CHAPTER 8

CONCLUSION AND FUTURE RECOMMENDATIONS

8.1 CONCLUSION

The mathematical models are simulated to express the process of the pulp and paper industry with advanced techniques so that the industry can make use of this to improve efficiency with minimum load on the environment. This target can only be achieved by promoting organized research on the mathematical models which describe the whole process. The purpose of this study is to solve the mathematical models of pulp washing with an improvised technique and derive the results to measure the concentration of black liquor which is reduced at the exit level with an increase in time. Although, many existing algorithms performed well to solve the pulp-washing model. Yet, the concern of time constraints and accuracy are major reasons that make the method applicable to solve these models.

In the present investigation, the QHCM is explored to find the numerical solutions of the models which are validated with the experimental results of different paper mills given by Grähs (1974), Kukreja (1996), and Arora and Potuček (2012). In the first instance, the technique is employed on four linear models to verify the applicability of the method. The computational experiments indicate similarity with the analytic results. Further, the results derived from the present technique confirm the high accuracy and good agreement with the exact solution. The stability is confirmed for linear models with the help of Euclidean and supremum norms. It is observed that better and more accurate numerical results are achieved in less CPU time with this method. The comparisons of the numerical solutions are made with OCFE, CHCM, MFEM, and CSCM which shows the superiority of the present method in comparison with previously published studies. The relative error using the present method is almost zero as compared to previous existing methods for a different range of Peclet number (*Pe)*. Thereafter, the method is applied to solve three one-dimensional nonlinear pulp-washing model equations with different boundary conditions and adsorption isotherms. After applying and verifying the present method for linear and non-linear model problems, the technique is applied to solve the two-phase model equation in the radial and axial domains.

The numerical results prove that better results can be derived with less number of equations and in minimum time as compared to CHCM. Therefore, it can be observed that the computational cost is reduced with the present technique. Also, it is noticed that QHCM gives a better result for the rate of convergence than CHCM. Further, it is found that *Pe* is an important parameter that influences the washing process. Besides, the other factors are axial dispersion coefficient (D_L), interstitial velocity (*u*), cake thickness (*L*) bed porosity (ε), Distribution ratio (ψ), and intraparticle diffusion coefficient (D_F). The numerical results are presented with the breakthrough curves which are plotted to give a clear view of concentration profiles for the different values of the above-mentioned parameters. In addition to this, the industrial parameters which are commonly used such as bed efficiency (*E*) and displacement ratio (*DR*) are also estimated. The method provides better results for linear as well as non-linear problems. The study highlights that the medium range (20-40) of *Pe*, the small value of D_L and ψ, the high value of ε, and the increase in *L* make the washing operation effective and proved to be true to achieve the optimum washing with less quantity of water. Further, the *u* on account of an increase in the D_L does not affect the concentration profiles. Also, the variation in the D_L and *u* is observed when the *L* is assumed constant. Besides, better washing can be attained, and maximum reduction of dissolved solids is possible when the *DR* is more and the value of *Pe* is high. The value of *E* is increased with the high value of *Pe* in comparison to the small value of *Pe*. The values of parameters $Pe < 20$, $Bi < 5$ and $R_d > 1$ play important role in the washing process. Further, it is noticed that results derived for the concentration of solute in the case of both nonlinear models are the same when the value of *Pe* is increased from 40.

The numerical results for the 2-D model are attained for the range of *Pe* =20.81, *Bi*=10, and ε = 0.6711. These are found to be better when compared with CSCM and OCFE. It is observed that a small distribution ratio causes more bulging in pores which results in improved washing. Also, it is noticed that large values of *Bi* cause an increase in mass transfer rate and indicate the fast convergence of solution profiles as compared to small *Bi*. Also, the greater value of ε shows the availability of more volume for displacement, and hence the absorbed impurities on the particle surface are leached away in a better manner.

It can be concluded from the above that the numerical scheme applied is very efficient, economical in use, takes less CPU time, and is easy to implement. It is also found to be reliable and can be employed to solve more problems related to application areas of convection, advection, diffusion, and dispersion in different phenomena. Based on the overall study, we conclude that this method is valid and can be used to solve the two-point BVPs for a large range of parameters.

8.2 RECOMMENDATIONS FOR THE INDUSTRY

During the simulation of the collected industrial data of a paper mill, it is noticed that efficient washing is achieved for the value of *Pe* between 10 and 20. Also, the concentration of solute is not much affected by the range of fibre consistency (C_F) between 55.88 - 81.52. It is further observed that for these models, the range of ε from 0.941 to 0.961 has little effect on the concentration profile. It is dependent on inlet vat consistency, the suitable limit for the same should be 1.2% - 1.4%. Further, the C_F lies between 55.88-81.52 which is dependent on the ε. It is witnessed that this range is suitable for better washing. The range of fibre porosity (0.848-0.902) is observed to be the best suitable for the above range of fibre consistency. The suitable range of interstitial velocity should be between 0.000556 m/s to 0.000998 m/s which is a suitable range of fibre porosity and bed porosity. These parameters are calculated for the pressure drop 19613 Pa, viscosity 11-12 kg/ms, specific surface of fibre 1.3 $cm^2/cm^{3,}$ and cake thickness 0.020-0.025 m. Keeping this range of parameters in mind, the industry can achieve optimum utilization of resources.

8.3 FUTURE RECOMMENDATIONS

Based on the overall work done in this study, the general recommendations for future work in the given areas are highlighted as under:

1. The work can be extended to verify the model equations with other industrial data.
2. The method can be extended to solve the model equation with different isotherm and boundary and initial conditions.
3. Approximating function can be discretized in the time domain also.
4. A comparative study of the present method can be carried out by exploring other existing methods.

5. The method can be extended to solve model equations in other areas based on advection-diffusion, advection-diffusion-reaction, and other phenomena.
6. Solutions to other problems applicable in the area of environment, biological and other modeling areas can be derived using the present method.