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BATCH-18

PERFORMANCE OF PASSIVE SOLAR STILL BY USING BLACK GRAVEL

BACHELOR OF TECHNOLOGY
IN
MECHANICAL ENGINEERING

Under the guidance of

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ABSTRACT

The usage of solar still is the simple and economical method for providing distilled water in remote and coastal areas. Various methods, such as use of heat storage materials like black gravel, are proposed to improve the effectiveness of the solar still. In this work, an experimental study is carried out to study the influence of the presence of heat storage material on the performance of solar still.

In this project we studied the performance of solar still using Black Gravel. Experiments are conducted on a single – slope solar still with condensing cover of 30° inclination. This study was performed in Indian coastal climatic condition for 24 hrs. The experimental study emphases that the overall distillate yield and efficiency of the solar still with Black Gravel is more compared with the conventional solar still.

Black Gravel has high heat storage capacity, due to this the distillate production is more compared to conventional still. More distillate production and efficiency are observed using Black Gravel.

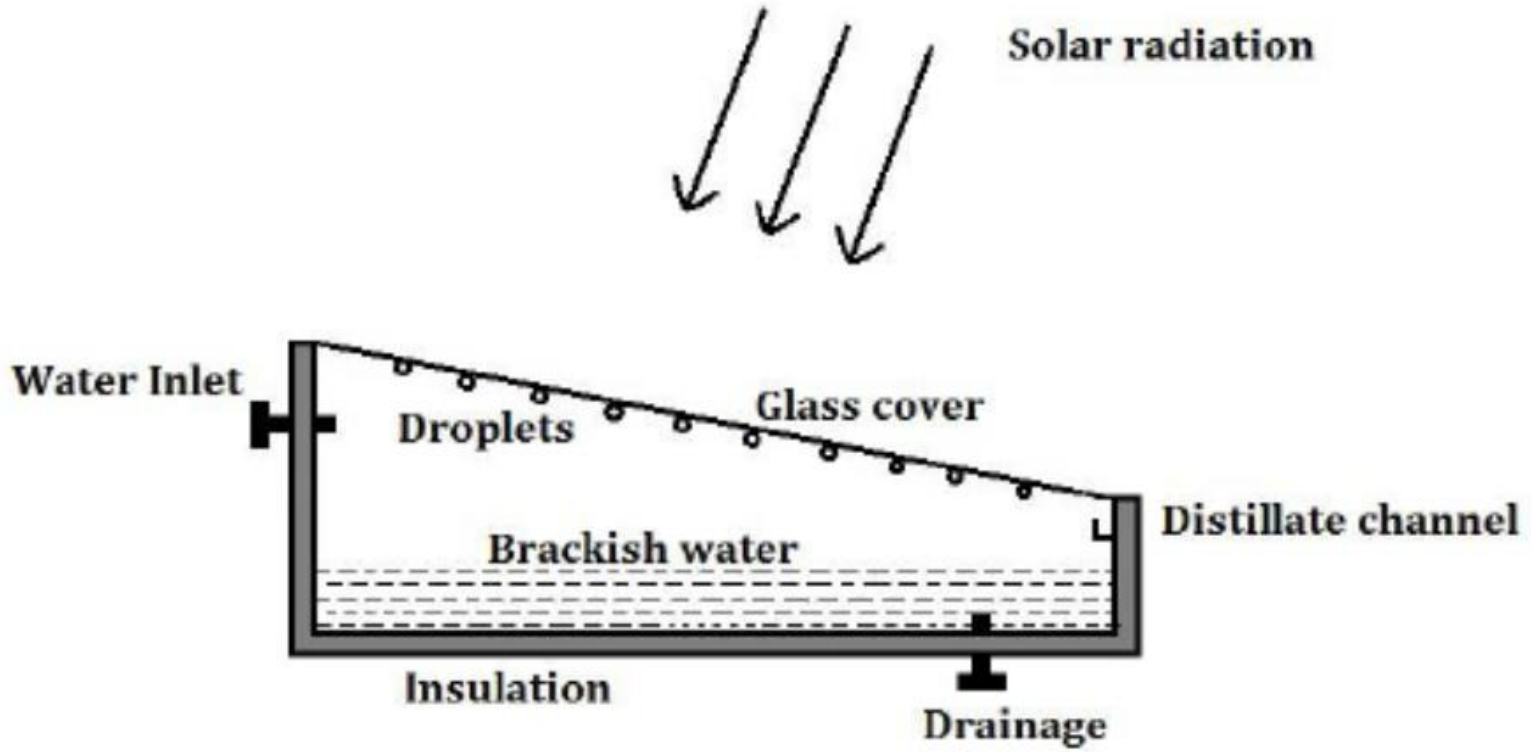
OBJECTIVES

- To study the performance of passive solar still with black gravel.
- To calculate the heat transfer coefficients for passive solar still by Dunkle's and K & T's models and compared it.
- To obtain potable water from impure sources using solar energy, offering a cost-effective and sustainable solution, especially in water-scarce regions.

