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Modeling for Adsorption Columns for Wastewater Treatment: a Review

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Abstract*— *Adsorption of various pollutants from effluent is very successful and widely studied area of research. The research has been reported in batch, packed bed and fluidized bed contactors. The modeling of the kinetic data is important aspect of this research. The modeling of the data obtained from the fixed column experiment is also very useful as it helps in predicting the break through curve; break point time and removal efficiency. These models need to be verified with the wide range of experimental results. Once these models are verified with experimental results, they are very useful as they save time and efforts. These model help in the design of column. The present review aims at presenting the research carried out on the modeling aspect of adsorption for removal of various pollutants from wastewater.

***Index Terms*—parameters, break through curve, packed bed, efficiency.**

I. INTRODUCTION

Adsorption in packed column is widely used and effective method for wastewater treatment [1]. The removal of dyes, organic matter, various heavy metals and many other pollutants has been reported to be highly efficient [2, 3, 4, 5, 6]. The prediction of effect of the various affecting parameters like bed depth, initial concentration, and flow rate is very important as it saves time and effort. Once the results of the models are verified with experimental data, these models can be used to predict the nature of breakthrough curves, mass transfer parameters etc. Also the column design can be carried out with the help of the data. The kinetic models for batch experiments and various models for breakthrough curves are studied by various investigators [7, 8]. The present review is aimed at summarizing these studies with respect to their accuracy and agreement with experimental data. Adsorption can be used for removal of various pollutants from wastewater as it has many advantages over other methods like simplicity, effectiveness and flexibility in terms of adsorbents used and the contact equipments. Adsorption of organic matter was investigated and the percentage removal was satisfactory. The removal of various metals like copper, chromium and cadmium was also very effective [9, 10]. Removal of phenol in batch and column was also carried out by various investigators. The treatment of domestic wastewater was also carried out successfully. The kinetic and isotherm studied are very important part of the investigations carried out for adsorptive treatment of wastewater [11]. The modeling batch results for kinetic study and isotherm studies for equilibrium data is also very important aspect of these investigations. For prediction of breakthrough curves, various models are used [12, 13, 14]. The present review aims at summarizing the studies and investigation carried out for modeling of adsorption in batch and column studies. It includes kinetic modeling and modeling of column studies to predict the breakthrough curves. Also model results are predicted and are related to batch data by few investigators [15].

II. STUDIES ON MODELING FOR ADSORPTION AND ADSORBER

Efficiency of removal of phenolic waste was studied by Sorour et.al. by using packed bed reactor model [16]. First they carried out laboratory experiments to study the phenol removal in batch process with different initial concentrations of phenol in the influent. Then they carried out experimentation in packed beds at various bed depths. They used activated carbon and filtration anthracite as sorbents in batch and column studies. The experimental results were in agreement with the model estimations. So the model, once calibrated can be used for predicting the required parameters. The adsorption kinetics of lead removal was analyzed using Thomas and Yoon and Nelson kinetic models by Nwabanne and Igbokwe[17]. According to their investigations the kinetics data were well described by both the models. The solute uptake increased with increase in flow rates. They used oil palm fibers as adsorbent. They carried out experiments with bed height of 50mm, 100mm and 150mm. The experimental breakthrough curve agreed with the break through curve obtained by modeling equations. Becknel et.al. presented studies on analysis of adsorption breakthrough and desorption elution curves[18]. They used stainless steel column for the packed bed. They used helium to equilibrate the system. Then CO_2 was fed with

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step input. The adsorption breakthrough was continued till equilibrium. They computed desorption-based isotherm by fitting the elution data to the local equilibrium model. Their study helped in better understanding of solute uptake and desorption. Albadarin investigated modeling and fixed bed column adsorption of chromium (VI) onto orthophosphoric acid-activated lignin [19]. They fitted the micro column data by the Thomas model, The modified Dose model and the Bed Depth Service Time (BDST) model. According to their studies, experimental data of individual runs were well represented by the Thomas and Modified dose-response model for variable influent initial pH, ionic strength, initial Cr (VI) concentration, flow rate and mass of the adsorbent. Sivakumar and Palanisamy investigated removal of acid blue 92 and basic red 29 dyes in packed column using various nonconventional adsorbents[20]. They used Euphorbia antiquorum L activated carbon for the purpose. They used Thomos and Yoon-Nelson models for evaluating column performance. They concluded that Yoon Nelson model described the column performance fo both the dyes bettr than Thomos model.

