

PAPER • OPEN ACCESS

Desiccant materials for the production of water from humid air with the help of concentrated solar power

To cite this article: Avipsita Das *et al* 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1130** 012054

View the [article online](#) for updates and enhancements.

You may also like

- [Dehumidification Analysis of Rotary Solid Desiccant Wheel System for different Surface Materials](#)
Taliv Hussain, Ashad Ahmad, Nabeel Hidayat et al.
- [Performance Enhancement of Rotary Desiccant Wheel using Novel Homogenous Composite Desiccant Designs](#)
Selvaraji Muthu, N Sekarapandian and K Ashok
- [Desiccant materials for air conditioning applications - A review](#)
R P Singh, V K Mishra and R K Das



The Electrochemical Society
Advancing solid state & electrochemical science & technology



249th
ECS Meeting
May 24-28, 2026
Seattle, WA, US
Washington State
Convention Center

Spotlight Your Science

**Submission deadline:
December 5, 2025**

SUBMIT YOUR ABSTRACT

Desiccant materials for the production of water from humid air with the help of concentrated solar power

Avipsita Das, V Thirunavukkarasu¹, M Cheralathan

Department of Mechanical Engineering, SRM Institute of Science and Technology, Kattankulathur- 603 203, Tamil Nadu, India

¹Email: vthiru77@yahoo.com

Abstract. Water is one such element that the human being cannot live without. In the last couple of decades due to global warming and unprecedented weather changes water has become scarce. Transportation of water to villages and desert areas cost a fortune and is not practical. In this study, water has been extracted from various desiccant materials while also employing the help of concentrated solar power. The desiccant materials that have been used are Silica Gel, Activated Clay and Activated Alumina. Activated Clay is a mixture of different elements which can be used as a desiccant material. These desiccants tend to adsorb the water present in the atmospheric air that is around it and when regeneration occurs it is unconfined as water vapour droplets. For the present work, a Scheffler- type concentrator along with a short cylinder type receiver is used as the solar radiation heat source for the regeneration process. Solar radiation or rather beam radiation is directed at the receiver that contains the desiccant material. It is observed from the experimental study that silica crystals produced 142 ml/kg/day of water whereas activated alumina and activated clay produced 100 ml/kg/day and 48 ml/kg/day of water respectively on a clear sunny day.

Keywords: Desiccant materials, Concentrated solar power, Scheffler reflector, Short cylinder receiver, Water production.

1. Introduction

To sustain life on earth, a prime need is clean drinking water, however, due to global warming and other effects such as water pollution and pollution in general; water has become a scarcity in many places of Chennai, Tamil Nadu. Water shortage can be resolved by various approaches that have already been researched. Some of the methods are:

- Water transportation – In this scenario water would be transmitted from another location such as bore well, river or even from the underground with the help of tankers supplying the water.
- Desalination of brackish water – There are various ways that one can achieve; some of the methods include desalination using a solar still, vacuum distillation etc.
- Water extraction from humid/atmospheric air using various desiccant materials.

Out of the above methods, the first two are expensive, as well its dependency on the availability in the regions. The third approach is comparatively inexpensive and it can be used in most humid places. Various methods can be used for extraction of water from the hot humid air. Any of the following methods can be used to extract water from humid air.



- Condensation of the water vapours below the dew-point temperature.
- Collect water from wet fog using meshes.
- Absorption of water using desiccant materials.

