



CHAPTER 4

STUDY OF FORWARD MIXING USING THE NUMERICAL SOLUTION OF THE DIFFUSION MODEL

4.1 Introduction

The development of mathematical approaches to modelize liquid-liquid extraction columns started with the plug flow model, that is plug flow in both phases, leading to the NTU, HTU concepts. In the early sixties a more realistic model emerged [8,9] which superimposed an axial dispersion term on the plug flow behavior of both phases. The model known as the Diffusion model gained widespread popularity. However for the Diffusion model to hold true a certain number of constraints formulated by Sleicher [5] would have to be verified. One major constraint was for the droplet phase to be homogeneously distributed within the column. However from separate investigations [12,14,15,16] the following behavior for the dispersed phase emerges: At low mechanical agitation in a liquid-liquid extraction column large droplets form at the distributor and as the droplet rises (or falls) in the column it breaks into smaller size droplets eventually reaching an average size. If velocities of passage of droplet phase is measured by radioactive tracer techniques [15] it appears that the velocities are high near the distributor and decrease to an average value. When the Diffusion model parameters are studied in light of the above exposed droplet phase behavior it appears that the Peclet number of the drop (or dispersed) phase and the number of transfer units vary as a function of column length.

Academically this behavior called Forward mixing gives rise to a host of mathematical models with additional parameters such as variable velocities, size distribution etc... and the normally 3 parameters Diffusion model may become a 5 or 6 parameters model. In practice it is inconvenient to handle mathematical models having many parameters as optimisation of such parameters are apt to yield combinations of values of the parameters such that the value of the optimised parameters do not correspond anymore with the physical process. As this phenomena of Forward mixing has been observed and apparently invalidates the Diffusion model the object of this investigation was to determine whether Forward mixing as seen through a variation in passage velocity in a pulsed perforated plate column plays a significant influence on the column efficiency. The simulated system was a liquid-liquid extraction column with an iodine solution as continuous phase and carbon tetrachloride as dispersed phase solvent.

4.2 Explanation of the Experiments on Variable Peclets and R_x

It was found during an investigatory work [15] on the behavior of the dispersed phase of a pulsed perforated extraction column that the dispersed phase was not an homogeneous phase. In particular this non-homogeneity appeared during a study of local dispersed phase velocities along a two-meters column using a radioactive tracer analysis method.

This nonhomogeneity translates into a variable velocity as a function of column height. If the column is modeled following the model of Miyachi then this variable velocity affects the Peclet number

of the dispersed x-phase and the number of transfer units. A computer program (see Appendix H) was therefore prepared to take into consideration variable Peclet numbers and variable number of transfer units and yield a theoretical concentration profile along the length of the column.

4.3 Study of the Variable Velocity as a Function of Column Height

The two-phase countercurrent system can be treated by the Miyachi differential equations (See equations 2-5 and 2-6). In this section, the Peclet numbers and the Number of transfer units will be changed with the variable velocity in which changed with the column height. So the equations 2-5 and 2-6 become

$$\frac{1}{P_y(Z)} \frac{d^2 Y}{dz^2} - \frac{dY}{dz} - R_y(Z) (Y - Y^*) = 0 \quad (4-1)$$

$$\frac{1}{P_x(Z)} \frac{d^2 X}{dz^2} + \frac{dX}{dz} + R_x(Z) (Y - Y^*) = 0 \quad (4-2)$$

and boundary conditions become

$$\text{at } Z = 0 \quad \frac{dX(0)}{dz} = 0 \quad (4-3)$$

$$Y_{in} = Y(0^+) - \frac{1}{P_y(0)} \frac{dY(0^+)}{dz} \quad (4-4)$$

$$\text{at } Z = 1 \quad \frac{dY(1)}{dz} = 0 \quad (4-5)$$

$$X_{in} = X(1^-) + \frac{1}{P_x(1)} \frac{dX(1^-)}{dz} \quad (4-6)$$

where

$$P_i(Z) = \frac{u_i(Z)L}{D_i} \quad ; \quad i = x \text{ or } y \quad (4-7)$$

$$R_x(Z) = \frac{k_x a L}{u_x(Z)} \quad (4-8)$$

$$R_y(Z) = R_x(Z) G_x/G_y \quad (4-9)$$

The four sets of experiments reported in [15] mentioned study were conducted for different operating conditions of the equipment but involved no transfer of solute between the two phases. Along with the data on the local velocities of drops flow are data on the agitation within the column D_x and D_y . But the value of Peclet number of continuous Y - phase is not varied with velocity. The input data is presented in the figure 4-1, 4-2, 4-3 and 4-4. Using the program for this chapter is explained in Appendix H.