Nwabanne and Igbokwe worked on kinetic modeling of packed bed for heavy metal removal [21]. They investigated the removal of lead and copper in their experiments. They used Thomas model and Yoon and Nelson kinetic models for their studies. They studied the effects of various parameters like initial concentration, flow rates and bed height. They observed that the kinetic data fitted both the isotherms. Also according to their studies the time required for 50 percent breakthrough decrease with initial concentration, bed height and flow rate. They also found that breakthrough profiles calculated by Yoon and Nelson method showed a satisfactory fit for activated carbon prepared from nipa palm nut. Lee et.al carried out studies on the simulation of fixed bed adsorber [22]. They used stochastic model for this purpose. They considered two solid phases for the adsorbent (activated carbon) and one liquid phase. They plotted concentration verses dimensionless residence time from experimental as well as model prediction data. The model predicted satisfactory results. Deshpande and Shah carried out investigation on aqueous phase adsorption of toluene in a packed bed of hydrophobic aero gels [23]. They used a mathematical model based on material balance and mass transfer theories. They used Pro-Designer set of software tools. By using this tool, it was possible to predict the effect of the parameters like temperature, empty bed contact time and flow rate on the removal of toluene. The predictions like decrease in adsorption with temperature, increase in adsorption with empty bed residence time are in well agreement with the mass transfer and material balance knowledge. Nouri and Ouederni carried out studies on the modeling of dynamics of phenol removal from effluent on activated carbon prepared from olive stones [24]. They used three models (namely Clark, Thomas, and Yoon - Nelson) to predict the breakthrough curves and to determine the characteristic parameters of the column which are useful for column design. For all the models the correlation coefficient (R^2) was above 0.9. So they found that these models described the adsorption process adequately. Tayler carried out studies to predict the pressure drop and flow distribution in packed bed filters[25].They used Computational Fluid Dynamics(CFD) technique in their studies. They modelled the effect of pressure drop on nonuniform voidage. Modified Mueller equation was used for radial voidage disribution. They validated their technique by carrying out experiments with wide ramge of filter parameters and inlet velocities. The factors like axial voidage and turbulence within the bed are the areas of research needed to be addressed.Studies were carried out on simulation of mathematical modeling for fixed bed desalting by Alhassan and Olutoye[26]. An investigation was carried out by them with respect to the parameters like the variation of the concentration of adsorbate (mol/l) and the amount of adsorbate (mol) of the simulated fixed bed. They used silica-allumnia as adsorbents.They used prototype simulated fixed bed. They developed the model equations rom prototype. They observed that the concentration of the effluent stream decreases as the height increases down the column. It was also observed during the investigation that that the concentration of the adsorbate in the fluid stream remains practically constant at a height of approximately 14m.
In their study Kyzas et.al. Studied the decolorization of industrial textile wastewaters [27]. They used Greek coffee wastes (COF) as low-cost adsorbents .They fitted the kinetic data to the pseudo-first, -second and -third order model. The best correlation that explained equilibrium data was for Langmuir-Freundlich (L-F) model .Immobilized Seaweed Biomass was used for copper removal in a continuous packed bed by Tan et.al. [28]. The brown seaweed sargassum baccularia, immobilized onto polyvinyl alcohol (PVA) gel bead was used in a packed bed. They studied breakthrough curve for the process. According to them, mathematical models are useful for design and optimization studies since they help reduce time-consuming and repetitive experiments. They carried out comparison between experimental and calculated breakthrough curves. They emphasized that that the dynamic behavior of the biosorption column was not entirely predictable on the basis of a simplified two parameter packed bed model as two parameter can explain only symmetric break through curves. Mass transfer studies on fluidized bed adsorption column for phenol adsorption were carried out by Kulkarni and Tapre[29]. Their study dealt with effect of initial concentration of phenol and particle size on the rate of adsorption. They observed that fluid phase mass transfer coefficient decreased with phenol concentration. Also they observed that high

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concentration favored adsorption. They carried out material balance across the bed for developing mathematical model. Kumar et.al carried out unsteady state column design for protein removal using nanostructured particles [30]. Bovine Serum Albumin protein was adsorbed on to the surfaces of nano structures. They used Thomas model (Bed Depth Service Time Model) to design the adsorption column. According to them Thomas model was very effective in design of the adsorption column. Studies were carried out on modeling and packed bed column studies on adsorptive removal of phosphate from aqueous solutions by Raut et.al. [31]. they used a mixture of ground burnt patties and red soil. They investigated the effect of various parameters on break through curve. The important parameters were bed height, flow rate and initial phosphate concentration. Thomas model, Yoon-Nelson model and Modified Dose Response model were used for nonlinear regression of data. Bed Depth Service Time model obeyed linear relation under different experimental condition. They found that Modified Dose Response model as the best fitted model to the experimental data.

III. CONCLUSION

Various models were developed effectively by various researchers for the data obtained in investigations. The kinetic and isotherm data was described by conventional equations like first, second order kinetics and Langmuir, Freundlich isotherms. The major modeling part in these investigations was prediction of break through curve and designing a column based on models results. Various models were able to successfully predict the break through curves and break through time. The studies were also carried out to relate the batch experimental results to predict the nature of break through curve. Multi parameter models are more accurate than two parameter models. This accuracy though is at the cost of increased complexity. It can be concluded that the modeling is very important and helpful tool in the adsorption studies and adsorber design as it saves time and effort and repetitive work.

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