iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** IV **Month of publication:** April 2025

DOI: https://doi.org/10.22214/ijraset.2025.67719

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Application and Development in Solar Stills: A Review

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Abstract: ***One-third of the Earth is covered by the sea water, yet there is a constant lack of water in many places. 97% of the water is present in the sea as saltwater, only 3% water is potable, out of which only 1% clean water reaches to the people. Therefore, a device is needed that can convert saltwater into clean water. Solar still is a sustainable device, through which dirty and salt water can be converted into clear water. Due to the very low productivity of conventional solar still; it is not popular in the market. Increasing the productivity of conventional solar still is a major challenge for researchers. Researchers are continuously working on the performance of solar still to increase its productivity. In present paper studies the modifications and designs made by researchers in solar still over the last 10 years. In which PCM, nanoparticles, reflectors, collectors, external condenser, wick material and differential angle based solar still have been studies and applications of distilled water produce by solar still have been also covered.***

Keywords: Solar Still, Distilled Water, Active Solar Still, Passive Solar Still,

I. INTRODUCTION

Water is a necessary component for the animal and humans life. 71% of the Earth surface is covered with water. Out of 97% is present in the oceans and seas, which is salty and cannot be used for drinking purpose.Only 3% potable water is available for drinking, of which 2% is placed in glaciers in the North and South Pole and rest of 1%is available in rivers, lakes, ponds and ground water so it is required to such a device which converts the saline water in portable water. As the population is increases the demand for potable water is also increases.

There are various types of water purifier devices are available in the market, but all are operated through the electricity, which are not environment friendly. Hence a device is needed which operate by the renewable energy and able to produce fresh water at low cost. Solar still is a sustainable device using direct solar radiation to purify impure and saline water[1]. Due to the low production rate solar still is not popular in the market.

As the population growth is increases the demand of clean water is also increasing, but the production rate of solar still(SS) is very low, so it is not used on large scale. Therefore, several methods are constantly being used by researchers to increase the productivity of SSs. The classifications of solar still are given in Fig.1. Solar still is categories in two sections first passive solar still and another is active solar still. When solar still is operated on natural mode that type of solar still is called passive solar still and when an external device is use to heat the basin water it is comes in the active solar still. The passive and active solar still is also divided into two parts single slope and double slope. Only one inclined condensing cover is consisting in the single slope solar still and in the double slope solar still two glass covers are installed.

How to increase the productivity of SS, parameters effected on the performance of SS and heat transfer of SS have been intensively studied by many researchers, as well as various types of modification have been made which can increase the productivity of SSs.

A comprehensive review has been prepared by Panchal and Mohan [2], they studied about the performance of fins, heat storage material and multi-basin, they have studied how to increase the productivity of stills through these three effects. Kabeel et al. [3] describes the various heat exchange mechanisms adopted by the researchers on different modified SSs. External and internal reflectors have been used by Tanaka [4] to increase the convective and evaporative heat transfer coefficient of SSs, as well as studies on its heat and mass transfer. Experimental study of a SS was done by Raju and Narayan [5], they added different number of flat plate collector to simple SS and it was found that when single flat plate collector was added to the setup, its distilled efficiency was 6.82% and when two flat plate collectors were added to the setup, the distilled efficiency was 7.29%, i:e as the number of flat plate collectors are added to the solar still the solar radiation receiving area is increases and water is preheated in short time before entering in the basin.

Kabeel et al.[6] has used a separate condenser chamber to increase the productivity of SS as well as nanoparticles have been used to increase the thermal conductivity and evaporation rate of the basin water.

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Productivity increased by 53.2% when an external condenser was added to the setup and productivity increased by 116% when the nanoparticle was added to the basin water of the condenser-based setup. Refalo et al. [7] has studied the effect on the productivity of SS due to solar chimneys and condensers and it was found that when the chimney was added to the SS, the setup produced 5.1 liters/m^2 of distilled water in a day and when the external condenser was added to the setup, the productivity of setup was 4.7 liters/m^2 in single day. The chimney and external condenser increase the condensation area of the vapor, hence the productivity was increases. Rashidi et al. [9] has placed a rectangular sponge of rubber inside the SS and has done an exergy analysis of it. The productivity of this modified SS was 17.35% higher than the conventional SS. The sponge produce the capillary effect, breaks the water molecules in small size and starts to evaporate in less time.

Present paper shows the development in the solar still and their applications.