In order to study the variable velocity as a function of column height the average velocity may be necessary occurred. The concentration profiles from variable velocity and average velocity are compared in figure 4-5, 4-6, 4-7 and 4-8.

In studying the concentration profiles for average velocities and variable velocities the value of k_x in equation (4-8) is set at 0.0002, 0.001, 0.005, 0.01 and 0.05

4.4 Discussion and Conclusion

Figures 4 - 5 to 4 - 8 are comparisons between two types of simulations. The dashed lines represent the simulated concentration profiles for extraction of iodine from an aqueous phase to an organic solvent using a modified diffusion model. The modified model accounts for a variation in the passage velocity of the drop phase as a function of height, a phenomena called forward mixing. The passage velocity data

used have been taken from an experimental study undertaken prior to this study (figures 4-1 to 4-4). The results are then indicated in the dashed lines. The solid lines represent the simulated concentration profiles for the same process using the diffusional model with constant average velocity corresponding to the average velocity of the above data. . The comparisons presented in figures 4 -5 to 4 - 8 represent four series of experiments.

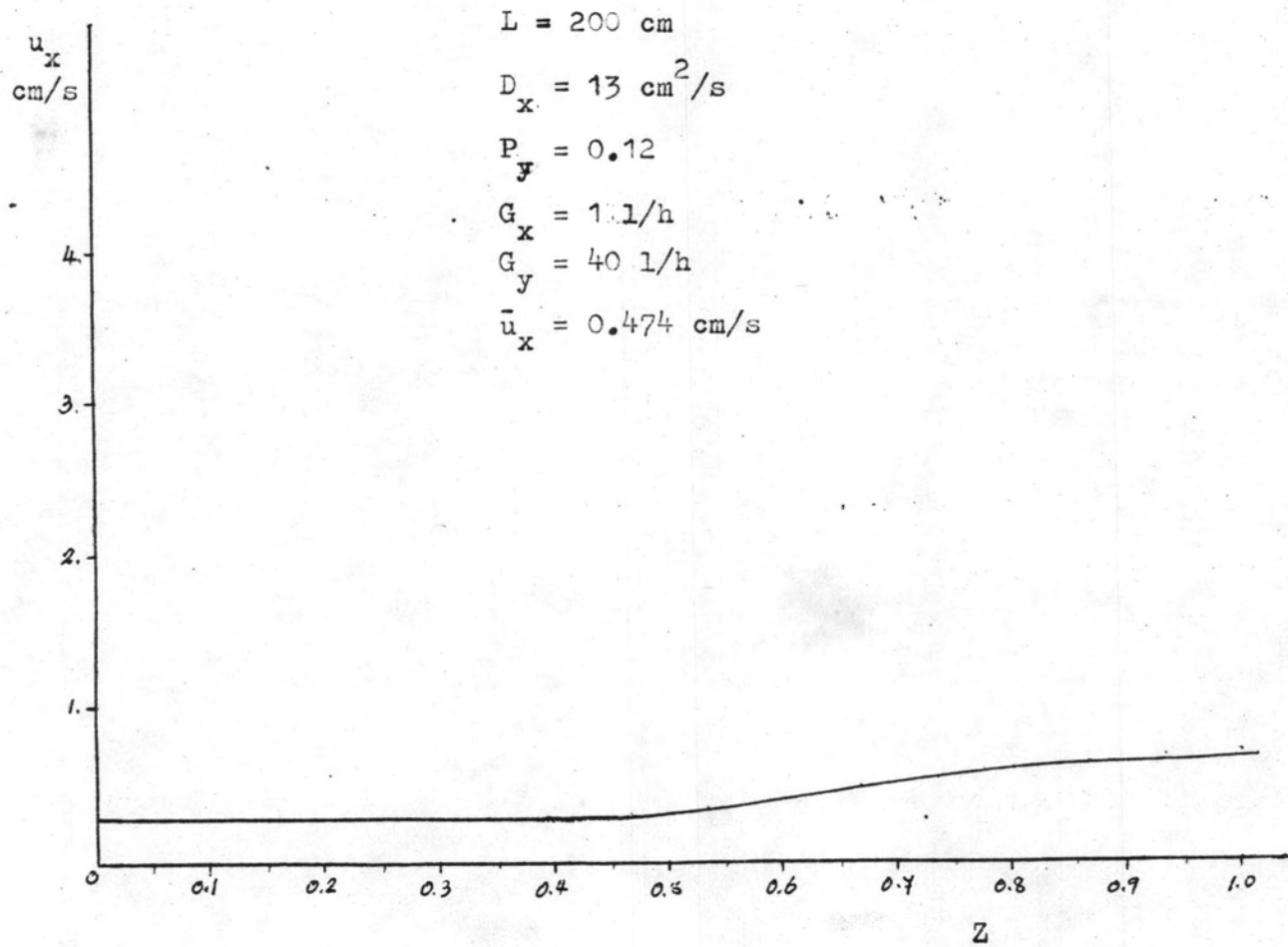


