CHAPTER VI
GENERAL CONCLUSIONS

In this study, the process of ethanol-water separation in the PSA process was studied. The research included analysis of kinetic and thermodynamic data of ethanol-water adsorption on commercial 3A zeolites. The research consists mainly of two experimental sections which are adsorption of ethanol-water mixture in a fixed bed adsorber and a pressure swing adsorption pilot plant. Pure ethanol was obtained under certain operating conditions, and there was a consistency among the findings of interest. The adopted variables influenced the obtained results.

The first phase of the testing was done in a fixed-bed adsorber under atmospheric pressure to study the optimum condition for adsorption. Two-level factorial design experiment was used in this research work to preliminary screen the influence and interaction among each factor. The experiment showed that increasing initial temperature of the bed would reduce water capacity of the zeolite and that breakthrough time was decreased as ethanol-water solution feed rate was increased. Furthermore, it can be suggested that the lower concentration of the feed solution, the sooner the bed saturated. In addition, the results of the experiment showed the water adsorption capacity of the zeolite which could help in the process of designing a PSA system. Lengths of equilibrium section of each experiment were discussed to assist in designing appropriate bed height. From the study, it was found that the most suitable condition for water adsorption on 30 g of zeolite was at 90 °C initial bed temperature, feed flow rate of 0.795 g/min (1 mL/min), and feed concentration of 95 wt% ethanol. Finally it was found that, Langmuir isotherm could best predict the experimental results with the corresponding equation of $q = (8.18C)/(1+42.83C)$.

The second phase of the experiment involved a design and development to study PSA cycle with a counter-current depressurization and a counter-current pressurization with the product. The pilot plant was used to study the dynamics and performance similar to an industrial PSA process used to break the ethanol-water azeotrope and deliver fuel grade ethanol product. The study has examined the effects of the feed concentration, feed rate, adsorption pressure, and cycle time. It was also shown that by increasing the feed concentration in a PSA process the quality of the product (enrichment of ethanol) increased marginally. At the same time, increased flow rate provided a significant increase in the ethanol recovery. On the other hand, increasing feed concentration led to a reduction of the recovery. Furthermore, it was found that, for similar adsorption and desorption conditions, shorter cycle within each operation gave a high-quality product but at a lower quantity. It was also proven that the designed PSA system was capable of continuously producing high concentration ethanol product. In addition, the performance of the PSA pilot plant in terms of enrichment and recovery of ethanol product from this study were compared to previous works under the same adsorption conditions. At the feed rate of 80 mL/min, feed concentration of 92 %vol, adsorption pressure of 2.4 bar and cycle time of 15 minutes gave the highest percentage of ethanol recovery at 85.26%. The results were found to be slightly superior, although different experimental designs were adopted.

The BET specific surface areas of the 3A zeolite were also analyzed before and after the experiment. It was found in the study that under inappropriate regeneration condition or thermal and physical stresses of each regeneration process can eventually deteriorate the performance of the zeolite.

Future work to improve the knowledge on removal of water from ethanol-water azeotrope may involve the investigation of the process of simultaneous adsorption for both water and ethanol, including experimental binary equilibrium data and mass transfer rate for adsorption and desorption.

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