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Performance Enhancement of Single Basin Single Slope Solar Still Using Absorbing Material

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Abstract
The simplicity of solar distillation makes it possible to have a sustainable solution for water purification in regions facing freshwater scarcity. This paper monitors the performance of a single basin single slope solar still coupled with different absorbing materials with the view to improving thermal energy absorption and hence water output. An experiment was made using black stones, charcoal powder, and sand as basin-lining materials. Results indicate a great daily yield improvement over that of a conventional still without absorbing materials.

1. Introduction

Clean water is a basic human need, yet billions of people face water scarcity. Conventional desalination and purification are often energy-intensive and costly. Solar distillation is cheap to run on the environment-rural, remote areas would benefit immensely!

A single basin single slope solar still is one of the very simple designs. It comprises a shallow basin, covers with transparent glass, and has a sloped surface for condensation. However, low thermal efficiency limits its duration of application practically. For this reason, researchers have tried various ways to enhance it- one method is through absorbing materials whereby the thermal performance gets improved. In this study, the effectiveness of different absorbing materials shall be evaluated; these materials are placed in the basin of the solar still.

2. Literature Review

Modifications intended to improve heat retention and solar absorption can have a substantial impact on solar still performance. The beneficial effects of material selection and energy storage on productivity were shown by Tiwari et al. [1]. Techniques like floating absorbers, dyes, and thermal insulation were reviewed by Murugavel et al. [2].

Sand, charcoal, and black stones have all been investigated for their high capacity to absorb and hold heat. They are feasible for widespread use due to their accessibility and low cost. According to studies, these substances raise the temperature of the water, which enhances the yield of distillate and increases evaporation rates.

To enhance the performance of solar stills, more research backs the incorporation of different absorbing and phase-change materials, altered basin designs, and reflector systems. For example, in order to increase efficiency, Omara et al. [3] looked into wick-type solar stills in conjunction with absorbing materials. Improvements utilizing local materials and nanofluids were reported by Madhu and Umashankar [4]. The impact of colored cotton wicks in solar stills and their function in thermal enhancement were examined by Gnanadason et al. [5]. The impact of selectively absorbing coatings on productivity was emphasized by Bait and Si-Ameur [6]. The thermal performance attained by embedding inexpensive materials like rubber and biomass was highlighted by Rajamanickam and Senthilkumar [7].

Additional studies demonstrate how geometric changes, absorber color, and basin coating improve performance. The effect of colored materials was assessed by Ahmed [8]. Different absorbing materials were compared by Sahota et al. [9] and Panchal et al. [10]. Iron oxide and carbon-based absorbers enhanced heat gain, as reported by Chaichan et al. [11]. Alternative solar collector designs that can be combined with absorbing materials were discussed by Kalogirou [12], Aybar et al. [13], and Arunkumar et al. [14].

The advantages of employing nanomaterials and advanced composites are described in detail in studies by Sharma et al. [15], Sakthivel et al. [16], and Kumar et al. [17]. El-Sebaii et al. [18] and Fath [19] emphasized the importance of PCM-based energy storage.

The potential for performance modeling and optimization is highlighted by energy and exergy analyses conducted by Nafey et al. [20], Sadineni et al. [21], and Reddy et al. [22]. Khalifa et al. [23] used various structural changes to show improvements in performance.

Tanaka [24] investigated the impact of both external and internal reflectors. Basin geometry optimization using absorptive coatings was investigated by Singh et al. [25]. After researching basin-integrated materials, Yadav [26] came to the conclusion that they were effective at lowering energy loss.

These findings are further supported by recent developments. Graphene-coated surfaces were introduced by Zhang et al. [27] to improve thermal absorption. Ali et al. [28] used composites of recycled carbon to create solar stills. Bio-waste was investigated by Prasad and Ranjan [29] as an absorber for environmentally friendly solar desalination. Solar stills enhanced with AI-based solar tracking were studied by Wang et al. [30]. Activated carbon beds were used in the study of hybrid PV-thermal stills by Kumari and Dutta [31]. 3D-printed absorbers were used by Lee et al. [32] to improve thermal conduction and geometry. The life-cycle evaluation of absorbing materials in solar desalination was given by Bhandari et al. [33]. Coatings of copper oxide nanoparticles were assessed by Patel and Singh [34]. Bamboo charcoal was investigated as an eco-absorber by Rahman et al. [35]. Mehta et al. [36] optimized heat using machine learning. Multi-layer absorbent textiles were examined by Devi et al. [37]. Hydrophobic coatings and nano-absorbers were combined by Noor et al. [38]. Smart sensor integration was studied by Das and Mohanty [39]. According to these recent studies, future advancements in solar still performance can be fueled by ongoing material innovation and integration with smart technologies.

