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A Review on Performance Analysis of Desalination System Working on Humidification-Ehumidification Technique

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Abstract: The scarcity of fresh water is an issue of high concern as most of the world population suffers from clean water shortage. One potential solution to tackle this issue is to develop efficient, reliable, and cost effective water desalination system to make the clean water accessible for most of the world population. Humidification-dehumidification (HDH) is a carrier gas based thermal technique that is ideal for a small scale water desalination system. An innovative design approach is to use the bubbler humidifier to enhance the performance of the HDH water desalination system. The aim of this work is to develop an analytical model for bubbler humidifier that can predict the heat and mass transfer. Various design and working parameters on the performance of the proposal system is to be evaluated. For performance evaluation a computer simulation program is to be prepared to solve the energy and mass balance equation of the proposed system.
Keywords: - water desalination; HDH systems; direct contact heat and mass transfer; bubbler humidifier

I. INTRODUCTION

A. Water Availability

Water resources are sources of that are potentially useful. Uses of water include agricultural, industrial, household , recreational and environmental activities. The majority of human uses require fresh water. 97% of the water on the Earth is salt water [1] and only three percent is fresh water; slightly over two thirds of this is frozen in glaciers and polar ice caps. The remaining unfrozen fresh water is found mainly as groundwater, with only a small fraction present above ground or in the air. Fresh water is a renewable resource, yet the world's supply of groundwater is steadily decreasing, with depletion occurring most prominently in Asia and North America, although it is still unclear how much natural renewal balances this usage, and whether ecosystems are threatened. The framework for allocating water resources to water users (where such a framework exists) is known as water rights.

B. Surface Water

Surface water is water in a river, lake or fresh water wetland. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, evapotranspiration and groundwater recharge. Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates. All of these factors also affect the proportions of water loss.

C. Under River Flow

Throughout the course of a river, the total volume of water transported downstream will often be a combination of the visible free water flow together with a substantial contribution flowing through rocks and sediments that underlie the river and its floodplain called the hyporheic zone. For many rivers in large valleys, this unseen component of flow may greatly exceed the visible flow. The hypothetic zone often forms a dynamic interface between surface water and groundwater from aquifers, exchanging flow between rivers and aquifers that may be fully charged or depleted.
This is especially significant in karsts areas where pot-holes and underground rivers are common.

D. Ground Water

Groundwater is fresh water located in the subsurface pore space of soil and rocks. It is also water that is flowing within aquifers below the water table. Sometimes it is useful to make a distinction between groundwater that is closely associated with surface water and deep groundwater in an aquifer (sometimes called; fossil water)

E. Frozen Water

Several schemes have been proposed to make use of icebergs as a water source, however to date this has only been done for research purposes. Glacier runoff is considered to be surface water. The Himalayas, which are often called The Roof of the World , contain some of the most extensive and rough high altitude areas on Earth as well as the greatest area of glaciers and permafrost outside of the poles. Ten of Asia's largest rivers flow from there and more than a billion people's livelihoods depends on them. To complicate matters, temperatures there are rising more rapidly than the global average.

F. Potable Water Availability

Drinking water, also known as potable water or improved drinking water, is water that is safe to drink or to use for food preparation, without risk of health problems. Globally, in 2012, 89% of people had access to water suitable for drinking [2]. Nearly 4 billion had access to tap water while another 2.3 billion had access to wells or public taps. 1.8 billion people still use an unsafe drinking water source which may be contaminated by feces. This can result in infectious diarrhea such as cholera and typhoid among others.

Water is essential for life. The amount of drinking water required is variable. It depends on physical activity, age, health issues, and environmental conditions. It is estimated that the average American drinks about one litre of water a day with 95% drinking less than three litres per day. For those working in a hot climate, up to 16 liters a day may be required. Water makes up about 60% of weight in men and 55% of weight in women. Infants are about 70% to 80% water while the elderly are around 45%.

G. Desalination Process

Different types of water desalination processes have been developed. Mainly desalination processes can be classified into the following two categories: phase change (thermal processes) and single phase (membrane processes). In the phase change process a thermal energy source, such as fossil fuels, nuclear energy or solar energy may be used to evaporate water, which is condensed to provide fresh water. The phase change desalination processes described here include, solar distiller, Multi-Stage Flash (MSF) distillation, Multi-Effect (ME) distillation Vapour Compression (VC) distillation and Freezing distillation. In the single phase processes membranes 14 are used in two commercially important desalination processes, Reverse Osmosis (RO) distillation and Electro Dialysis (ED) distillation.

H. Types of Desalination processes

1) Multi-Stage Flash Distillation
2) Vapor Compression Distillation.
3) Reverse Osmosis.
4) Solar Evaporation.
5) Electro dialysis.