Figure 4-1 Input velocity at different height

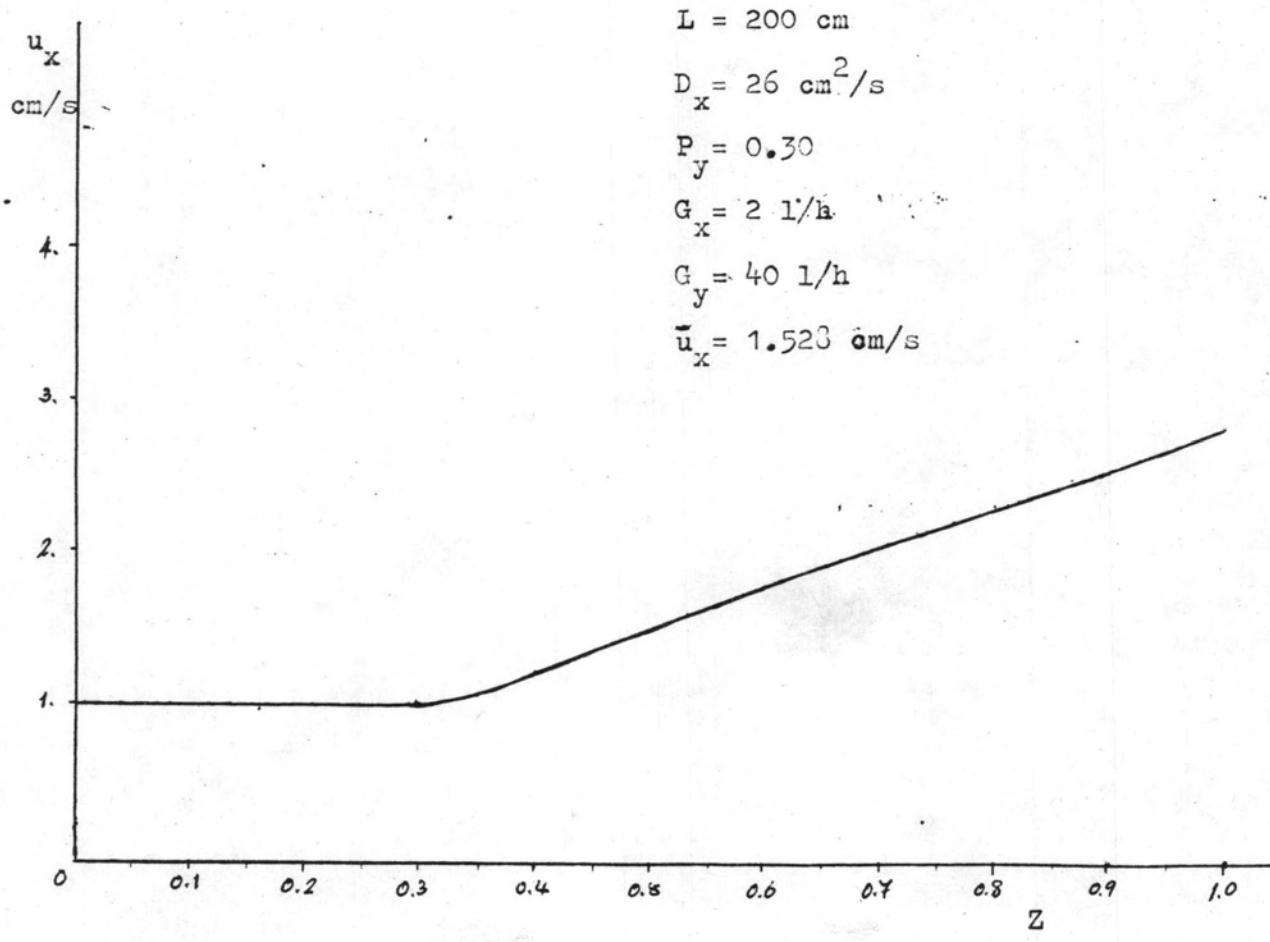


Figure 4-2 Input velocity with different height

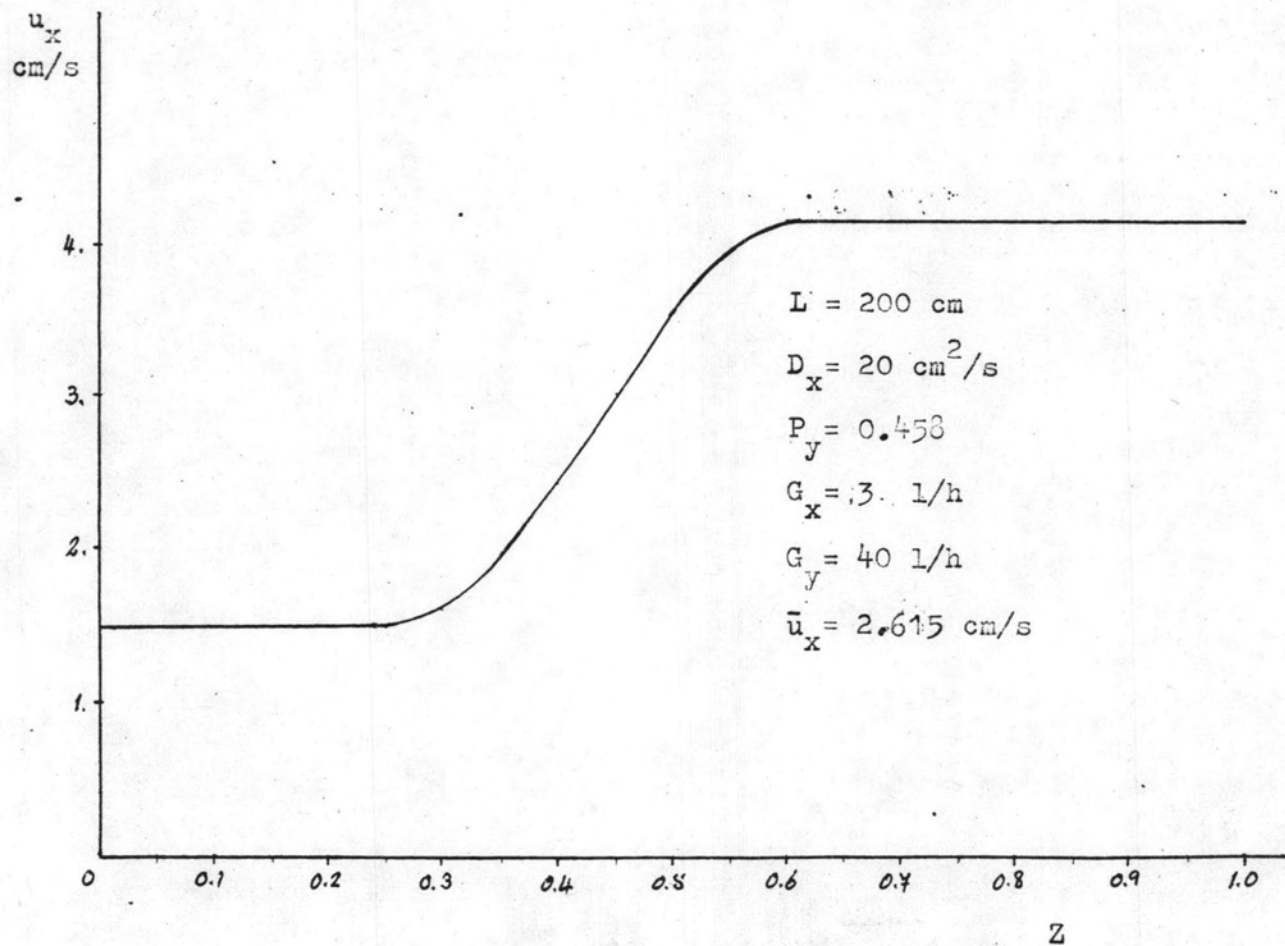


Figure 4-3 Input velocity at different height

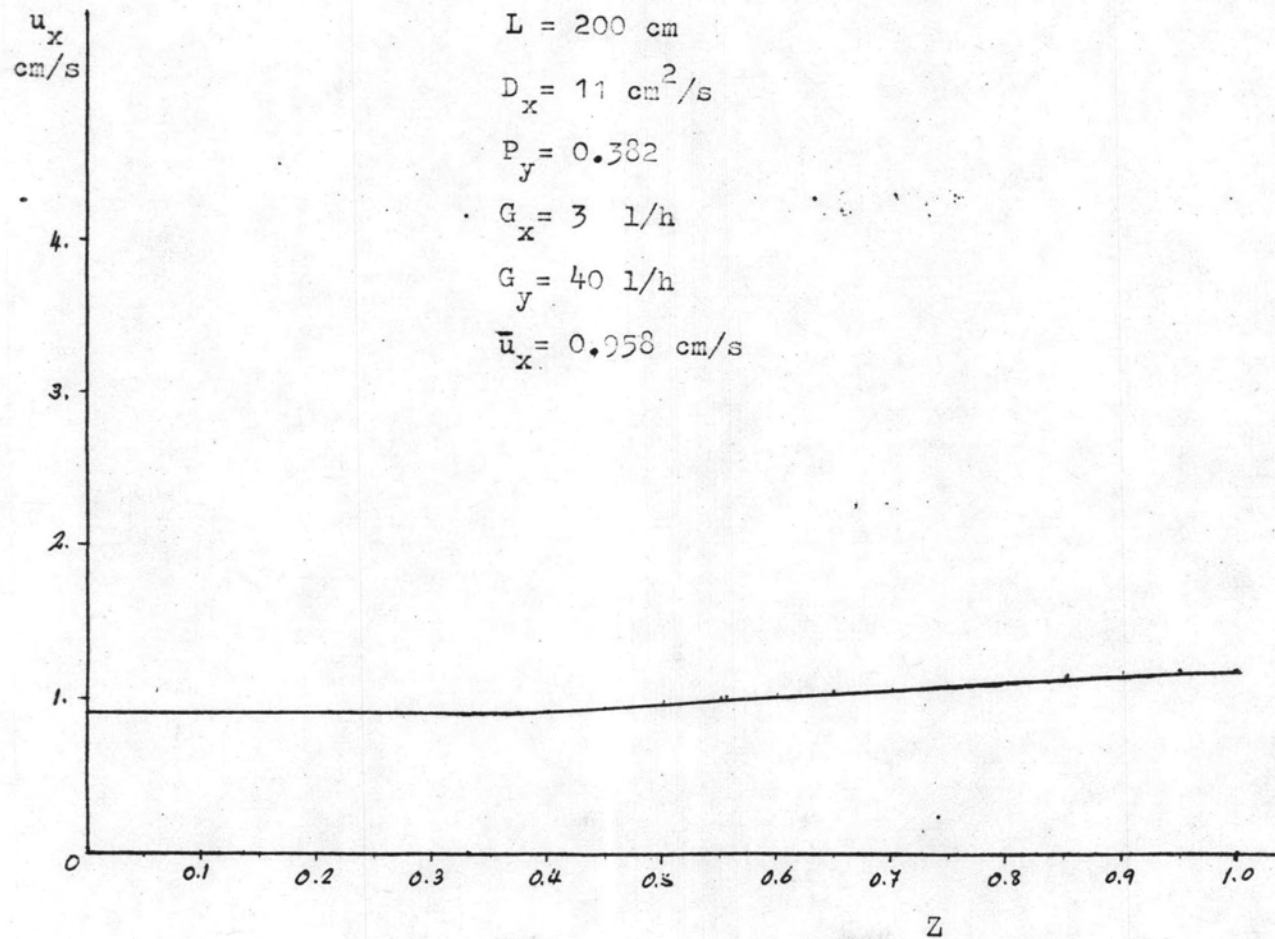


Figure 4-4 Input velocity at different height

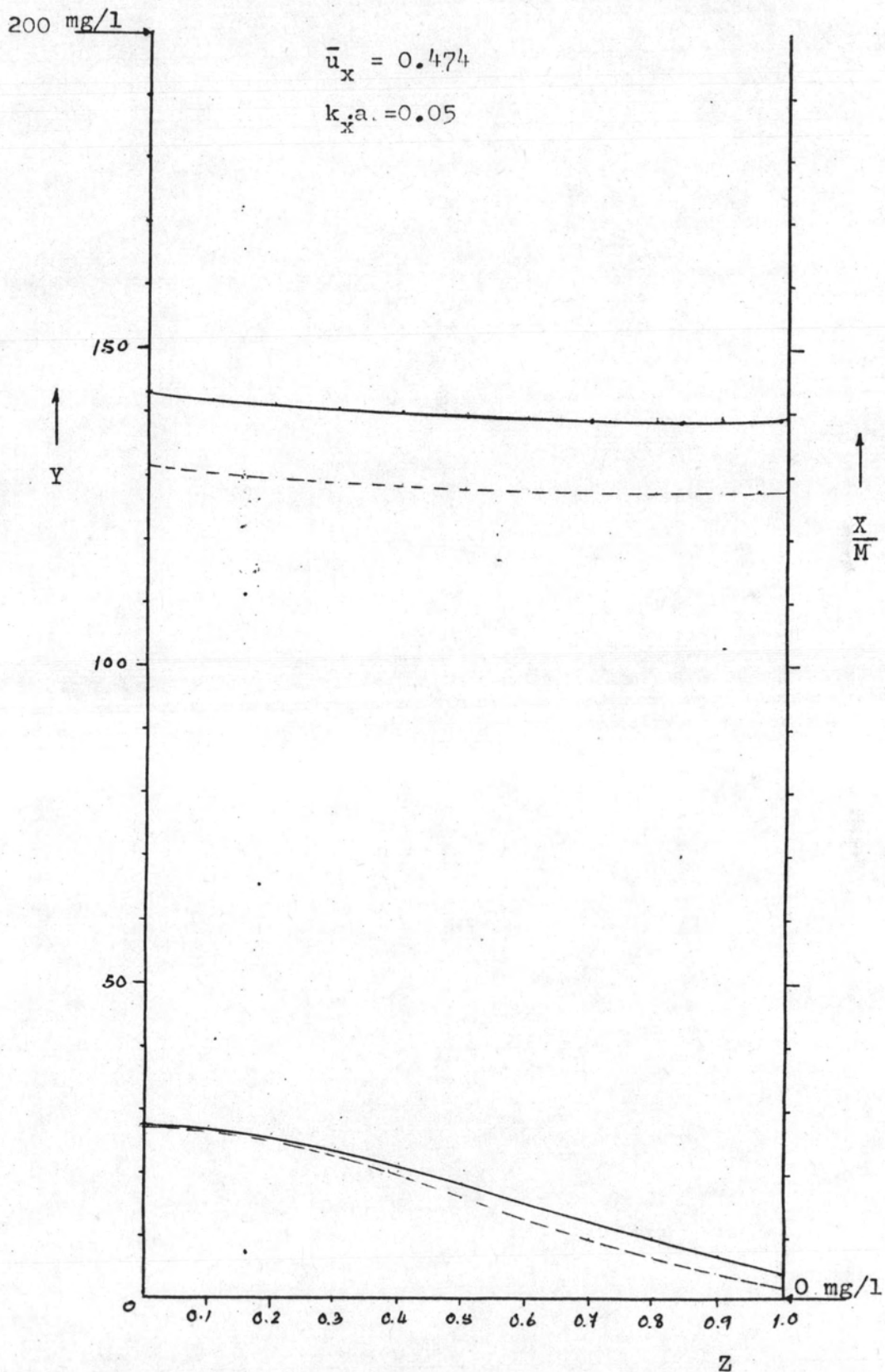


Figure 4-5 Concentration profiles for iodine-water / carbon tetrachloride from figure 4-1