3. Methodology

3.1. Experimental Setup

For the present investigation we using two numbers of Single basin single slope solar still in sown in figure 1 for real-time competition with following Specifications and

Table 1: Specifications of Single basin single slope solar still

Sr. Nos	Specifications	Dimensions(mm)
1	Basin Area	1000 * 1000
2	Glass Area	1040 * 1080
3	Glass Depth	5
4	Water Depth	150
5	Inclination of glass	15.38
6	Thermo-couple wire	0-150 C
7	Insulation Thickness	2.5

Figure.1 Actual Single slope solar still

3.2. Absorbing Materials

For the Enhancement of the performance of Single basin single slope solar still following Absorbing Materials are Used

1. Black color red bricks substance

   There are number of black brick particles used in solar still. A number of brick particles are put in a layer on to the basin of a solar still. The brick has 0.65 solar Absorptivity which give higher productivity than simple solar still. The number of bricks particles is easily available.

2. Black concrete particles

   There are number of black concrete particles used in solar still. A number of concrete particles are put in a layer on to the basin of a solar still. The brick has 0.65-0.85 solar Absorptivity which gives higher productivity than simple solar still. The number of concrete particles is easily available.

3. Black aluminum foil

   A black aluminum foil put on to the basin or use as basin materials. It absorbs higher solar rays which give higher productivity. A black aluminum foil has 0.15 solar absorption values and the cost is very law.

3.3. Absorbing Materials Property

In this study solar absorption and emissivity of absorb material are taken as per following table 2.

Table 2: solar absorption properties

SUBSTANCE	SOLAR ABSORPTION	SOLAR EMMISIVITY
BLACK - RED BRICKS	0.65	0.93
BLACK CONCRETE	0.65 – 0.85	0.85 – 0.93
BLACK ALUMINUM FOIL	0.15	0.05

3.4. Measurement Parameters

- Ambient temperature: Ambient temperature measured on hourly base
- Temperature inside the solar still
- Distillation Output

Measurements were recorded hourly from 7:00 AM to 8:00 PM. The still was cleaned and refilled daily to ensure consistent testing conditions.

4. Results and Discussion

The research was done from 7 am to 6 p.m. (i.e. 12 h) on a particular month, i.e. May-2025 which was a clear sky day at Visnagar,Gujarat,India. The inner temperature of solar still, ambient temperature and the distillate output were measured every hour. The inner temperatures of solar still were recorded with the help of thermocouple wire having the least count of 0.1 °C. The ambient temperature and the distillate output were recorded with the help of calibrated mercury thermometer having a least count of 0.1 °C. Table 3 shows the productivity of solar still with and without included black brick particle on the basin.

Table 3: productivity of solar still with and without included black brick particle

Time	Ambient Temp.	Without Absorbing Material (black brick particle)		With Absorbing Material (black brick particle)	
		Temp. Inside the Solar Still	Distillation Output	Temp. Inside the Solar Still	Distillation Output
(Hr.)	(^{O}C)	(^{O}C)	(ml)	(^{O}C)	(ml)
7:00A.M.	28.3	29.5	0	29	0
7:00A.M.to 8:00A.M.	29.6	31	0	31.3	0
8:00A.M. to 9:00A.M.	31.4	37.6	12	39.8	10
9:00A.M. to 10:00A.M.	33.6	43.5	28	45.5	23
10:00A.M. to 11:00A.M.	36	45.3	112	51.4	98
11:00A.M. to 12:00 PM	38.3	48.5	258	55.6	295
12:00 to 1:00 P.M.	40	53	440	58.2	520
1:00P.M. to 2:00P.M.	41.6	62.6	635	65.5	688
2:00P.M. to 3:00P.M.	41.4	58.4	618	64	670
3:00P.M. to 4:00P.M.	41.2	55.2	366	58.1	384
4:00P.M. to 5:00P.M.	40.2	48	164	53	205
5:00P.M. to 6:00P.M.	38.6	43.7	32	47.7	46

