CHAPTER 6

ISOTHERMAL FLOW OF NONHOMOGENEOUS AQUEOUS SOLUTIONS

Under natural conditions, the soil solution is never really homogeneous. The effects of salt concentration gradients on water flow may be neglected in many cases, while in others they are of primary importance. When the movement of the solutes is more restricted than the movement of the solvent, phenomena develop which are related to the reverse osmosis processes used in water desalinization plants. Even when the salts are not more restricted than the water solvent, density differences and molecular diffusion processes may be important in determining the movement of the soil solution. This latter case will be considered first, followed by analysis of solute-restricted flow in unsaturated soil.

As the soil solution is displaced by rain or irrigation water, the two solutions tend to mix at their boundaries. This mixing is caused by thermal diffusion and by hydrodynamic dispersion. Thermal diffusion is random movement due to thermal motion of ions and molecules. Hydrodynamic dispersion develops because of the lower fluid velocities next to the solid-liquid interfaces and in the smaller pores.

Several mathematical treatments have been considered in Chapter 3. The treatment which has appeared most often and has, in general, fit experimental conditions best was derived (i.e., Lapidus and Amundson, 1952) from equation [3.68] for concurrent thermal motion and dispersion of the solution components. The derivation of equation [3.68] stemmed from equation [3.67]—a relation which at best is approximate as was discussed in Chapter 3. If it is further assumed that no sources or sinks exist within the soil (\( f_n = 0 \) in equation [3.68]), and that \( D \) and \( v \) do not depend upon \( x \) (the soil is uniform and the distribution of pores in the x-direction is completely without order), then

\[
\frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial x^2} - v \frac{\partial C}{\partial x} \tag{6.1}
\]

in which \( D \) must necessarily be a coefficient combining diffusion and hydrodynamic dispersion. Although \( D \) was assumed to be an apparent diffusion coefficient independent of the average interstitial flow velocity, \( v \), we know that it does indeed depend upon \( v \) for reasons discussed earlier about equation [3.68]. In writing equation [6.1], it has been assumed that movement of solutes with respect to the average solution velocity, whether by dispersion or diffusion, will be directly proportional to the concentration gradient in the moving solution. In an equation equivalent to Fick's first law, this assumption appears