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PE18) Simultaneous Removal of NH_3 and H_2S Odors by Absorption and Oxidation in a Multi-Stage Chemical Scrubber

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1. INTRODUCTION

Simultaneous emission of odorous compounds into the atmosphere, primarily hydrogen sulfide (H_2S) and ammonia (NH_3) occur in various facilities such as petrochemical plants, food manufacturing, landfills, paper manufacturing, sewage treatment plants, composting works, livestock farms, and wastewater treatment plants. These emissions, aside from being toxic, constitute a source of olfactory nuisance due to their very low odor thresholds. Therefore it is necessary to develop a versatile odor control technology that can handle complex odor streams. Amongthe available odor control technologies (Adsorption, Biofiltration, Incineration, Condensation), chemical scrubbing proved to be effective, reliable and versatile especially for odor stream containing 10-50 g/m^3 at 100-10,000 m^3/hr gas flowrate. Scrubbing is often the best method for treating large gas flows containing low to medium concentrations of odorous compounds. One major disadvantage of this technology, however, is wastewater generation and high operating cost (power and chemical requirements). To address this problem, a compact multi-stage, multi-chemistry scrubber was designed using a packing material having large surface area for absorption and oxidation of odors in appropriate reagents.

This study aims to; (1) characterize and test the applicability of open-pore polyurethane foam as packing material for chemical scrubbing of NH_3 and H_2S, (2)optimize the concentration of scrubbing solution, pH and ORP to achieve high NH_3 and H_2S removal efficiency, (3) evaluate operation parameters such as pressure drop, temperature, liquid and gas flow rates at optimum conditions, (4) characterize scrubbing liquid salinity, conductivity and dissolved oxygen with increasing scrubbing operation time, (5) identify the critical and maximum NH_3 and H_2S loading rates at optimum scrubbing conditions, (6) set-up and evaluate the performance of a multi-stage, multi-chemistry scrubber for the simultaneous removal of mixed NH_3 and H_2S gas streams.

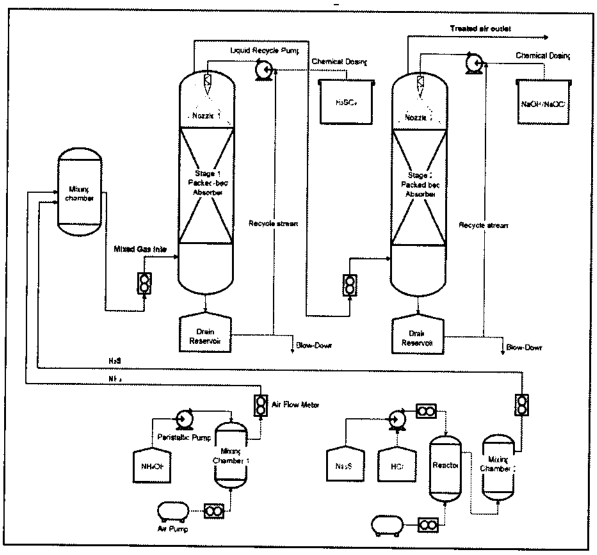

Fig. 1. Process flow diagram of the 2-stage mixed gas chemical scrubber.

2. MATERIALS AND METHODS

Two columns packed with open-pore polyurethane foam were connected in series each having a different scrubbing reagent specific for NH_3 and H_2S removal. Figure 1 shows the process flow diagram of a 2-stage, multi-chemistry scrubber used in this experiment for the simultaneous removal of NH_3 and H_2S contaminated odor stream. The bench-scale wet chemical scrubber consists of a gas generation system, chemical feed and recirculating liquid reservoir. The odor streams weremixed in a gas mixing chamber to achieve uniform concentration before it was fed to the packed-bed of the first stage scrubber where it will be in intimate contact with dilute H_2SO_4 scrubbing solution that was continuously recirculated. Ammonia reacts with sulfuric acid optimally at low pH to produce ammonium sulfate, a soluble non-volatile salt, as by-product which will be removed from the scrubber effluent through the overflow.

