ScienceDirect

Journal of Energy Storage
Volume 36, April 2021, 102415

Optimal concentration of El Oued sand grains as energy storage materials for enhancement of hemispherical distillers performance

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Received 2 December 2020, Revised 25 January 2021, Accepted 19 February 2021, Available online 2 March 2021, Version of Record 2 March 2021.

https://doi.org/10.1016/j.est.2021.102415
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Abstract

The present experimental study aims to improve the performance of the hemispherical distillers via the utilization of El Oued sand grains as sensible storage materials. The El Oued sand grains characteristic by having SiO_2, large concentrations of Al_2O_3, and Fe_2O_3. These characteristics of the El Oued sand grains make them a good choice in the solar energy storage field especially in solar distillers, as they increase the absorption rate of solar radiation inside the basin in addition to improving the rate of heat transfer. To obtain the optimal concentration of El Oued sand grains that achieves the highest performance of the hemispherical distillers, eight different concentrations of El-Oued sand grains (0.5, 1, 2, 3, 4, 5, 6, and 7%) were studied. To achieve this goal, three hemispherical distillers were designed and constructed, the first and second are the modified hemispherical distillers (MHSS) which contain the sand grains with different concentrations, and the third is a traditional hemispherical distiller (THSS) which represents the reference distiller. The experimental tests of the eight concentrations were conducted on four consecutive days, on each day two concentrations were tested and compared to the reference distiller. The experimental results presented that, the concentration of 3% represents the optimal concentration of El Oued sand grains that achieves the highest performance of hemispherical distillers. The accumulative yield of the reference distiller reached 4780 mL/m^2/day, while the utilization of El Oued sand grains with a concentration of 3% improves the accumulative yield to 7270 mL/m^2/day with a 52.1% improvement in accumulative yield. Also, the daily efficiency of the reference distiller reached 39.2%, while the utilization of the El Oued sand grains

with a concentration of 3% improves the daily efficiency to 59.1% with a 50.8% improvement in daily efficiency.

Introduction

Although bodies of water represent 71% of the total area of the globe, 1% of this water is suitable for drinking [1], [2]. Algeria also suffers from a problem of a shortage of drinking water despite the presence of a large reservoir of groundwater in its vast desert area [3]. Several mechanisms have been adopted to reduce this problem, and among these solutions is the production of fresh water from salt water, knowing that desalination requires high-cost energy [4,5]. Solar distillation is one of the ways to use solar energy directly for the purpose of water distillation, as it uses a simple device called solar distillation that works similar to the process of natural evaporation of water on the surface of the earth, which evaporates as a result of the sun's heat, then condenses to form clouds and then falls as water droplets [6,7]. Projects have appeared in the field of solar energy since 1872 where the first solar distillation station was established by a Swedish engineer with a productivity of 4.255L/m^2 and an area of 4450 m^2 [8]. But the problem that remains is that the yield of the traditional solar distillers remains weak. For this, many researchers are seeking to find thermal storage materials to increase the yield of solar distillates.