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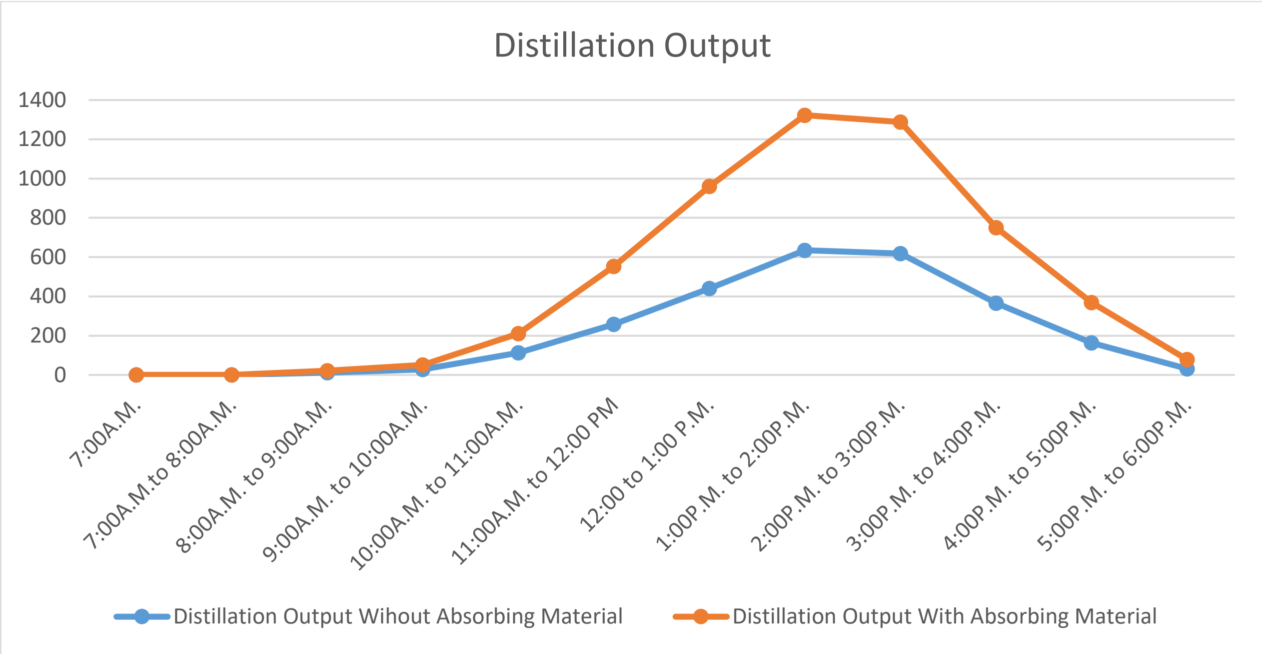

FIg 2: productivity of solar still with and without included black brick particle

As shown in the figure 2 we Cleary see the output of distillation output was higher in without absorbing in before noon but after noon the process was reversed and with absorb material 274 ml more distillation output achieved with black brick particle similarly same trend find other absorb materials was find as shown table 4 and figure 3 for concreteparticle 334 ml more distillation output achieved.

