6.3.2 Determination of the critical recirculation rate

Fig. 6.8 shows that the superficial loading rate T_{sm} decreases with increasing sludge concentration X_t. This increase is exponential in the case of clarification and even more accentuated in the case of thickening. As the increase of the required settler volume with increasing sludge concentration is so rapid, in principle it is not an advantage to have thickening as the limiting function of the settler. Hence, it is advantageous to increase the recirculation factor until clarification becomes the limiting function of the settler. Furthermore Eq. (6.27) shows that the superficial loading rate, and hence the settler volume, are independent of the recirculation factor when clarification is the limiting factor. Therefore, in principle one will choose the minimal recirculation factor required for clarification. This minimum recirculation factor for clarification is called the critical recirculation factor s_c.

The value of the critical recirculation factor can be determined conveniently by using Fig. 6.7, where the straight line represents the inlet sludge concentration X_t as a function of the return sludge concentration X_r. In conformity with Eq.(6.10), the critical recirculation factor can now be calculated by intersecting the straight line with the curve for X_l or X_m as a function of X_r. It can also be observed in Fig. 6.7 that for recirculation factor s < l, the straight line of X_t intersects with X_m, whereas for s > l the intersection is with X_l. Hence:

$$X_t = s_c/(s_c + 1)\cdot X_r = X_l = (X_r/2)\cdot[1 + (1 - 4/(k\cdot X_r))^{0.5}] \text{ or} \quad (6.36a)$$

$$X_t = s_c/(s_c + 1)\cdot X_r = X_m \quad (6.36b)$$

In Eq.(6.36b) the X_m value is given by Eq.(6.25). Equation (6.36a) can be solved analytically giving:

$$k\cdot X_r = (s_c + 1)^2/s_c \quad (s_c > 1) \text{ and} \quad (6.37a)$$

$$k\cdot X_t = (s_c + 1) \quad (s_c > 1) \quad (6.37b)$$

Equation (6.36b) does not have an analytical solution, but can be solved numerically. In Fig. 6.9 the critical recirculation factor is shown as function of the adimensional unit k·X. Fig. 6.9 is very useful when the values of $k\cdot X_t$ and $k\cdot X_r$ need to be determined for a particular s_c. In Fig. 6.9, for example, when $s_c = 0.5$ it is necessary that $k\cdot X_t = 1.37$ and $k\cdot X_r = 4.11$ g.l^{-1}. It can be verified that effectively $k\cdot X_t = s_c/(s_c + l)\cdot k\cdot X_r = 0.5/1.5\cdot 4.11 = 1.37$.

kX_t	s_c	kX_t	s_c
2.0	1.00	1.0	0.30
1.9	0.90	0.9	0.25
1.8	0.81	0.8	0.21
1.7	0.73	0.7	0.18
1.6	0.66	0.6	0.14
1.5	0.59	0.5	0.11
1.4	0.52	0.4	0.08
1.3	0.46	0.3	0.06
1.2	0.40	0.2	0.03
1.1	0.35	0.1	0.01

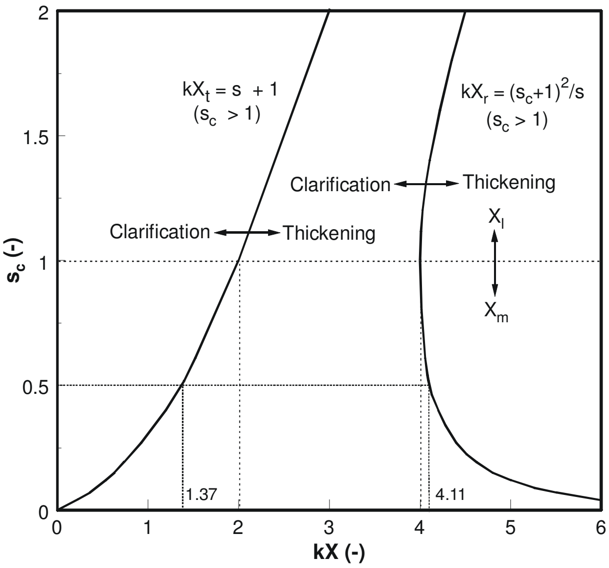

Figure 6.9 Relationship between $k{\cdot}X_t$ and $k{\cdot}X_r$ and the critical recirculation factor s_c