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Effect on air quality and flow rate of fresh water production in humidification and dehumidification system

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Abstract. Water is the vital need of any living organisms of the world when water fails, functions of nature cease the world. The water scarcity is one of the major problems to be faced by the developing world, which indicates a critical need to develop inexpensive small-scale desalination technologies. The cost of the desalination process takes more, so the world expecting the desalination plants with minimum operating cost, so the utilization of renewable energy source is a preferable one. This research article provides a glimpse of an overview of the humidification-dehumidification (HDH) based desalination method which uses the solar energy. The HDH based desalination method monitored and evaluated the performance parameters, i.e. mass flow rates of water and air.

1. Introduction

Fresh water is indispensable for the every survival of all beings on this mother planet of the Earth. There are many regions of the world which are blessed with an abundance of fresh water. But, in thick-populated areas burgeoning with rapid industrialization are experiencing more water stress, particularly when located in arid regions [1]. A survey on water resource reveals that more than a billion of people belonging to the mostly in lower-income groups, lack of access to safe drinking water in worldwide. According to the United Nations statement; in this millennium, one of the important goals is to highlight the critical need for impoverished and developing regions of the world to achieve self-sustenance in the potable water supply [2 and 3]. Especially in India the contamination content is very high fluoride and bacterial contamination is high in brackish water.

2. Desalination: A solution to scarcity of fresh water

Desalination is a technology to remove all contaminants including almost all dissolved ions, microorganisms and other pollutants [4 - 7]. The various popular desalination technologies are

1. Solar stills
2. Multi-stage flash (MSF)

3. Multi-effect distillation (MED)
4. Vapor compression (VC)
5. Reverse osmosis (RO)
6. Electrodialysis (ED)

The challenge is; How to implement the desalination technology into low-cost? and How to provide them in a community-scale and How to make them relatively maintenance-free (at least maintainable by non-technical laborers)?. Over the past five decades through the research and development in desalination has resulted that various advanced techniques have been made for desalination more efficient and cost-effective [5, 8 and 9]. In future, the desalination will be a viable technique for generating fresh water, in this research work made an attempt for desalination processes for getting fresh.

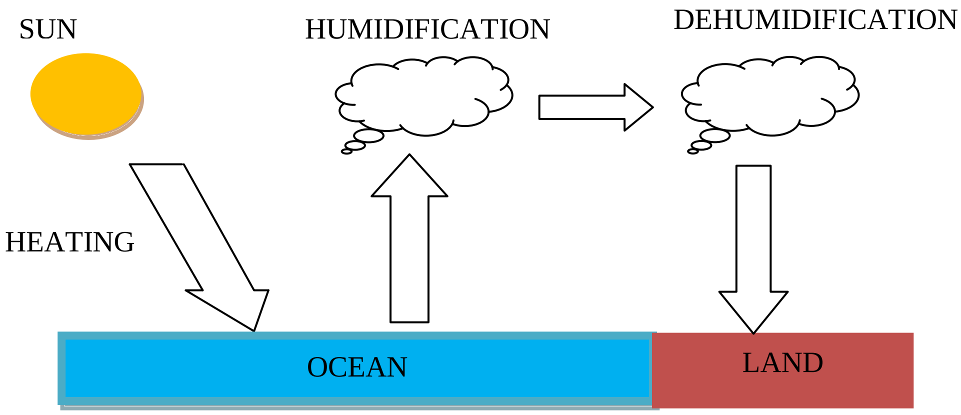

Figure 1. Rain Cycle

3. Principle of HDH system

Humidification-dehumidification (HDH) technology is one of the known techniques that offer the desalination systems of different scale depending on the demand and requirements. The operation of the rain cycle system is exemplified in Figure 1. In nature the solar energy used as a desalination resource the sea water gets heated (by solar radiation) and humidifies by the air and which acts as a carrier [10 and 11]. The humidified air rises and forms clouds and after some time the clouds dehumidified as rain. Humidification Dehumidification Desalination (HDH) system is the most promising in the recent development of the desalination processes [12]. The HDH process is based on the fact that the air can be mixed with large amounts of water vapor when the flowing air in contact with salt water [14]. A certain amount of vapor is extracted by air, which provokes cooling.