The principle of the concentrated solar power systems is that they work by concentrating the incident solar radiation on to the receivers of smaller area, thereby increasing the radiation intensity and hence the temperature. The desiccant materials can be solids, liquids or even composites. They absorb moisture from the surrounding air and release moisture in the form of water droplets when these materials regenerate. This regeneration process needs the help of an external heat source, which can be provided by any means including renewable energy technology. The amount of water collected from the three different desiccant materials has been analysed and compared in this study. With the aid of various desiccant products, various attempts have been made to extract water from the ambient air. Abualhamayel et al. [1] made use of a modified earth water collector using calcium chloride as a liquid desiccant component which they then used to extract fresh water from the humid atmosphere. A water performance of 1.92 kgm^{-2} from their unit was recorded. Gad et al. [2] made use of an integrated solar collector system; by which they numerically and experimentally explored the extraction of water from ambient air. Their findings showed a water gathering of 1.5 litres from the device in one day with an efficiency of 17%. Gordeeva et al. [3] used selective sorbents of varying composition for the production of freshwater, achieving a yield of 3 to 5 kg of water per 10 kg of dry sorbent per day. Kabeel [4] demonstrated the extraction of water from the atmospheric air with the assistance of a sandy bed device. The experiment was performed at three different angles of tilt and stated that at a tilt angle of 25 degrees, a higher volume of water was collected. 1.2 litres of fresh water per day was attained by their scheme.

Kabeel [5] continued his research and fabricated a multi-shelved solar glass square based pyramid with a cloth bed and a saw wood bed which helped with the extraction of water from atmospheric air. Each of these beds consisted of 30% of saturated CaCl_2 . Water is provided at a rate of 2.5 litres per m^2 per day by this process. Compared to his previous development, the productivity increase is stated as 90-95%. A numerical model was tested by Kabeel et al. [6] using Star-CCM+. Under the ambient conditions, various design parameters were defined for three different climatic conditions. Their findings showed that the maximum amount of water generated by using an air fan with pumping power below 9.1W was about 3.9 litres per hour per square meter. Kim et al. [7] developed a system for capturing water from air at lower levels of humidity using the porous metal-organic framework. Their system produced 2.8 litres of water at low relative humidity using natural sunlight. Kumar and Yadav [8] used various concentrations of CaCl_2 (liquid desiccant) on saw wood. They discovered that the rate of production of water is governed by the concentration of CaCl_2 and a maximum yield of water produced was 180 ml per kg per day at a concentration of 60% of CaCl_2 . Kumar and Yadav [9] in their additional research work, used different concentrations of CaCl_2 as their desiccant material on floral foam and produced a maximum yield of 0.35 ml/cm^3 per day of water with a system efficiency of 37%.

Mohamed [10] made use of calcium chloride solution as a desiccant material under various operating conditions. The efficiency of the device for the spring and summer weather conditions was also examined. In spring, the volume of water obtained was around 3.02 litre per m^2 per day. Talaat et al. [11] investigated the extraction of water, both experimentally and theoretically, using a double-faced conical finned absorber with a double-faced conical transparent surface type apparatus. For this apparatus, the researcher used calcium chloride as a desiccant material. The unit provided water ranging from 0.3295 to 0.6310 kg/m^2 per day. A comprehensive analysis of the advancement of atmospheric water harvesting techniques was provided by Tu et al. [12]. Wang et al. [13,14] focused on new solid composite sorbents; eight variants of composite sorbents were used and it is found that activated carbon felt (AFC) with LiCl absorbed the maximum amount of water and has a significant amount of desorption rate.

Willam et al. [15] made use of a new type of apparatus that was a trapezoidal prism solar collector. It consisted of different host materials such as sand and cloth that were impregnated with a liquid desiccant material (calcium chloride is used as the desiccant material). Various concentration levels of CaCl_2 desiccant material was used. Their outcome showed that with a preliminary concentration of 30% CaCl_2 , a gross vaporized water for cloth and sand bed 2.32 and 1.23 slit/ day/ m^2 . The efficiency obtained by the method of cloth and sand beds arrangement is 29.3% and 17.6% respectively.

For the regeneration process, Srivastava et al. [16] used concentrated solar energy as a heat source. Six distinct desiccant materials have been economically studied. They concluded that, relative to other solid desiccant materials, silica gel is the most rational based on annual cost per litre and CaCl_2 on the river sand bed is the most economical compared to other composite materials. They have shown that, as opposed to other desiccant products, silica gel has a high absorption rate. Also, the quantity of water produced upon regeneration by silica gel is comparatively high. Sultan[17] used a device that performs water absorption by forced convection and regeneration through a packed tower consisting of two identical columns with identical beds lined with several different layers of CaCl_2 solution of different concentrations infused with cloth content. Their findings showed that the peak value of system efficiency depends on the temperature of regeneration, final concentration, and airstream velocity of absorption. Alahmer et al. [18] planned, modeled, and analyzed a solar atmospheric water generation system using HOMER Software.