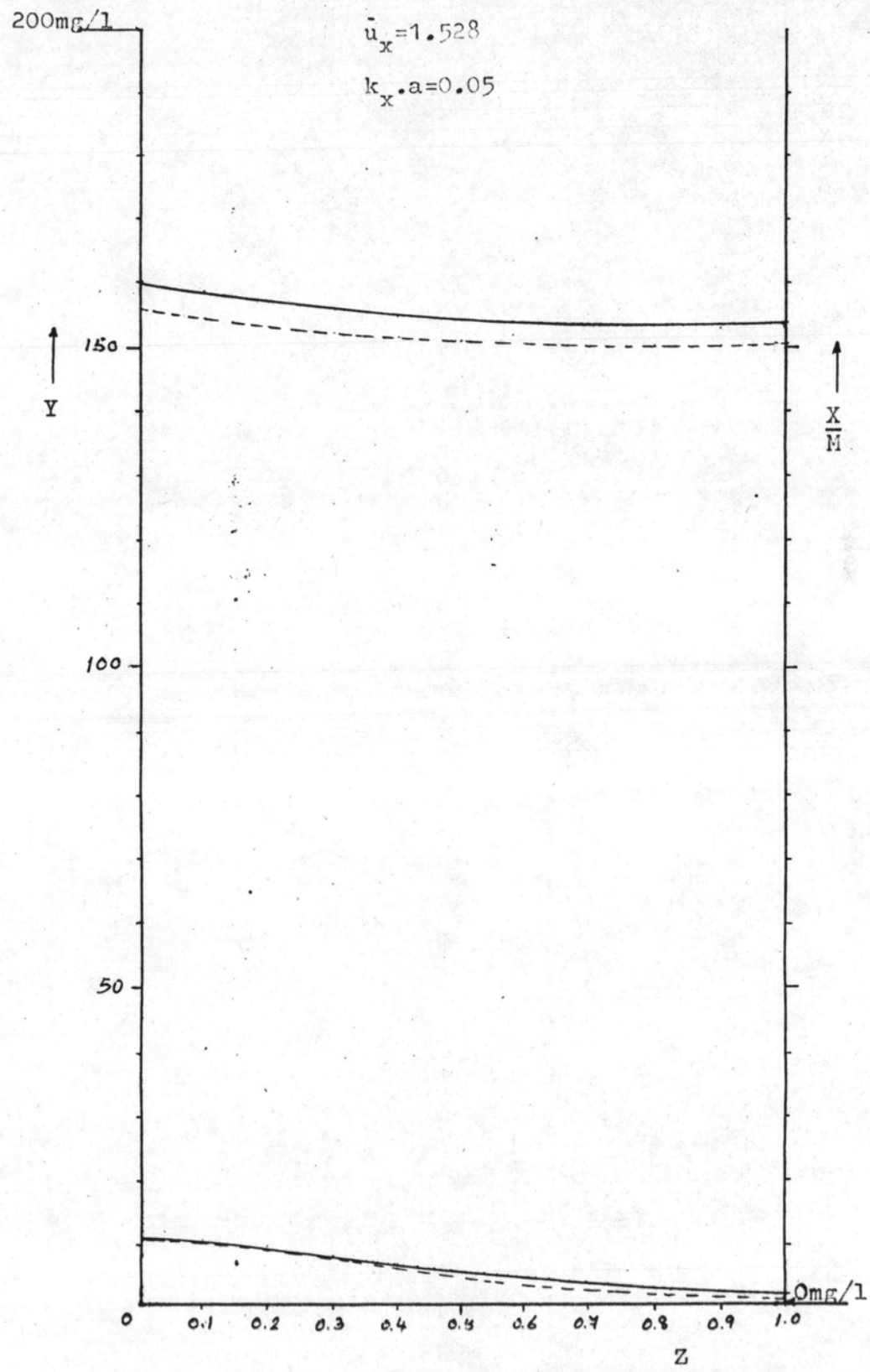


Figure 4-6 Concentration profiles for iodine-water / carbon tetrachloride from figure 4-2

