Abstract

Fresh water is an essential gradient of life however, a rapid increase in population and shrinking freshwater bodies make it a commodity for a large world population, specifically in remote locations and minimal rain areas, people are poorly thrashed by water scarcity. In this work, an attempt is made to resolve this issue sustainably by using solar energy. Solar desalination is a technique that uses solar energy to convert saline water into distilled water, and solar still (SS) is a device that is used for this purpose. This device works on evaporation and condensation phenomenon. The low yield and low efficiency of SS make it a low-esteem device. To take as a challenge, an experimental setup of novel SS is designed, fabricated, and compared with conventional SS performance. Also, the effect of quantum dot (QD) material with phase change material (PCM) is analyzed with solar still. In the first phase, a parametric study is done on the effect of the tilt angle of the condenser surface on SS performance during daylight and nocturnal period in the winter season. Three models are fabricated, namely Model-1, a single slope SS with a tilt angle of 25º facing south, Model-2 a single slope SS with a tilt angle of 30º facing south, and Model-3, a double slope SS with a tilt angle of 15º from both sides facing east-west. After several experimental investigations, the results showed that Model-1 and 2 give a maximum yield of 760 and 925 mL/m^2. In contrast, Model-3 gives a maximum yield of 320 mL/m^2 with maximum thermal and exergy efficiency of 17.15% and 0.6%, 17.25%, and 1.1%, and 7% and 0.3% respectively, over seven hours working period in the winter season. This investigation also reveals the heat retaining capacity of SS and the effect of polystyrene coverage on glass cover that helps to obtain a maximum nocturnal yield of 435, 735, 320 mL/m^2, from Model-1, 2, and 3, respectively,

on different days that make total distilled output to 1195, 1660, 560 mL/m^2 on a particular day. In the second phase, a novel black phosphorus QD-doped Pyrex glass material is coated on the basin liner to improve the solar absorbance range. Four different concentrations of QD material are developed as 0g, 5g, 10g, and 15g by weight in the black paint of 500 mL and coated on the absorber surface of the basin. The experimental results showed a maximum yield of 991, 1282, 2010, and 2710 mL/m^2 with energy and exergy efficiencies of 15.21% and 0.50%, 19.68% and 0.84%, 30.57% and 1.41%, 41.22% and 2.75% for SS with 0g, 5g, 10g, and 15g QD material respectively. Theoretical modeling is also performed and validated by experimental results with a maximum deviation of 7.6%.

Moreover, the economic study gives a payback period of 1 year and 11 months with 15g QD-coated SS. In the third phase, black phosphorus QD is used with lauric acid. Prismatic solar still (PSS, modified design) performance is compared with conventional solar still (CSS). The results showed that CSS and PSS without PCM and BPQD yield up to 1660 mL/m^2 and 1830 mL/m^2 with heating efficiency and exergy efficiency of 19.72% and 0.36% for CSS and 25.59%, and 1.08% for PSS. Whereas, with PCM and BPQD, yields reached up to 3040 mL/m^2 and 3400 mL/m^2 with exergy and heating of 1.79% and 37.23% for CSS and 2.20%, and 49.30% for PSS. Moreover, the economic analysis showed that the monetary and energy cost of distilled water with PSS incurs only INR 1.6/liter and INR 2.48/kWh as compared to CSS of INR 2.71/liter and INR 4.10/kWh with a payback period of 3 years and 3 months for CSS and 2 years and 10 months for PSS.