Experimental Investigation on The Performance of a Solar Still Using SiO₂ Nanoparticles /Jatropha Curcas L.

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Abstract

Now, enticing systematic civic since everywhere the world is used in green synthesis and benefit of the simple is eco-friendly with an emergent method of producing nanoparticles (NPs). The aim of a single slope single basin solar still (SBSS) have been synthesized using Silicon dioxide (SiO_2) nanoparticles (NPs)/leaf extract of *Jatropha curcas* L. (JCL) and the productivity enhancement to an evaluation for the photocatalytic treatment of the system. The synthesized of SiO_2 NPs/JCL have been characterized by XRD (X-ray Diffraction), SEM (Scanning Electron Microscopy) prepared through EDS (X-ray Energy Dispersive Spectroscopy), studied FT-IR (Fourier Transform Infrared) spectroscopy, UV-Vis (UV-Visible spectrophotometer) was verified. The SiO_2 NPs/JCL was established to explain in anatase then phase phytochemicals the synthesis of leaf extracts, the NPs involved in stabilization, and was applied for the first time to testify its potential in the SBSS process. An effect of SBSS is 82.26% during the treatment with synthesizing SiO_2 NPs/JCL successfully active for the solar still process. The SBSS has been produced the total summer distillate yield of 8.79 L/day (SiO_2 NPs /JCL), winter is 6.49, L/day (SiO_2 NPs) to over all of the system at 24 h cycle in the local climatic condition at Vijayawada, Andhra Pradesh, India. The yield of the SBSS is enhanced due to the increased absorption of solar radiation by the SiO_2 NPs/JCL, and the thermal energy is absorbed by utilization during nighttime for distillation. This is due to the convection of absorbed thermal energy to the saline water and established in a clean-green treatment solution.

Introduction

The thermal energy source is employed to harvest solar energy absorption materials and newly established hopeful submissions energy storage associated paraded. A solar radiation use of photothermal apostles was an effective path for collecting and based on solar selective absorber coatings. An optimized to exploit the light absorption range of the samples by [1]. Peyman *et al.* [2] were studied in single slope solar still and is nano-coated in condensation surface plays an important role in the water production rate of the systems. The condensation process improved solar productivity still at cover tilt angles of 35° and 45° . Swellam *et al.* [3] have shown a theoretical analysis of modified solar stills (MSSs) using micro/nanoparticles to improve thermal performance. They are estimated the energy and exergy productivities for improvement to the conventional solar still. It is improved by 41.18% and 32.35% for graphite, CuO and compared with classical solar (CSS). The exergy efficiency of MSSs is 4.32% and 3.78% for graphite, CuO and CSS is 2.63%. It is valued the costs of solar still with and without micro/nanoparticles. Peyman *et al.* [4] were developed as condensing cover of solar still and were coated in condensation surface by a nano-silicon solution. It is used in nano-coating to condensate manufacture of solar to grow significantly and verified in AFM tests of condensing cover effects dripping with 23%. Suresh *et al.* [5] studied single basin solar nano-basin still and calculated the fuzzy logic technique was in summer and winter intension of the sullage water into clean water. 24 hours cycle is $7.624 \text{ kg/m}^2\text{day}$ of drip production, and without drip, production is $5.254 \text{ kg/m}^2\text{day}$, and Overall efficiency is 45%. Sayed et al. [6] was synthesized in ZnO nanoparticles using the Hydrothermal technique. This sample is used a