INTRODUCTION

- **Water**, a substance composed of the chemical elements hydrogen and oxygen and existing in gaseous, liquid, and solid states. It is one of the most plentiful and essential of compounds. A tasteless and odourless liquid at room temperature, it has the important ability to dissolve many other substances.
- **Solar energy,** the earth receives radiation from sun in the form of electromagnetic radiations. Solar radiation is cheap and pollution free . India receive solar energy equivalent to more than 5000trillion kwh per year.

- **Solar still,** is a device that produces pure water without the use of any conventional source of Energy. A solar still is a device that uses solar energy to convert impure water, into pure, potable water through a process of evaporation and condensation.



- **DISTILLATION,** a separation technique where a liquid is heated to its boiling point, converted into a vapor, and then the vapor is condensed back into a liquid.

Heating ⟶ Vaporization ⟶ Condensation

- **DESALIATION,**the process of removing salt and other dissolved minerals from water, typically seawater or brackish water, to make it suitable for drinking or other uses.
- **Heat transfer coefficient** The heat transfer coefficient (HTC) is a measure of how quickly heat moves from a fluid to a surface.

Conventional coefficient:
“Conventional heat transfer coefficient can be defined as the rate of heat transfer between a solid surface and a fluid per unit surface area per unit temperature difference.”

Evaporative coefficient:
An "evaporative heat transfer coefficient" refers to a measure of how efficiently heat is transferred from a liquid surface to the surrounding air through the process of evaporation,

HEAT STORAGE MATERIAL

The main aim of the experiment is to increase the performance of the solar still by using the **Black gravel** as energy storage material. Black gravel is a volcanic rock that is hard, durable, and resistant to weather and abrasion. It has good thermal properties, allowing it to store heat efficiently and release it gradually, even after the sun sets.

LITERATURE REVIEW

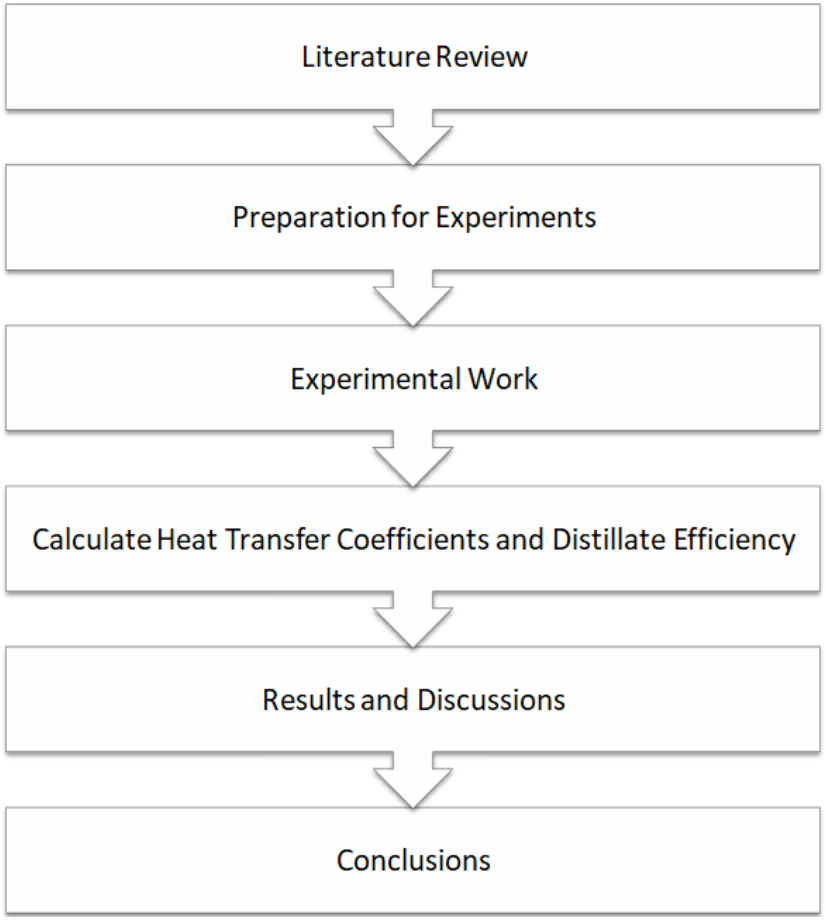
Sourabh Kumar Nougriaya et. [1]. all says that the review work focus on the effects of different water depths (1–15 cm) on the distillate productivity for various designs. This will help researchers to select optimized water depth experimentation with various solar still designs.

A. Jahanbakhsh et al. [2]. concluded that factors like collector water flow and glass cover evacuation had minimal impact on thermal performance

S.A. EI-Agouz et al. [3] found that factors like water film thickness, velocity, and wind velocity affect solar still efficiency.

Naga Sarada et al. [4] achieved improved efficiency using Phase Change Materials for solar water distillation.

