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Performance Analysis of Solar Still with Nanomaterial Coating on Absorber Plate

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ABSTRACT

The purpose of this research is to design a water distillation system that can purify water from nearly any source, a system that is relatively cheap, portable, and depends only on renewable solar energy Improved sun-oriented stills are contrasted with a newer type of sun-based still in this dissertation. Coated absorbers are used in the solar still, which makes use of reduced graphene oxide /Copper oxide nanoparticles. The solar still's absorber plate and walls are coated with a commercial black paint that contains the hybrid nanomaterial. Researchers have identified and analyzed areas of the solar-powered stills where energy was lost. Alternate sunlight-based stills have faster dissipation and higher exergy compared to regular ones. As a result, the newer stills have higher exergy and energy efficiency than older models. Additionally, a brief discussion of the influence of various limits on the efficacy of sunlight-based stills is introduced. Reduced graphene and Copper oxide/water blends have a daily energy productivity of 44.18 percent, whereas the old-style has just 30.17 percent.

Keywords: Solar Still, Solar Intensity, Nanomaterial, Coating, Exergy.

I. INTRODUCTION

Solar water distillation is simple distillation replicates by which the nature way makes rain. The sun's energy heats water to the point of evaporation. As the water evaporates, water vapour rises, condensing on the glass surface for collection. This process removes impurities such as salts and heavy metals as well as eliminates microbiological organisms. The end result is water cleaner than the purest rainwater.[1]-[5].

Water can be purified for drinking purpose by following methods —

- Distillation
- Filtration
- Chemical Treatment
- Irradiative Treatment

Water and energy are the two essential components that impact the nature of cultivated life. Water utilization is expanding all around the world because of quick increment of populace and the farming undertakings. This causes a genuine interest on the new water. New water is a need for the congruity of life. It is additionally the way in to man's flourishing. Despite the fact that there is an adequate measure of water on the earth, but it isn't generally accessible in the amount and quality where it is required for explicit purposes. These days, there is developing interest in the non-industrial nations towards the potential outcomes of use of sun based energy for filtering water and their reasonable application in the farming area.[6]-[8]. The most important uses of water are in three sectors, namely-

- Domestic,
- Agriculture and
- Industrial.

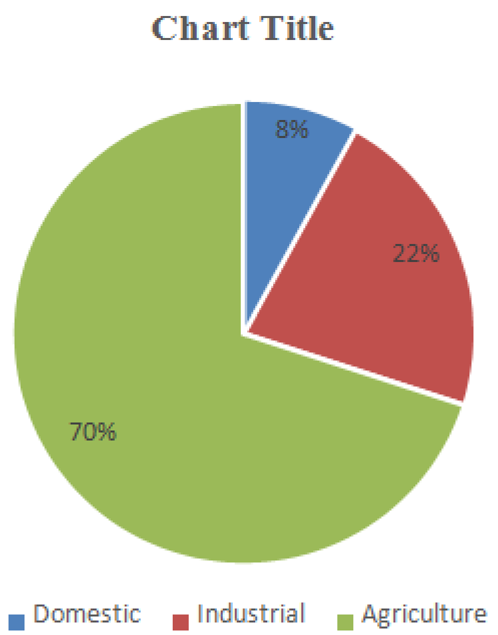
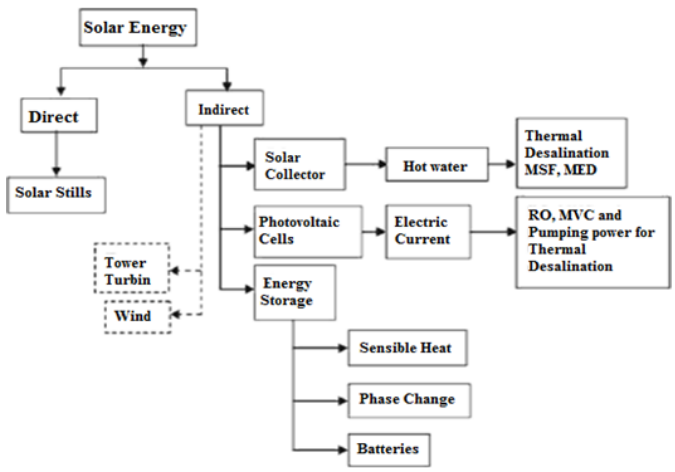


Fig. 1: Shows the percentage of world water use by different sectors for the year 2020