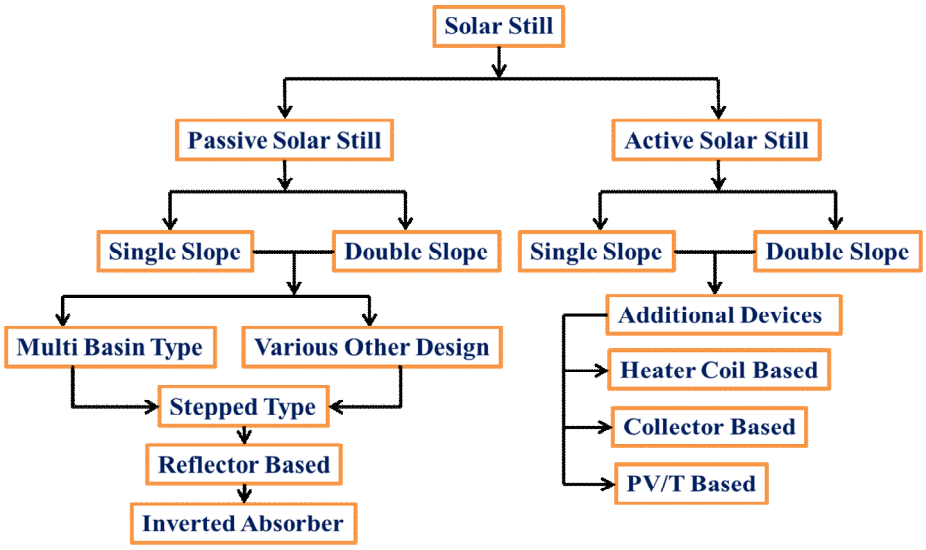


Fig.1. Classification of solar still

II. DEVELOPMENTS

There have been many changes in solar stills over time to time, due to its low productivity rate, it is not used extensively. Therefore, to increase the productivity of solar still many different techniques have been used, which are shown below.

A. Solar still with reflector:

Amount of solar radiation inside the solar still is increases by the reflectors. Reflector are placed external and internal parts of the solar still, In fig.2 shows the external and internal based solar still. Thus solar radiations travel outer from the setup it transmitted to the basin liner by the external reflector, hence the amount of radiation flux are increases inside the setup. Internal reflector isreflecting the radiations which are incident on the side wall of the solar still; hence the evaporation rate is increases.

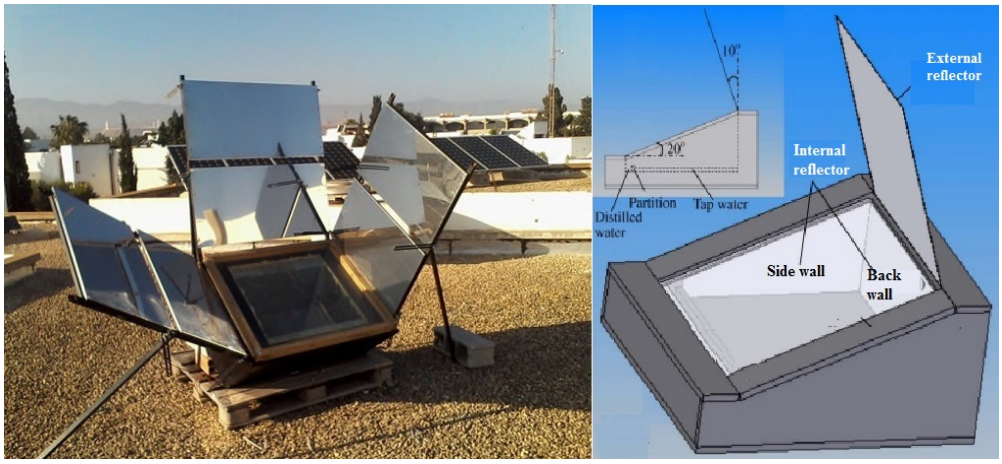


Fig.2. Solar still with external and internal mirror [2][3]

B. Solar still with collector:

Collectors are used to preheat the water before entering the basin; hence less heat energy is required to evaporate the basin water inside the still. The saline/brackish water is preheated in solar collectors and then it is supplied to the solar still. So, the less amount of heat is needed to be supplied to evaporate the saline water. Thus the evaporation rate increases, as more water is evaporated at the same time as compared to traditional still. Due to the preheat water take few minutes to warm up and starts to evaporate in very short period. Generally two types of collectors are integrated to the solar still, which is shown in the Fig. 3. First one is evacuated tube collector and another is flat plate collector.Insulated borosilicate glass tube was consist in evacuated tube collector, vacuum effect is created inside the tubes to reduce the heat loss through convection, and a flat black surface were used in the flat plate collectorfor increasing the absorption capacity and a pipe is placed inside the flat surface and it covers by the transparent material (Glass, FRP and Plastic) for creating the greenhouse effects. At natural mode both collectors are working on the thermo-siphon effects.



