a. What are the effectiveness factors for $D_P = 4$ mm and $D_P = 7$ mm?

b. The following data were obtained for $D_P = 4$ mm at different substrate concentrations. Assuming no liquid film resistance, determine the r_m and K_s for the microbial system.

S_0 (mg/l)	r (mg/l-h)
100	85
250	200
500	360
1000	630
2000	1000

9.13. A waste-water stream of $F = 1$ m³/h with substrate at 2000 mg/l is treated in an upflow packed bed containing immobilized bacteria in form of biofilm on small ceramic particles. The effluent substrate level is desired to be 30 mg/l. The rate of substrate removal is given by the following equation:

$$r_s = \frac{kXS}{K_s + S}$$

By using the following information, determine the required height of the column (H).

$k = 0.5$ h^{-1}, $X = 10$ g/l, $K_s = 200$ mg/l, $L = 0.2$ mm, $a = 100$ m²/m³, $A = 4$ m², $\eta = 0.8$