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H_2S Removal in an Oxidative Packed Bed Scrubber Using Different Chemical Oxidants

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Abstract: The liquid-gas absorption is by far the most applied system for odor control. A bench scale packed bed scrubber was used to evaluate of H_2S removal as the odorant model compound using three chemical oxidants of NaClO, H_2O_2 and $KMnO_4$ at various operation conditions. Results showed that more than 99.5% of the H_2S was removed from the inlet air in the EBCTs of 3 to 35 s and H_2S concentrations in the range of 30 to 300 ppm_v. Also, the pressure drop across the bed of the reactor increased from 1.5 to 13.1 cm H_2O m^{-1} for the superficial air velocities in the range of 1.2 to 14 m min^{-1} which a linear relationship was observed between pressure drop and superficial air velocities.

Key words: Odor control, hydrogen sulfide, packed bed scrubber, chemical oxidants

INTRODUCTION

Odor emission is a major concern for wastewater treatment plants and many other facilities such as composting plants, petroleum and gas refineries, petrochemical industry, food production, etc[1]. Due to their very low odor threshold value (ppb_v range), high toxicity and potential corrosive effect, the presence of the volatile sulfur compounds (VSC_s) including hydrogen sulfide (H_2S), methanothiol (MeSH), dimethyl sulfide (Me_2S), dimethyl disulfide (Me_2S_2), carbon disulfide (CS_2) and Carbonyl Sulfide (COS) in waste gases deserves special attention[2]. A range of technologies are available to treat odorous emissions among which the chemical scrubbing in packed-bed tower is an established technique which is effective in low contact times[3]. Applicability of the different methods of air pollution control according to air flow rates and pollutant concentration has been shown study in Fig. 1[4]. In the present work, removal of H_2S as a model odorant compound has been examined in a chemical scrubber using three oxidants including sodium hypochlorite (NaClO), hydrogen peroxide (H_2O_2) and potassium permanganate ($KMnO_4$).

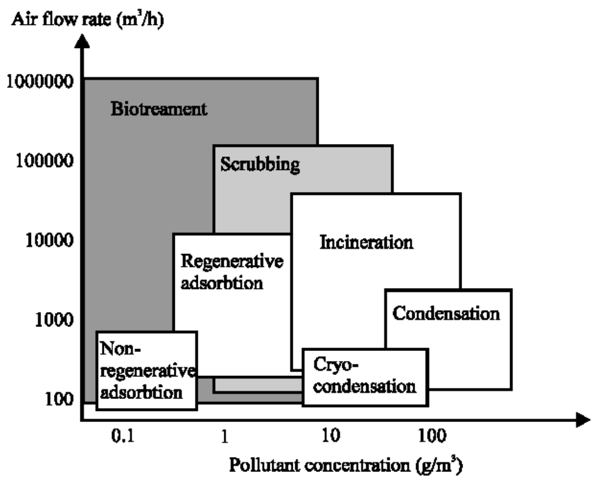

Fig. 1: Applicability of air pollution control methods based on air flow rates and concentration to be treated[4]

MATERIALS AND METHODS

Experimental set up: A schematic of the experimental set up of the lab scale scrubber is shown in Fig. 2. The reactor was water and air-tight plexiglas cylinder packed with corrugated plastic tubes as media on a support plate. Two perforated plates were provided at the top and middle part of the bed for redistributing the scrubbing liquid. Table 1 gives the main characteristics of the investigated reactor.

As it can be seen in Fig. 2, two sampling ports were installed at the two ends of the bed. The flow meter and valves were installed for monitoring and controlling the gas flow rate through the reactor. Pressure drop across the bed was measured using a U-shape water manometer.

H_2S was generated and stored in a custom-made equipped cylinder. It was first diluted with a compressed air which was primarily passed through an activated carbon column for removal of oil and other impurities.