Restricted use of concentrated solar power for water production from ambient air is seen in the literature review. Srivastava et al. [16] used Scheffler – type reflector as a heat source and a cuboid shape receiver for the regeneration process. The present study uses a similar form of reflector. Since this reflector is a type of point focus and has a circular focal image, for the regeneration process, a short cylinder type receiver has been experimented with. Experimental investigations are done on a clear sunny day to examine the water extraction capability of the developed system.

2. Desiccant Materials

Silica gel, activated alumina and activated clay are the three desiccant material chosen for the experimental study. Silica gel or silica crystals are a porous and amorphous type of silicon dioxide. It consists of an irregular tri-dimensional structure, which has alternating atoms of silica and oxygen with minute nano-scale pores and small spaces (voids). These voids are capable of containing water or other types of liquid. It may also be filled with gases or no gases i.e (vacuum). Silica xerogel is a property when the silica gel's pores or voids are filled with water. Thus, it is widely used as a desiccant material in many different applications. After the gel has been saturated with water or moisture, it can be regenerated by heating it up to a temperature of 120°C for about one to two hours.

In this study we have used blue silica gel that is mainly used in breathers found in transformers. Before absorbing moisture, the colour is blue and once the gel has absorbed all the moisture the colour changes to pink. Thus giving an indication of the silica gel being saturated. The properties of silica gel are given in Table 1. The raw material that makes activated alumina is aluminium hydroxide and it is usually manufactured by dehydroxylating the compound in such a way that it creates a very porous material that has an area of surface of more than $200\text{ m}^2/\text{g}$. Activated alumina has a very unique property in which it has very high surface area to weight ratio. This above property is created due to the 'tunnel' like pores that can be found on the surface. As well as this activated alumina has many other properties, such as withstanding thermal shock and abrasion. When immersed in solution, mainly water it can be seen that activated alumina won't shrink or swell.

Activated alumina has many applications such as being used as a desiccant material. As well as this activated alumina has the capability to be the ultimate adsorbent as it can reduce the ppm level of various compounds such as fluoride and arsenic that are found in water. As compared to silica gel and molecular sieve, activated alumina has a much higher surface area. Activated alumina can come in various different shapes and sizes. There are various types of activated alumina such as AAFS50, F200 and AA400G. In the present study we have used F200 as the test material, as it is used as a desiccant material mainly for gases and air. The specifications of activated alumina are given in Table 2.

Table 1. Specifications of Silica Gel desiccant material

Silica Gel Blue	Index
Absorption Capacity	RH= 20%, 12.70% RH= 50%, 30.40% RH=90%, 37.10%
Percentage of Cobalt Chloride	0.52
Percentage of Silica	99.2
Bulk Density	0.68 g/cm ³
Ph	7.2
Loss on Drying	4.2%
Appearance	Blue Crystals
Product weight 10%	250 grams

Table 2. Specifications of Activated Alumina

Properties	Index
Absorption Capacity	RH= 20%, 6.70% RH= 50%, 10.5% RH=90%, 20.9%
Particle Size	8 mm
Specific Surface Area	≥ 280 m ² /g
Pore Volume	≥ 0.38 ml/g
Bulk Density	0.70 g/cm ³
Crush Strength	≥ 180 N
Loss on Drying	≤ 8 %
Appearance	White beads
Percentage of Aluminium oxide	95 %

Activated clay is fairly a new desiccant material found in the industry. It is made up of a composition of various different elements. It is a naturally occurring porous compound that is dried to produce an adsorbent material. It has various properties such as good absorption capacity in normal temperatures and various humidity ranges.