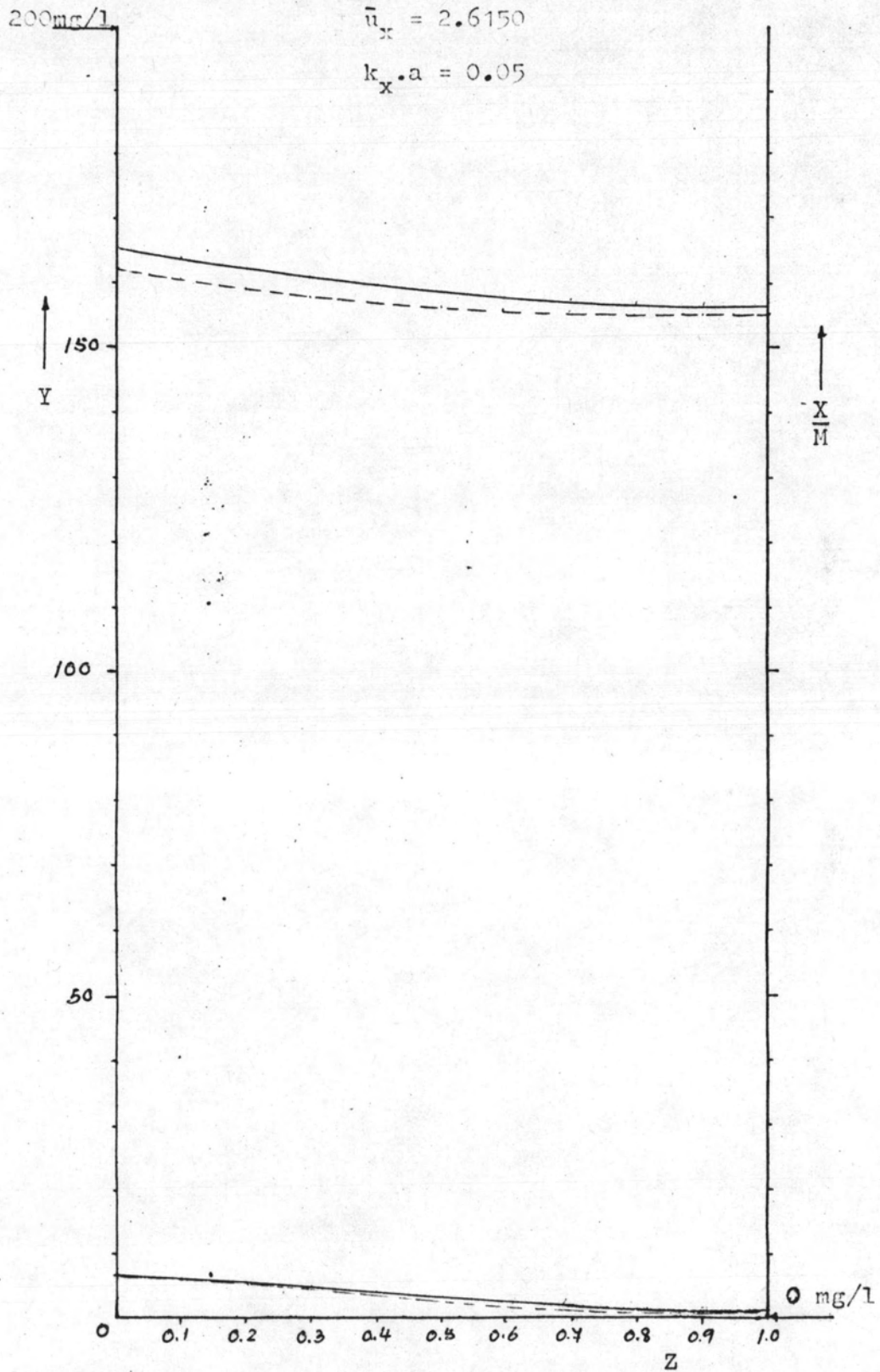


Figure 4-7 Concentration profiles for iodine-water /
carbon tetrachloride from figure 4-3