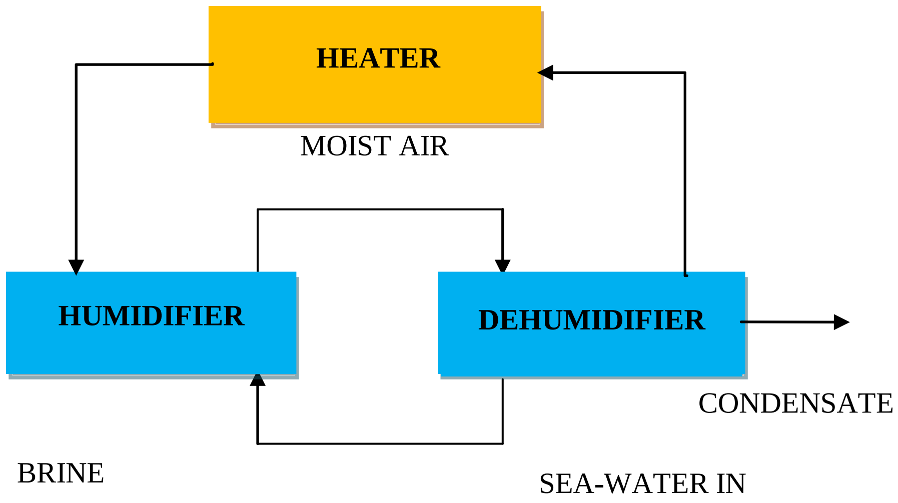

Figure 2. Simple CAOW HDH cycle

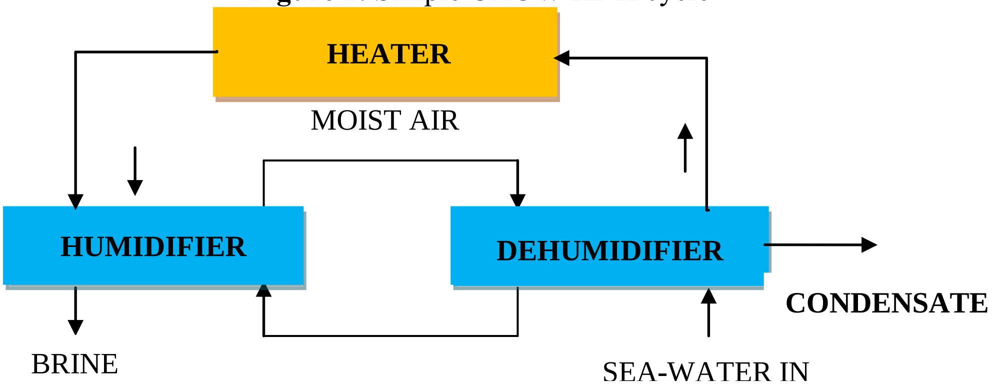

Figure 3. Simple CAOW HDH cycle

The purified water recovered from the humid, bringing air in which contact with cold surfaces. It causes the condensation of a part of the vapor-air, this occurs at the dehumidifier in which salt water is preheated by the latent heat of condensation [13].

