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Pilot-Scale Experimental Study on the Coupling of Venturi-Bubbling Reactor to Promote the Absorption of Leaked H_2S

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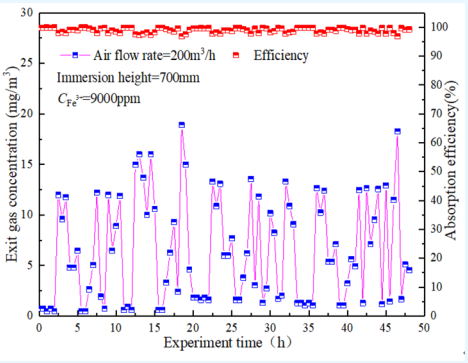

ABSTRACT: Natural gas generates varying concentrations of H_2S during natural formation and extraction, and H_2S leak accidents are frequent, posing a significant threat to the safety of human life and the environment. Conventional treatment technology equipment is large and does not meet the emergency requirements of the complex topographical gas field. This study aimed to design a pilot-scale method coupling the venturi and bubbling reactors to reduce equipment size and improve emergency capabilities for the absorption of leaked H_2S. It found that the ring system self-priming venturi reactor, which was suitable only for the coarse treatment of toxic gases, maintained an absorption efficiency of around 50% under most operating conditions, with substantial variations due to changes in process parameters, but that redundancy of the bubbling reactor was high. With the synergistic effect of venturi and bubbling, the coupling process had an extremely high absorption efficiency, basically more than 95%. The experiments also showed that the H_2S concentration at the outlet of the venturi−bubbling reactor increased with increasing inlet gas concentration and gas volume. The absorption performance improved significantly on increasing Fe^{3+} concentration; it increased first and then remained constant, and the optimum Fe^{3+} concentration for the absorption of leaked H_2S was 21 000 mg/m^3. The absorption performance decreased with increasing submergence height and then remained stable after the size of the inlet approached 600 mm, whereas the overall absorption efficiency of the venturi−bubbling reactor remained constant. The optimum operating temperature range was 10 °C−50 °C. The experimental system kept the outlet concentration below the emergency discharge standard for a continuous period of 48 h following practical use in the gas field and resulting in significant enhancement in mass transfer performance, fully satisfying the emergency requirements.

1. INTRODUCTION

H_2S is a flammable, highly toxic gas with an irritating odor. It is widely produced in industrial processes such as coal and gas extraction, coke ovens, sewage treatment, and petrochemicals.[1−4] When H_2S gas leaks into the environment, the olfactory threshold is extremely low, with a concentration of 20 ppm already reaching a dangerous value. At a concentration of 700−1000 ppm, the person immediately falls into a coma or dies from respiratory paralysis.[3] Of China's natural gas reserves, those with H_2S concentrations of more than 1% account for one-fourth of the total reserves. Also, the H_2S content of some gas fields exceeds 15%, posing an enormous threat to people's lives and property if H_2S leaks out.

H_2S removal in the industry is performed using dry[2,5−8] and wet methods.[9−11] Dry methods are dominated by Claus's high-temperature desulfurization and desulfurizer adsorption.[7,8] These processes are relatively mature and could purify sulfur-containing gases well, but the equipment is large and does not satisfy the emergency requirements of H_2S leakage from gas