Fig.3. (A) Solar still with evacuated tube collector [4], (B) Solar still with flat plate collector[5].

C. Solar Still with external condenser:

An external condenser has been used to increase the condensation rate. The temperature of the external condenser is much lower than the internal surface glass of the solar still, due to which the water vapor rapidly releases its latent heat and changes the phase and converts into the distilled water.In an external condenser, the water vapor is transferred through a fan and natural mode, allowing evaporation inside the solar still as well as outside the external condenser. Along with the external condenser, potable water is also obtained from the internal surface of glass cover.Solar still with external condenser is shown in fig.4.

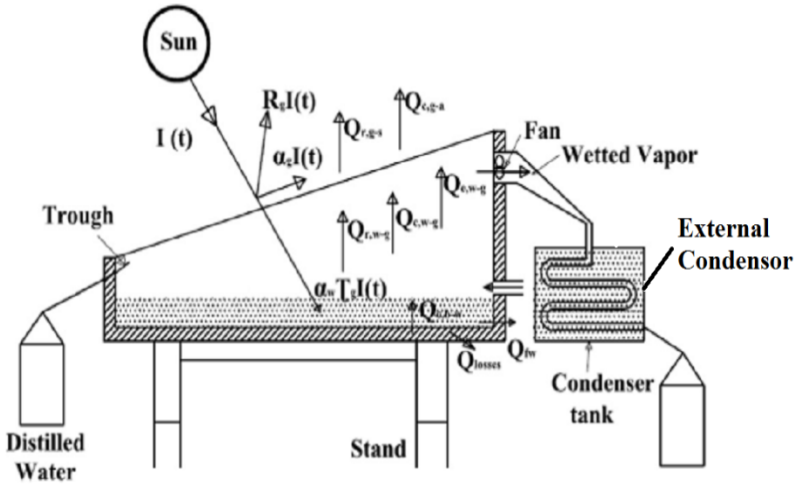


Fig.4. Solar still with external condenser [6]

D. Solar still with ultrasonic vibrator/fogger:

The ultrasonic transducer vibrates at ultrasonic speeds and causes water molecules to break apart into individual droplets. These droplets are instantly vaporized into the air. Hence the evaporation and convection heat transfer coefficient into the basin water has been increases compare to convectional still. In fig. 5 shows ultrasonic fogger is placed inside the solar still.

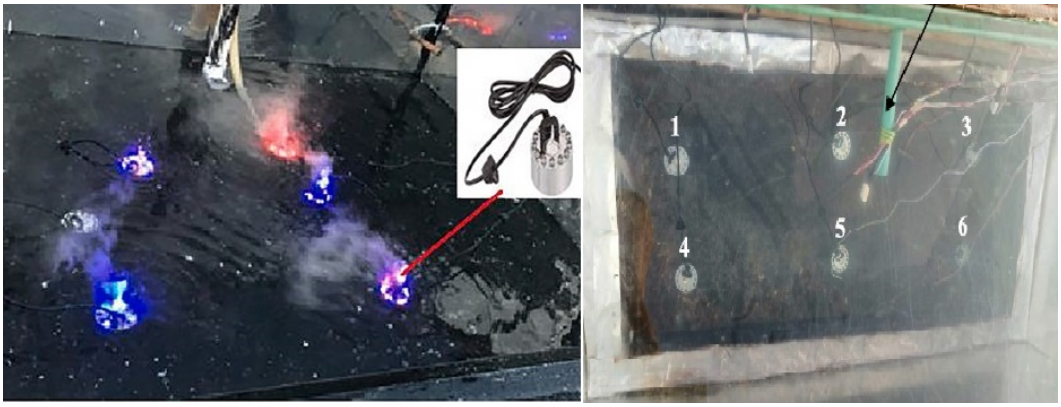


Fig.5. Solar still with ultrasonic vibrator [7]

E. Solar still with wick materials:

Wick materials have good capillary properties, due to this water molecules are absorbed by the wick materials and a thin layer of water is formed at the surface of wick materials. Also wick materials are increasingsurface area of the water compare to conventional solar still. Various types of wick materials are used in the solar still to improve he evaporation rate. Jute cloth, sponges, and cotton are used as wick materials. In fig. 6 shows wick materials, which are used in the basin water.