Table 4: productivity of solar still with and without included concreteparticle

Time	Ambient Temp.	Without Absorbing Material		With Absorbing Material	
		Temp. Inside the Solar Still	Distillation Output	Temp. Inside the Solar Still	Distillation Output
(Hr.)	(^{O}C)	(^{O}C)	(ml)	(^{O}C)	(ml)
7:00A.M.	28	29.2	0	27.3	0
7:00A.M.to 8:00A.M.	29.2	30.6	0	28	0
8:00A.M. to 9:00A.M.	31.4	37.6	12	38.4	12
9:00A.M. to 10:00A.M.	34.4	44.5	29	44	26
10:00A.M. to 11:00A.M.	36.8	46.3	114	51	119
11:00A.M. to 12:00 PM	39	49.4	263	56.2	293
12:00 to 1:00 P.M.	40.7	53.9	448	61.2	530
1:00P.M. to 2:00P.M.	41	61.7	626	68.6	705
2:00P.M. to 3:00P.M.	41.7	58.8	622	67	682

3:00P.M. to 4:00P.M.	41.5	55.6	369	60.8	396
4:00P.M. to 5:00P.M.	41.1	49.1	168	54.2	218
5:00P.M. to 6:00P.M.	36.8	41.7	30	52	54

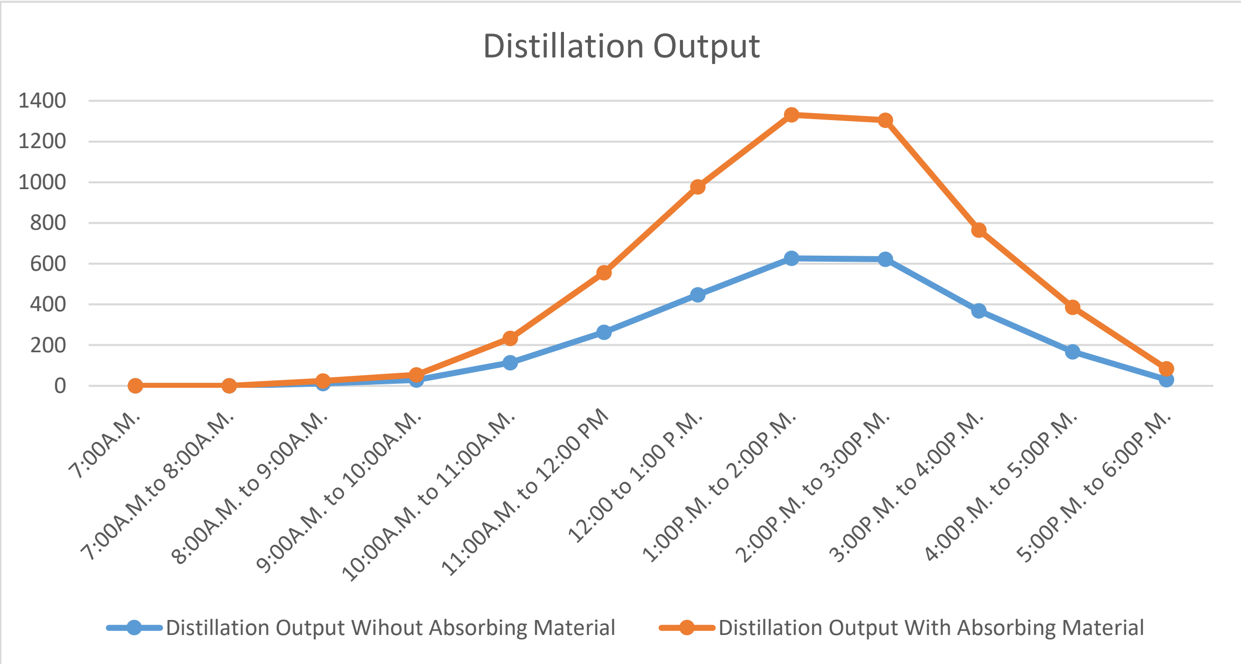

Figure 3: productivity of solar still with and without included concreteparticle

Due to low abosbility of aluminum foil the same trend was followed but productivity was not increased that much only 138ml distillation output increased. As shown in table 5 and Fig 4 output of with aluminum foil is increased earlier but aggregate output was low then bricks and concrete.

Table 5: productivity of solar still with and without included Aluminum foil.