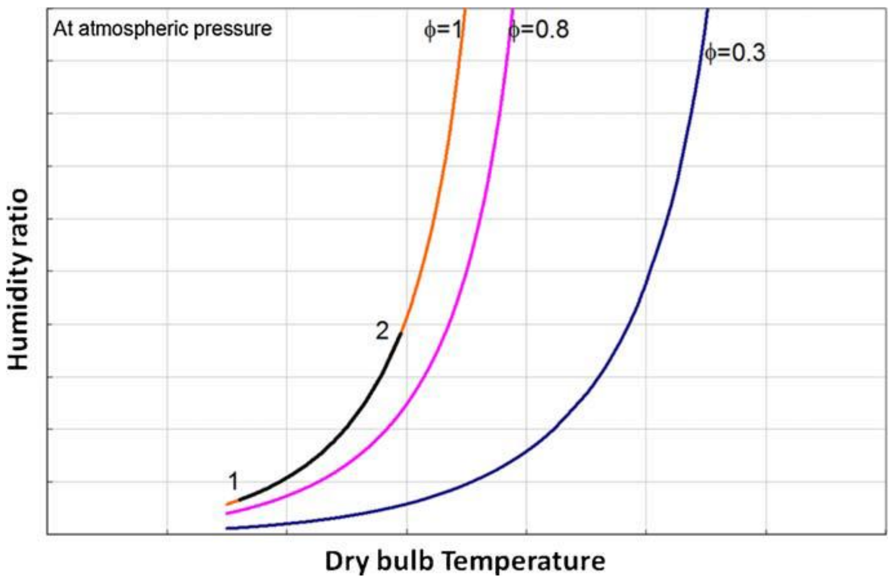

Figure 4. Water-heated CAOW HDH process on psychometric chart

4. RESULT AND DISCUSSION

The thermophysical properties required for air and sea water are computed by using thermodynamic relations; similarly, specific humidity, relative humidity, vapor pressure, and enthalpy are obtained through psychometric relations. A Program was developed in ‘C’ language for simulation for analyzing the HDH Desalination system, it involves input parameters such as inlet sea water temperature, inlet air temperature, inlet sea water mass flow rate, inlet air mass flow rate, heater input, the salinity of sea water spray water temperature. The ‘C’ program was developed to calculate and provides the information based on the various input parameters, the effect of input parameters, the condition of fluid at various stages like the temperature of fluids at each stage, relative humidity of air at each stage, specific humidity of air at various stages.

4.1: The effect of relative humidity of inlet air on the productivity of different heat input to the heater

Figure 5 provides the increased humidity of the inlet air is reduces the productivity of the system, due to the amount of water vapor required to reach the outlet state is reduced, so the amount of water evaporated in the humidifier reduced, the productivity of the system which depends on

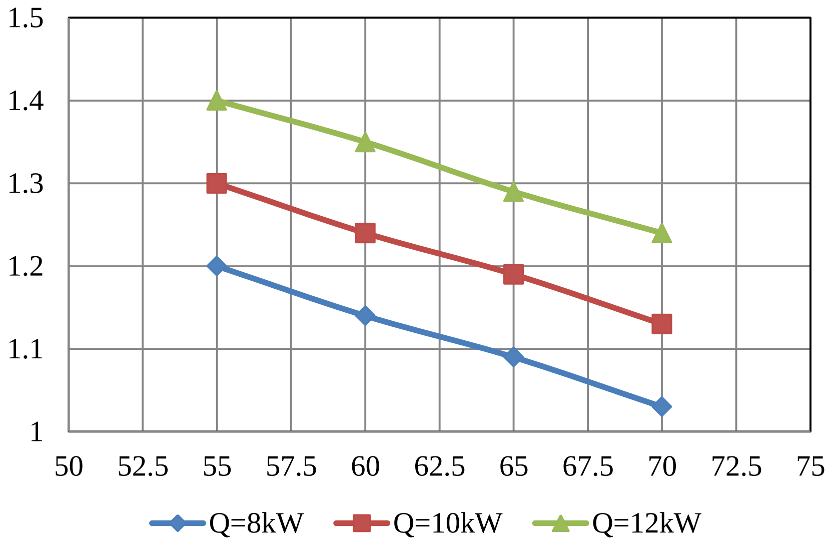

Figure 5. Effect of relative humidity of inlet air on the productivity at different heat input to the heater