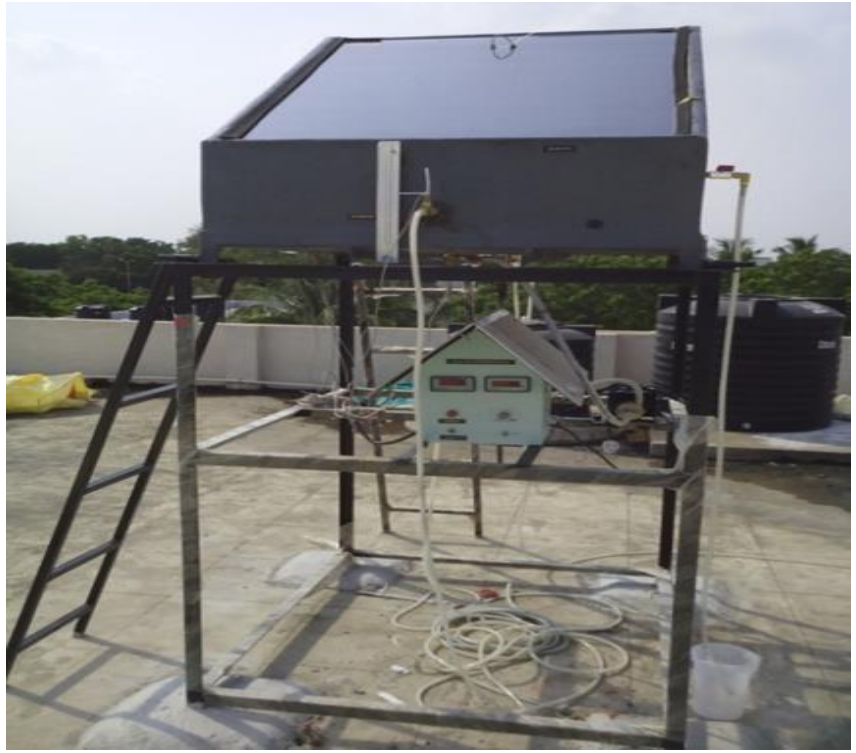
METHODOLOGY



EXPERIMENTAL PROCEDURE

1. Introduction and Experimental Setup:

The experiments were performed in summer climatic condition of 2025 in JNTUK, Kakinada, and Andhra Pradesh, India. March is usually the hottest month of the year in this region and typical results for 2 days during the period have been reported here. Experiments were conducted from 8.00 A.M. to 5.00 P.M. at a constant water depth of 0.04m for conventional solar still and the next day for solar still with gravel. Sufficient care is taken for obtaining steady state condition during the experimentation. The inclination of 30_0 is fixed for two experiments. The parameters, viz, glass outer and inner surface temperatures, vapor temperature, water temperature, ambient temperature, incident radiation, relative humidity(γ) inside still and distillate output are measured on 10 hr. basis for two experiments.



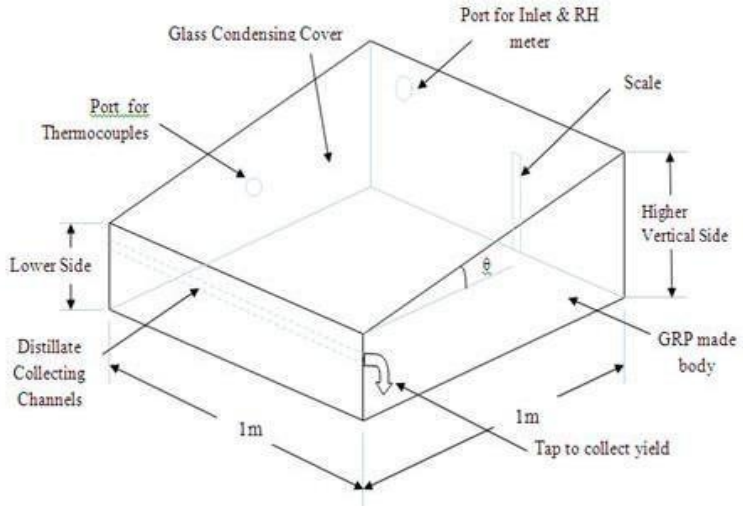
photograph of the working solar still

2. Solar Still Design and Components

- **Basin:**
  - Depth: 0.20m max; walls: 0.30m (lower), 0.88m (higher) to prevent spillage.
  - Painted black (Nichrome) for max solar absorption, pre-baked to remove toxins.

- **Condensing Cover:**
  - Glass with rubber gasket (sealed using Araldite/Bond Tite).
  - Sloped at 30° to guide condensate into collection trough.

- **Other Features:**
  - Inlet pipe for water, outlet at basin bottom for drainage.
  - Thermocouple holes for temperature monitoring.



Schematic Diagram of Solar Still

3. Role of Black Gravel

- **Purpose:** Enhances heat absorption, boosting evaporation rates, Heat storage material.
- **Setup:**
  - Black gravel fills basin
  - Transparent cover traps heat while allowing sunlight.
- **Advantage:** Higher internal temperature → Improved distillate yield.

Photograph of the Working Solar Still with black gravel

Photograph of Solar Still with Black gravel Before Experiment

4. Key Factors Affecting Performance

- **Environmental:** Solar intensity, wind speed, ambient temperature.

- **Design:**
  - Water-glass temperature difference.
  - Glass angle (30° fixed), water depth (0.04m tested).
  - Surface area of water/absorber.

- **Outcome:**
  - Gravel increases efficiency by raising basin temperature.
  - Sealed design prevents water loss, ensures pure condensate.