Time	Ambient Temp.	Without Absorbing Material		With Absorbing Material	
		Temp. Inside the Solar Still	Distillation Output	Temp. Inside the Solar Still	Distillation Output
(Hr.)	(^{O}C)	(^{O}C)	(ml)	(^{O}C)	(ml)
7:00A.M.	29.5	29.2	0	29	0
7:00A.M.to 8:00A.M.	29.8	30.6	0	31	0
8:00A.M. to 9:00A.M.	31	37.6	8	37.2	5
9:00A.M. to 10:00A.M.	33.2	44.5	25	45	27
10:00A.M. to 11:00A.M.	37.5	46.3	100	47	106
11:00A.M. to 12:00 PM	37	49.4	260	52.2	285
12:00 to 1:00 P.M.	39.6	53.9	455	57.4	460

1:00P.M. to 2:00P.M.	42	61.7	639	62.5	645
2:00P.M. to 3:00P.M.	41.8	58.8	612	62.8	658
3:00P.M. to 4:00P.M.	40	55.6	358	57.4	375
4:00P.M. to 5:00P.M.	39.7	49.1	172	54.2	192
5:00P.M. to 6:00P.M.	39	41.7	44	43.3	58

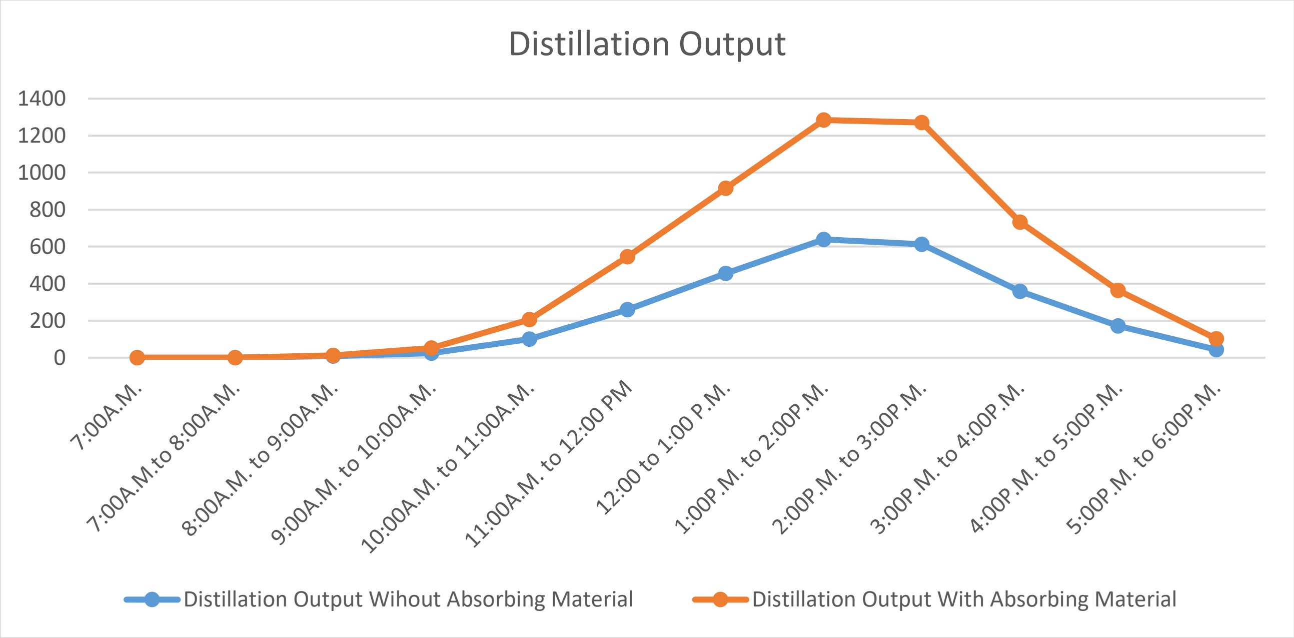

Figure 4: productivity of solar still with and without included Aluminum foil.

5. Conclusion

Water output is greatly increased when absorbing materials are added to a single basin, single slope solar still. Because of its superior thermal characteristics, charcoal powder showed the highest efficiency among the materials tested. In areas with limited resources, this modification offers a practical and affordable way to increase the viability of solar stills for producing drinkable water.

6. Future Scope

Future studies can focus on:

- Combining absorbing materials with phase change materials (PCMs) for heat storage
- Application of nanomaterials for enhanced absorptivity
- Integration with photovoltaic or hybrid renewable energy systems

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