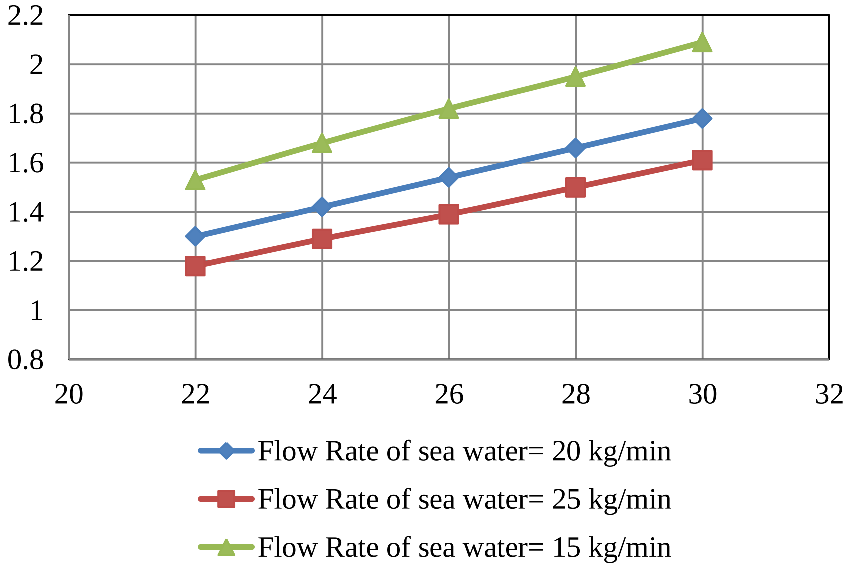

Figure 6. Effect of mass flow rate of air on productivity at different mass flow rate of sea water

Figure 6 represents the theoretical yield of fresh water production at a different mass flow rate of air and mass flow rate of water. It indicates that an increase of mass flow rate of air will increase the total amount of air carried out by the air if the sea water temperature increases then the productivity of the system to be reduced. Because it is due to the fact that for the same heat input into the outlet temperature of the heater outlet water temperature; it reduced with an increase in the mass flow rate of air, thus the productivity of the reduced system.

4.3: Effect of mass flow rate of water on productivity at different mass flow rate of air

Figure 7 shows the effect of mass flow rate of water on productivity at a different mass flow rate of air, from this it was inferred that the desalination rate decreases when the increase of the sea water flow rate and it has two opposite effects on the system performance. At the time of starting it decrease the system temperature due to the increase in the water flow rate and the associated thermal load. It effects to reduce the driving force for evaporation and, in turn, the amount of producing water. On the other hand, increasing the flow rate of air stream increases the distillate flow rate.

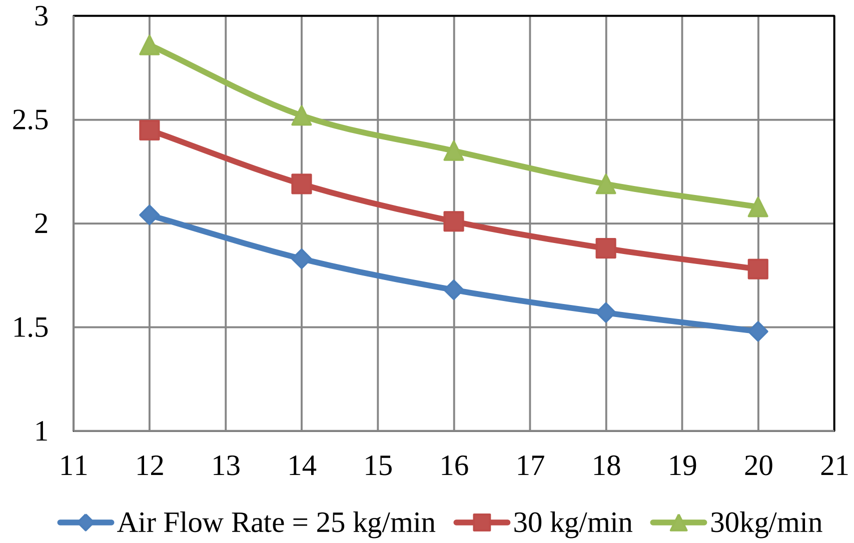

Figure 7. Effect of mass flow rate of water on productivity at a different mass flow rate of air of the increase in the total amount of water vapor carried by the air stream.