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Table 1: Operation conditions and dimensions of the investigated reactor

Parameter	Value
H_2S inlet concentration	Variable (30-300 ppm)
Gas flow rate	Variable (17-200 L min^{-1})
EBCT	Variable (35-3 S)
Liquid recirculation rate	5 L min^{-1}
Recycle liquid volume	5 L
Packing material	PVC rings (7*15 mm)
Specific area	625 (m^2 m^{-3})
Internal diameter	13.5 cm
Reactor height	120 cm
Bed height	70 cm
Gas/Liquid flow	Counter current

H_2S-containing air then flowed upward across the reactor bed while the recycle liquid was pumped by a centrifuge pump, flowed downward across the bed. Discharge tube of centrifuge pump was connected to a spray nozzle to evenly distribute the liquid on the surface of the bed. A solution containing a specific concentration of an oxidant was injected to the discharge line using a dosing pump. During the experiment course, performance of the reactor in H_2S removal as the model odorant using NaClO, H_2O_2 and $KMnO_4$ as the oxidants at different loading rates and recycle liquid flow rates was monitored.

H_2S generation: H_2S gas was generated in a custom-made cylinder equipped with a gas flow rate regulator and a pressure gauge. A specific amount of H_2S was first produced from the reaction of Na_2S solution and HCl and then stored into the cylinder. The cylinder was then pressured to 10 atm by compressed oil-free air. The desired concentration of H_2S in the air flowed to the reactor was obtained by injecting of the concentrated H_2S to the compressed air line.

Analytical procedure: Samples for H_2S were taken from the inlet and outlet air by absorbing in a cadmium hydroxide solution. The air sampling set up was consisted of an impinger, an air flow meter, a vacuum air pump and valves. H_2S concentration was then determined by colorimetric method using PerkinElmer Lambda 25 spectrophotometer at the wavelength of 670 nm[5]. Total sulfide in unfiltered recycle liquid samples was determined by the methylen blue method[6]. Chlorine was measured by iodometric method[6]. Hydrogen peroxide was determined by permanganate titration[7]. Concentration of potassium permanganate in the samples taken from recycle liquid line before oxidant dosing point was determined by spectrophotometric method[6]. All other analyses were performed according to the Standard Methods[6]. The performance of the reactor was reported as Removal Efficiency (RE) defined in Eq. 1:

$$RE = \frac{(C_{in}-C_{out})}{C_{in}} \quad (1)$$

Where, C_{in} and C_{out} are H_2S concentrations in the inlet and outlet air, respectively.

RESULTS AND DISCUSSION

Chemical demands for H_2S oxidation: A preliminary objective of our investigation was to determine the oxidant demand for H_2S oxidation. Figure 3 shows the results of the batch tests for H_2S oxidation by the three oxidants of NaClO, H_2O_2 and $KMnO_4$ in a wide range of pHs (acidic, neutral and basic). As it can be seen, the minimum ratio of oxidant demand to H_2S belonged to the hydrogen peroxide at the acidic and neutral pHs. Also, according to Fig. 3, the pH of the recycle liquid plays an important role in the oxidation of odorous compounds such as H_2S. From these results, the optimum pH for any oxidant was selected for further study. It could be concluded that the ratio of oxidant to H_2S is slightly more than stoichiometric amount[8]. As the only oxidizable substance in the solution was H_2S, it could be also concluded that the oxidants were only consumed for the oxidation of hydrogen sulfide. The amount of the chemicals corresponding to the optimum pH obtained from batch tests, were used to determine H_2S removal in the reactor.