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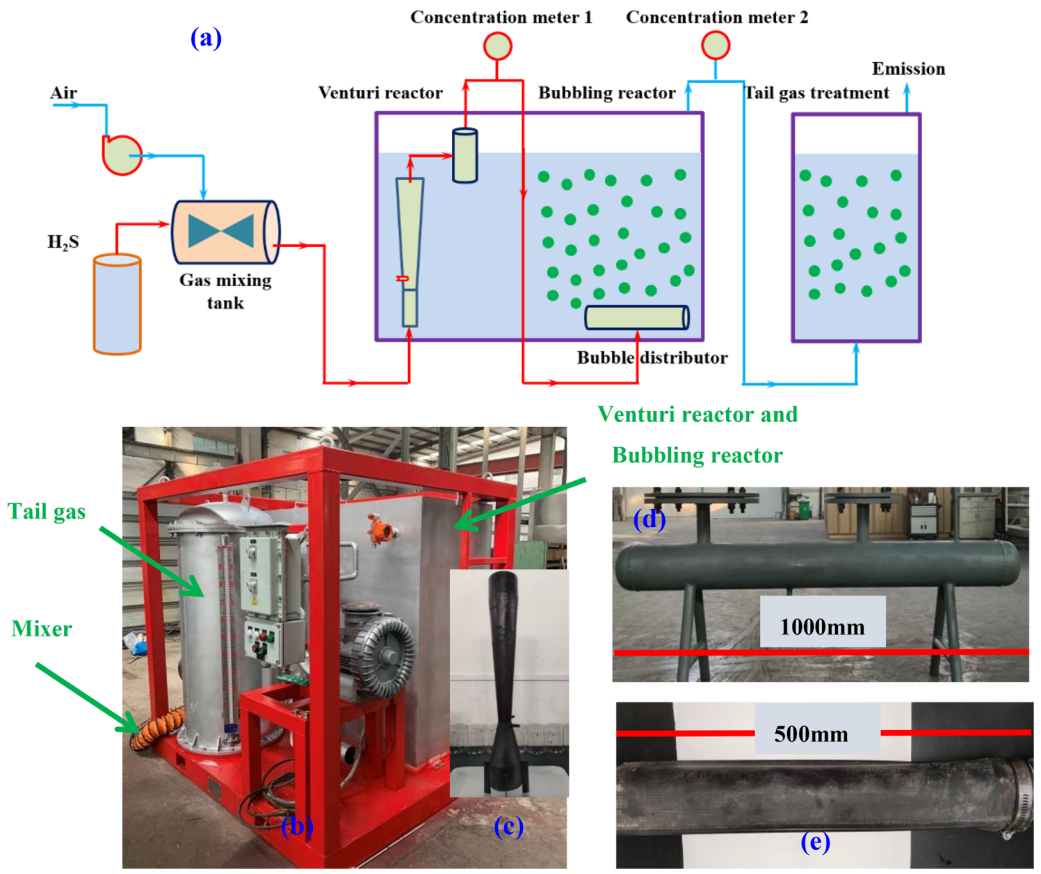

Figure 1. Diagram of experimental platform (a) flow diagram (b) experimental device, (c) Venturi reactor, (d) gas distribution tank, and (e) bubbling distributor.

fields with complex terrain. The wet H_2S removal including chemical and physical solvents is a typical gas−liquid two-phase absorption process. The transfer performance is affected by the type of absorbent and the movement characteristics of the gas−liquid interface, and is globally employed to remove sour gas.[9−12]

Extensive research has been conducted to examine the absorption performance of various alkaline solutions, such as sodium hydroxide solution, monoethanolamine, diethanolamine, methyl diethanolamine, 2-amino-2-methyl-1-propanol, and piperazine, in the last decades.[9,13] Üresin et al.[11] investigated the effect of sodium hydroxide solution on the absorptive effect of H_2S and CO_2 mixture at different residence times in the reactor. They found that the absorptive effect of H_2S increased with increasing residence time, and the maximum absorption efficiency was 80% when the H_2S concentration was above 500 ppm. Yang et al.[14] used numerical simulations to analyze the mass transfer law of H_2S inside the venturi reactor to achieve mass transfer performance using different process parameters. Azizi et al.[15] analyzed the effect of the type of absorbent on the absorption efficiency of a mixture of H_2S and CO_2. They pointed out that the presence of CO_2 significantly inhibited the absorption of H_2S gas. Hence, increasing the selectivity of the absorbent would help reduce the operating costs and improve the absorption performance. Jiao et al.[16] analyzed the effect of centrifugal force on the absorptive effect of H_2S and found that the gas−liquid rotation changed the contact form between the gas phase and the liquid film. Further, the absorption efficiency could reach 99.13%, and the treated H_2S emission concentration was close to the ppb level. The sodium hydroxide solution could effectively absorb the leaked H_2S but could not regenerate it. It is only capable of the emergency filling during actual emergencies because of its reaction with the CO_2 in the air, thus increasing the difficulty in disposal and the volume of equipment at the accident site.

