing of energy is analytically solved using elimination technique.

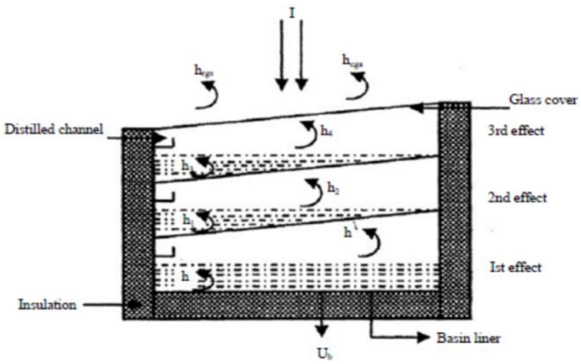

Fig. 18: Schematic diagram of triple basin solar still (El-Sebaii, 2005)

The results showed that, for a triple basin solar still the productivity of water is higher in the lower basin than that of the middle The depth of water in the lower basin is higher in order to store the energy. As the depth of water Daily yield of water is maximum with least water depth in the middle and upper basin.
increases the yield from the solar still becomes less dependent on specific heat capacities of water. The daily productivity of water increases with an increase in the velocity of wind. For a triple basin the results indicate daily yield from solar still is 12.635 kg m–1 day–1 with an average intensity of 651 W m.

Table 1: Existing research work and different process parameters

S.no.	Authors name	Type of solar still	Output parameters	Analysis type
1.	Kabeel (2009)	Single Basin Solar still Concave Wick Solar Still	Solar still efficiency improved by 50% than conventional single slope solar still.	Experimental analysis
2.	Arun Kumar (2012)	Hemispherical solar still	Yield improved by 1.25 times than without cooling	Experimental analysis
3.	G.N. Tiwari. Tiwari and Suneja (1998)	Inverted absorber solar still	The yield of inverted absorber increases by two times than conventional solar still yield	Experimental analysis
4.	Nagarajan (2014)	Triangular pyramid solar still	Yield from solar still is higher and for a least water mass of dw = 2 cm it was found as 4.2 kg m–2 day–1	Experimental analysis
5.	Dhiman (1988)	Spherical solar still	Efficiency of solar still is increased by 30% than the conventional solar still.	Experimental analysis
6.	Ismail (2009)	Transportable hemispherical solar still	Efficiency decreased by 8% when the depth of water increased by 50%	Experimental analysis
7.	Ahsan and Fukuhara (2009, 2010)	Tubular solar still	Economic viability of the new tubular solar still has reduced from 92-61%	Experimental analysis
8.	Cappelletti (2002)	Double basin solar still	Due to the lower temperature in the bottom basin the maximum efficiency of the still is found as 16%	Experimental analysis
9.	Suneja and Tiwari (1999)	Inverted absorber double and triple basin solar still	Average yield of 4.15 and 6 kg m–1 day–1 for single effect and double effect solar still	Experimental analysis
10.	Hamdan (1999)	Pyramid multi basin solar still	Yield of solar still is improved by 24% which is higher than that of single basin	Experimental analysis
11.	Tiwari (1985)	Single slope double basin solar still	Increases the production rate by 20%	Experimental analysis
12.	El-Sebaii (2005)	Triple basin solar still	For a triple basin solar still the productivity of water is higher in the lower basin than that of the middle	Analytical Analysis

5. CONCLUSION

Many solar stills have been studied in detail in this review covering all the aspects of design specifications. Also the effect of design and operating parameters on the distillate productivity of various stills has been presented. Write about design of solar still following conclusions may be drawn. Maximum yield was achieved using the least water depth. Lower thickness glass cover is preferred compared with higher thickness glass cover. Feed water temperature and quality can also affect output. The greatest enhancement to solar still performance is obtained using multi-effect and active concepts. Two main bottlenecks to the output are the solar energy collection for evaporation and the dissipation of heat for condensation. Many types of solar energy collector can be used to enhance performance, including flat plate collectors, evacuated tubes ,and solar ponds Particularly promising among these is solar still with solar pond which enhances the productivity by about 80% over the conventional stills. Typically such active concepts require pumps and/or fans, which may use electricity, adding to expense and complexity.

REFERENCES

[1] A. Bhatacharyya, *"Solar still for desalination of water in rural house hold,"* International Journal of Environment and Sustain ability, vol. 2, no. 1, pp. 21-30, 2013.

[2] D. B. Gupta, T. K. Mandraha, P. J. Edla and M. Pandya, *"Thermal Modeling and efficiency of solar water desalination: A review,"* "American Journal of Engineering and Science, vol. 2, no. 12, pp. 203-213, 2013.

[3] R. S. Hansen, C. S. Narayanan and K. K. Murugavel, *"Performance Analysis of Inclined Solar Still with Different New Wick Material and Wire Mesh,"* Desalination, vol. 358, pp. 1-8, 2015.