H_2S removal efficiency: H_2S removal in chemical scrubber using different oxidants has been investigated by numerous authors[2]. In this research, we have investigated the H_2S removal in a packed bed scrubber using three of the most common chemical oxidants. The H_2S removal efficiencies at the various EBCTs using NaClO, H_2O_2 and $KMnO_4$, have been indicated in Fig. 4-6,

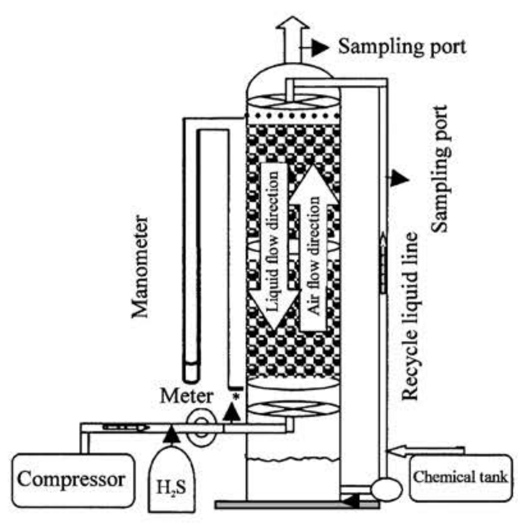

Fig. 2: Schematic of the investigated packed bed reactor

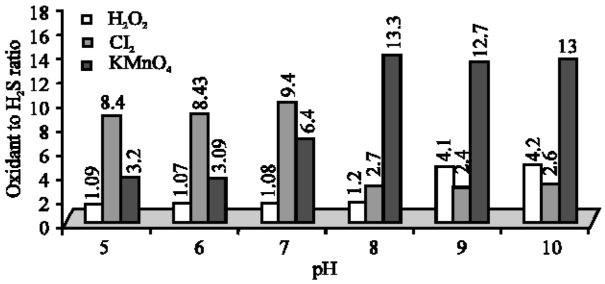

Fig. 3: Ratios of oxidant demand to H_2S concentration at different pHs in batch tests

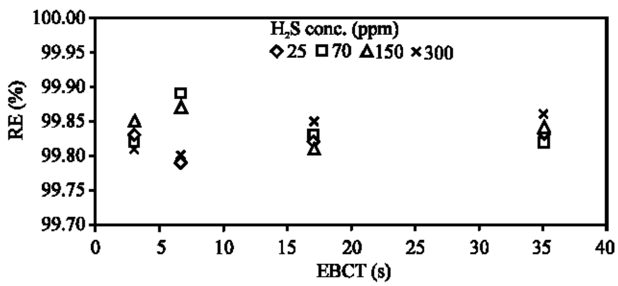

Fig. 4: H_2S removal efficiency versus EBCT at different inlet concentrations and EBCTs using H_2O_2

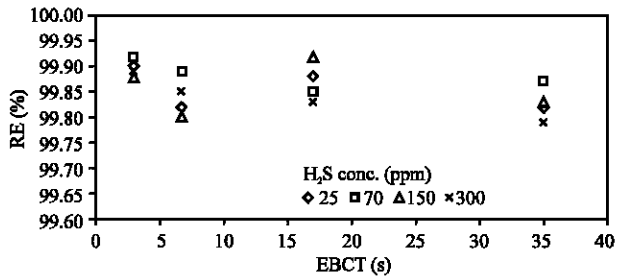

Fig. 5: H_2S removal efficiency at different inlet concentrations and EBCTs using H_2O_2

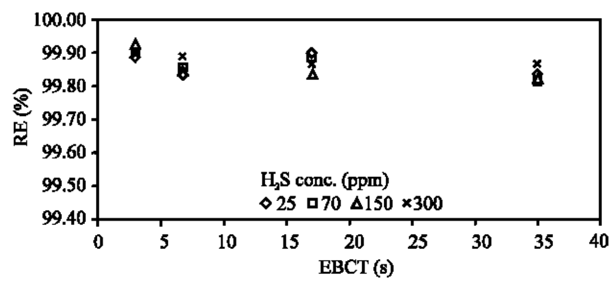

Fig. 6: H_2S removal efficiency versus EBCT at different inlet concentrations using $KMnO_4$

respectively. During the study, H_2S concentration was increased from 30 to 300 ppm_v and air flow rate was increased from 17 to 200 L min^{-1} corresponding to the EBCTs in the range of 3 to 35 s. Figures 4 to 6 revealed that the scrubber efficiency in H_2S removal as a model