4.4: Effect of heat input to the heater on productivity at different mass flow rate of air

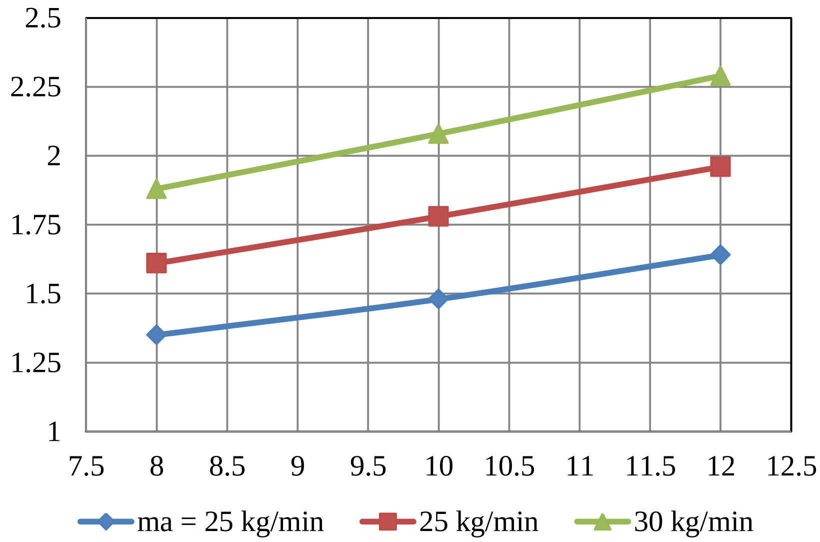

Figure 8. Effect of heat input to the heater on productivity at different mass flow rate of air

Figure 8 shows the effect of heat input and the mass flow rate of air on the productivity, the graph represents the increased heat input causes the increase the productivity of the system, due to increase of heater input temperature causes the higher heater outlet water temperature, an increase in the water temperature leads to the increased evaporation of water through the flowing air. So the amount of water evaporated increased per kilogram of dry air, so the productivity increased; on the other hand, if the mass flow rate of air increases the total amount of water carried by air is increased.

4.4: Effect of relative humidity of humidified air on productivity at different mass flow rate of air

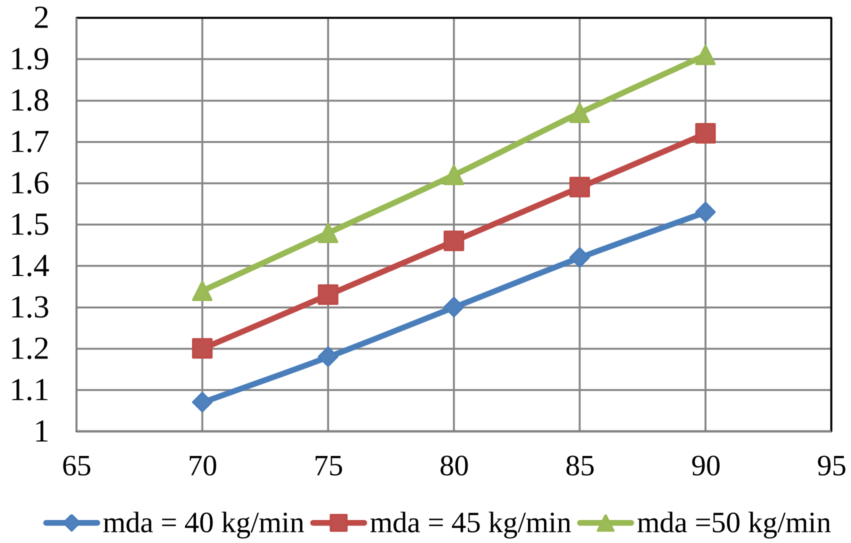

Figure 9. Effect of Relative Humidity of humidified air on productivity at a different mass flow rate of air.

The Figure 9 shows that the effect of relative humidity of the humidified air and the mass flow rate of dry air on the productivity of the total system, the relative humidity of the air increases, then the productivity also increased, this is due to increase relative humidity will lead to the increased water carrying capability of air. So the amount of water vapor per kilogram of dry air has been increased, due to this the productivity of the system also increased.

