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Modelling and Performance Enhancement of Single Slope Solar Still using CFD

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Abstract

With rising population, development, and environmental pollution, availability of potable water is shrinking fast. Thus, it is required to focus on the distillation of available water. Solar Still is one of the promising technologies available to purify water because of its low cost, energy, and skill requirement. However, the efficiency of present technology is low, so it is required to advance the designs of existing solar stills. In this study, a multi-phase three-dimensional CFD model of a simple solar still developed for simulation with using ANSYS FLUENT. The simulation has been done for transient state to validate the results with experimental data for climate conditions of Jaipur (26º13'N, 75º49'E). Within the scope of this study, simulation results were found to be in good agreement with the experimental data. It is also examined that thermal efficiency of the Solar Still is higher from 16:00 to 17:00 hrs. Parametric analyses has been done to enhance the productivity of Solar Still. Different materials were used in the basin to increase the heat capacity, absorption capacity and the evaporation rate. The impact of varying the depth of the basin water was also studied. It has been found that the Solar Still have more productivity for low water depth.

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Keywords: Solar Still; Solar Desalination; CFD; Multiphase Model; Productivity

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1. Introduction

The continued deficiency of consumable water is an significant issue in developing countries, and contaminated water can result in various diseases, which are often lethal. According to World Health Organization (WHO) report, about 30,000 people die every day, due to water-borne diseases [1]. As per UNICEF, globally, 1 billion people are currently without access to potable water supply and 2.6 billion have no form of sanitation services (figures for 2004) [2]. Therefore, purification of available water is essential for the general well-being of the masses. Solar energy can be used as an important source for purifying water for its low manufacturing expenses; and its usage has no adverse impact on the environment. Hence, application of solar stills for distillation of salty water to produce fresh water is economical in terms of energy, but the distillate rate is little low. [3] The solar distillation involves all the three modes: conduction, convection, and radiation of heat transfer. Heat flows from inside the solar still to the environment through the transparent glass cover and the walls by conduction. Heat from the basin to the water, from vapors to the glass cover and from glass cover to the environment is transferred by convection. While heat flows from the sun to the solar still through radiations [4]. F.F. Tabrizi, A.Z. Sharak [5], used inbuilt sandy heat reservoir under climate conditions of Iran. He showed that integrated sandy heat reservoir increases the productivity of solar still during cloudy day and night, and it also does not require any pumping element for night mode usage. K. Kalidasa Murugavel et.al [6] worked on double slope basin solar still with mild steel plates with a lower mass of water and different wick materials like light cotton cloth, sponge sheet, waste cotton pieces, coir mate pieces in basin with aluminum fins. He found from an experiment that, the light black cotton cloth is effective wick material compared with other wick materials as well as aluminum fin covered with cotton cloth and arranged in lengthwise was more efficient.

The objective of this study is to develop a 3D CFD model of Simple Solar Still to understand the evaporation and condensation phenomena in solar still. The model has been developed with the help of ANSYS Workbench and then simulated with Fluent. Water temperature and production rate of fresh water from the simulation results compared with the actual results. Further comparison has been made between simulation result and experimental results of water temperature, glass cover temperature. Parametric analyses have been done to enhance the productivity of Solar Still. Different materials were used in basin to improve the heat and absorption capacity to increase the evaporation rate. The impact of varying the depth of the basin water was also studied.

2. Mathematical Modelling

The performance of solar still based on productivity as well as internal heat and mass transfer coefficient was studied. Internal heat and mass transfer coefficient in the solar still based on convection, radiation, and evaporation. Its effectiveness is directly proportional to internal heat transfer coefficient and distillate output. Heat transfer coefficients of different types are convective heat transfer coefficient, radiative heat transfer coefficient and evaporative heat transfer coefficient. Single slope solar still is preferable for higher than 20° altitude. For north latitude places the single slope still with south facing cover and for south latitude places with north facing cover are used [7]. A 3-dimensional three-phase model was developed in the mixture model for air, liquid water and water vapor system at transient state condition which means only surface evaporation of liquid occurs. Energy and mass transfer have been considered in this work. For each phase, the time and volume-average continuity, energy and mass equations were numerically solved.

2.1. Governing Equations

Equations follow steady state condition that is modeled based on the continuity, momentum, energy and mass transfer conservation principles. When solar energy is incident inside the basin water, heat transfer mechanism starts. Energy balance equation can be written with taking following assumption [9]:

1. There is no vapor leakage in solar still.
2. The heat capacity of absorbing material, insulation, and cover is negligible.