The Soil Chemistry of Hazardous Materials

Second Edition

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T = surface tension

r = radius of the tube

d = density of the liquid

g = force of gravity

For water, this equation can be simplified to the following equation:

$$h\ (cm) = 0.15 / r\ (cm) \tag{2.12}$$

This equation reveals the inverse relation between the magnitude of capillary rise and tube radius (i.e., pore size). Figure 2.30 illustrates the values of capillary rise for various soils. Numerical and analytical models are available to estimate capillary rise[23].

Water moves very slowly from the water table upward. Tables 2.5 and 2.6 and Figures 2.31, 2.32, and 2.33 list data on the rates of capillary water movement from water table in soil columns.

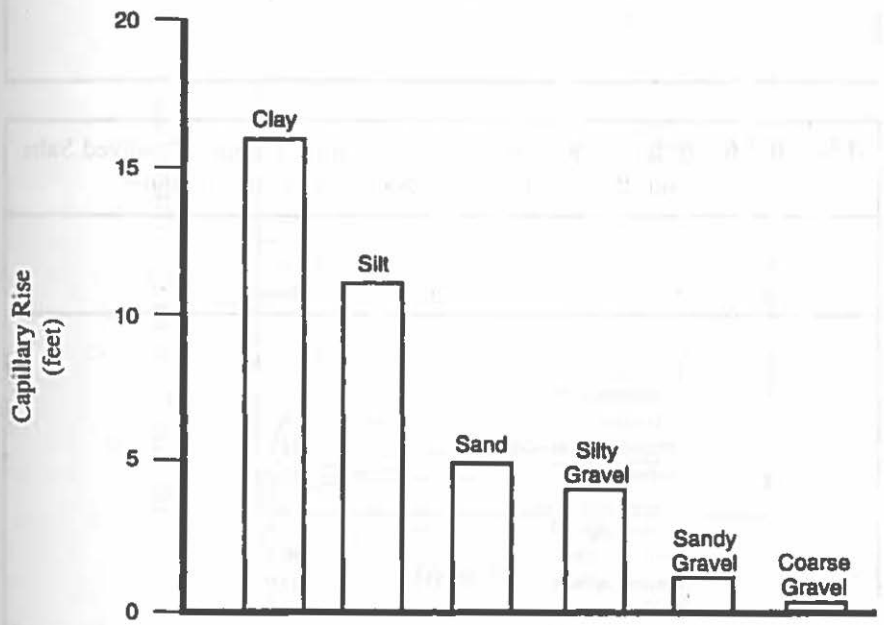

Figure 2.30 Typical Values for Capillary Rise in Various Soils

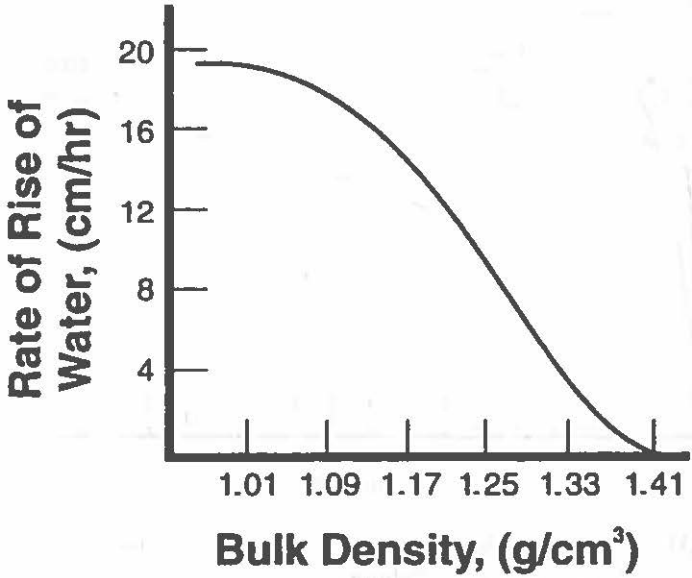

Figure 2.33 The Rate of Rise of Water in Chernozem Clay Loam with a 3.5% Humus Content and Varying Bulk Density[60]

The capillary fringe does not exert a significant effect, for the most part, on the movement of chemicals in unsaturated zone soils. Even with a fluctuating groundwater table, the movement of the capillary fringe should not exert a significant effect on the movement of chemicals in unsaturated zone soil. The reason can be exemplified by the following conceptual model: In a relatively uniform soil, a rise in the groundwater table toward the soil surface would cause a corresponding upward movement of the capillary fringe. This upward movement would result in the addition of a small amount of water from the capillary fringe to existing water, some quantity of hygroscopic and capillary water will already be within unsaturated zone soil pores. However, when the groundwater table drops, the capillary fringe moves downward. As a result, the net flux of a relatively small amount of water in the capillary fringe passing through a fixed point in the soil is approximately zero. Since the leaching of an organic or inorganic chemical in soil depends on water flux, chemical movement should be negligible because the net flux of water is zero.

There is one condition in which the upward flow of water from the ground water table will affect the transport of a chemical in the unsaturated zone. When the water table is about five feet below the surface of a sandy soil, about eleven feet below a silt soil, or about 16 feet below a clay soil, evapotranspiration causes the upward movement of groundwater through the capillary fringe

(see Figure 2.30). This process is responsible for the upward movement of dissolved salts and chemicals in saline soils[46,47,48,49,50] and salinization of agricultural soils in the western U.S. Under this circumstance, the net migration of a chemical in the unsaturated zone would be upward. Table 2.7 lists evaporation rates in various soils containing different water table depths.

PERMAFROST

The previous discussions in this chapter have focused on liquid water. Liquid water is a medium of transport for many chemicals. Yet water as a solid can affect the migration pathway of dissolved chemicals as well as adsorbed chemicals. Many soils around the world, including some continental U.S. soils, are temporarily frozen (see Figure 2.34). Many soils around the world are permanently frozen; approximately 20% of the earth's total, 50% of Canada's, 50% of the former USSR's, and 85% of Alaska's land surface is underlain by permanently frozen soils (see Figure 2.35). These soils are known as *permafrost* (see Figure 2.36 and 2.37).

Permafrost is classified as either discontinuous or continuous (see Figure 2.35). Discontinuous permafrost resides adjacent to tracts of frozen soil. Continuous permafrost contains no discontinuities. Immediately below the land surface of regions where permafrost exists is the *suprapermafrost zone*. This zone is several meters in thickness. It may contain pockets of material known as *taliks* that never freeze, as well as soil that thaws during the summer and refreezes in the winter. This upper section of the suprapermafrost zone is known as the *active zone*. The *permafrost table* resides at the base of the suprapermafrost layer; this is the upper boundary of the layer that remains permanently frozen.

Processes that shape the landscape in cold climates are called *periglacia* processes. These processes, dominated by freeze and thaw activity, occur in any cold climate, even climates where glaciers are not present. Periglacial processes effect water movement and soil movement. For example, under certain situations, isolated *ice lenses* form in soil and expand in size by collecting water from unfrozen soil that migrates via capillary movement. Predominantly silty soils are most susceptible to the formation of ice lenses. Clay soils are substantially less susceptible because they retard water migration toward the ice lens. Sandy soils are substantially less susceptible because they contain large pores that do not support movement of capillary water. For a second example, ground freezing in winter months causes the formation of vertical cracks due to thermal contraction of soil. For a third example, during the summer months, meltwater in the active zone cannot drain downward due to the presence of impermeable frozen soil. As a result, soil within the active zone