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CONCENTRATION PROFILE IN THE GRADIENT ZONE OF SMALL SOLAR PONDS

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It is important to know the shape of the concentration profile in the gradient zone of a solar pond in order to predict the rate of salt diffusion from lower to upper convective zones. Most investigators assume that the concentration profile is linear. This assumption is violated in many cases. Akbarzadeh[1] has highlighted the effect of sloping walls on the salt concentration profile in a solar pond.

The diffusion coefficient of salt in water is a strong function of temperature. Tabor and Weinberger[2] have suggested the following variation of diffusion coefficient with temperature:

$$D = 1.39(1 + .029(T - 20)) \times 10^{-9}, \quad (1)$$

where D is in m^2/s, T is in C.

In small solar ponds the surface area of the pond changes substantially with depth. Hence the steady state one dimensional equation for salt diffusion must be written as

$$\frac{\partial}{\partial Z}\left(AD\frac{\partial S}{\partial Z}\right) = 0 \quad (2)$$

where S = salt concentration in kg/m^3, A = area at depth Z and Z = distance from the surface of the pond.

The steady state assumption is reasonable unless there are rapid changes in salinity and temperature of the upper and lower mixed zones. For a small solar pond with total depth H and length L, breadth b and side slope α (see Fig. 1) the area of the pond at depth Z can be written as

$$A(Z) = [L + 2(H - Z)\cot\alpha][b + 2(H - Z)\cot\alpha], \quad (3)$$

A_b = bottom area of the pond = $L \times b$. The temperature profile in the solar pond in the gradient zone can be assumed to be linear for the purpose of calculation of the diffusion coefficient.

$$T = T_s + (T_b - T_s)(Z - Z_1)/(Z_2 - Z_1), \quad (4)$$

where T_s = temperature of the upper convective layer of the pond, T_b = temperature of the lower convective layer of the pond, Z_1 = Interface between upper layer and gradient zone, Z_2 = Interface between lower convective layer and gradient zone.

Equation (2) can be integrated once to obtain

$$AD\frac{\partial s}{\partial z} = G, \quad (5)$$

where G is the constant salt diffusion rate in kg/s. The above equation can be integrated once more to obtain

$$S(Z_2) - S(Z_1) = G\int_{Z_1}^{Z_2}\frac{dZ}{AD}, \quad (6)$$

where $S(Z_1)$ and $S(Z_2)$ are the salinity in the upper and lower convective zone and these are usually known. Using Eqns (1), (3), (4) in (6) we can obtain the salt diffusion rate G for given salinities in the upper and lower convective layers. Once the salt diffusion rate is known we can obtain the salinity profile as

$$(S(Z) - S(Z_1)) = \int_{Z_1}^{Z}\frac{G}{AD}\,dZ.$$

We have compared the results obtained from the above analysis with measurements made in 240 m^2 (L = 30 m, b = 8 m, α = 45°) solar pond at the Indian Institute of Science, Bangalore. The density measurements were made with hydrometers. The density of the sample at 30 C was related to salinity through a calibration curve. The salinity profile was obtained during a period when the temperature and salinity remained fairly constant. The salinity profile obtained has been compared with the linear profile and the profile obtained by the method described above. We find that the salinity profile departs substantially from the linear profile. The inclusion of the effects of variation of area and diffusion coefficient are able to account for the departure from linearity. We have also indicated the salinity profile if the variation of area is ignored but the variation in diffusion coefficient is included. This profile is steeper than the observed profile. This is because the variation in area partly counteracts the variation in diffusion coefficient. For proper maintenance of solar ponds it is essential to

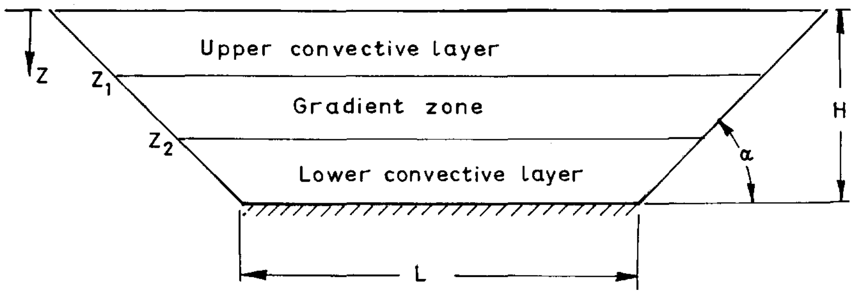

Fig. 1. Small solar pond.

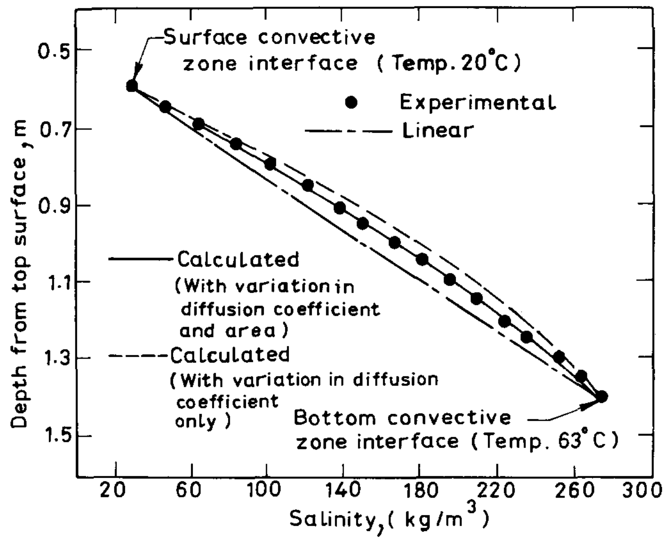

Fig. 2. Comparison of calculated and recorded salinity profile (11 Jan 1985, I. I. Sc Solarpond).

know precisely the rate of salt diffusion in order to estimate the amount of salt that needs to be injected periodically in the lower convective zone. The above analysis shows that for an accurate estimate of salt diffusion it is essential to account for the variations of area and diffusion coefficient with depth. It is interesting to note that Nielsen *et al.*[3] have suggested that the Soret effect may have an influence on the salt diffusion rate. The good agreement between theory and measurements in the present case indicates that Soret effect is not important in this case.

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