In India, significant water requests come from the agrarian area, as it is obvious from the above Figure. Home grown area alone requests 8% of the all-out interest for water. Sunlight based refining is the most proper interaction for new water supply, particularly for little networks in parched zones. The nature of water required by and large relies upon the sort of utilization. For example, the public water supply ought to be liberated from pathogenic living beings, clear, wonderful to the taste, at sensible temperature, neither destructive nor scale shaping and liberated from minerals which would somehow or another produce bothersome physiological outcomes. Considering the wide scope of varieties in synthetic dissertation of water accessible in various pieces of India, it is difficult to endorse any unbending guidelines in Indian setting. [9]-[11]. Sun based Refining progressive precipitation of crude water, in this manner filtering it. Fundamentally, there are two standards to be recognized: direct sun powered refining, which is described by its nearby utilization of sunlight based energy to dissipate crude water; and backhanded sun powered refining, which utilizes more complex energy change procedures for crude water warming. Sun oriented refining furthermore isolates the dissipation and buildup measures spatially to raise the distillate yield.



Source: Ettouney, H. and Rizzuti, L. (2007).

Fig. 2: Classification of solar distillation systems

Passive Distillation: This kind of sun powered still just has somewhat higher material expenses, as it requires the utilization of a greater number of glass sheets. For down to earth reasons (water supply for whole networks), this sort of still habitually is built as a profound bowl still on ground level with water profundities somewhere in the range of 10 and 50 centimeters, though the single-incline actually having a water profundity of a couple of centimeters for the most part fills in as sanitization unit for limited scope homegrown purposes [12]-16]. The general energy efficiencies of the two kinds of sun based stills fluctuate somewhere in the range of 25 and 45% for usually fabricated models with the single-slant still by and large having a 10% higher productivity than the twofold incline still. Specifically cases, efficiencies of up to 60% have been reached.

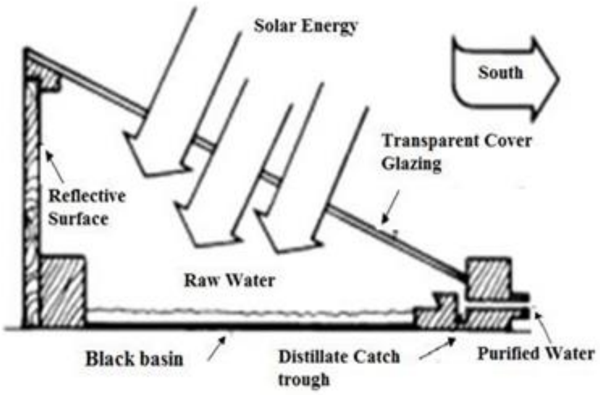


Fig.3 (a): Single-slope, basin-type solar still designs for passive distillation

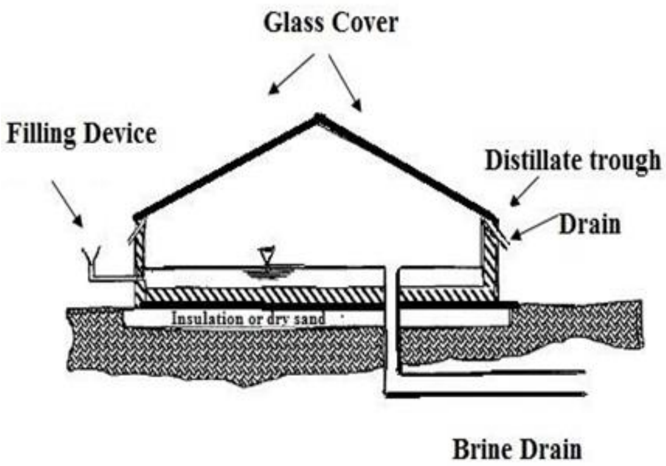
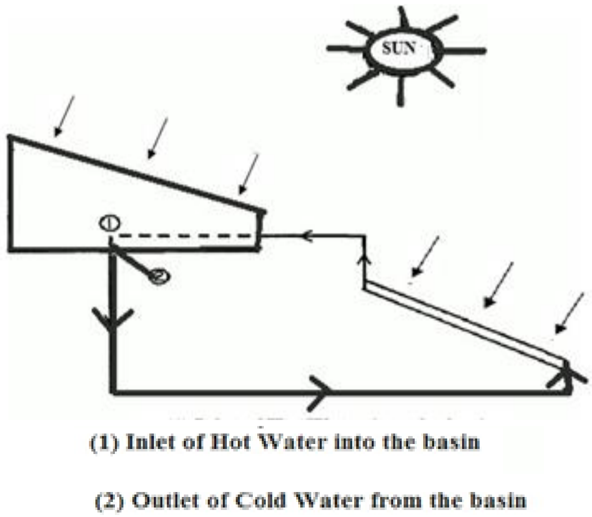