Activated clay has been used as a desiccant material in this study, as in previous literature studies it has not been compared as to a conventional desiccant material. This desiccant material is found to be a naturally occurring porous mineral that is dried & processed to boost its adsorption ability, enabling it to absorb up to 25% of its weight in humidity. The specifications of the activated clay are provided in Table 3.

Table 3. Specifications of Activated Clay

Properties	Index
Absorption Capacity	RH= 20%, 16% RH= 50%, 28% RH=80%, 50%
Particle Size	3mm
Bulk Density	0.6 g/cm ³
Melting Point	3680°C
Boiling Point	4200°C
Loss on Drying	≤ 4-15 %
Appearance	Odourless black solid granules

3. Experimental Setup and Procedure

The setup for experimentation is developed in the rooftop of Mechanical block of SRM Institute of Science and Technology. The concentrator is a Scheffler-type reflector of 16m² reflector area and the receiver is a short cylinder type. The exit of the receiver is connected to a measuring jar with the help of a connecting hose. The receiver is perfectly insulated with glass wool insulation of 25mm thickness, except the front surface which receives radiation. Various instruments are used for data collection during the experiment. Solar radiation data is recorded with the help of pyranometer, receiver surface temperature is measured with the help of infrared thermometer, and ambient temperature is measured with the help of a PT-100 temperature sensor and wind speed with cup type anemometer. Humidity sensor is used for acquiring the relative humidity data. Water quality is also checked with the help of ph meter and TDS meter.

Before starting the experiment, the desiccant material is laid out at night, where the first process begins (adsorption). This was done for every single desiccant material. At night time, the desiccant material is able to adsorb the moisture from the humid air due to the difference in vapour compression that occurs between the desiccant's surface and the humid air. For the regeneration process to occur, which is the second stage, a heat source/energy has to be applied on to the surface of the receiver which in turn transfers the heat to the desiccant material by one of the first heat transfer methods- conduction. The experiment was conducted on different days of the month of February and March. Once the desiccant material gains enough energy, the water particles leave the surface of the desiccant material and turn into vapour. Due to the pressure difference as well as change in latent heat of vaporization, condensation occurs and water production takes place in the morning time. For the measurement of solar concentration, pyranometer is used. Since experiments began, all calibration was taken within 15 minutes of interval.

The receiver is filled with 4 kg of desiccant material and kept at the focal point of the Scheffler dish reflector. The dish is focussed onto the receiver to heat up the desiccant material. The heating is performed throughout the day and the water is collected in the measuring flask. The various parameters measured are beam radiation, wind speed, ambient temperature, the temperature at the receiver surface and the relative humidity. The water production from humid air mainly depends upon the following parameters regeneration rate of the materials, the temperature of the receiver and it depends upon the solar concentration falling on the receiver.

4. Results and discussion

The experiments are done on a clear sunny day during the months of February and March 2020 to assess the water production capacity of the system. Fig. 1 shows the variation of the beam radiation and the amount of water collected throughout the day for Silica gel (08/03/2020). The beam radiation was perceived to rise from a minimum value to peak value of 1089 W/m^2 at around 12:45 PM followed by a gradual decrease to a lower value of 275 W/m^2 at the end of the day. Slight fluctuations are observed in beam radiation values because of the passing clouds. The average beam radiation recorded during the whole day is 720 W/m^2 . It can be seen from the graph that the amount of water collected varies according to the beam radiation intensity. After 14:30 PM, water production is observed to be low due to the diminishing characteristic of beam radiation. The amount of water collected is also found to vary according to the receiver surface temperature. The highest temperature recorded at the surface of the receiver is $223 \text{ }^\circ\text{C}$ at around 12:45 pm. The ambient temperature is almost constant throughout the day with a mean value of 31.35°C . The wind velocity was fairly low with an average value less than 2m/s . The total water collected over an 8 hour period during the test is 565 ml.