H. The Humidification Dehumidification Desalination Technology

The solar HDH is a thermal water desalination method. It is based on evaporation of seawater or brackish water and consecutive condensation of the generated humid air, mostly at the ambient pressure. The solar HDH process is also called the multiple-effect humidification-dehumidification process; solar multistage condensation evaporation cycle (SMCEC) or multiple-effect humidification (MEH) is a technique that simulates the natural water cycle on a shorter time frame by evaporating and condensing water to separate it from other substances. The driving force in this process is the solar thermal energy to produce water vapour, which is later condensed in a sepa- rate chamber. In sophisticated systems, waste heat is minimized by the heat from the condensing water vapour and pre- heating the incoming water source. This system is effective for small- to mid-scale desalination systems in many arid and semi-arid countries because of the relative inexpensiveness of solar collectors.

II. LITERATURE REVIEW

A. Hafiz M.abd-ur- Rehman, fahad A. al-souiman [4]

The scarcity of fresh water is an issue of high concern as most of the world population suffers from clean water shortage. One potential solution to tackle this issue is to develop efficient, reliable, and cost effective decentralized water desalination system to make the clean water accessible for most of the world population. Humidification-dehumidification (HDH) is a carrier gas based thermal technique that is ideal for a small scale decentralized water desalination system. An innovative design approach is to use the bubbler humidifier to enhance the performance of the HDH water desalination system. The aim of this work is to develop an analytical model for bubbler humidifier that can predict the heat and mass transfer without introducing any adjustable parameters. The effect of air inlet velocity, water column height, and perforated plate hole diameter on the heat and mass transfer is analyzed and engineering justifications are presented. Results indicate that the increase in air inlet velocity significantly enhance the heat and mass transfer coefficient. The increase in water column height and bubble diameters slightly decrease the total heat flux. The efficiency of humidifier in terms of water vapor contents in the air stream at the outlet of the humidifier is analyzed and findings showed that the increase in the temperature difference between the air and water stream increases the efficiency of the humidifier.

B. Mahmoud shatat, Saffa Riffat and Guohui [5]

A new multi-effect solar desalination system based on humidification–and dehumidification (HDH) process was investigated experimentally in this paper. Several hourly yields with operation temperatures were tested and analyzed. The warm saline water is sprayed upon the porous ball humidifiers, which is simple and effective for enhancing the evaporation process. Mathematical model based on the mass and energy balances in each unit of the system is developed which is used to optimize the test. In addition the performance ratio (PR) of the device was investigated under different feeding water mass flow rates and heating temperature conditions. The experimental results indicate that the yield of system increases with the increase in water flow rate and air flow rate. The maximum PR of the system at the heating temperature of 85 °C can reach up to about 2.65. When the heating temperature increases from 60 to 90 °C and the feed water flow rate is 2 t/h, the fresh water yield increases from 59.41 to 182.47 kg/h. The yield per unit volume is calculated as 22 kg/m3 h. The numerical results based on the mathematical model are well in agreement with the experimental results. The maximum relative deviation is only 5%.

C. Abu Elnosr M, Kamal M, Saad H and Elhelaly M [6].

The objective of this paper is to demonstrate an experimental investigation of a water desalination system using solar energy that applies the humidification and dehumidification principle. A prototype/test rig was designed, fabricated and assembled in order to study the effect of water flow rate and the humidifier inlet water temperature against desalinated water productivity. The system consists of a spray type with no packing bed humidifier, a copper coiled Dehumidifier, a flat plate solar water heater, an air blower, a water pump, a water flow meter, a water tank, three thermocouples and four gate water valves. The system is based on an open water closed air cycle. A new approach is used such that the humidifier, dehumidifier and the connecting duct between them are made of Poly Vinyl Chloride (PVC) pipes; which makes the system lighter in weight, doesn't need insulation unlike metal sheets and anti-rust. The effect of operating parameters on the system characteristics has been controlled, measured and investigated. It was found that the hot inlet water temperature to the humidifier has a significant impact on the water productivity; they are relatively proportional, thus, the more the hot inlet water temperature increases, the more the water productivity increases. It was also found that Saline water flow rate has an impact on the
water productivity but inversely proportional.

D. Reza Enayatollahi, Timothy Anderson, Roy Nates [7]

In recent times the issue of fresh water shortages and salinity contamination of existing water sources has become a serious problem in a number of locations around the world. Hence, developing an environmentally friendly desalination technique is essential. In this work a theoretical model is developed in order to optimize a novel humidification-dehumidification desalination system. A sensitivity analysis was carried out, in order to find the optimum values for air and water flow rates. From this analysis it was found that a maximum of production rate of 1.5 kg/hr.m2 was achievable, however it was also found that this rate was particularly influenced by the incident radiation, the inlet water temperature and the water flow rate.