Kabeel et al. [9] studied the influences of cement-coated red bricks as energy storage materials on a yield of solar distillers. The results conducted that the utilization of cement-coated red bricks improved the yield by 45% compared to reference distiller. Sakthivel et al. [10] studied the effect of various absorbing materials (black granite gravel) on the thermal performance of solar still. They found that black granite gravel gives the best rate of production (17% higher) compared to conventional solar distiller. Naima et al. [11] studied the effect of absorption materials (charcoal particles of different sizes) on a yield of solar distillers. The results showed that the use of coarse charcoal particles increases daily productivity. Khechekhouche et al. [12] conducted the influence of El Oued sand deposited on the basin of single slope solar distiller. Naima et al. [13] studied the effect of energy storage materials (a mixture of paraffin wax, paraffin oil, and water in which aluminum turning added) in non-conventional solar stills. The results showed that use of the energy storage material mixture increases the distiller productivity. Rahim [14] studied horizontal solar distillation still using aluminum sheet as heat storage materials. It was found that the horizontal solar distillation with aluminum sheet gives more system efficiency compared to the reference distiller. Attia et al. [15] compared two distillates, one of which contains aluminum balls as thermal storage materials and the other without aluminum balls. They found that the daily productivity when using aluminum balls was 1.37 times better than the case without aluminum balls. Bassam et al. [16] investigated the effect of sponge cubes on the thermal performance of the solar still. The researchers found that sponge cubes have a better rate of production compared to reference distiller. Badran et al. [17] used the absorbing materials (black rocks and black coated and uncoated metallic sponge) as a thermal storage material in the solar still. The results showed that black rocks achieve better results in terms of daily accumulation compared to coated and uncoated black mineral sponge. Murugavel et al. [18] compared the effect of quartz, cement, and washed stones in large and small sizes on daily productivity in a single basin and double slope solar still. The researchers found that large quartz rock achieve greater productivity compared to cement and washed stones. Madhu et al. [19] used sand cuboidal boxes as heat energy storage in solar still system, for 8-h operation. They found that the cumulative yield is found to be 3.3L/m^2 from solar still with sand cuboidal boxes and is found to be 1.89L/m^2 from solar still without sand cuboidal boxes, Results show that the exergy efficiency improved by 30% comared to the reference distiller, the maximum exergy efficiency reached 13.2%. Murugavel et al. [20] studied the effect of light cotton cloth, sponge sheet, coir mate and waste cotton pieces on a yield of the solar still. The results showed that daily accumulation when using light black cotton cloth is better than daily accumulation when using foam boards, fibers and cotton waste. Panchal et al. [21]

compared the effect of aluminum plates and galvanized iron plates on the behavior of solar distillery. The researchers concluded that a daily throughput when using the aluminum plate (Al) was 30% better than conventional distillation and 12% when using galvanized iron.

Energy storage materials used to enhance the yield of solar still during the day and after sunset [22], [23], [24], [25], [26], [27], [28], [29]. Aslfattahi et al. [30] studied the thermo-physical properties of nanocomposite (paraffin wax/MXene nanoparticles). Aslfattahi et al. [31] studied the thermal properties of novel nanocomposites consists from pure binary molten salt dispersed with hexagonal boron nitride. Aslfattahi et al. [32] prepared a nanocomposites containing a pre-defined mass ratio of solar salt dispersed with magnesium oxide nanoparticles were prepared in solid and liquid states. Aslfattahi et al. [33] studied the thermal properties of nano PCM (paraffin wax)-based graphene nano-composites. Kean et al. [34] presented a comprehensive review of studied used the nanoparticles to improve the heat transfer performance of phase change material. Kabeel et al. [35,36] improved the yield of solar distiller by utilizing the hybrid storage materials which consists from a mix of graphite nanoparticles and paraffin wax.

The present study aims to improve the performance of the hemispherical distillers. The El Oued sand grains characteristic by having distinguished properties such as quartz (SiO_2) and large concentrations of aluminum oxide (Al_2O_3) and iron oxide (Fe_2O_3). Based on the distinguished properties characterized by El Oued sand grains, the utilization of El Oued sand grains for store thermal energy in solar applications is very effective. In the present experimental study, the El Oued sand grains were utilized as thermal energy storage mediums to improve the accumulative yield of hemispherical distillers. To obtain the optimal concentration of El Oued sand grains that achieves the highest performance of the hemispherical solar distillers, eight different concentrations of El-Oued sand grains (0.5% (5g/L), 1% (10g/L), 2% (20g/L), 3% (30g/L), 4% (40g/L), 5% (50g/L), 6% (60g/L), and 7% (70g/L)) were studied. To achieve this goal, three hemispherical distillers were designed, constructed, and they were tested under the same conditions. The first and second are the modified hemispherical distillers (MHSS) which contain the sand grains with different concentrations and the third is a traditional hemispherical distiller (THSS) which represents the reference distiller. The experimental tests of the eight concentrations were conducted on four consecutive days during July 2020 in El-Oued-Algeria, on each day two concentrations were tested and compared to the reference distiller. This study will be useful and very effective in thermal energy storage applications within the field of solar water desalination.