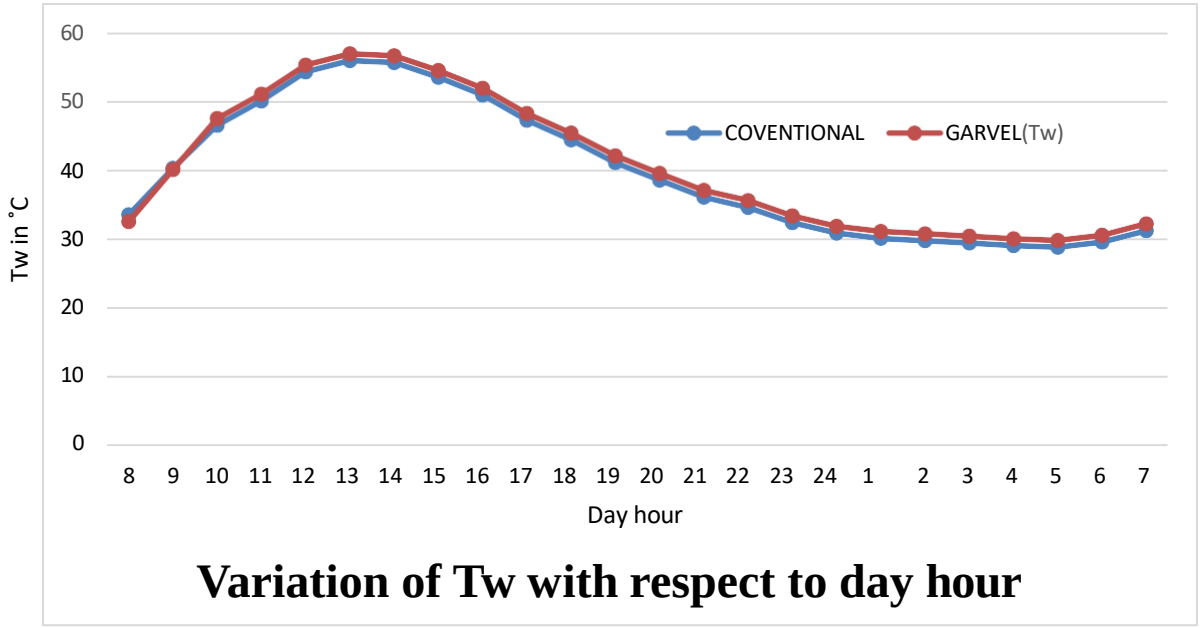
RESULTS & ANALYSIS

Results:

Table1: Hourly Average values calculated using 24hrs experimental data for a passive solar still with black gravel