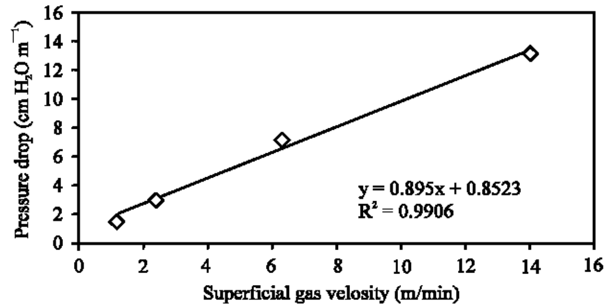

Fig. 7: Variation trend of pressure drop versus superficial gas velocity across the reactor bed

odorant remained well more than 99.5% at various tested conditions. It can be concluded that the EBCTs of 3 to 35 sec for H_2S concentrations in the range of 30 to 300 ppm, did not significantly decrease the reactor performance. Furthermore, it is clear that all the three oxidants could efficiently oxidize H_2S and so are technically applicable for H_2S removal in chemical scrubbers.

Pressure drop through the reactor bed: Because of the increasing energy requirements, pressure drop value is an important factor used for economic analysis of the scrubbers. This being the case, behavior of the reactor was studied at four different superficial air velocities from 1.2 to 14 m min^{-1}. Pressure drop was increased from 1.5 to 13.1 cm H_2O m^{-1} as air velocity was increased to 14 m min^{-1}. Figure 7 indicates a linear relationship between the superficial gas velocity and pressure drop which can be considered as an important parameter in determining the operational expenses[1] and obtaining the optimal operating conditions[9].

CONCLUSIONS

A pilot scale packed bed scrubber was investigated for H_2S removal at various operational conditions using NaClO, H_2O_2 and $KMnO_4$ as oxidants. Results indicated removal efficiencies of more than 99.5% for H_2S in all of the different studied conditions. Also, a linear relationship between pressure drop and superficial air velocities in the range of 1.2 to 14 m min^{-1} was obtained. This relationship gives information to control and optimize the operation of the packed bed systems for the process of the odor control.

REFERENCES

1. Chung, Y.C., C. Huang, C.P. Tseng and J.R. Pan, 2000. Biotreatment of H2S- and NH3- containing waste gases by co-immobilized cells biofilter. Chemosphere, 41: 329-336.

2. Smet, I., P. Lens and H. Van Langenhove, 1998. Treatment of waste gases contaminated with odorous sulfur compounds. Critical Review in Environ. Sci. Technol., 28: 89.117.
3. Gabriel, D. and M.A. Deshusses, 2003. Retrofitting existing chemical scrubber to biotrickling filter for H_2S emission control. Proc. Acad. Sci., USA., 100: 6308-6312.
4. Deshusses, M.A. and H.H.J. Cox, 1998. Biological waste air treatment in biotrickling filters. Curr. Opin. Biotechnol., 9: 256-262.
5. Lodge, J.P., 1990. Methods of Air Sampling and Analysis. Lewis Publisher INC. 3rd Edn., pp: 486-491.
6. APHA., AWWA. and WEF., 1998. Standard Methods for the Examination of Water and Wastewater. 20th Edn., Washington DC, USA.
7. EPA., 1999. Alternative disinfectants and oxidants guidance manual. EPA 815-R-99-014., pp: 7-12.
8. Rafson, H.J., 1998. Odor and VOC Control Handbook, McGraw-Hill Co.
9. Humeau, P., J.N. Baleo, F. Raynaud, J. Bourcier and P. Le Cloirec, 2000. Flow characterization in a gas-liquid column: Application to a bioscrubber for the odorization of waste gases. Wat. Sci. Technol., 41: 191-168.