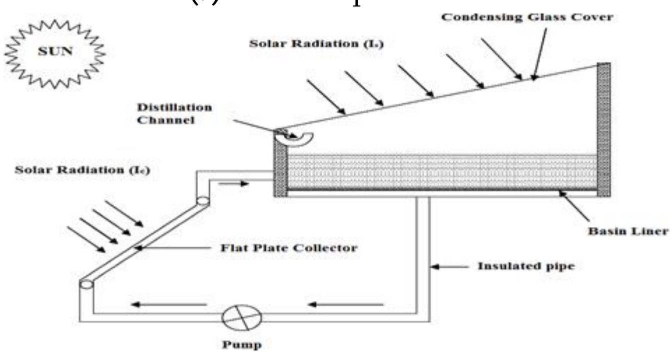
Fig.3 (b): Double-slope, basin-type solar still

1) **Active Distillation:** The extra energy needed for the course of dynamic sun oriented refining is gotten from different sources. The general distillate yield is raised by around 35 to half by the use of pre-warmed crude water raises, which likewise raises the dissipation rate contrasted with a solitary bowl sunlight based still. Ordinarily, there are two working standards of the extra heated water gatherers:

- Thermo siphon mode
- Forced course mode



(a) Thermo siphon mode



(b) Forced-circulation mode

Fig.4: Active distillation systems coupled with flat-plate water collector

II. Literature Review

M. Elashmawy [17] shows a detailed review of current developments in SSs with nano/micro materials was presented. Firstly, nanoparticles can enhance the productivity of SS and barely increase the cost. The daily productivity of nanoparticles-based SSs can be from 3 to 7 L/m^2 and from 4 to 9 L/m^2, for passive and active SSs respectively. The cost of freshwater with nanoparticles can be around 0.01–0.027 $/L and 0.021–0.05 $/L, for passive and active SSs respectively. The main reason for the improvement by nanoparticles is the enhancing of both the thermal conductivity of base fluids and solar absorptivity, which improves the evaporation process in SS. **A. E. Kabeel [18]** described the solar desalination test plant in Abu Dhabi, UAE and gave a summary of its first year performance and economics. The plant has been operating successfully for 18 years supplying fresh water to the city of Abu Dhabi. The aim of the plant was to investigate the technical and economic feasibility of solar desalination of seawater in providing fresh water to remote communities in the Middle East and to obtain long-term performance and reliability data on the operation of the plant. **A. E. Kabeel et al. [19]** concluded that the double slope FRP solar still was most economical for domestic applications mainly for drinking and cooking purposes while the active solar still was more suitable for commercial applications. **A. S. Abdullah** et al. [20] designed this study to develop an efficient and cheaper solar-still, which could be used in Tsunami affected areas. The work reported here was concentrated on a solar still which would work automatically utilizing the capillary action of materials to pump water from the reservoirs. Tsunami affected areas were purified and the conductivity, turbidity and pH values of the samples were measured before and after distillations to check whether the distillated water has achieved drinkable standards. **M. Shalaby et al. [21]** designed a solar still and tested in Mubi, Adamawa State of Nigeria. The radiation from the sun evaporates water inside the solar still at a temperature higher than the ambient. The principle of operation was based on greenhouse effect. Energy balances were made for each element of the still; solar time, direction of beam of radiation, clear sky radiation, and optical properties of the cover, convection outside the still, convection and evaporation inside were accounted. The results clearly depicted that the instantaneous efficiency increases with the increase of solar radiation and with the increase of feed water temperature. **M. S. Yousef et al.** [22] carried out investigations under the open environmental conditions of Egypt on single slope solar still inclined 20º of one direction. The highest still average productivity was obtained at August compared to May, June and July, as no productivity was obtained on June. **H. Aburideh et al.[23]** designed to evaluate some different units of solar stills constructed as follow a: (control unit, preheating unit, air blower unit and air suction unit). They studied parameters, which effect on the productivity of solar still units, such as brine depth, slope angle of glass cover, feed water and cover material. **M. Arslan [24]** described a new water distillation method and apparatus operating at low temperature and sub-atmospheric pressure that can produce water at different scales, for large cities or remote rural communities. The system is low cost. **T. Arun kumar et al. [25]** devised a model which converted the dirty/saline water into pure/potable water using the renewable source of energy (i.e. solar energy). The efficiency of plant was 64.37%. **K. Sampath kumar [28]** designed a water distillation system that could purify water from nearly any source, a system that is relatively cheap, portable, and depended only on renewable solar energy. **G. Singh et al. [29]** described the design and performance of a solar-powered still. It was based on the simple principle of using solar energy to evaporate water, and then condense it on an inclined glass surface. **Y. Taamneh et al.[30]** designed and constructed five single basin solar stills with varying angles of inclination of the covers but having the same aperture area of 0.24m^2 were designed and constructed.

