Chapter VI

Conclusions and recommendations

The salient conclusions of the experimental results on simultaneous removal of SO_2 and NO using different absorbents in separate columns and future recommendations of the process are illustrated in this chapter.

6.1 Conclusions

6.1.1. Absorption of SO_2 and NO in bubble column

- The simultaneous removal of SO_2 and NO was studied by using NaClO as absorbent in bubble column with varying operating conditions of temperature, absorbent concentration, absorbent pH, etc.
- The change in initial concentration of SO_2 and NO were measured to observe the reactive tendency of NaClO with SO_2 and NO.
- The optimum conditions for maximum removal of SO_2 and NO with the use of NaClO as absorbent in bubble column were found to be as temperature 305 K, absorbent

concentration 0.032 M NaClO and pH of 5.6. Maximum removal efficiencies of 99% for SO_2 and 91% for NO were obtained under optimal experimental conditions.

- The saturation time for the process was determined as 260 min for NO and 350 min for SO_2 with experimental conditions; SO_2 concentration 6348 ppm, NO concentration 1804 ppm, temperature 305 K and absorbent concentration 0.032 M and pH 5.6.
- NaClO showed an effective removal efficiency of both SO_2 and NO in bubble column absorption.

6.1.2. Absorption of SO_2 and NO in magnetic stirred vessel

- A detailed study was carried out to check the effects of various parameters on simultaneous NO and SO_2 removal using NaClO solution in stirred vessel and optimal operating conditions of the process were found as initial SO_2 6340 ppm, initial NO 816 ppm, temperature 313 K, absorbent concentration 0.01 M, initial pH 5.8 and time 120 min.
- Results showed that there was no appreciable change in SO_2 removal efficiency showing a value of almost 100% but the removal efficiency of NO had an increasing trend with the rise of operating conditions like NaClO concentration, initial SO_2 concentration and NO concentration.
- Removal efficiency of SO_2 remained almost 100% but NO removal efficiency significantly decreased with increase in time. Regarding the effect of temperature

removal efficiency of SO_2 was independent on temperature, but removal efficiency of NO initially increased upto a maximum value and then decreases with increasd in temperature.

- The maximum removal efficiencies of SO_2 and NO using NaClO was found as 100 and 92% respectively at optimal operating conditions.
- The dissolved SO_2, HSO_3^-, SO_3^{2-}, SO_4^{2-}, NO-NO_2, HNO_2, NO_2^-, HNO_3 and NO_3^- free radicals played a leading role in removal of NO and SO_2 by wet scrubbing using NaClO.
- Addition of NaOH in NaClO showed appreciable removal of NO but less than NaClO alone as absorbent. Although the conversion of NO in NO_2 was only due to NaClO. The optimum conditions for simultaneous removal were obtained at a process temperature of 313 K, absorbent concentration about 3 mole ratios of NaOH to NaClO and pH of 5.9 in the simulated flue gas absorption. Removal efficiencies of 98% for SO_2 and 87% for NO were accomplished, respectively under optimal experimental conditions.
- Complex absorbent $Ca(OCl)_2$ had shown an effective removal efficiency of both SO_2 and NO of this integrative process. The optimum conditions for simultaneous removal were obtained at a process temperature of 313 K, absorbent concentration was 5 g/100 ml and pH of 5.6 in the simulated flue gas absorption. Removal efficiencies of 99% for SO_2 and 85% for NO were accomplished, respectively under optimal experimental conditions.

- The results of NaClO with additive NH_3 were promising and helpful to meet environmental condition. The optimum conditions were found out as time 180 min, temperature zone 313-323 K, the molar blend ratio of 1 (moles of NH_3/moles of NaClO), initial SO_2 concentration range of 214-5028 ppm, NO initial concentration range of 663-1276 ppm and pH level of 5.5. The maximum removal efficiencies of SO_2 and NO obtained in the semi batch magnetic stirrer vessel for simultaneous absorption were 99 and 93%, respectively.

6.1.3. The kinetics, mass transfer and thermodynamics of the process

- For simultaneous removal of SO_2 and NO, the kinetics of NO absorption into NaClO was accompanied by a pseudo first order reaction with rate constant 3.98×10^7 s^{-1}.
- The rate of chemical reaction was considerably faster than the mass transfer rate. The absorption of SO_2 was a completely gas phase controlled with the value of $k_{{SO_2}_g}$ equal to 0.0142 mol/m^2·s atm at temperature of 313 K.
- The thermodynamic properties of the process of simultaneous removal of SO_2 and NO for both NaClO/NH_3 scrubbing were calculated.
- The significance of enthalpy change, Gibbs free energy, equilibrium constant and equilibrium partial pressure indicated the feasibility of the process and that temperature is not the only variable which affects the simultaneous absorption of SO_2 and NO by NaClO solution. The similar phenomenon was also happened for simultaneous absorption of SO_2 and NO in NaClO/NH_3 blend.

6.1.4. Absorption of SO_2 and NO in spray column

- The continuous mode experimental results using spray column would be helpful for prediction or modeling the process suited for large scale operation.
- In the continuous spray column, similar operating conditions were performed with gas flow rate 600 ml/min and liquid flow rate of 1500 ml/min.
- The maximum removal efficiencies for SO_2 and NO removal using NaClO in spray column were 97 and 87.8%, respectively.
- The maximum removal efficiencies for SO_2 and NO removal using NH_3 and NaClO in spray column were 97 and 89%, respectively.
- Addition of CO_2 had a minimal effect on removal efficiency of SO_2 and NO; and showed maximum of 40% removal efficiency of CO_2 itself under optimum experimental condition of simultaneous absorption of SO_2 and NO.
- As the efficient results observed in simultaneous absorption of SO_2 and NO, this process can be used for removing SO_2 and NO from coal fired thermal power plant stack gases.
- Even though removal efficiency drop for SO_2 and NO was found in the spray column as compared to semi batch stirrer vessel, the results are still strong enough to design a pilot plant for the process.

6.1.5. Proposed method for preparation of bio layer

- A feasible process was proposed to use the minute fertilizers from absorption operation and to reduce environmental pollution with the help of bio layers.
- The main intention for preparation of bio layer is to reduce the contamination in water body and groundwater as well.
- By converting the toxic SO_2 and NO gasses in to useful fertilizers will effectively reduce the contamination in water but it may contain minute amount of fertilizers and direct discharge of it can cause harmful effects to environment. So, it can be used for making bio layers around the power plant.

6.2. Recommendations

- The pilot scale unit should be commissioned for simultaneous removal of SO_2 and NO_x using the results of the present study.
- The indigenous data generated out of this work should be used to upscale and design of optimized wet scrubber for industrial application especially for simultaneous removal of NO and SO_2 from coal-fired thermal power plant stack gases.
- The presence of foreign components present in the gas stream should be studied along with SO_2 and NO.
- Other columns should be tested for simultaneous absorption of SO_2 and NO.