Table 1. Summary of design, operating conditions and analytical methods

Variable	Description
Design	
Column height	80 cm
Column inside diameter	10 cm
Packing material	Open Pore Polyurethane Foam
Bed height	50 cm
Bed volume	3.93 L
Gas/Liquid flow	Countercurrent
Recycle liquid rate	3-9 L/min
pH control	Addition of 1 N H_2SO_4/NaOH
Operation	
Gas flow rate	15 – 60 L/min
EBCT[a]	3.93 - 15.72 sec
Volumetric loading[b] (m^3 m^{-3} hr^{-1})	229 - 916
Superficial liquid velocity	1 – 3 m/s
Inlet concentrations	≤ 265 ppm$_v$ H_2S ≤ 155 ppm$_v$ NH_3
Type of gas diluting air	Compressed air from laboratory
Analysis	
H_2S	MultiRAE Plus PGM 50/5P, 4M/4L/4S Gas detector tubes, GV100 Gastec Sampling pump, Pyrotec Pyrolyzer
NH_3	SampleRAE Automatic Sampling Pump ASP-2000, 3L/3La Gas detector tubes, GV100 Gastec Sampling pump
pH/ORP	CyberScan Hand-held pH/mV/Temp RS 232 Meter
Salinity/Conductivity	Alternating 4-electrode Method (Horiba Water Quality Checker U-10)
Temperature	Testo Digital thermocouple
Pressure Drop	Dwyer Series 477 Digital Manometer

NH_3 was scrubbed with acidic water solutions containing H_2SO_4 (low vapor pressure acid) becausehigher vapor pressure acids such as HCl can potentially react in the gas phase to form

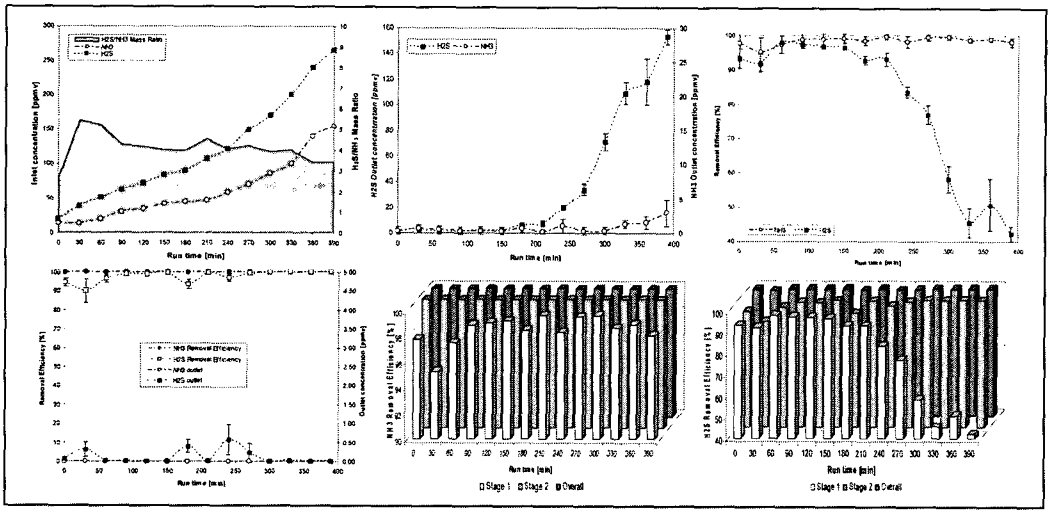

Fig. 2. Removal Efficiencies and Concentration Profiles of NH3 and H2S Mixed gas in the 2-stage Chemical Scrubber.

submicron chlorine salt particulates that can cause another air pollution problem.The outlet gas in stage 1 was then fed to a second packed-bed scrubber where H_2S was absorbed and oxidized by NaOH and NaOCl scrubbing solution that are recycled continuously and maintained at high pH. The treated air stream was then vented to the atmosphere. NH_3 and H_2S concentrations was measured and monitored continuously at three points (stage 1 inlet, stage 1outlet/stage 2 inlet, and stage 2 outlet) to evaluate the scrubbing efficiency and elimination capacities. Scrubbing liquid parameters (salinity, conductivity, pH, ORP) was also measured and controlled if necessary to achieve desired scrubbing performance. Scrubbing solutions were collected and recirculated in separate drain reservoirs in order to accomplish chemical treatments at high and low pH concurrently in a single system. A summary of the design, operation and analytical methods is presented in Table 1