solar still performance has studied. The nanomaterials performance of a solar still productivity is 30% and 38% and compared against the nano-sphere shape. El-Gazar *et al.* [7] have developed a fractional classical for the solar still performance using hybrid nanofluid and analyzed the fractional model's error of 3.243% associated with 20.08% for the classical one. The effect of hybrid nanofluid in summer and winter performance is daily productivity of 27.2% and 21.7%. They are conculcated that hybrid nano increases the summer and winter for average energy efficiency of 12.6% and 13.4% and exergy efficiency is 22.5% and 13.4%. Weiwang *et al.* [8] designed and coated for double metal-dielectric solar selective absorbers using co-sputtering techniques. The samples developed that nano-multilayered MoOx-based solar selective absorber coatings. It is showed that good solar absorptance of 0.93 and low thermal emittance is 0.06. Its presentations an ideal spectral selectivity of 0.92/0.07. Douyang *et al.* [9] have fabricated by nano-multilayered AlCrSiO film using cathodic arc ion plating. The solar absorber in the selectivity range is (0.923–0.927) / (0.160–0.193) and improved thermal stability of the absorber at 650°C. The bio-based composites of PLA and hybrid have been invented by 30 wt% of dried kenaf fiber, then 0, 1, 2, and 3 wt% is montmorillonite clay filler. The consequences of water absorption and biodegradability properties show that the water-resistance of hybrid bio- composites is improved by Ramesh *et al.* [10]. Pufleau [11] was proposed the parabolic oxidation kinetics of polycrystalline silicon nanoparticle aggregates at 1000 °C and surface area with the range is 3 to 19 m²/g. It is crystallite size up to 50 to 70 nm. Zulhelmi *et al.* [12] have prepared hydrophobic silica aerogels and rice husk ash-derived sodium silicate method of sol-gel method. The optimal quality of silica aerogels is 668.82 m²/g. 9 days attained that heat treatment on silica aerogels was 200, 300, and 400 °C for 2 h results and decreased of aerogel's density range of 0.048 g/cm³ to 0.039 g/cm³

The determination to donate the JCL direction synthesis of SiO₂ nanoparticles the present-day study reports is the biosynthesis of SiO₂ nanoparticles using LCL leaf extract. Outcomes of the documented work by various researchers have been considered, and efforts have been made to overcome the inconveniences in the on-hand solar stills to devise and fabricate new single-basin solar stills. We organized a SiO₂ nanoparticles/JCL bio-composite material with good photocatalysis activity for the solar absorption materials. The temperature's stability on different days (summer and winter) was also considered on a solar still. The preparation development of the system has shown an important commercial and eco-friendly standard.

Experimental Materials And Procedures

2.1. Investigates of Chemicals and Leaf's material

The SiO₂ nanoparticles (NPs) were purchased from Suvarna Scientific, Vijayawada, Andhra Pradesh, India. KL University nearest includes at Mellempudi village is collected the (Barbados nut) *Jatropha curcas* L. (JCL) fresh leaves as shown in Fig. 1. The green synthesis of SiO₂ NP_s has been utilized with a mixture of all the chemicals. To developed SBSS was a physicochemical characterization of analytical

grade (purity $\geq 99\%$). We are used in Whatman Qualitative Filter Papers with a grade of 42: 11cm (white color) of pore size by 1.2 μm and the filtration is used in leaf extracts. All experiments were used in distilled water (DW).

2.2. Synthesis of SiO_2 /Jatropha curcas L.

The Jatropha curcas L. (JCL) has been collected and washed systematically by DW to confiscate the associated dust particles and censored to actual acceptable pieces than dehydrated in sunshine incidence. 100 leaves of Jatropha curcas L. are absorbed in the 150ml of DW water and simmered at 100°C for 60 minutes and investigate leaf extracts. Gained the leaf extract was to possess for cooling at ambient temperature, it is used in filter Whatman Qualitative Filter Papers and utilized with a green synthesis of SiO_2 NPs. The sample with 110ml of 0.75M SiCl_4 is mixed through 110ml of filters of leaf extracts with a ratio of 1:1 (volume per volume) with a constant for the magnetic stirring at ambient temperature. The solutions to change the color with transparent whitish-brown have been observed within 35min after socializing organized precursor than the leaf extract is owed by reducing Si^{4+} . It is designated a green synthesis of SiO_2 NPs, as shown in Fig. 2. The novel NPs are obtained to 30ml of ammonia with a mixture solution of NPs drop-wise under constant magnetic stirring at ambient temperature. Finally, the novel NPs have been obtained to complete filtration after the tracked through ethyl alcohol's washing to eradicate the ionic impurities. Then, the cleaned NP_s of air-dried of 600°C was calcined for 4hours in a muffle furnace. The grind has concluded the arrangement of ash by SiO_2 NPs with a crystal mortar pestle. Fig. 3 shows a conceivable response mechanism of green synthesis of SiO_2 NPs.