Therefore, a renewable H_2S wet oxidation process with a long storage time is more valuable for the emergency disposal of H_2S spills.[17−20] For this reason, researchers carried out theoretical and experimental studies on various oxidation systems. Zou et al.[18] synthesized a novel heteropoly acid system that exploited the high selectivity and oxidative properties of heteropoly acids to effectively remove very low concentrations of H_2S with an optimum absorption efficiency of 99.1%. Maia et al.[21] investigated the effect of Fe^{3+}-EDTA on the removal of trace amounts of H_2S. The absorption efficiency of H_2S could still reach 99% after 35 min of gas−liquid contact. Vikrant et al.[1] explored the effect of Fe^{3+} concentration on the absorption efficiency of H_2S; the optimum absorption efficiency reached 96% at a Fe^{3+} concentration of 200−250 ppm.

At this stage, the main equipment used for the absorption of toxic gases containing H_2S includes bubbling towers,[20,22] venturi scrubbing towers,[14] and packed towers.[23] Still, the conventional equipment is large, cannot be transported over long distances, and is suitable mainly for stable working conditions and not for the emergency requirements of H_2S leaks from gas fields with complex terrain. Meanwhile, scholars have carried out many laboratory-scale performance tests on H_2S tail gas absorption.[1,21,23] However, emergency response

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ACS Omega 2024, 9, 21260−21269

data for pilot-scale H_2S leaks are still lacking.[9,24] Efficient and intensive processes are urgently required in emergency response. To this end, a pilot-scale method for highly integrative coupling of venturi and bubbling reactors has been developed. Also, the effect of the venturi−bubbling reactor on the absorption efficiency of leaked toxic gases has been experimentally tested, and the effects of process parameters such as flow rate, submersion height, and inlet gas concentration on the absorption efficiency of H_2S have been researched. Further, field experiments have been carried out at a gas field effluent transfer site.

2. EXPERIMENTAL PROCESS

A pilot-scale-leaked H_2S absorption experimental platform with a maximum gas treatment capacity of 520 m^3/h was built based on previous findings. The process flow diagram is shown in Figure 1a and 1b. The experimental platform contained a gas distribution system, a toxic gas absorption system, and a tail gas disposal system. The gas distribution system included a gas cylinder, a gas-mixing tank, a mass flow meter, and an explosion-proof axial flow fan. The H_2S gas in the gas cylinder was mixed with air in the gas-mixing tank. Then, it entered the primary venturi absorber and the secondary bubbling reactor for the gas−liquid contact after the flow fan. The toxic gas absorption system consisted of a primary venturi reactor, a secondary bubbling reactor, and a gas−liquid separator. The venturi and bubbling reactors were used in series after gas−liquid separation. After the reaction, the gas entered the tail gas treatment system, which contained a tail gas treatment tower and an online concentration meter, which was the security device for the experiment. In the experiments, the gas distribution was used to simulate the variation in leaked H_2S concentration; H_2S concentrations at the outlets of the venturi and bubbling reactors were obtained by gas chromatography (Agilent 7890B).

The physical diagrams of the mixed gas distribution tank, venture reactor and the bubbling distributor are shown in Figure 1(c∼e). The venturi reactor was self-priming consisting of a tapering nozzle and an outer jacket tube, which could be divided into a liquid convergence section, a throat, and a diffusion section (Figure 1c).[14] The bubbling distributor was a cylindrical distribution tube wrapped around the outer surface with a bubbling membrane The pore diameter range was 100−600 μm, the diameter of the bubbling distributor was 60 mm, the length was 500 mm, and the installation height was 100 mm from the bottom side of the laboratory table (Figure 1e). The total size of the absorption chamber was 2000 mm, with a width of 1100 mm and a length of 1000 mm. The self-priming venturi reactor was adopted and placed vertically inside the absorption chamber at a height of 200 mm from the bottom. The sulfur solvent, oxidizing agent (complexed iron Fe^{3+}/Fe^{2+}), and chelating agent in the absorption solution mixture were provided by China Shandong Province Yantai Xinrui Environmental Protection Technology Co. The error of the experimental installation is shown in Table 1.

