

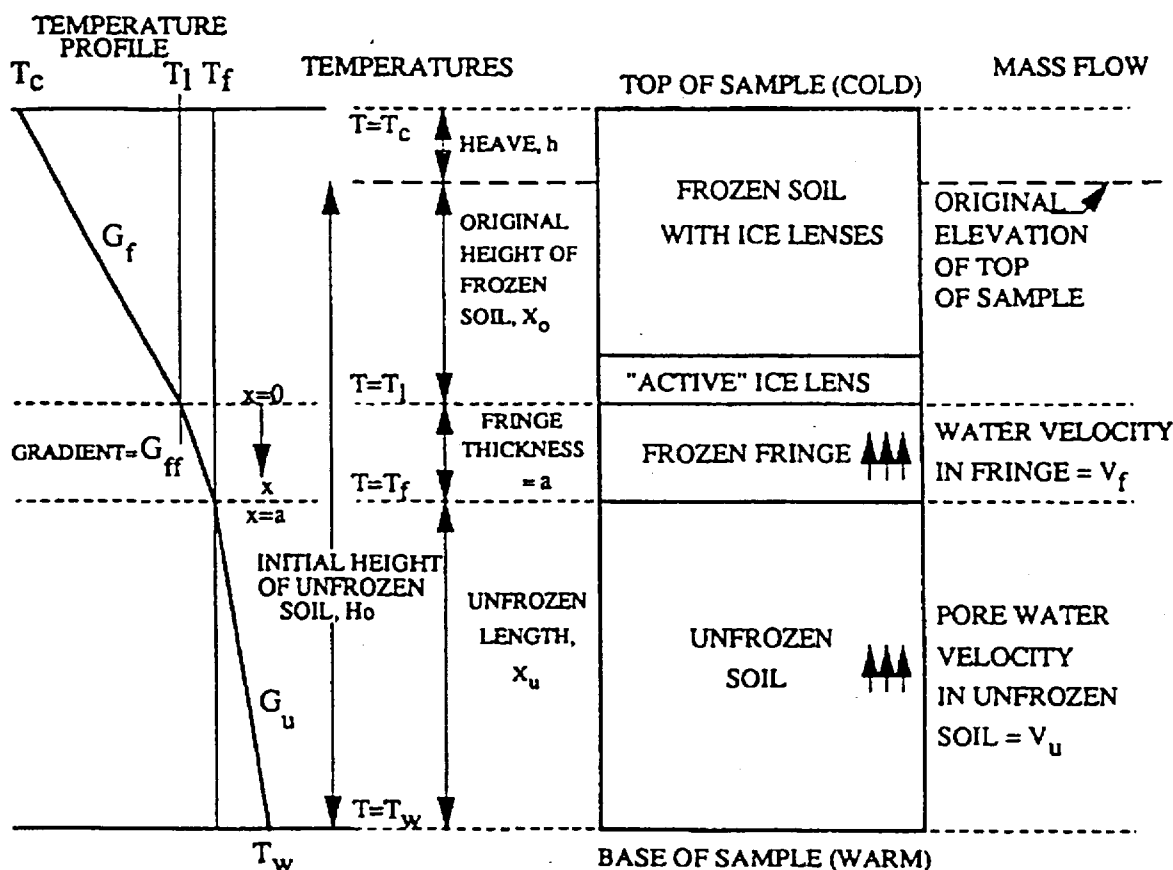


Fig. 3. Frost heave in idealized kinetics for a general pollutant

saturation of the active ice lens zone; and the magnitude of soil overburden opposing growth of ice lenses and expansion of the soil skeleton. More available pore space (ie, a thicker active ice lens zone, and saturation less than 100%), and less overburden pressure (which allows easier expansion of the soil skeleton through ice lens development and frost heave) provides greater volume for pore fluid.

2) The temperature gradient, both in the vicinity of freezing in the frozen fringe, G_{ff} , and overall, governed by T_c and T_w , affects both the duration and the rate of flow. As temperature gradients increase, especially G_{ff} in the frozen fringe, seepage is reduced because permeability of the frozen fringe decreases. In addition, if T_c falls quickly, the frozen fringe and the active ice lens zones penetrate faster, allowing less time for flow to occur to any particular point.

3) In order for seepage to occur, there must be a reservoir of accessible pore fluid. This depends on the proximity of the groundwater table, and the pore fluid content in soil above the groundwater table. In this case a higher groundwater table and greater general availability of pore fluid will increase flow volume.

4) The soil pore size influences both the ability of the soil to sustain continuous capillary pumping in response to the thermally induced suction, and the rate of flow. Smaller pores will allow the capillary suction pumping to draw water from a greater distance, on the one hand, but their small size will limit the quantity of flow that reaches the active layer during the freezing period. Pore size, both initially in the unfrozen state, and after pores begin to fill with ice, is relevant.

5) As pore ice forms, it does so starting at the center of the pores. Unfrozen pore fluid can persist as a film on particle surfaces at temperatures well below 0°C for water. This creates unfrozen seepage conduits along the particle surfaces that feed the growth of ice lenses above the frozen fringe. These conduits remain open at lower temperatures in fine grained soils, but exist even in gravels. For example, at -4°C , West Lebanon gravel can sustain an unfrozen water content of 1%; Fairbanks silt can sustain an unfrozen water content of 3%; and Umiat Bentonite can sustain an unfrozen, uncontaminated water content as high as 42% (from Andersland and Ladanyi, 1994).

6) The effect of the suction on the pore