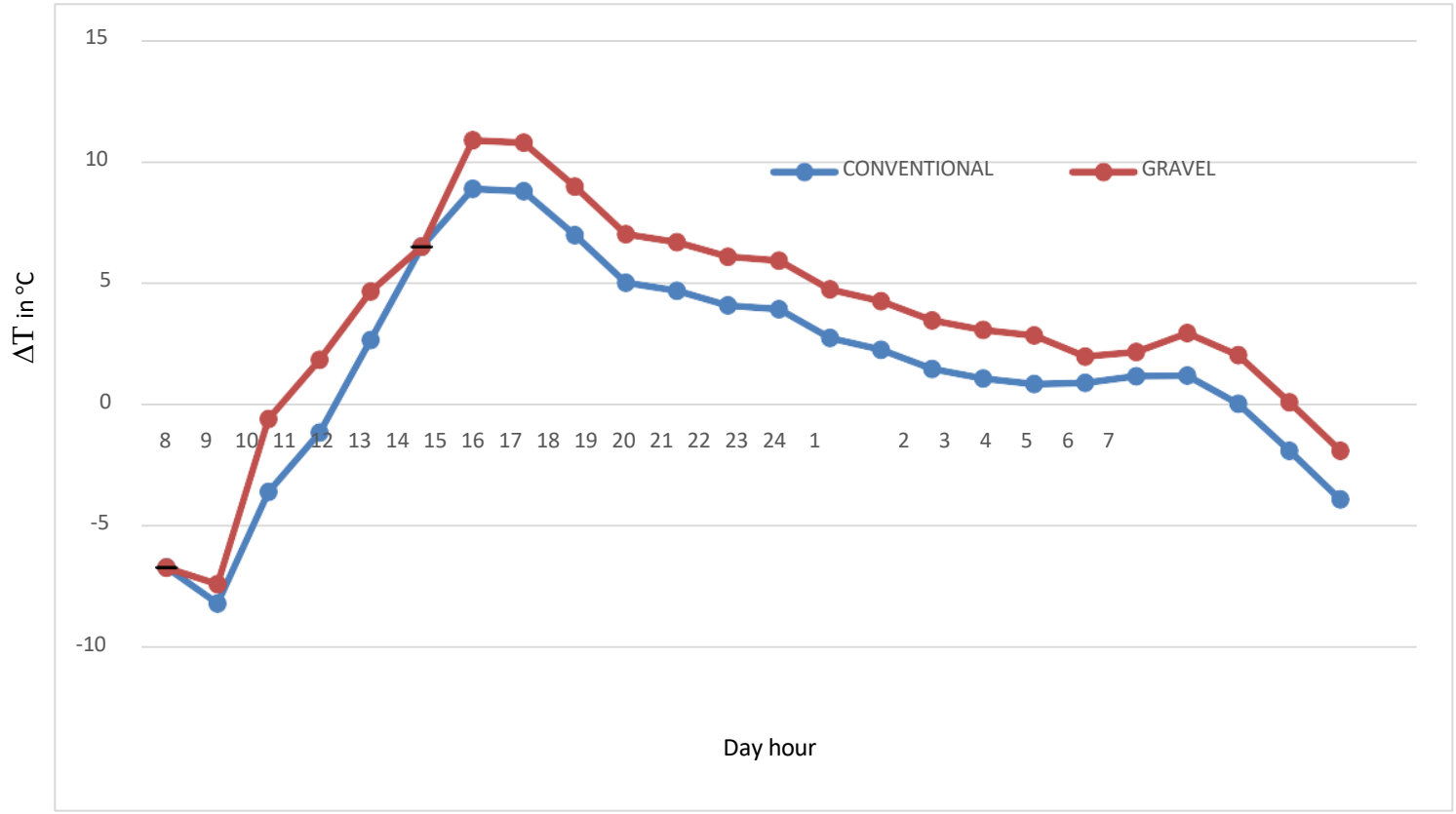
I(t) W/m²	Time	T_{ci} °C	T_v °C	T_w °C	m_{ew} kg	h_{cw} W/m² °C	h_{ew} W/m² °C	h_{cwDM} W/m²0 C	h_{ewDM} W/m²0C
420	8am-9	39.35	41.51	32.64	0.008	2.53	4.62	3.63	6.56
590	9-10	47.57	49.19	40.18	0.015	2.67	2.18	3.78	3.95
760	10-11	48.2	49.80	47.61	0.030	2.79	18.79	2.47	32.42
870	11-12	49.29	50.16	51.14	0.070	2.81	34.42	1.35	56.41
940	12-13	50.7	51.18	55.36	0.100	2.83	51.25	1.97	78.27
820	13-14	50.49	53.92	57.00	0.140	2.85	67.12	2.73	93.72
650	14-15	45.82	53.29	56.71	0.190	2.82	43.92	3.34	45.85
360	15-16	43.78	50.90	54.57	0.205	2.79	31.67	3.29	35.52
210	16-17	43.01	50.26	51.99	0.175	2.78	25.32	2.89	26.43
50	17-18	41.32	44.73	48.34	0.168	2.75	22.83	2.68	22.81
0	18-19	38.81	41.69	45.50	0.130	2.72	19.72	2.61	21.27
0	19-20	36.10	38.89	42.19	0.110	2.68	15.15	2.52	20.53
0	20-21	33.72	37.40	39.65	0.095	2.66	12.28	2.23	17.69
0	21-22	32.43	35.19	37.18	0.085	2.63	10.12	2.19	14.89
0	22-23	31.43	34.25	35.69	0.065	2.61	9.37	1.75	12.41
0	23-24	30.01	33.10	33.48	0.055	2.59	8.49	1.37	11.57
0	24-1	28.88	31.81	31.96	0.050	2.58	7.63	1.16	9.72
0	1-2	28.36	30.82	31.21	0.045	2.56	7.45	1.12	8.94
0	2-3	28.89	30.28	30.87	0.040	2.55	7.41	1.29	7.12
0	3-4	28.36	29.76	30.53	0.030	2.53	7.35	1.45	7.10
0	4-5	27.20	29.21	30.15	0.025	2.52	7.21	1.54	7.28
20	5-6	27.87	29.61	29.91	0.015	2.51	7.89	0.83	1.89
100	6-7	30.57	33.63	30.67	0.015	2.50	6.75	1.78	10.73
290	7-8am	34.22	38.65	32.32	0.025	2.54	6.98	2.57	14.65

Analysis:



Variation of Tw with respect to day hour

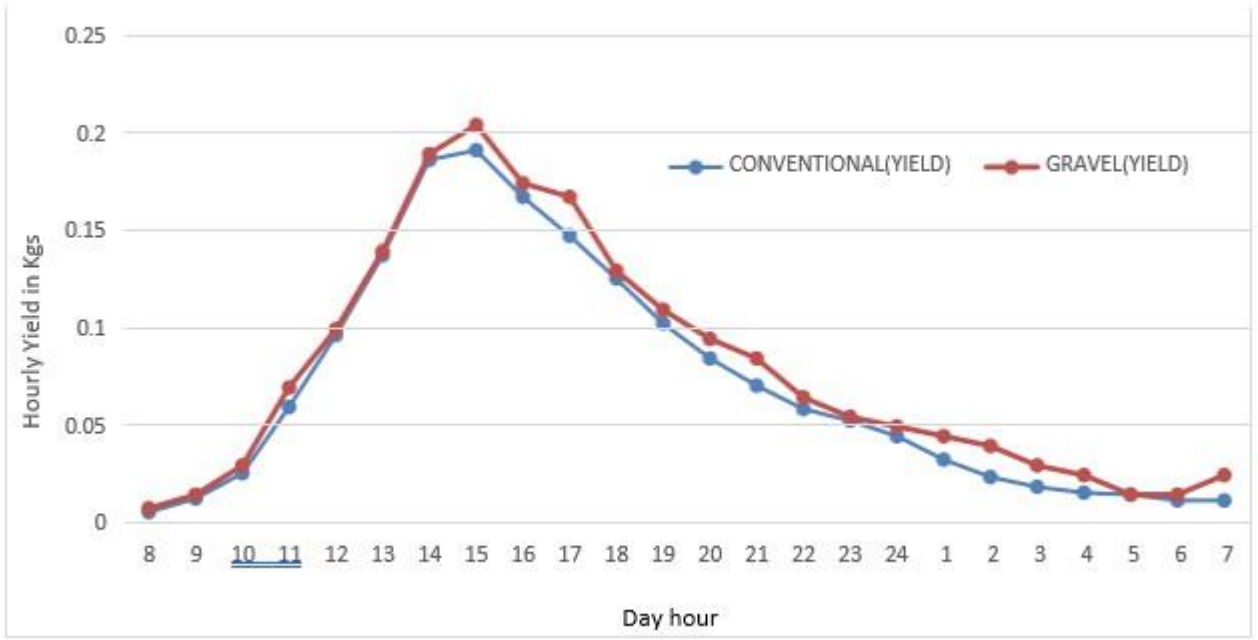
- In the Proposed curve, the highest Basin water temperature is 57.0occurred at the time 1pm.



ΔT=Temperature difference between water and inner glass cover surface

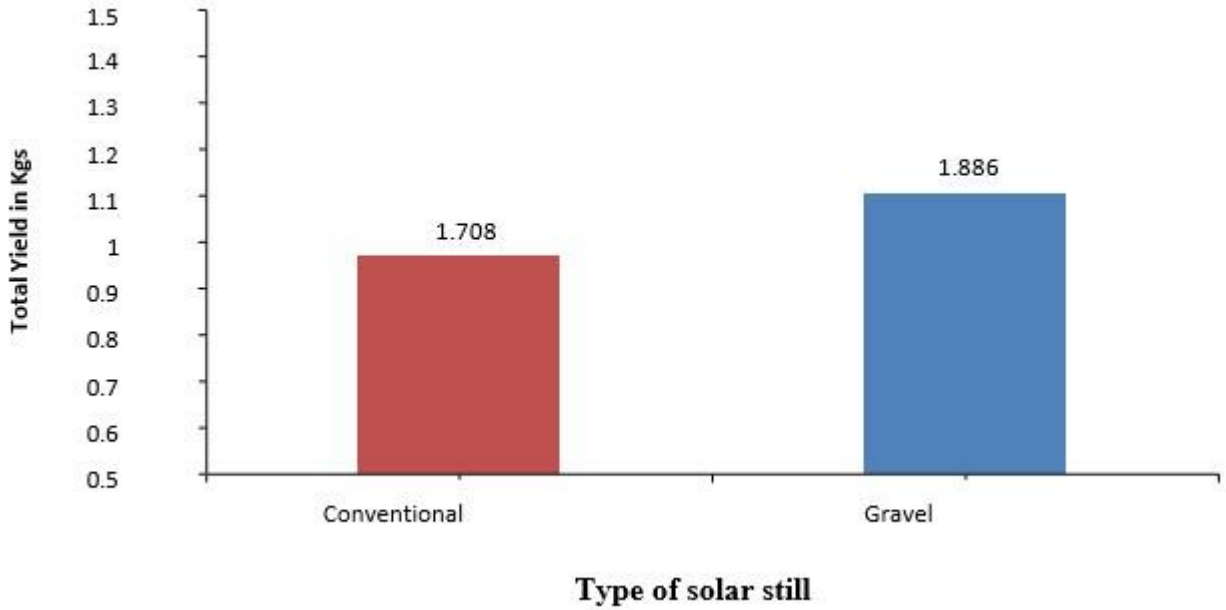
Variation of ΔT with respect to day hour

- In the Proposed curve, the Temperature variation from negative to positive occurred between 10 am to 11 am.
- In the Conventional curve, the Temperature variation from negative to positive occurred between 11 am to 12pm.