During the actual experiments, the maximum outlet gas concentration was set to the emergency emission standard (ERPG2, 20 mg/m^3) in the nonmeasurement upper limit experiments to ensure safety, and the experiments were stopped immediately when the concentration exceeded. The H_2S concentration at the outlets of the venturi and bubbling reactors were recorded at two different concentration collection ports in real time during the experiments. The absorption efficiency is calculated as follows:

$$\text{efficiency} = \frac{(\text{inlet concentration} - \text{exit concentration})}{\text{inlet concentration}} \times 100\% \quad (1)$$

Table 1. Experimental Error of Apparatus

instrument	error
flow fan (NK-GF-8700)	±2.5%
gas chromatography (Agilent 7890B)	±0.05 ps
meter ruler	±0.5 mm
trivalent iron content tester (KYORITSU)	0.1 mg/L
pH meter (BPH-7800)	±0.002 pH
thermocouple	±0.5 K

3. RESULTS AND DISCUSSION

The concentration of the leaked H_2S in the experiment was 100−10 000 mg/m^3, the inlet gas volume was 0−520 m^3/h, and the submerged height of the device was 300−900 mm. The absorption solution was a complexed iron solution, in which the concentration of Fe^{3+} was 3000−35 000 mg/m^3, and the temperature of the absorption solution was 0 °C−50 °C.

The H_2S concentration in an actual spill is uncertain and fluctuates considerably. The absorption performance was experimentally tested at different inlet H_2S concentrations to closely match the real accident scenario (H_2S concentration of 0%−15% in a gas field of Sinopec), with the inlet gas concentration range of 0−10 000 mg/m^3 (Figure 2a and 2b).

Figure 2(a) shows that the venturi reactor outlet concentration increased almost linearly and the absorption performance decreased gradually with the increase in inlet gas concentration. The absorption efficiency of the venturi reactor first decreased rapidly with the increase in inlet gas concentration. After the inlet concentration was higher than 2000 mg/m^3, the absorption efficiency of the venturi reactor did not change and was maintained at about 45%. Therefore, the venturi reactor alone could not achieve the effective absorption of toxic gas. The analysis also found that the absorption efficiency of the venturi reactor was lower than the experimental findings.[25,26] This was because the process adopted the ring suction self-priming design, which had a sizable liquid diversion, to reduce the pressure drop. And, the atomization rate and droplet size were large, leading to a particular gap in performance. However, compared with equipment with a simpler structure and lower pressure, it was perfectly suitable for the coarse treatment in the process.

The absorption effect of H_2S by a single bubbler reactor was illustrated in Figure 2(b). The outlet concentration of the bubbler reactor continued to increase with an increase in the inlet concentration. However, when the outlet concentration exceeds 2000 mg/L, it surpasses the acceptable limit of 20 mg/L, failing to meet emergency requirements. It can be observed that a single bubbler reactor exhibits high absorption efficiency, typically exceeding 90%. Nevertheless, its maximum applicable concentration is limited to only 2000 mg/L, which deviates from real-world scenarios encountered in high acid gas fields.

The influence of intake H_2S concentration on the absorption performance of the venturi−bubbling reactor is depicted in Figure 2(c). As the intake H_2S gas concentration surpassed 9000 mg/m^3, the outlet H_2S concentration of the coupled