Fig.6.Different type of wick materials were used in the solar still [8]

F. Solar still with different tilt angle:

Tilt angle of solar still is very important factor to effects the production rate. The glass cover of the solar still must be in such a position that the solar radiation falls in the normal direction on the glass cover because when the sun falls in the normal direction the highest radiations are reaches to the basin liner and the reflection is reduced. If the angle of the glass cover is not perfect, then the solar radiation is reflected from the glass cover, so that a sufficient amount of radiation does not reach to the basin liner. The position of the sun varies from season to season, such as: In the summer, the sun travels above from the latitudes, hence the lower tilt angle of glass cover is gives higher productivity and higher angle is achieved maximum productivity in winter season because sun travels lower from the latitude. Based on yearly performance latitude based solar still gives higher productivity because sun travel maximum time at the latitude angle. In fig. 7A, shows the sun position in different season and in fig. 7B shows the different angle based solar still.

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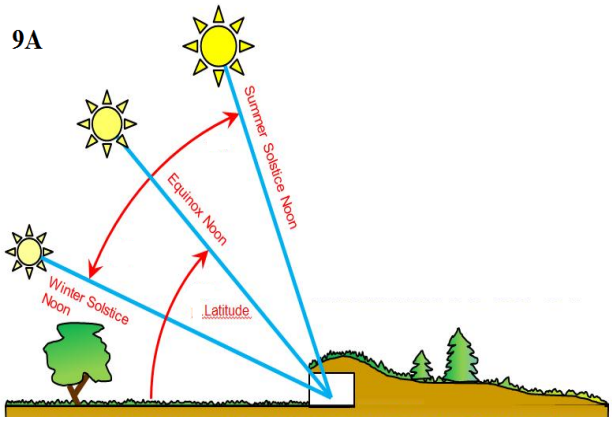


Fig.7A.Sun position in different seasons



Fig.7B.Solar stills with different angles [9]

G. Solar still with parabolic trough collector:

Parabolic trough collector preheats the base fluid after entering the basin. Parabolic trough collector used as reflector and concentrator of the solar radiation. The water pipe is positioned at a focal point of the parabolic trough collector, causing maximum amount of solar radiation are incident on the surface of the solar still. The preheated basin water in enter in the basin hence less energy is required to evaporate. Fig. 8 shows the parabolic trough collector based solar still.

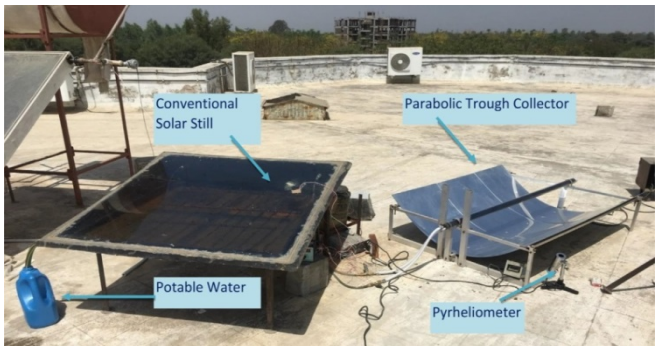


Fig.8.parabolic trough collector based solar still [10]

H. Solar still with charcoal cylinder:

Charcoal have a good absorption capacity, when it placed inside the basin water it absorbs highest rate of solar radiations and converts into the heat energy. This heat energy is transfer to the basin water and water gets heated in very less time and starts to evaporate. Due to good absorption capacity charcoal stored the solar energy and release it after the sun set, hence the productivity of the solar still is also achieved at the night time. In fig. 9 shows the charcoal based solar still.

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Fig.9.Charcoal based solar still [11]

I. Solar still with stepped basin:

A stepped solar still is shown in the fig. 10. Stepped type of basin is constructed inside the still; each step has consisted of a thin layer of water. The amount of water mass in each steps of the basin is less than the flat basin hence water heated very quickly and starts to evaporate at very less time. In stepped solar still the cavity area is also less compare to conventional solar still hence the less air is present inside the stepped solar still, hence the volume of stepped still is heated much faster than conventional still.