2.3. Characterization of SiO_2 NPs/Jatropha curcas L.

The sample has been characterized through the XRD (Powder X-ray Diffraction) and investigates that crystal structure and phase by green synthesized SiO_2 NPs. The XRD pattern was recorded on an X-ray diffractometer (Philips X' Pert Pro MPD, The Netherlands) equipped with Cu-K α radiation ($\lambda = 0.154 \text{ nm}$) within a 2θ range of 10° - 70° at 40 kV/40 mA. SEM (Scanning Electron Microscopy-JSM-7610F, JEOL, Japan) characteristics of the morphological with the size of the green synthesized SiO_2 NPs have been determined. The samples are analyzed by the FT-IR (Fourier Transform-Infrared) spectrometer with Model Nicolet 6700, Thermo Fisher Scientific, USA, which is utilized to illustrate the functional groups. The samples are also studied an optical properties analysis of the UV-Visible spectrophotometer (Evolution TM -201, Thermo Fisher Scientific, USA).

2.4 Analysis of SBSS

A photograph of the experimental analysis of a single slope single basin solar still (SBSS) is depicted in Fig. 4 as by Feilizadeh *et al.*, [13]. The basin area of 100cm uses them, and the width*breadth of the magnitude's basin area is 100cm *100cm. The SSBS of the front wall height is 20cm, and the back-wall height is 30cm. The absorber basin area is made of copper sheet, and the saline water is filled level of maintained 1cm depth of water in the basin area. The organization has used a glass cover thickness of

4mm, an inclination of 11° for the horizontal and insulated sidewalls. The bottom of the basin was with glass wool with a thickness of 5cm. The SSBS is in progress from 09.00 am to 5.00 pm, and measured variations of the parameters like the stepped basin, saline water, moist internal air, and glass cover were at 30 minutes time interval. The experiment was conducted under the weather condition of KLEF at Vijayawada, Andhra Pradesh. The solar radiation data was measured using a solar radiation monitor. A thermometer measures the ambient temperature. The RTD measures the SBSS - PT-100 types with sensor absorption of the thermocouple wire in range 0 - 800°C with $\pm 0.1^\circ\text{C}$ correctness of the data separately on the systems.

2. 2. The SBSS reactor design effective environments

Designed and fabricated single slope single basin solar still (SBSS) has been working for the solar absorption of the system with a performance of photocatalytic treatment. The SBSS has been made using a highly copper sheet with basin area width and breath trough of 100cm length. A UV transparent glass thickness of 4mm has used a length of 100cm. The water inlet rubber tubes are further joined with a completely closed plastic tank (capacity 15 L) and maintained that water depth is 1cm of the basin area by the saline water in the solar photocatalytic treatment method. The presence of SBSS has been worked on a sunny day of winter (November, December) and summer (April, May) with the period from 09:00 to 18:00 for the photocatalytic treatment of SBSS. The system's working is performed with a photocatalytic treatment process by the average solar irradiation in the winter of 645 W/m^2 and summer is 876 W/m^2 . They are followed and calculated by Kusam Mecco KM-SPM-530 Digital Solar Power Meter (KUSAM-MECO, India), as shown in Table 1. As a photocatalyst, the green synthesized SiO_2 NPs are performed that average temperature achieved by the SBSS during the experimental thermal performance is 75°C . The experimental work is followed in a schematic diagram, and the original picture of the SBSS made for the photocatalytic degradation Fig. 5 and Fig. 3.