[4] B. A. Akash, M. S. Mohsen and W. Nayfeh, *"Experimental study of the basin type solar still under local climate condition,"* Energy Conservation & Management, vol. 41, pp. 883-890, 2000.
[5] B. Zala, K. Dodia and H. N Panchal, *"Present Status of Solar Still: A Critical Review,"* International Journal of Research Review in Engineering Science 7 Technology, vol. 2, 2013.
[6] M. K. Phadatre and S. K. Verma, *"Influence of water depth on internal heat and mass transfer in a plastic solar still,"* Desalination, vol. 217, pp.267-275, 2007.
[7] H. N. Singh and G. N. Tiwari, *"Monthly Performance of Passive and Active Stills for Different Indian Climate Conditions,"* Desalination, vol. 168, pp. 145-150, 2004.
[8] Edoeja, A. Okibe, Unom and Fadoo, *"Investigation of the Effect of Angle of Cover Inclination on the Yield of a Single Basin Solar Still under Makurdi Climate,"* The International Journal of Engineering and Science, vol. 2, pp. 131-138, 2013.
[9] N. Singh, *"Performance Analysis of Single Slope Solar Still at Different Inclination Angle: An Indoor Simulation,"* International Journal of Current Engineering & Technology, vol. 3, 2013.
[10] T. Elango, A. Kannnan and K. K. Murugavel, *"Performance study on single basin single slope solar still with different water Nano fluids,"*Desalination, vol. 360, pp. 45-51, 2015.
[11] M. K. Sain and G. Kumawat, *"Performance enhancement of single slope solar still using nano particles mixed with black paint,"* Advanced Nano science and Technology, vol. 1, 2015.
[12] D. S. S. Priya and U. I. Mahadi, *"Effect of different absorbing materials on solar distillation under the climate condition of manipal,* "International Journal of Application or Innovation in Engineering & Management, vol. 2, 2013.
[13] A. Ahsan, M. Imteaz, U. A. Thomas, M. Azmi, A. Rahman and N. N. N.Daud, *"Parameters affecting the performance of a low cost solar still,* "Applied Energy, vol. 114, pp. 924-930, 2014.
[14] A. M. Burbano, "*Evaluation of basin and insulation materials in solar still prototype,"* International Conference on Renewable Energies and Power Quality, vol. 12, 2014.
[15] A. Y. Hasim, J. M. Al-Asadi and W. A. Taha, *"Experimental Investigation of Symmetrical Double Slope Single Basin Solar Stills Productivity with Different Insulation,"* Journal of Kufa, vol. 1, 2009.
[16] V. Velmurugan, S. S. Kumaran, V. N. Prabhu and K. Shrithar, *"Productivity Enhancement of Stepped Solar Still-Performance Analysis,"* Thermal Science, vol. 12, no. 3, pp. 153-163, 2008.
[17] T. Arun kumar, K. Vinoth kumar, A. Ahsan, R. Jayaprakash and S. Kumar, *"Experimental Study on Solar Still Design,"* International Scholar Research Network, vol. 2012.
[18] M. K. Gnanadason, P. S. Kumar, V. H. Wilson, A. Kumarvel and B.Jebadason, *"Comparison of Performance Analysis Between Single Basin Solar Still Made up of Copper and GI,"* International Journal of Innovative Research in Science, Engineering & Technology, vol. 2, no. 7,2013.
[19] A. E. Kabeel, Z. M. Omara and F. A. Essa, *"Enhancement of Modified Solar Still Integrated with External Condensor using Nano fluids,* "International Water Technology Conference, 2013.
[20] R. Kannan, C. Selvaganson, M. Vignesh, R. R. Babu, M. Fuentes, M.Vivar, I. Skryabin and K. Shrithar, *"Solar Still with Vapour Absorption Basin,"* Renewable Energy, vol. 62, pp. 258-264, 2014.
[21] Abu-Arabi, M., Y. Zurigat, H. Al-Hinai and S. Al-Hiddabi. "*Modeling and performance analysis of a solar desalination unit with double-glass cover cooling."* Desalination, 143: 173-182. 2002
[22] Kumar, P.V., A. Kumar, O. Prakash and A.K. Kaviti, *"Solar stills system design: A review. Sustain. Energy"* Rev., 51: 153-181. 2015
[23] Sampath kumar, K. and P. Senthil kumar. *Utilization of solar water heater in a single basin solar still: An experimental study.* Desalination, 297: 8-19. 2012
[24] Sathyamurthy, R., D.G.H. Samuel and P.K. Nagarajan. "*Theoretical analysis of inclined solar still with baffle plates for improving the fresh water yield*." Process Safety Environ. Protection, (In Press). 10.1016/j.psep.2015.08.010 2015
[25] Sodha, M.S., A. Kumar, U. Singh and G.N. Tiwari. "*Further studies on double solar still"*. Int. J. Energy Res., 5: 341-352. 1981
[26] Suneja, S. and G.N. Tiwari. "*Effect of water depth on the performance of an inverted absorber double basin solar still."* Energy Convers. Manage. 40: 1885-1897, 1999.
[27] Taamneh, Y. and M.M. Taamneh. "*Performance of pyramid-shaped solar still:* Experimental study." Desalination, 291: 65-68. 2012
[28] Tiwari, G.N., S.K. Singh and V.P. Bhatnagar. "*Analytical thermal modeling of multi-basin solar still"*. Energy Convers. Manage. 34: 1261-1266. 1993
[29] Voropoulos, K., E. Mathioulakis and V. Belessiotis. "*Solar stills coupled with solar collectors and storage tank": Analytical simulation and experimental validation of energy behavior.* Solar Energy, 75: 199-205. 2003