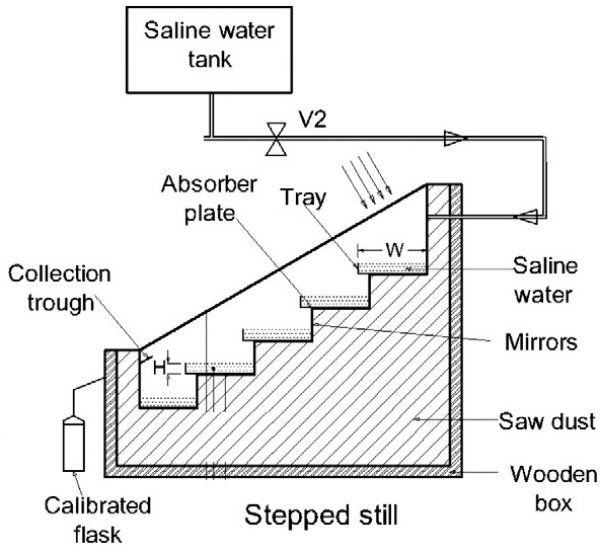


Fig.10. Stepped solar still [12]

J. Solar still with Nanoparticles:

Nanoparticles are very popular among researchers due to their thermo physical properties. Nanoparticles are high thermal conductive materials, which after adding to water also change their thermal conductivity. The thermal conductivity of plain water is 0.6 W/mK, while its thermal conductivity increases after adding nanoparticles. For example the thermal conductivity of CuO (Copper oxide) nanoparticles is 33 W/mK[13], therefore the thermal conductivity of water also increases when CuO nanoparticles are added to the basin water. The thermal conductivity of nanoparticles and water mixtures depends on the size and concentration of nanoparticles. Nanoparticles absorb solar radiation and transfer heat to water thus increasing the water temperature. When the thermal conductivity of basin water increases, convective and evaporative heat transfer coefficient has also increases, which increases the daily productivity of solar still.

K. Solar still with PCM:

The PCM changes its phase after absorbing the heat, from solid to liquid and liquid to solid. Due to these properties, PCM is used to save the heat from solar radiation and the absorbed radiation is used as heat energy after the sun set.

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PCM absorbs solar radiation during the day time and at night when the basin water temperature is low, the PCM transferthe heat energy to the basin water, and hence the productivity is also achieved at night time. PCM is used in solar stills so that the basin water temperature does not decrease even after the sun sets. In fig. 11 shows the PCM based solar still, in which PCM is filled around the still basin.



Fig.11. Solar still with PCM [14]

L. Applications of solar still:

The application of solar still is divided into two parts first one is domestic applications and second one is industrial applications.Water achieved by solar still is not only used for drinking purpose, but there are many industrial applications in which distilled water is used. The pure water obtained by solar still is also used in battery industries, automobile industries, hospitals, food technology (preservation) and cosmetic industries. The utility of distilled water is described below in detail.

M. Domestic applications:

In arid and remote zone solar still mostly use for the drinking water productivity. Due to the lack of proper access to clean water in the village, consumption of dirty water leads to many fatal diseases, such as cholera, jaundice and fever etc. The scene shown in Fig. 12 is of a village, the villagers consume such water without any cleaning, which makes them sick, so the use of solar still can easily convert such dirty water into clear water. Solar still is use by a villager is shown in fig. 13.



Fig.12. Dirty water uses by the villagers [15]

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Fig.13 Solar still is using by villager [16]

Industrial applications:Due to the low productivity solar still is not widely used, but the distilled water can be used in various applications.



1) Battery industries:Distilled water contains no dissolved minerals, salts, organic and in-organic compounds that may harm the battery. Therefore battery manufacturers recommend distilled water for better performance and longer battery life.

2) Medical field: Instruments used during surgeries need to be sterilized. The zero mineral content of distilled water means sterile instruments won't have any spotting or residue left on them. It also won't leave deposits on the equipment used to sterilize them. To clean the wounds, distilled water is also used due to its purity and it prevents the infection.

3) Automobile field: In the automobile industries distilled water is used in the coolant because it prevents the corrosion and gives the longer life of the engine.

4) Food preservation: Distilled water is used to keep fruits and vegetables safe for a long time, when the food is cleaned with normal water it spoils quickly.