Fig.2 shows the variation of the beam radiation and the amount of water collected throughout the day for Activated Alumina (09/03/2020). The beam radiation was perceived to rise from a minimum value to peak value of 874 W/m^2 at around 12:00 PM followed by a gradual decrease to a lower value of 384 W/m^2 at the end of the day. Slight fluctuations are observed in beam radiation values because of the passing clouds. The average beam radiation recorded during the whole day is 565 W/m^2 . It can be seen from the graph that the amount of water collected varies according to the beam radiation intensity. After 14:45 PM, water production is observed to be low due to the diminishing characteristic of beam radiation. The highest temperature recorded at the surface of the receiver is $220 \text{ }^\circ\text{C}$ at around 12:15 pm. The ambient temperature is almost constant throughout the day with a mean value of 33°C . The wind velocity was fairly low with an average value less than 2m/s . The total water collected over an 8 hour period during the test is 400 ml.

Fig.3 shows the variation of the beam radiation and the amount of water collected throughout the day for activated alumina (11/03/2020). The beam radiation was perceived to rise from a minimum value to peak value of 864 W/m^2 at around 12:30 PM followed by a gradual decrease to a lower value of 400 W/m^2 at the end of the day. Slight fluctuations are observed in beam radiation values because of the passing clouds. The average beam radiation recorded during the whole day is 549 W/m^2 . It can be seen from the graph that the amount of water collected varies according to the beam radiation intensity. After 14:30 PM, water production is observed to be low due to the diminishing characteristic of beam radiation. The highest receiver temperature recorded at the surface of the receiver is $250 \text{ }^\circ\text{C}$ at around 12:45 pm. The ambient temperature is almost constant throughout the day with a mean value of 30.9°C . The total water collected over an 8 hour period during the test is 190 ml.

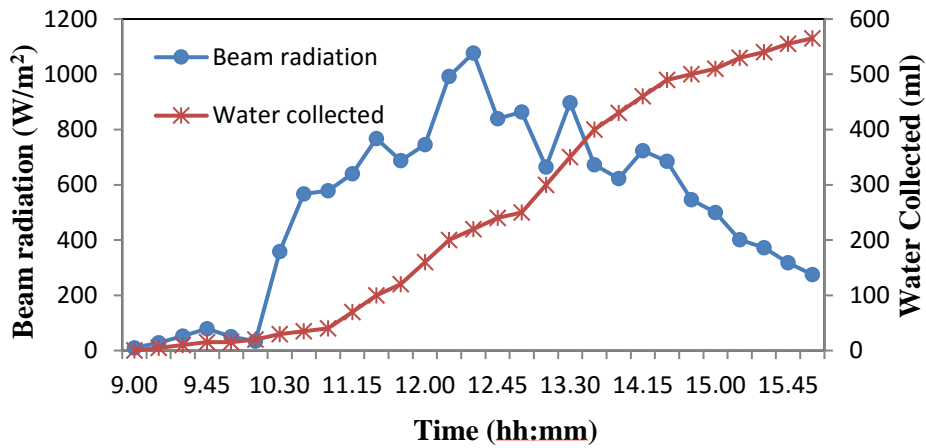


Figure 1. Variation of beam radiation and water collected over time (Silica Gel)