4.5: Effect of mass flow rate of water on productivity of different heat input to the heater

Figure 10 shows the effect of mass flow rate of sea water entering into the system and the heater input rate on the productivity. The mass flow rate of inlet sea water will decrease the system productivity, due to the temperature of sea water at the outlet of heater decreases with an increase in the mass flow rate of inlet sea water at constant heater input. So the humidification efficiency of the air will be reduced due to the decrease in temperature, which leads to the reduction of the water evaporation amount and reduces the productivity of the system.

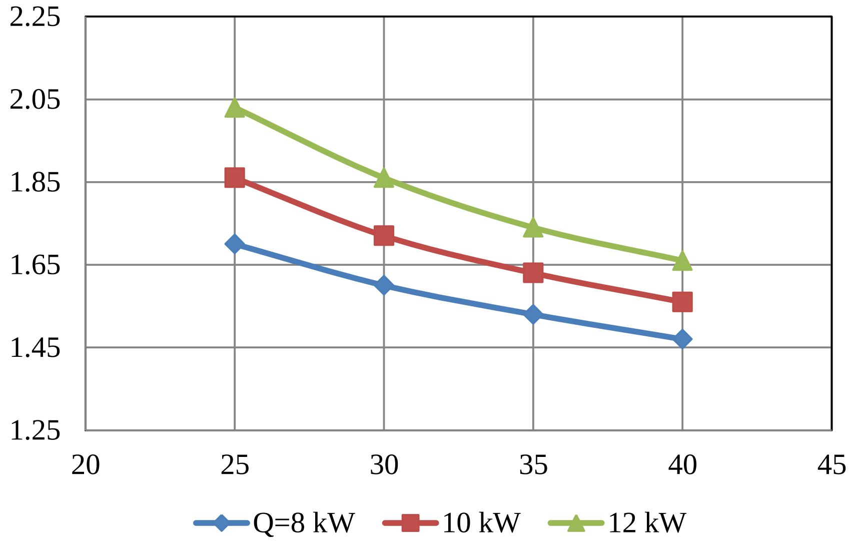

Figure 10. Effect of mass flow rate of water on productivity of different heat input to the heater

4.6: Effect of flow rate of air on recovery ratio of different heat input to the heater

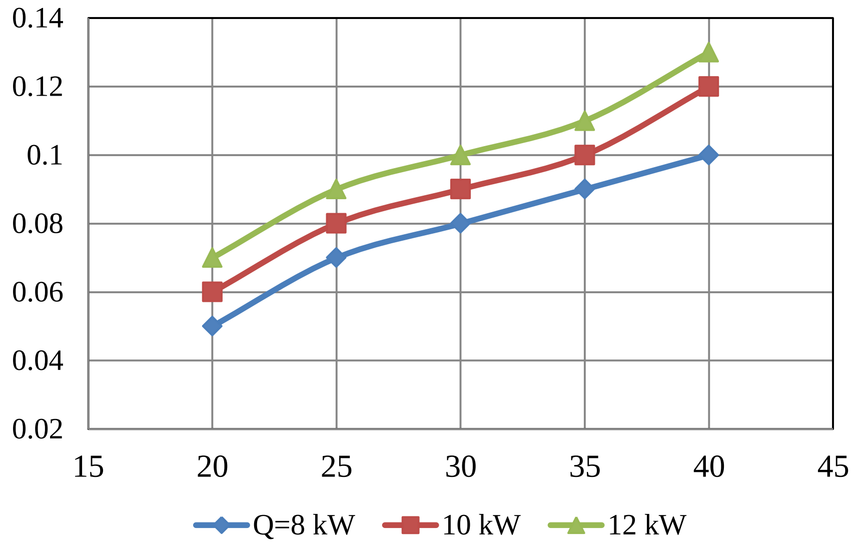

Figure 11. Effect of flow rate of air on recovery ratio of different heat input to the heater

The Figure 11 shows the effect of mass flow rate and the heater heat input rate on the recovery ratio, which represents the flow rate of air will increase the productivity of the system with constant inlet sea water mass flow rate into the system. So the amount of pure water recovered per kilogram of feed seawater increased, this shows the increase in the recovery ratio with an increase in the mass flow rate of air flowing into the system. The increased heater input leads to the higher humidification efficiency of the humidifier so the amount of water extracted in the humidifier is also increased. So the increase in heater input caused the increase of extraction efficiency or Recovery Ratio.