III. CONCLUSIONS

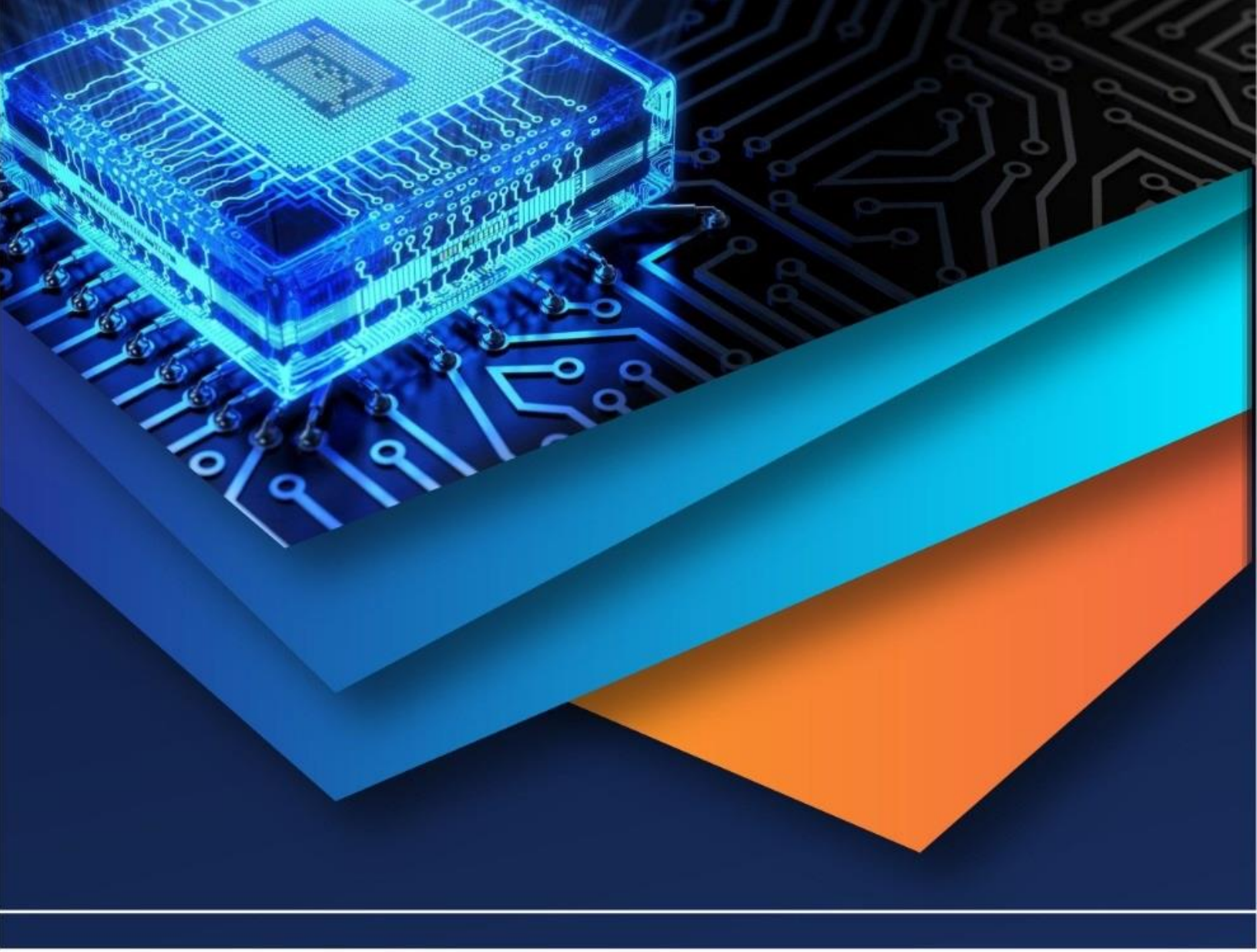
The productivity of solar still depends on the solar radiation. The higher the amounts of solar radiation received by the setup, itincreases the productivity. Hence, solar collectors, wick materials, stepped basins, and parabolic trough collectors have been used by the authors to increase the surface area for receive the large amount of solar radiation. Heat storage materials are used to store solar radiation such as PCM, charcoal cylinders, etc. The higher the amount of solar radiation reaches to the basin, the increase the evaporation rate of the basin water, so, the mirrors and reflectors have been used by the authors. Increasing the evaporation rate alone does not increase productivity, for this, the condensation rate also has to be increased. That is, the faster the evaporation, the faster the latent heat will release, then the condensation rate will increase, Hence the external condenser has been used by the authors.

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