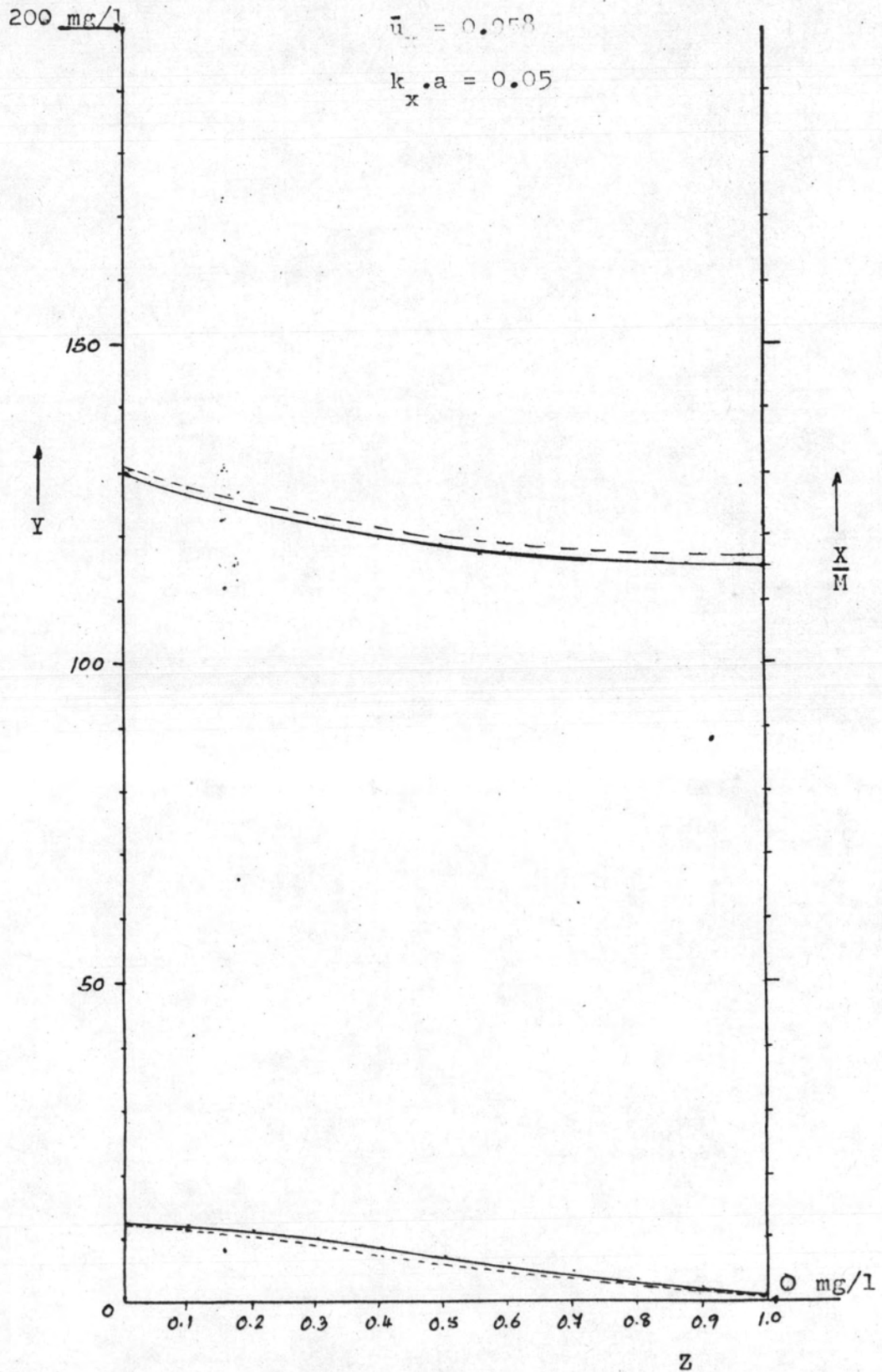


Figure 4-3 Concentration profiles for iodine-water / carbon tetrachloride from figure 4-4