From the literature survey, it is difficult to obtain pure drinking water, since the pollution is increasing day by day with the increased use of technology, be it air, soil or water everything has become polluted. In this technology provide safe drinking water to people and highly polluted water can be treated it can be used at least for agricultural purposes. Moreover the majority of the population cannot afford expensive technologies for purifying water. So we need to evolve a technology which is cost effective also. The design of distillation plant using solar energy could be a solution to a large extent.

III. Methodology

The sun oriented water refining standards are straight forward yet viable. The sun's energy warms water to the place of dissipation. As the water vanishes, water fume rises, consolidating on the glass surface for assortment. This interaction eliminates debasements, for example, salts and substantial metals other than taking out microbiological life forms. The outcome is perfect water. Sun oriented stills utilize the water interaction which is regular dissipation and buildup. This takes into account normal pH buffering that produces amazing taste when contrasted with steam refining. They can without much of a stretch give sufficient water to family drinking and cooking needs. Sunlight based distillers can be utilized adequately to eliminate numerous pollutants going from salts to microorganisms and are even used to make drinking water from seawater.

Design Concept and Working Process

Design Concept: A simple asymmetrical solar still was used on the basis for improved by adding various features from researched. The idea is to thoroughly improve the efficiency of the basic solar still design. The following features were added:

- To prevent solar energy and heat flow from leaving the device insulated basin andside walls were added.
- For multiple smaller bodies of water to be heated at a faster rate than a single bodyof water Slotted basin was added.
- To regulate water in basin to the optimal level of 1.5 to 2 cm Float valve was introduced.
- On the side walls of the basin to reflect all incoming solar radiation into the waterrather than absorb the energy into the walls.
- Input tank that was preheated throughout the day so that less solar radiation isrequired for evaporation.
- Door that opens to allow for easy cleaning of the basin and removal of salt debris.
- Effective water collection and easy access spout to fill containers with distilledwater.

The stills were constructed by bending a sheet of galvanized iron (GI), since it was cost effective and easily available. To absorb the incoming radiation and prevent corrosion the inside walls painted with black paint. The dimensions on the back and sides were adjusted so that the top cover was inclined at the desired angle. All the experiments were done at an angle chosen was 15º.

Effect of insulation: The effect of insulation, we built two identical stills with the above specifications.one with 10 mm thick with Styrofoam insulation on all the sides, and the second non-insulated. The insulated model gave 17% more output due to insulation prevents heat loss from the still.

Table 1: Source: Reddy et al., (2013)

Mode l	Size	Angle	Insulatio n
1	0.7 m x 0.5 m	13°	Styrofoam
2	0.7 m x 0.5 m	13°	None

Cover material: Two kinds of common transparent materials glass and Plexiglas Glass has the advantage of good transmission of the solar spectrum but is breakable whereas Plexiglas is a clear plastic that is almost unbreakable. We found that even though the water-vapours condensation rate was faster in the Plexiglas model probably because of its lower temperature, though there was no measurable water collection.

Table 2: Source: Reddy et al., (2013)

Model	Size	Angle	Cover
1	0.7 m x 0.5 m	13°	Plexiglas
2	0.7 m x 0.5 m	13°	Glass

Volume of water inside: The total volume of water in the still is expected to be an important factor affecting the output because it determines the heat capacity of the water, which has to be overcome before significant evaporation starts. Therefore, we tried amounts varying from 2 l (water depth of 5 mm) to 6 l (water depth of 15 mm).