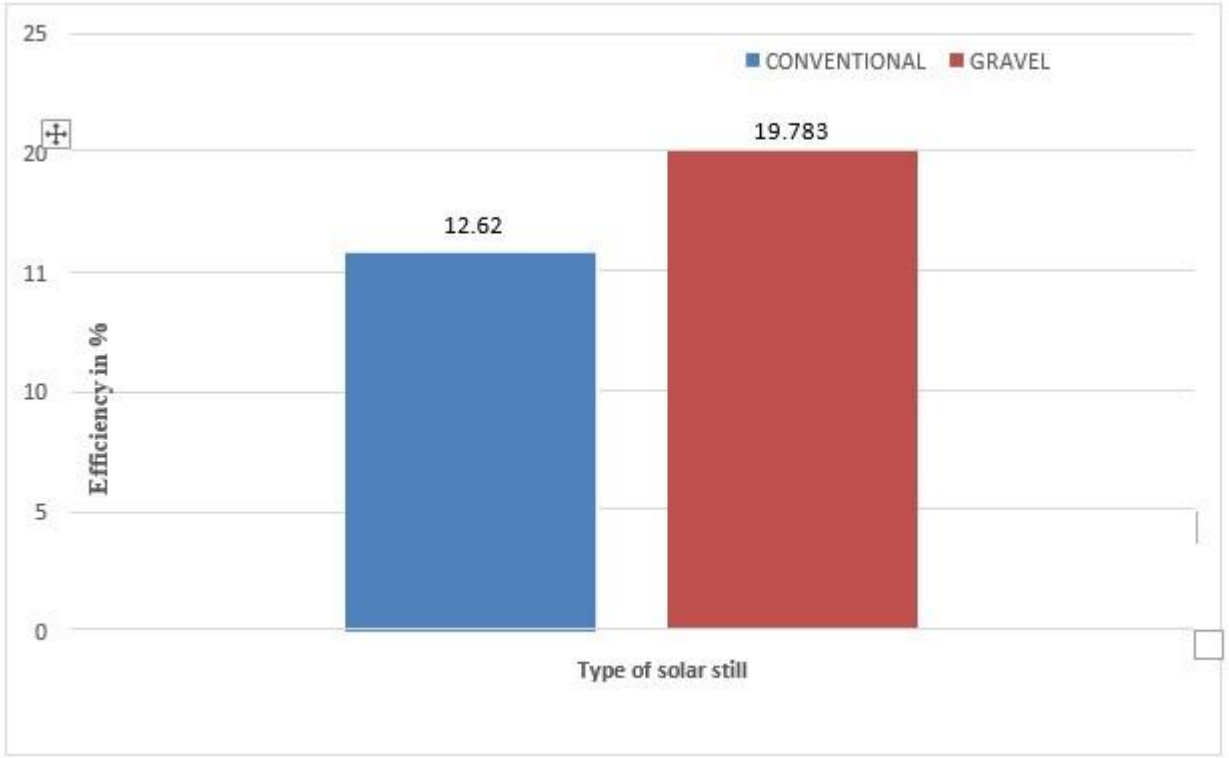
Variation of yield with respect to day hour

- In the graph the highest yield difference occurred between Conventional and the Proposed curve at 3 pm.
- The highest Yield point in Proposed Yield curve is 0.235.



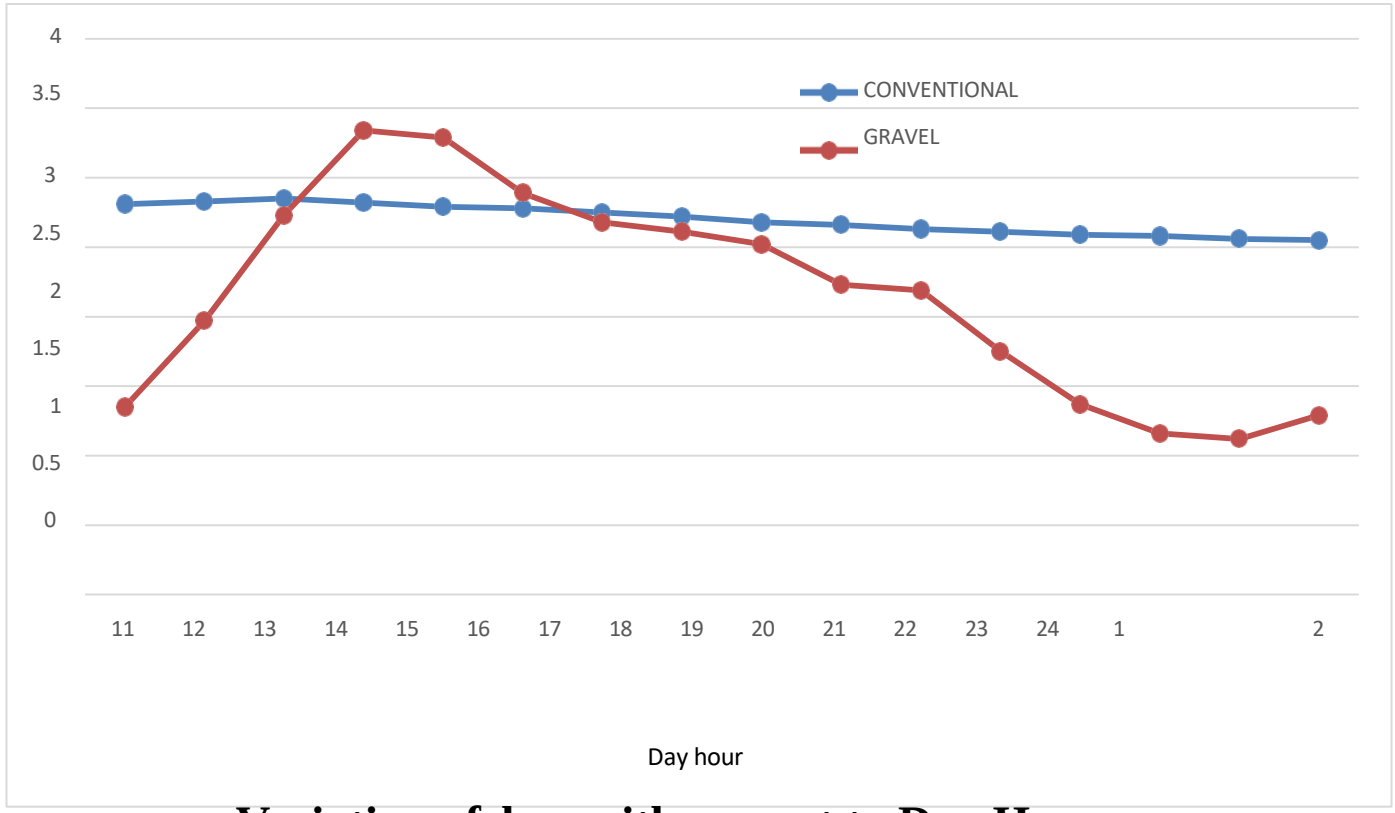
Variation of Total Yield with respect to various solar stills

