CHAPTER XII

SUMMARY OF RESULTS AND CONCLUSION

The transparency of the salt solution in the pond at various depths is analyzed both theoretically and experimentally (chapter IV). Two types of shallow solar pond are considered for this study. An one dimensional model for shallow solar pond is developed for the 5 cm and 10 cm thickness of water in the chapter V. The maximum temperature of the shallow solar pond I (SSP I) is 80.7°C for 5 cm thickness of water and 66.6°C for 10 cm thickness of water. They are found to be 91.2°C and 70.2°C for shallow solar pond II (SSP II). The variations of the temperature of SSP due to variation of solar radiation for different flow rates and heat extraction are analyzed. The effectiveness of the exchanger decreases with the increase of flow rate. The instantaneous efficiency is studied for both SSP I and SSP II.

The experimental study of the SSP I and SSP II is discussed in chapter VI. The maximum temperature of SSP II is found to be 61.3°C and 59.0°C for 5 cm and 10 cm thickness of water and that of SSP II are 76.4°C and 62.6°C. The maximum collection efficiencies are 13.89% and 15.93% for SSP I and 20.76% and 23.67% for SSP II for 5 cm and 10 cm thickness of water. The low efficiencies of the SSP I are due to more overall thermal loss and shadow effect. The heat extraction from SSP I is more than that of SSP II. As the side walls and the bottom of the SSP II are exposed to air, the convective losses and the influence of the ambient temperature are more than that of SSP I which is kept inside the ground. The effectiveness of the heat exchanger for SSP I is more than that of SSP I and almost remain in constant with temperature. The retention capacity of the pond after 12 hours night is 51.82% and 32.82% for SSP I and 36.96% and 15.54% for SSP II.
The simulation model for the thermal performance for the different depths is discussed in chapter VII. The time elapsed to reach stability of the pond is 246 hours for 0.9m, 626 hours for 1.2m, 1038 hours for 1.5m and 1815 hours for 2.0m at 93°C LCZ. This time taken increases with increase in thickness of LCZ and depth of the pond. The rate of decrease in LCZ temperature during heat extraction depends upon the flow rate and time. This effect is analyzed for different depths of the pond (0.9m, 1.2m, 1.5m and 2.0m). The concentration variation is also simulated using diffusion equation and analysed that the initial concentration of 18.8% is decreased to 17.2% after 12 days.

The experimental study of the salt gradient solar pond I (SGSP I) and salt gradient solar pond (SGSP II) is discussed in chapter VIII. The maximum storage temperature of LCZ in SGSP I is observed as 57.5 °C and time elapsed is 408 hours. The maximum collection efficiency SGSP I is determined as 37.98%. The retention capacity of the SGSP I is 88.13%. The surface evaporation on clear sunny days is found to be 5.5236 x 10^{-5} liter sec^{-1} m^{-2}. The maximum temperature is observed as 50.7 °C in SGSP II and time elapsed to reach this temperature is 264 hours. The maximum collection efficiency is predicted as 30.57%. The retention capacity for this system is determined as 72.46%. The performance of the SGSP I is better than that of SGSP II due to comparison, because the collection capacity and retention capacity are more in SGSP I than in SGSP II.

The velocity of the rise in liquid is studied during filling process. The upward velocity of the solution decreases as the level of the solution increases. The initial velocity is 5.01 x 10^{-5} m sec^{-1} and final velocity is 1.341 x 10^{-5} m sec^{-1} for SGSP I. The initial velocity is 1.489 x 10^{-4} m sec^{-1} and final velocity is 0.7795 x 10^{-4} m sec^{-1} for SGSP II. The velocity of the solution during filling the pond for the SGSP II is more than that of SGSP I because volume content of the SGSP I is greater than that of SGSP II.
In SGSP I, the concentration at the LCZ varies from 19.0% to 17.2%. The quantity of salt flux diffusion is given as 4.05 kg m\(^{-2}\) in SGSP I. In SGSP II concentration varies from 19.5% to 18%. The quantity of salt flux diffusion is given as 3.0 kg m\(^{-2}\) in SGSP II. The quantity of salt flux diffusion is high for SGSP I because the volume of the adjacent layer is more due to the sloped side walls. The quantity of salt flux diffusion for SGSP II is less than that of SGSP I because the volume of the adjacent layer over the LCZ is uniform because the side walls of the SGSP II is vertical.