Table 3: Source: Reddy et al., (2013)

Model	Size	Angle	Volume (Depth)
1	0.7 m x 0.5 m	13°	21 (5.0 mm)
2	0.7 m x 0.5 m	13°	41 (10.0 mm)
3	0.7 m x 0.5 m	13°	61 (15.0 mm)

Angle of inclination: The canonical angle of the cover of 15° was chosen so as to match the latitude of Ahmedabad, which gives the best angle of incidence for the incoming rays averaged over the year. To investigate how much variation in output is caused by using different angles, we built three models with angles of 10, 13 and 16, respectively. Their water output was measured for three days in the month of June (Table). Reading was taken simultaneously on all the models after a few hours of operation in the morning.

Table 4: Source: Reddy et al., (2013)

Model	Size	Angle
1	0.4 m x 1.0 m	10°
2	0.4 m x 1.0 m	13°
3	0.4 m x 1.0 m	16°

Table 5: Source: Reddy et al., (2013)

Date	Water collected (cc)		
	10°	13°	16°
23-Jun	400	400	400
26-Jun	435	450	440
27-Jun	410	420	385

The readings showed that there was no significant difference in the operation of the three stills. So it was concluded that the same angle of still can be used in all tropical countries with no significant change in their performance.

Design Parameters:

There are a number of parameters which affect the performance of a solar still which are broadly classified as-

1. Climatic parameters
   - Solar radiation
   - Wind speed
   - Outside humidity
   - Ambient temperature
   - Sky conditions
2. Operational Parameters
   - Water depth
   - Preheating of water
   - Coloring of water
   - Salinity of water

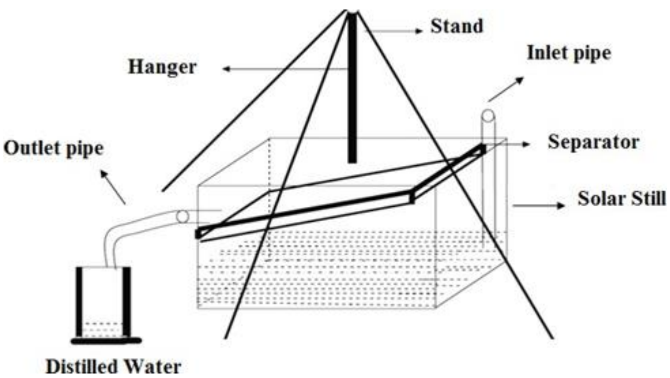


Fig.5: Shows the systematic view of the working

IV. Experimental Setup

Solar still is the size of 120 cm x 65 cm. The small side of the solar still is 15cm and the bigger one is 32cm and it has an angle of 15°. The solar still has thermocouple for insulation which covered by double sheet. 2.5 cm width is provided for the flow of distilled water in the solar still. The solar still is covered by two pieces of Glass with handles of size 56cm x 67cm for covering the top tilted surface. The solar still's inside walls is black painted mix with reduced grapheme and Copper oxide for better absorbency of solar radiations. The inlet and outlet is also provided for water flow which is shown in the fig.

Fig.6: Solar distillation system

2) Construction:

- Dimensions of the solar still – 120 cm x 65 cm.
- Smaller side (height) – 15 cm
- Bigger side (height) - 32 cm
- Angle-15°

3) Procedure

1. Without nano particles, Water depth-2.0 Cm, Water quantity - 16.0 lts.

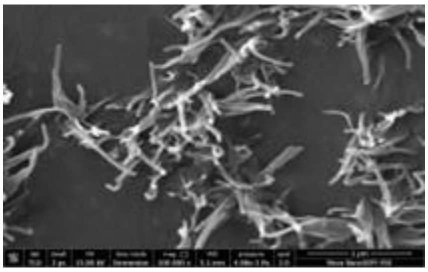
First take 16 ltr water and at depth of 2cm in the solar still. Then measure the TDS of water and measure the radiations at horizontal & inclined surfaces. Temperature reading of the water is taken with the help the thermocouple. The humidity and wind speed and outside temperature of atmosphere is measured. The hourly reading is taken from 9 am to 5pm at the interval of 1 hour. TDS and volume of water after distillation is measured aftereach interval.