Result And Discussion

3.1. Characterization of SiO_2 NPs/*Jatropha curcas* L.

The SiO_2 NPs/JCL analysis of an XRD pattern is successfully synthesized and calculated by Debye Scherrer's equation as by Hargreaves [14]. It is crystalline nature and anatase phase, as shown in Fig. 6(a).

$$d = \frac{0.89\lambda}{\beta \cos \theta}$$

where NPs diameter is d for an average value, the X-ray radiation source for the wavelength (λ) is 0.89 of a constant crystalline structure is used the Bragg's diffraction angle (θ), the angular full width is β at half maximum XRD peaks values are verified at a diffraction angle of 2θ . The JCL synthesized SiO_2 NPs

average crystalline size of 50 μm is a good performance. The amorphous SiO_2 microspheres are increased to the anatase phase's diffraction peaks. They also seemed on XRD patterns on the samples of SiO_2 NPs/JCL, and the intensity of diffraction peaks of the anatase phase has been increased with the increase in the SiO_2 ratio.

The SiO_2 NPs of an XRD pattern were synthesized by a peak value range of 2 angle peak values and formed in miller indices of hkl values as shown in Fig. 6(a). The XRD pattern of SiO_2 NPs/JCL seemed to all the anatase diffraction peak (JCPDS 21-1272) and above said significances designated that SiO_2 nanoparticles occurred anatase phase. The sample is conformed to the crystalline structure's anatase phase, and the obtained that results suitable to join the committee on power diffraction X-rays by Chen and Zhang [15]. The lattice parameters are $a=b= 3.792 \text{ \AA}$, $c= 9.554 \text{ \AA}$ by the tetragonal anatase phase of crystalline for the samples, the space groups are $I4_1/amd$ in between all the SiO_2 crystal phases, and the anatase showed the maximum photocatalytic movement, it results reliable to photocatalytic activity of the samples to the high crystallinity on the nano-sized- SiO_2 . It is measured in favor of photocatalytic activity directly connected to the controller recombination rate and the sufficiently long-lifetime thermal performance reactions.

The SEM analysis of SiO_2 NPs/JCL has been performed and evaluated with the shape and effect of the samples' size. The SEM images are successfully done of the samples, as shown in Fig.6(b), and the diameter range is 20-100 μm . SiO_2 NPs/JCL was clearly given to many small and observed lengthwise with less rather great sized agglomerate NPs; it is easily got with SEM images. The SiO_2 NPs/JCL group has formed the low pH by a solution, and the phytochemicals are presented as the leaves of *Jatropha curcas* L. possibly rolled as capping agents. It is improved the synthesis of the variability of NPs, and the dispersion between SiO_2 NPs has reduced their groups by Asuk *et al.* [16]- Bar *et al.* [17].

The SiO_2 NPs/JCL elemental composition has been synthesized on the X-ray Energy Dispersive Spectrometer (EDS) as Khade [18] Fig. 6(c) and Fig. 6(d) is the EDX spectrum and exposed the purity of the sample as both silicon (Si), carbon (C), and oxygen (O) is present by the material of the weight percentages of 40.53% (Si. K), 28.22% (C. K), 31.26% (O. K). The sample of the atomic percentage is 42.25% (Si. K), 39.19% (C. K), 18.66% (O. K), respectively. The JCL synthesis of SiO_2 NPs was established to the C, and Cl also existed for the sample. The chloride (Cl) group present in the precursor has been increased and used for the JCL synthesis of SiO_2 NPs. The C peak of the phytochemicals was outstanding to the incidence existing in the leaf extracts of JCL. An important role with playing in the synthesis of NPs are studied on the FT-IR spectroscopy. The categorize of the biomolecules based on chemical groups existing in the leaf extracts of JCL role for the capping/reduction of metallic ions (Si^{+4}) of the precursor. Fig. 6(e) is an FT-IR spectrum on the SiO_2 NPs/JCL, and the hydroxyl group in JCL was broadband on 3437 cm^{-1} by the phenols. The life of JCL with a phenolic group is possibly owned rate of polyphenolic tannins and was covered the surface of green synthesized SiO_2 NPs and primary amine groups were band range of $2917\text{-}3863 \text{ cm}^{-1}$. The strong band of 1631 cm^{-1} is presented C-H stretching