Section snippets

Experimental setup

In recent years, interest in natural and inexpensive energy storage materials has increased due to their availability as well as to their physical-chemical properties. Many researchers concerned about sand and used it on a wide range of fields, such as industry, nanotechnology, etc.… [37]. The main components of the El Oued sand grains are quartz (SiO_2), and contain large concentrations of aluminum oxide (Al_2O_3) and iron oxide (Fe_2O_3), in addition to small amounts of other materials [38] cal…

Results and discussions

Solar energy is the main source of energy for the driving the solar stills, and since the rate of water vapor generation inside the hemispherical distillers as well as the rate of water vapor condensation inside the hemispherical distillers depends on both the intensity of solar radiation and the temperature of the

surrounding medium. From this standpoint, both the intensity of solar radiation and the temperature of the surrounding environment were recorded every hour throughout the test days,…

Economic evaluation

A comprehensive economic analysis was performed to determine the period of time required to recover the total cost of THSS, MHSS-1/2, MHSS-1, MHSS-2, MHSS-3, MHSS-4, MHSS-5, MHSS-6, and MHSS-7 are shown in Table3. As indicated in this table the payback period required to recover the total cost of THSS, MHSS-1/2, MHSS-1, MHSS-2, MHSS-3, MHSS-4, MHSS-5, MHSS-6, and MHSS-7 are 32, 27, 24, 23, 21, 24, 27, 29, and 33 days, respectively.…

Conclusions

During the current period of interest in natural energy storage materials such as sand, The El Oued sand grains characteristic by having SiO_2, large concentrations of Al_2O_3, and Fe_2O_3. These characteristics of the El Oued sand grains make them a good choice in the solar energy storage field especially in solar distillers, as they increase the absorption rate of solar radiation inside the basin in addition to improving the rate of heat transfer. The use of El Oued sand grains was evaluated…

Author statement

Mohammed El Hadi Attia: Conceptualization, Project administration, Writing, Validation

Abd Elnaby Kabeel: Supervision, Methodology, Software, Formal analysis

Mohamed Abdelgaied: Writing- Reviewing, Editing.…

Declaration of Competing Interest

None.…

Reference (42)

A.E. Kabeel *et al.*
Enhancing the performance of single basin solar still using high thermal conductivity sensible storage materials
J. Clean. Prod. (2018)

P. Dumka *et al.*
Performance evaluation of single slope solar still augmented with sand-filled cotton bags
J. Energy Storage (2019)

A.E. Kabeel *et al.*
Performance enhancement of a photovoltaic panel with reflectors and cooling coupled to a solar still with air injection
J. Clean. Prod. (2019)

A.E. Kabeel *et al.*

Observational study of modified solar still coupled with oil serpentine loop from cylindrical parabolic concentrator and phase changing material under basin
Sol. Energy (2017)

A.E. Kabeel *et al.*
Modified pyramid solar still with v-corrugated absorber plate and PCM as a thermal storage medium
J. Clean. Prod. (2017)

A.E. Kabeel *et al.*
A comprehensive review of tubular solar still designs, performance, and economic analysis
J. Clean. Prod. (2020)

M.M. Naim *et al.*
Non-conventional solar stills Part 2 Non-conventional solar stills with energy storage element
Desalination (2003)

N.H.A. Rahim
A new method to store heat energy in horizontal solar desalination still
Renew. Energy (2003)

M.E.H. Attia *et al.*
Effect of aluminum balls on the productivity of solar distillate
J. Energy Storage (2020)

Bassam A/K Abu-Hijleh *et al.*
Experimental study of a solar still with sponge cubes in basin
Energy Convers. Manag. (2003)

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Cited by (33)

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2023, Thermal Science and Engineering Progress

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