2. After Nano particles mixed in paint 16.0 lts.

Reduced graphene and Copper oxide mixed in black paint and then painted inside the wall of solar still. Water is taken 2cm depth and the quantity of water is 16 ltr. Water temperature, TDS, humidity, wind speed, radiations, atmosphere temperature are measured at interval of 1 hour from 9 am to 5 pm. TDS and volume of water after distillation is measured after each interval.

V. Results and discussions

Characterization of Material: Reduced graphene/Copper oxide nanoparticles coated in black paint were characterized using SEM images collected at various resolutions. Tests are done with FESEM machines at CSIR-CSMCRI, Bhavnagar. At a resolution of 100 times, the SEM picture of exfoliated graphite may be seen in below. The expanding graphene/Copper oxide layer may be seen as streaking lines in the sample. Increased solar energy absorption is a result of the nanoparticles' exceptionally vast surface area and compact size. Because of the presence of nanoparticles, reduced graphene/Copper oxide black paint has a much greater heat conductivity and absorption than the base fluid. The CuO_2 and graphene nanoparticle purchased from Platonic Pvt. Ltd. for the experiment purpose.



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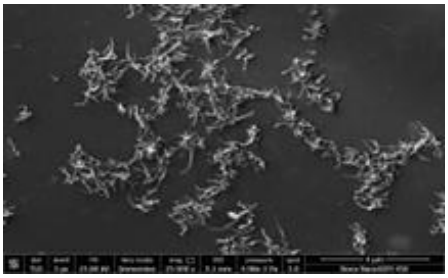

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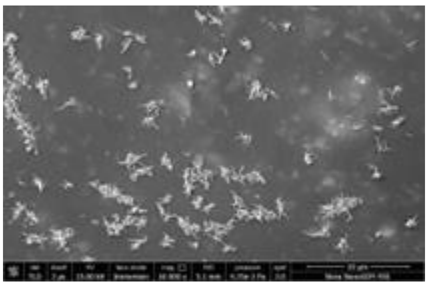

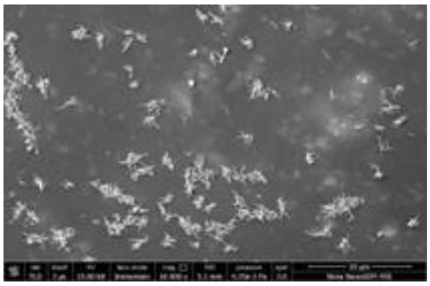

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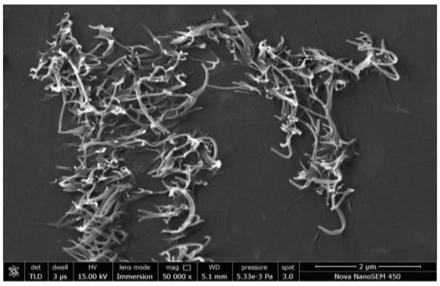

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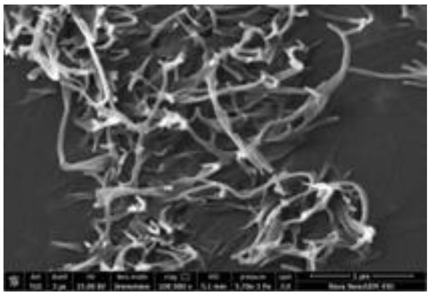

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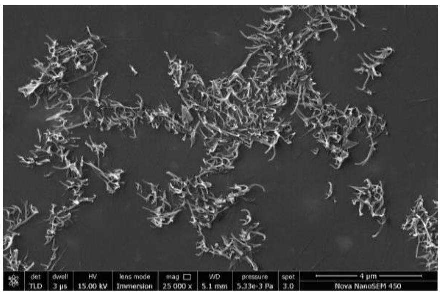

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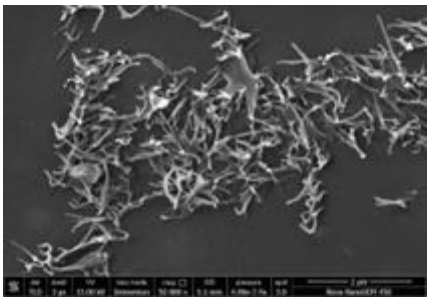