through the intense peak of 2233 cm^{-1} , and the carbonyl group has qualified to stretch vibrational frequency of C=O of anhydrides. The JCL is a strong peak of 1059 cm^{-1} . It is given to C-Cl. The weak band is 1440 cm^{-1} , and the alkene group was showed the incidence of C=C by Kumar *et al.* [19].

The green synthesis of SiO_2 NPs is confirmed that improve studies of the optical properties, and absorption spectra are also achieved on the samples, as shown in Fig. 6(f). The green synthesis of metallic SiO_2 NPs has been exposed by the strong absorption peaks of 331 nm with a range from 200-800 nm. The bulk SiO_2 NPs of 342 nm was clearly showed the increases in the bandgap and have been compared within absorption spectra of blue modification experimental functions. It is confirmed that the sharp and forceful peak individual circulation pattern is verified in the samples' absorption spectra. The impurities current in the solution of NPs is associated with the previous literature by Karakitsou *et al.* [20] observed in the peak value an interference caused by absorption, and the bandgap energy is analyzed conferring to Tauc equation by Tauc [21]. The photon energy ($h\nu$) is used in the linear portion of the curve. A novel sample got the direct bandgap of 3.72 eV, and indirect bandgap energy is 3.32 eV, the bandgap energy (E_g) is 0.57 eV transition in both semiconductors. The bulk SiO_2 NPs are bandgap energy higher than that of 3.3eV and changed the strong quantum confinement higher to the samples' valence and conduction bands.

3.2. Synthesized SiO_2 NPs/JCL with Performance evaluation of a solar still

The experimental of a solar still was carried out during January 2020 to January 2021 at Vijayawada, (latitude 16.5062° N , longitude 80.6480° E) Andhra Pradesh, India. The solar still with parameters have been measured with the effect of internal thermal performance improved temperature. It is coated in basin area with operation at 1cm water's depth of the basin more absorption on the solar radiation intensity. Among the experimental days, observations for one of the typical days in winter (January 2021) and summer days (May 2020). The intensity of solar radiation and ambient temperature are plotted concerning the typical day's working hours, as shown in Fig. 7. The hourly variations of different parameters (temperature, production) of the SBSS during experiment day were qualitatively similar. Consequently, the solar still is presented the hourly of these parameters during shine hours was characterized by average an ambient temperature and solar radiation on winter days of 33°C and 774 W/m^2 then summer days in both of a maximum solar radiation and ambient temperature is 985 W/m^2 and 37°C . Incident solar radiation and ambient temperature increases from the sunrise until maximum value equal to 985 W/m^2 and 37°C observed at 13:00 local time, then decrease to a minimum value observed at sunset as shown in Fig. 7

The Fig 8 as active nanofluids is used by the SBSS achieved the temperature with during days like glass cover is 36.5°C (winter), and 45.8°C (summer), the basin temperature was 70.2°C (winter), and 74.4°C (summer), the water temperature is 70.2°C (winter), and 72.2°C (summer), by Abdullah *et al.*, [22]; respectively. The internal heat transfer modes have layered the SiO_2 NPs/JCL to contact the glass, basin, and water temperature, improving the heat energy process.