E. Summary

Humidification-Dehumidification (HDH) is a carrier gas based thermal technic that is ideal for small scale water desalination system. Several literature studies are available that explore HDH as an effective mean of sea water desalination system. The main focus of researches in developing a small scale water desalination unit is to achieve an evaporation and condensation to increase the productivity of humidification-dehumidification system by introducing different techniques.

The present work introduces an innovative humidification technique by using bubbler humidifier. In this humidifier configuration, air is passed through the perforated plate to form bubbles in the hot water column. As the air bubble propagate through hot water column, simultaneous heat and mass transfer takes place and air comes out hot and humid at the outlet of the humidifier. The bubbles formation increases the surface of contact, which leads to the performance enhancement of the humidification process [4].

III. CONCLUSION

Variation of productivity with the variation in inlet temperature of water entering the humidifier. Variation of productivity with the variation in inlet temperature of air entering the humidifier. Variation of productivity with the variation in mass flow rate of air entering the humidifier. Variation of productivity with changing the mass flow rate of cooling water entering the dehumidifier.

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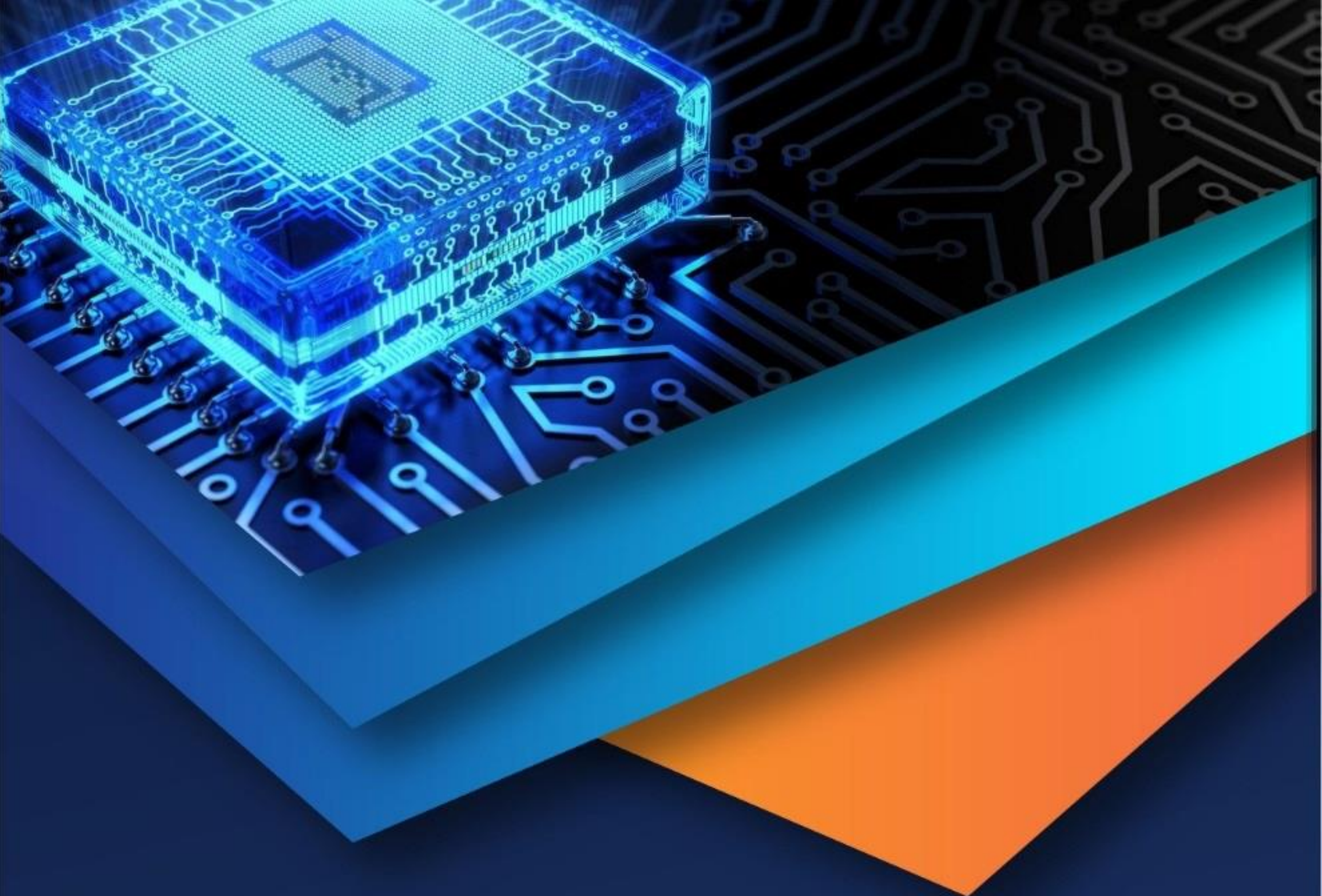

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