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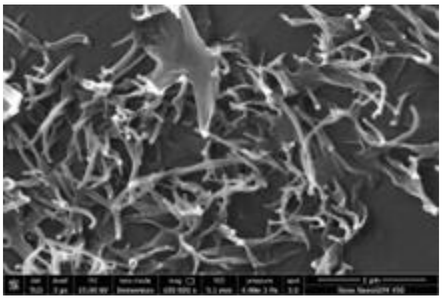
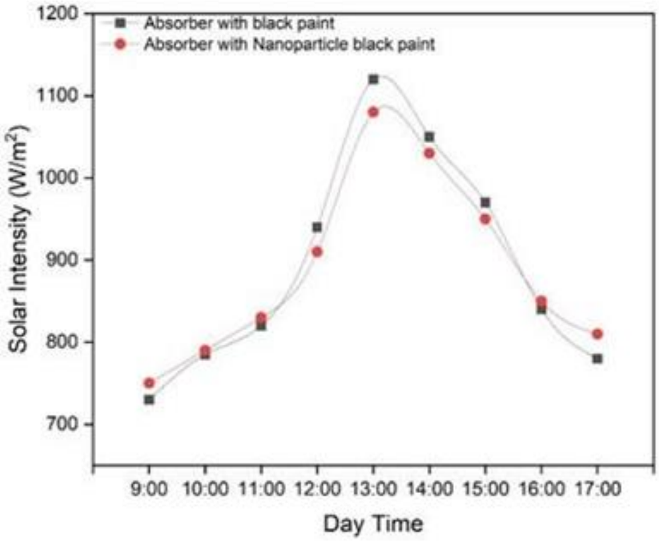


(h)

Fig.7: SEM Analysis

Performance analysis of solar still: The performance of Solar Still was tested by mixing the reduced graphene/Copper oxide mixed with the black paint. The sun's intensity ranged from 700–1120 W/m² as shown in figure and wind speeds ranged from 1.8–3.5 m/s shown in figure during the experimental days. Also, the performance of solar still with the nanoparticle and without nanoparticle assessed and compared.



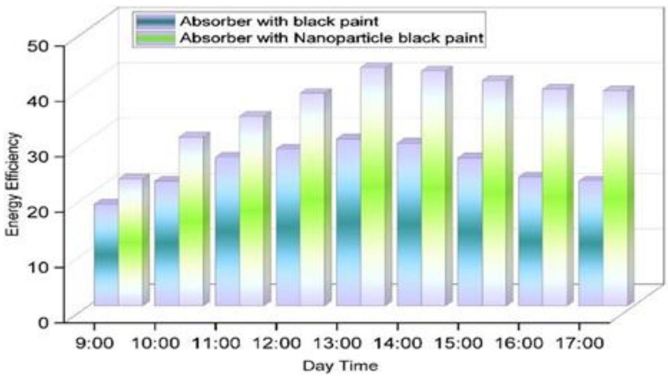


Fig.8: Variation of energy efficiency vs daytime

Exergy analysis of solar still: Exergy analysis can reveal the extent and location of exergy loss. The rate of instantaneous exergy destruction was calculated for different components of the solar still with and without nanoparticle coating such as absorber plate. The variation of the exergy efficiency with day time shown in figure.

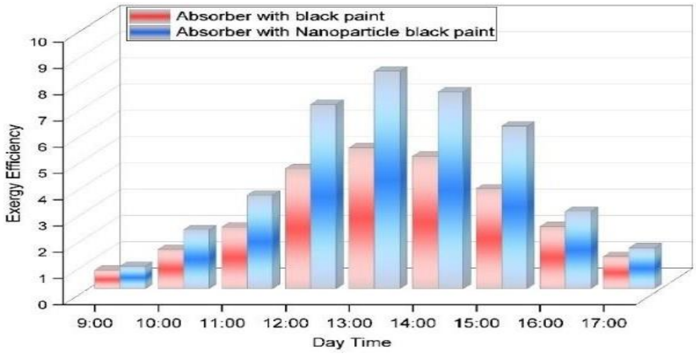


Fig.9: Variation of the exergy efficiency with daytime

VI. Conclusion

As a result, we conclude that the following are the values of the results:

- The hourly exergy efficiency of black paint and nanomaterial with black paint coating is 2.02%, 1.5% respectively.
- When the intensity of solar radiation was at its highest and temperatures for all of the solar still's components were increasing at the same time of day, a high distillate production was recorded.
- The hourly energy efficiency of black paint and nanomaterial with black paint coating is 44.18% and 30.17%, respectively.

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