with the boundary condition $C_L = C_{L0}$ at $Z = H$ for liquid feed into the top of a column.

Equation 11.46 can be integrated to determine the height of the column for a certain degree of separation.

$$-\frac{U}{K_a(1-\varepsilon)}\int_{C_L}^{C_{L0}} \frac{dC_L}{C_L - C_L^*} = \int_0^H dZ = H \tag{11.47}$$

By using an equilibrium relationship, we can integrate eq. 11.47 to determine the height of the column. To complete the analysis, a relationship between the unsaturated resin and the liquid concentration is needed. This relationship is called an *operating line* (Fig. 11.16) and represents a mass balance. Note that the volumetric resin flow is denoted by B and the volumetric liquid flow rate by F. Also note that

$$F = UA \tag{11.48}$$

where A is the cross-sectional area of the column.

From mass balance considerations on the solute,

$$F(C_{L0} - 0) = B(C_{S0}^* - 0) \tag{11.49}$$

or

$$\frac{B}{F} = \frac{C_L}{C_S} = \frac{C_{L0}}{C_{S0}^*} \tag{11.50}$$

where C_{S0}^* is the resin concentration of solute in equilibrium with C_{L0}. As noted in Fig. 11.16, the operating line is straight.

For fixed-bed columns, the absorptive capacity is limited to a maximum level. In this view, a column would consist of three zones: a *saturated zone*, an *adsorption zone*, and a *virgin zone*. The adsorption zone moves down a column at a rate determined by the feed rate of the solute and the mass transfer characteristics of the bed. When the leading edge of the adsorption zone reaches the bottom of the column, there will be a rapid increase in the exit concentration of solute. Normally, the column would be shut down at this point and the resin replaced or regenerated. However, if the column were operated for a period of time equal to the time for the adsorption zone to travel its own height, we

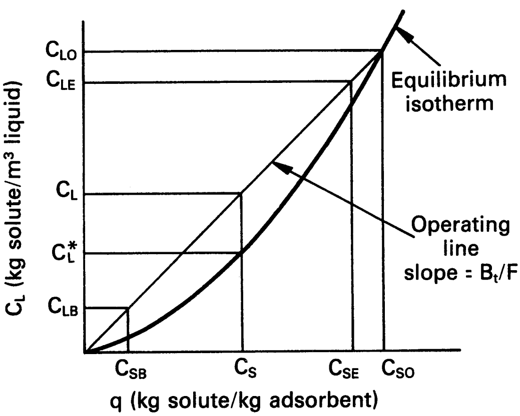

Figure 11.16. Operating line for steady-state adsorption column. (With permission, from D. W. Sundstrom and H. E. Klei, *Wastewater Treatment*, Pearson Education, Upper Saddle River, NJ, 1979, p. 261.)