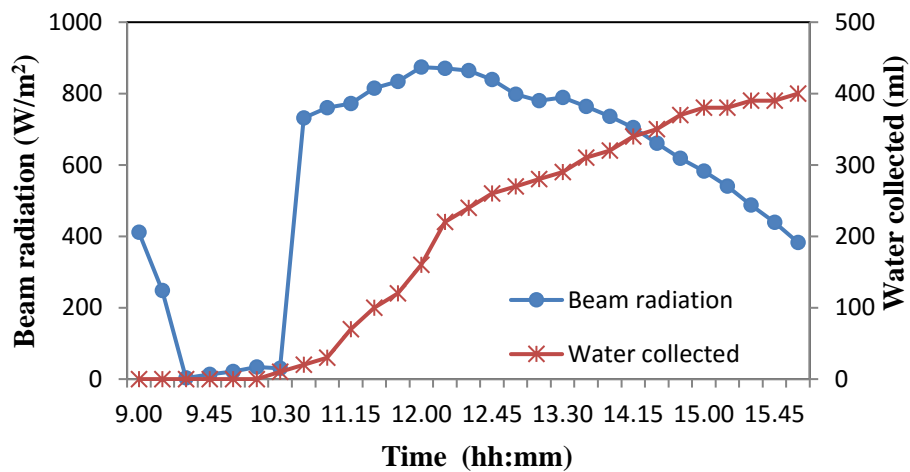


Figure 2. Variation of beam radiation and water collected over time (Activated Alumina)

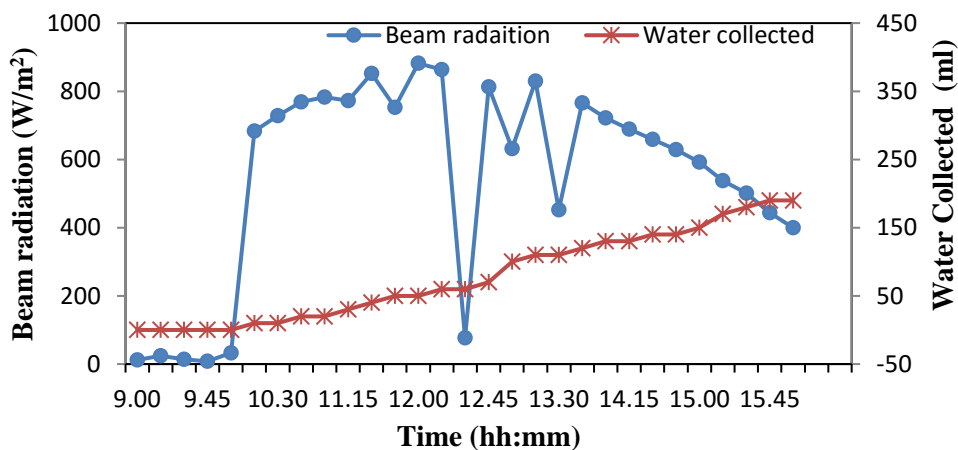


Figure 3. Variation of beam radiation and water collected over time (Activated Clay)

The testing of quality of water collected from each of these desiccant materials is done with the help of a TDS meter and pH meter. The results for testing of the water collected are provided in Table 4 :

Table 4: Results of Water quality testing

Desiccant Material	pH	TDS (ppm)	Colour of water
Silica Gel	6.23	19	Clear
Activated Alumina	6.54	41	Clear
Activated Clay	5.46	54	Brownish

5. Conclusion

In this experimental work, utilization of concentrated solar power is attempted to extract potable water from the ambient air. The water generating capacity of the short cylinder receiver is evaluated using three different desiccant materials like silica gel, activated alumina and activated clay. For a clear sunny day in the month of March, the production of water is 142 ml/kg/day, 100 ml/kg/day and 48 ml/kg/day while using silica gel, activated alumina and activated clay as the desiccant material respectively. The cost of water produced is observed as high when compared to the commercially available water, but it is a promising option for production of water at places where there is scarcity and there is no electricity. Overall, it is found that Silica crystals is the best water producing and economically viable desiccant material as compared to activated clay and activated alumina.