In Chapter IX, the density temperature and surface evaporation and unsustainability of the SGSP I are studied. The maximum storage temperature of LCZ during this study is 62.4 °C and it reduces to 58.4 °C next morning. The quantity of salt flux increases with temperature and it decreases as the depth of the pond increases. The quantity of salt flux diffusion is predicted as 1.4 \times 10^{-6} \text{ kg s}^{-1} \text{m}^{-2} \text{ theoretically. It is observed as } 1.3 \times 10^{-6} \text{ kg s}^{-1} \text{m}^{-2} \text{ experimentally.}

The simulation model for the thermal performance of complementary solar pond is discussed in chapter X. The time elapsed to reach stability for different flow rates and for the depths such as 0.9 m, 1.2 m, 1.5 m and 2.0 m are analyzed. The time elapsed to reach the thermal stability for a flow rate of 100 ml s\(^{-1}\) is 4465 min for 0.9 m, 5745 min for 1.2 m, 7305 min for 1.5 m and 11280 min for 2 m. Similarly time required for the thermal steady state varies for different depths and flow rate.

The experimental study of the CSP I & CSP II system is discussed in chapter XI. The supply of energy from SSP I with the 10 cm thickness of water layer to the SGSP I (CSP I system) is observed. The maximum temperature of the pond is 58.3 °C. Similarly it is 59 °C for 5 cm thickness of water. The overall collection efficiency of the CSP I system is 5.268% for 5 cm thickness of water and 6.026% for 10 cm thickness of water. The quantity of salt flux diffusion is analyzed as 1.30208 \times 10^{-6} \text{ kg s}^{-1} \text{m}^{-2}. 

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The retention capacity for CSP I system is 93.03% per day. The temperature rise of the CSP I system up to 65 °C is studied by electrical heating. The quantity of energy supplied is 36,787.8 KJ.

In CSP II system, the rise in temperature is 52 °C for 10 cm thickness of water in SSP II and 54 °C for 5 cm thickness of water. In the above cases the energy is transferred to the SGSP II for 60 minutes. The time is increased to 80 minutes and the performance of CSP II system is studied. This speeds up the thermal stability of the pond. The quantity of salt flux diffusion is $7.71605 \times 10^{-7}$ kg m$^{-2}$s$^{-1}$. The retention capacity is 89.64% for CSP II system. The temperature raise of the CSP II system up to 60 °C is studied by electrical heating. The quantity of energy supplied is 30,955 KJ.

The advantages of CSP over SGSP are given here. (Chapter VIII & Chapter XI). The warming up period to achieve thermal stability of the pond reduces to 6 days. So the cost of salt replenishment to maintain concentration profile also reduces for these days. The experimental studies confirmed the trend of the theoretical model. The deviations are due to the boundary and initial conditions.

By combining the SSP with SGSP, the warming up period is reduced. This effect may also be studied by combining SSP with other types of ponds such as Partitioned solar pond (PSP), Membrane stratified solar pond (MSSP), Gel pond and saturated solar pond. In saturated solar pond, crystallization of salt in the LCZ may be avoided. In the CSP, as the salt gradient pond can be easily warmed at any time during day using SSP and frequent heat extraction from SGSP can be done without much affecting its thermal stability.

Fig 12.1 - 12.6 show the comparision between the experimental data with those from the simulation model. As the simulation model is of one dimensional only, the values will not exactly coincide with the experimental data. But a similarity can be observed.
Fig 12.1 Comparison of experimental data with the simulation model in SSP I

Fig 12.2 Comparison of experimental data with the simulation model in SSP II
Fig 12.3 Comparison of experimental data with the simulation model in SGSP I

Fig 12.4 Comparison of experimental data with the simulation model in SGSP II
Fig 12.5 Comparision of experimental data with the simulation model in CSP I

Fig 12.6 Comparision of experimental data with the simulation model in CSP II