- The Proposed yield is higher than the Conventional Yield.
- The Proposed experiment produce more yield than the Conventional one.



Variation of efficiency with respect to various solar stills

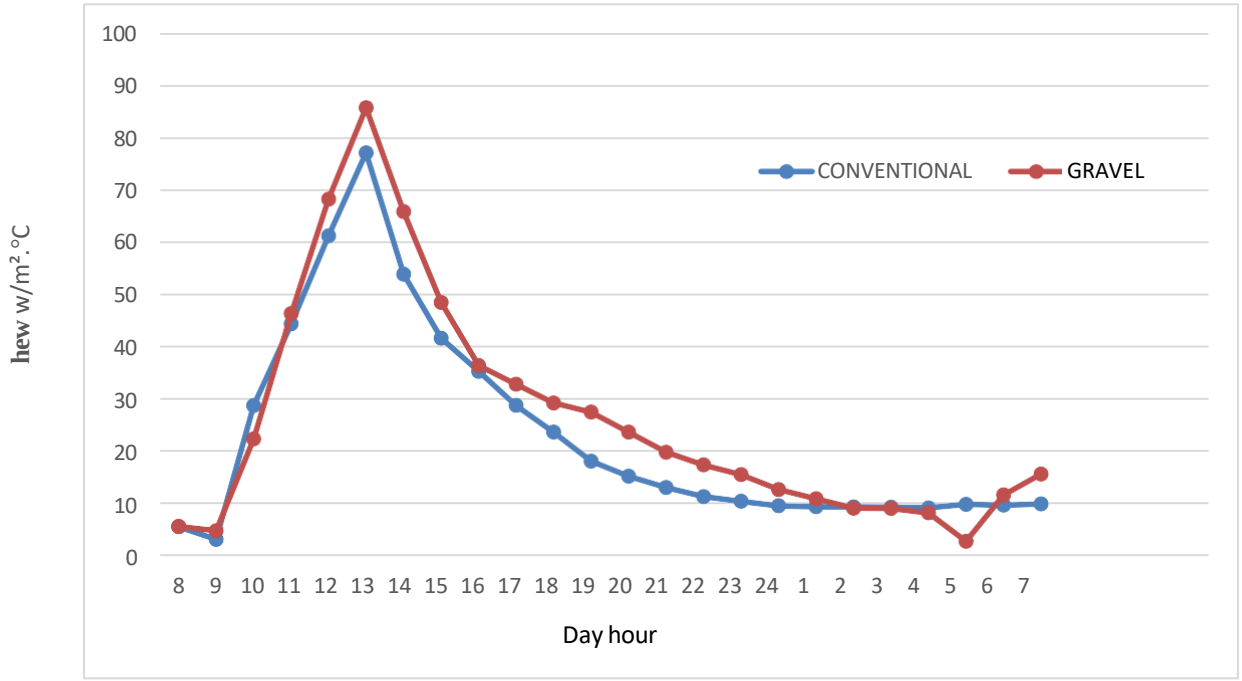
- The total efficiency of the proposed experiment is 19.783%



Variation of h_{cw} with respect to Day Hour

h_{cw} =Convective heat transfer coefficient

- The Proposed h_{cw} values is higher than the Conventional h_{cw} values.
- The highest h_{cw} value occurred in Proposed experiment is 2.81 at 11am.



Variation of h_{ew} with respect to Day Hour

h_{ew}=Evaporative heat transfer coefficient

- The Proposed h_{ew} values are higher than the Conventional Hew values.
- The highest h_{ew} value occurred in Proposed experiment is 84.242 at 12 pm

CONCLUSIONS

The important conclusions from the present work are summarized below

- The highest yield and efficiency of the still are obtained at 1pm. The partial pressure difference between water temperature and condensing cover temperature is found to be highest for the 0.04 m water depth, which directly influences the yield.

- The distillation efficiency of solar still with **Gravels is 19.783%** , efficiency of **conventional solar still is 12.62%.** The total yield of 1.886kgs is obtained for solar still with gravels. **Increased in yield is 10.94%** and **Increased efficiency is 7.61 %**

- The study will be useful for designing efficient solar distillation systems for remote and coastal climatic conditions.

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