References

- [1] Abualhamayel H I, Gandhidasan P 1997 A method of obtaining fresh water from humid atmosphere. *Desalination*. 51-63. [https://doi.org/10.1016/S0011-9164\(97\)00114-8](https://doi.org/10.1016/S0011-9164(97)00114-8)
- [2] Gad H E, Hamed A M, El-Sharkawy II 2001 Application of a solar desiccant/collector system for water recovery from atmospheric air. *Renewable Energy* **22(4)** 541–556. [https://doi.org/10.1016/S0960-1481\(00\)00112-9](https://doi.org/10.1016/S0960-1481(00)00112-9)
- [3] Gordeeva L G, Tokarev M M, Parmon V N, Aristov YuI 1998 Selective water sorbents for multiple application, 6: freshwater production from the atmosphere. *React Kinet Catal Lett* **65(1)** 153–159. <https://doi.org/10.1007/BF02475329>
- [4] Kabeel A E 2004 Application of sandy bed solar collector system for extraction of water from air. In: *Proceedings of the eighth international water technology*. <http://www.water-observatory.net/sources/iwtc2004/03-5.PDF>. Accessed 30 Apr 2018
- [5] Kabeel A E 2007 Water production from air using multi-shelves solar glass pyramid system. *Renewable Energy* **32(1)** 157–172. <https://doi.org/10.1016/j.renene.2006.01.015>
- [6] Kabeel A E, Abdulaziz Mohamed, El-said E M S 2016 Solar-based atmospheric water generator utilisation of a fresh water recovery: a numerical study. *Int J Ambient Energy* **37(1)** 68–74. <https://doi.org/10.1080/01430750.2014.882864>
- [7] Kim H, Yang S, Rao SR, Narayanan S, Kapustin E A, Furukawa H, Umans A S, Yaghi O M, Wang E N 2017 Water harvesting from air with metal-organic frameworks powered by natural sunlight. *Science* **356** 430–434
- [8] Kumar M, Yadav A 2015 Experimental investigation of solar powered water production from atmospheric air by using composite desiccant material ‘CaCl₂/saw wood’. *Desalination* **367**:216–222. <https://doi.org/10.1016/j.desal.2015.04.009>

- [9] Kumar M, Yadav A 2016 Solar-driven technology for freshwater production from atmospheric air by using the composite desiccant material 'CaCl₂/floral foam'. *Environ Dev Sustain* **18**(4) 1151–1165. <https://doi.org/10.1007/s10668-015-9693-3>
- [10] Mohamed M H, William G E, Fatouh M 2017 Solar energy utilization in water production from humid air. *Sol Energy* **148** 98–109. <https://doi.org/10.1016/j.solener.2017.03.066>
- [11] Talaat M A, Awad M M, Zeidan E B, Hamed A M 2018 Solar-powered portable apparatus for extracting water from air using desiccant solution. *Renewable Energy* **119** 662–674. <https://doi.org/10.1016/j.renene.2017.12.050>
- [12] Tu Y, Wang R, Zhang Y, Wang J 2018 Progress and expectation of atmospheric water harvesting. *Joule* **2**(8) 1452–1475. <https://doi.org/10.1016/j.joule.2018.07.015>
- [13] Wang J Y, Liu J Y, Wang R Z, Wang L W 2017a Experimental research of composite solid sorbents for fresh water production driven by solar energy. *Appl Therm Eng* **121** 941–950. <https://doi.org/10.1016/j.applthermaleng.2017.04.161>
- [14] Wang J Y, Wang R Z, Wang L W, Liu J Y 2017b A high efficient semi-open system for fresh water production from atmosphere. *Energy* **138** 542–551. <https://doi.org/10.1016/j.energy.2017.07.106>
- [15] William G E, Mohamed M H, Fatouh M 2015 Desiccant system for water production from humid air using solar energy. *Energy* **90** 1707–1720. <https://doi.org/10.1016/j.energy.2015.06.125>
- [16] Shobhit S, Avadhesh Y 2019 Economic analysis of water production from atmospheric air using Scheffler reflector, *Applied Water Science* **9** 3. <https://doi.org/10.1007/s13201-018-0883-7>
- [17] Ahmed Sultan, (2002) Absorption/regeneration non-conventional system for water extraction from atmospheric air, *Renewable Energy* 1515-1535. [https://doi.org/10.1016/S0960-1481\(03\)00020-X](https://doi.org/10.1016/S0960-1481(03)00020-X).
- [18] Alahmer A, Al-Dabbas M, Alsaqoor S, Al-Sarayre Ah 2016 Utilizing of Solar energy for Extracting Freshwater from atmospheric air *Applied Solar Energy* 110-118. <https://doi.org/10.3103/S0003701X18020044>.