3. RESULTS AND DISCUSSION

Open-pore polyurethane foam was found to be a suitable packing material for wet scrubbing of NH_3 and H_2S because of the following factors: relatively inexpensive, high void space (low pressure drop), corrosion resistant, provides large surface area per unit volume desirable for mass transfer, light weight (no additional support material required), physically and thermally stable.

A compact multi-stage, multi-chemistry scrubber was successfully operated for the simultaneous removal of mixed NH_3 and H_2S gas streams. Aqueous solutions of low vapor pressure acid, H_2SO_4, effectively remove NH_3 up to loading rates or 82.69 g N/m^3-hr. Similarly, high H_2S removal efficiencies were achieved using aqueous NaOH and NaOCl scrubbing solutions up to loading rates of 148.99 g-S/m^3-hr. pH and ORP control was found to be the critical factor that dictates the effectiveness of the scrubbing system.

Using H_2SO_4 scrubbing solution, a removal efficiency of 99.61% NH_3 was achieved with gas rate of 60 L/min and liquid recirculation rate of 7.36 L/min having a pH of 2.07 and ORP of 284 mV. Using NaOH/NaOCl scrubbing solution A removal efficiency of 99.99% H_2S was achieved with gas rate of 15 L/min and liquid recirculation rate of 6.63 L/min having a pH of 11.52 and ORP of -269 mV. Overall NH_3 and H_2S removal efficiencies of 99-100% was achieved at EBRT as low as 3.93 sec and volumetric loading rates as high as 916 m^3/m^3-hr.

Scrubbing liquid salinity increases with operation time because of accumulation of salts [$(NH_4)_2SO_4$ and NaCl]. Similarly, increase in conductivity with time was also observed because of accumulation of dissolved ions in the scrubbing solution. On the other hand, dissolved oxygen

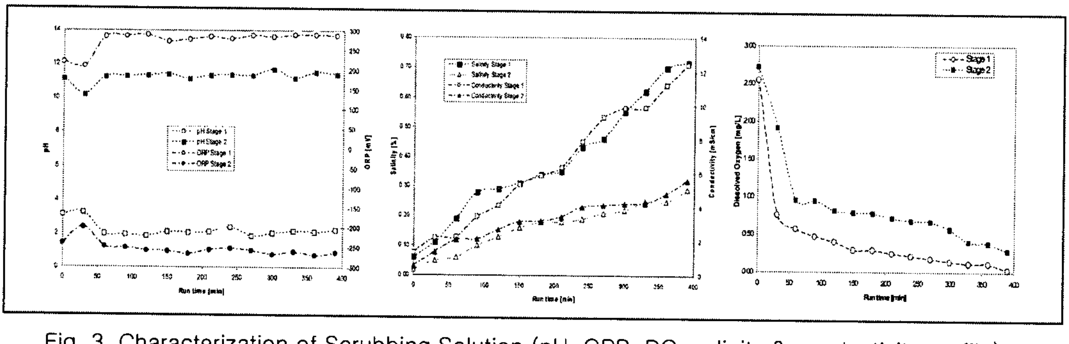

Fig. 3. Characterization of Scrubbing Solution (pH, ORP, DO, salinity & conductivity profile).

decreases with time. This verifies wastewater generation during the scrubbing operation requiring further treatment before disposal.

The applicability in removing other odorous compounds (e.g. methyl mercaptan, dimethyl sulphide, aldehydes, ketones, etc.) are yet to be explored.Advanced scrubbing systems can also be tested such as: ultraviolet (UV) enhanced packed tower system to pre-condition the inlet odorous gases and promote oxidation in the recirculating scrubbing solution, metal-oxide catalyzed systems, and use of dissolved ozone for effective oxidation of odorous gases. Electrolytic decomposition of saltwater can also be carried out to generate cheap alkali and acid scrubbing solutions

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