4.7: Effect of inlet water temperature to the heater on recovery ratio of different seawater mass flow rate

The effect of heater inlet sea water temperature and mass flow rate of water is shown in Figure 12 from the graph the increased water inlet temperature leads to the increased outlet temperature of the sea water from the sea water, so increase in the spray water temperature leads to the increase of humidification efficiency of the air so that the amount water extracted per kilogram of sea water also increased, due to this the Extraction efficiency or the Recovery Ratio increased with increase in inlet sea water temperature to the heater. On the other side increase of sea water mass flow rate decrease the productivity of the system as discussed earlier, so the amount of water evaporated per kilogram of feed water also reduced it caused the reduction of the recovery ratio with an increase in the mass flow rate of inlet sea water.

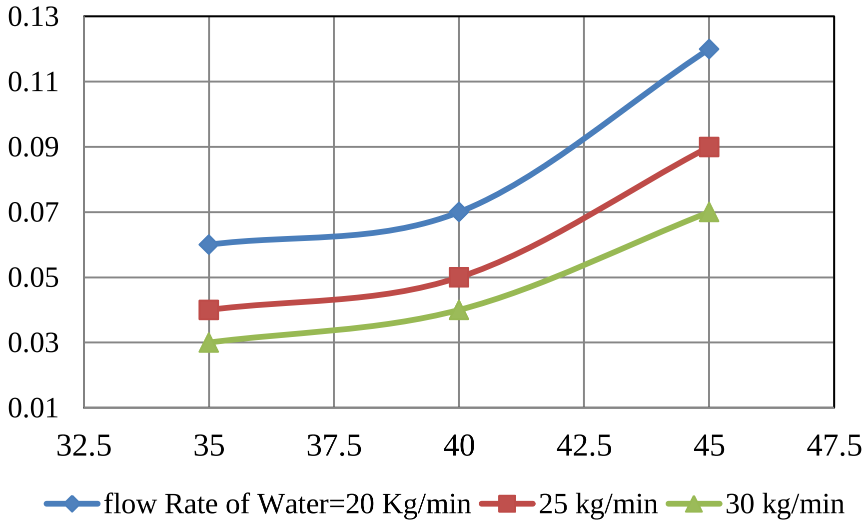

Figure 12. Effect of inlet water temperature of the heater on recovery ratio of different seawater mass flow rate

4.8: Effect of heat input to the heater on recovery ratio of different heater inlet sea water temperature

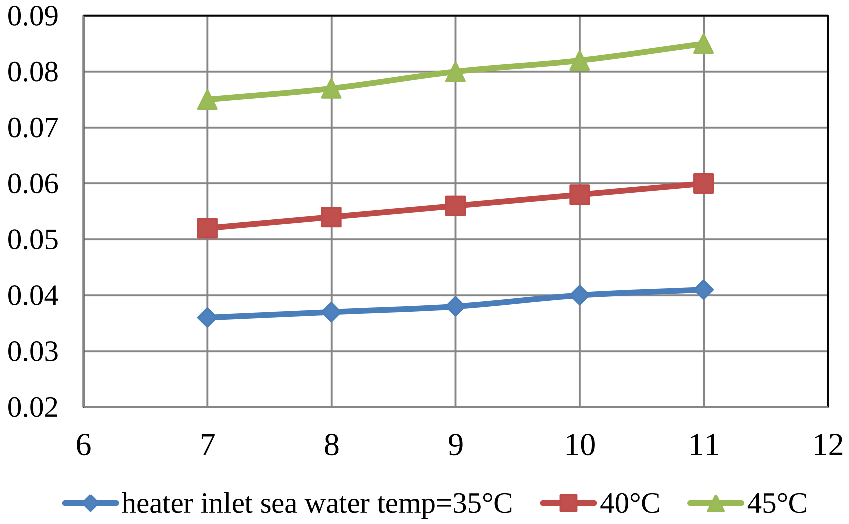

Figure 13. Effect of Heat input to the heater on recovery ratio of different heater inlet sea water temperature