The weather condition is occupied on the typical days in January 2020 to January 2021 analysis of the amount of distillate yield the system as shown in Fig. 9. The progress of the SBSS is achieved over the sunshine at 60 minutes from 8.00 to 18.00. 12kg saline water was used by the SSBC and improved that temperature effectively at 30 minutes. From 11.30 to 15.00, the system's maximum distillate production is 0.459 (summer), 0.342 (winter) mL, respectively. SiO₂ NPs/JCL on the SBSS basin area has enhanced freshwater yield during the days (summer and winter). The 24-hour cycle of the total daily distillate yield by the proposed system has been considered in both weather conditions (winter and summer) to be 6.49, 8.79 L/day, respectively. The SiO₂ NPs/JCL used in SBSS has enhanced the typical heat energy for the everyday concert by 20.15% (winter), 25.8% (summer). It is concluded that basin area temperature in the highest period a sunshine hour.

The system achieves ambient, solar radiation, glass cover, basin, saline water, and distillate water invention during the year. The distillate of an SBSS was attained with a mockup of the development to all the parameters are glass cover, basin, saline water, and distillate invention throughout the year. The SBSS, as presented in Fig. 10, was attained that SiO₂ NPs/JCL nanolayer coated in basin area enhancement of harvest invention. The overall efficiency of SiO₂ NPs/JCL nanolayer used in SBSS has been achieved that of the system is 55.14% (summer) and 39.69% (winter) is achieved by Shanmugan *et al.* [23] and Essa *et al.* [24].

Conclusion

The novel work is to synthesize the SiO₂ NPs/JCL and evaluated them to using for the first time in solar still. The synthesis of SiO₂ NPs/JCL has been characterized by various techniques and improved solar's internal heat energy process. The average crystalline size of 50µm and the bulk SiO₂ NPs are bandgap energy higher than that of 3.3eV. The green synthesis of SiO₂ NPs is stabilized the responsible for reducing metallic ions, and the analysis of leaf extracts revealed as phenols and tannins. The green synthesis of SiO₂ NPs has been established by UV-Vis., SEM, EDS, and FT-IR results. January 2020 to January 2021 with solar radiation absorption activity of the green synthesized SiO₂ NPs are well performed of the solar still process with qualified pure crystalline anatase phase, great total surface hydroxyl groups and higher surface area non-toxic JCL is an actual talented method then suitable for an environment-friendly.

Declarations

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Table

Table 1 analysis of a SBSS values an uncertainty

S. No	The equipment used by a SBSS	Quantity	Accuracy	Uncertainties
1	Beaker values	0–6 L	± 0.01 mL	0.00006 mL
2	Range of voltmeter	0–1000 V	± 0.01 V	0.01 V
3	Ohmmeter value	0–2500 Ω	± 0.1 Ω	0.1 Ω
4	Pyranometer values	0–2000 W/m ²	± 16 W/m ²	0.758 W/m ²
5	Thermocouple wire range	0 - 800°C with	± 0.1 °C	0.088 °C

Figures

Figure 1

shown collection in *Jatropha curcas* L.

Figure 2

Shown the green synthesis of SiO₂ NPs using *Jatropha curcas* L. nanofluid.

Figure 3

Shown the mechanism function of a hydroxyl group (-OH) by SiO₂ NPs/*Jatropha curcas* L.

Figure 4

shown an experimental analysis of SBSS.

Figure 5

Shown the SiO2 NPs using Jatropha curcas L. mechanism of photocatalysis functions.

Figure 6

(a). Shown SiO₂ NPs of XRD patterns. (b) SiO₂ NPs/JCL synthesized of SEM images. (c) SiO₂ NPs/JCL synthesized of EDS spectrum. (d) SiO₂ NPs/JCL synthesized of EDS spectrum. (e) FT-IR spectra of SiO₂ NPs/JCL. (f) shows the absorption spectrum of UV-Vis.

Figure 7

Hourly variation of the solar radiation, ambient temperature by using SiO₂ NPs/JCL with performance of a SBSS.

Figure 8

Hourly variation of basin, water, glass cover temperature by using SiO₂ NPs/JCL with performance of a SBSS.

Figure 9

Hourly variation of basin production water by using SiO₂ NPs/JCL with a performance of an SBSS.

Figure 10

Compare overall efficiency on SiO₂ NPs/JCL of an SBSS.