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The fig.13 shows the effect of heater heat input and temperature of sea water at outlet of the dehumidifier on the recovery ratio of the system, the increase in the heater input with constant mass flow rate of inlet sea water to the system will increases the productivity of the system as discussed earlier the increased heater input will increase the humidification efficiency of the air, so that the amount of water evaporated per kilogram of feed water increased, due to this the recovery ratio increases with increase in heater input. The fig.13 shows the effect of heater heat input and temperature of sea water at outlet of the dehumidifier on the recovery ratio of the system, the increase in the heater input with constant mass flow rate of inlet sea water to the system will increases the productivity of the system as discussed earlier the increased heater input will increase the humidification efficiency of the air, so that the amount of water evaporated per kilogram of feed water increased, due to this the recovery ratio increases with increase in heater input. In another view the inlet sea water temperature in the heater also causes the increase in the spray water temperature so the productivity of the system also increased, this is caused the system to increase the extraction efficiency.

4.9: Effect of RH of humid air on recovery ratio of different mass flow rate of sea water

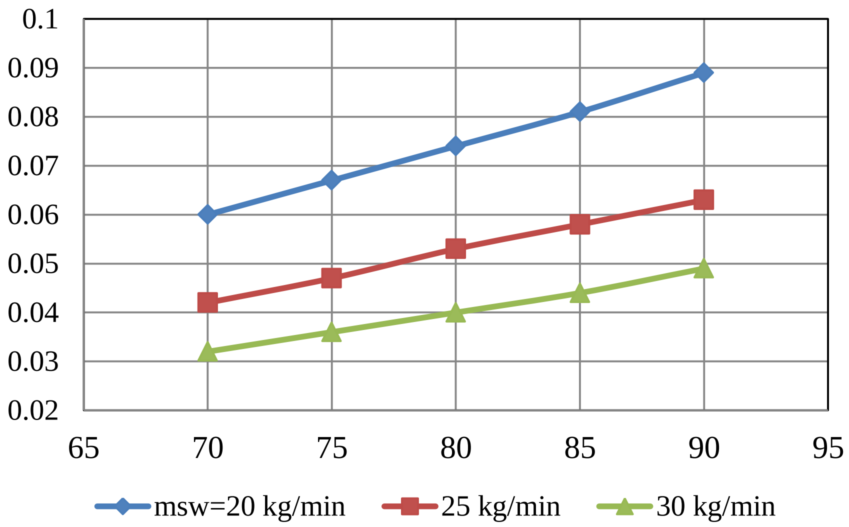

Figure 14. Effect of RH of Humid air on recovery ratio of different mass flow rate of sea water

The figure 14 shows that the effect of RH of humidified air and the mass flow rate of sea water on the recovery ratio, when the relative humidity of the humidified air increased the amount of water vapor mixed with the air also increased so the productivity of the system also increased as discussed earlier in this chapter, due to the increased productivity extraction efficiency of the system has been improved. With the increased mass flow rate of sea water with constant heater input reduces the extraction efficiency, this is due to that the increase of mass flow rate of sea water reduces the evaporative efficiency so that the recovery ratio reduced to increase a mass flow rate of inlet sea water.

5. Conclusions

The experimental study of humidification-dehumidification (HDH) system, works based on thermodynamic principles. It reveals that the increased flow rate of fresh water produced by increases the relative humidity of humid air from the humidifier. The flow rate of the dry air increases, then the evaporation efficiency of the humidifier is increased, hence the flow rate of distillation also increased. In case the flow rate of seawater increases, then the flow rate of distillate is decreased.

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