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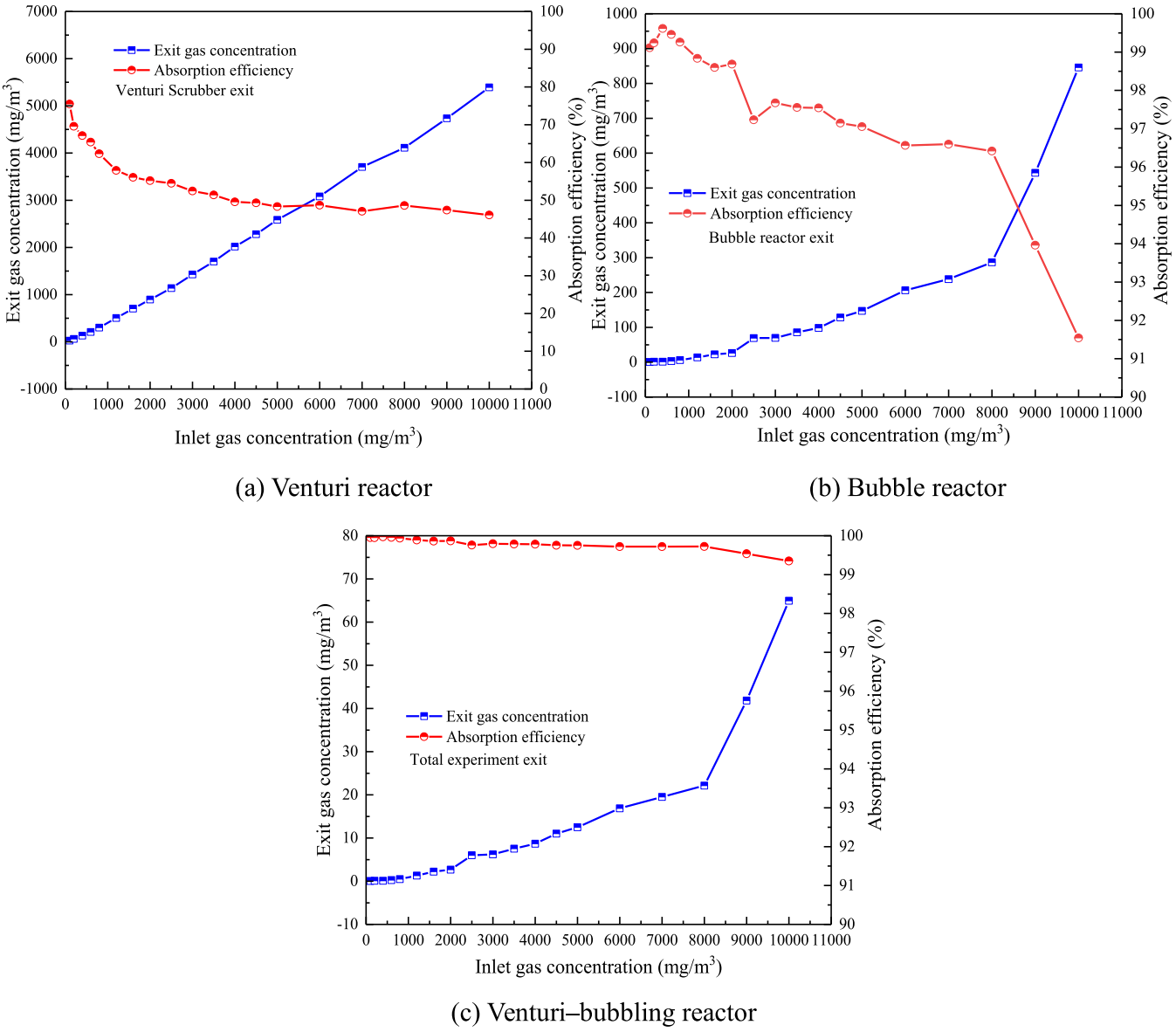

Figure 2. Influence of inlet gas on concentration on H_2S absorption performance (gas volume of 200 m^3/h).

process exceeded 20 mg/m^3, exceeding the emergency discharge requirement. At this point, raising the inlet concentration became hazardous as the outlet concentration was already dangerously high. The trials also revealed that the overall absorption efficiency of the linked process for leaked H_2S surpassed 99% and did not fluctuate significantly with the increase in intake concentration. Further investigation revealed that the maximum absorption observed in the bubbling reactor experiments was approximately 4000 mg/m^3. This value was significantly lower compared with the individual absorption using the bubbling reactor, which yielded absorption levels of approximately 6000−7000 mg/m^3. This indicated that the effect of gas−liquid separation in the venturi−bubbling reactor reduced the impact on the overall absorption. Experiments showed that the venturi−bubbling reactor had strong absorption performance for leaked H_2S across a wide working range and was flexible.

Figure 3 depicts the influence of the inlet gas flow rate on the absorption performance of leaked H_2S. At the same inlet concentration, the higher the inlet gas flow rate, the higher the outlet H_2S concentration, but the effect on the absorption performance was not insignificant (Figure 3a). For example, at the corresponding inlet concentration of 520 mg/m^3, the venturi−bubbling reactor tail exit concentration increased by a factor of approximately 60 (from 0.50 mg/m^3 to 31.28 mg/m^3) when the gas flow rate increased from 50 to 500 m^3/h. The exit concentration was already higher than the emergency emission standard, but the absorption efficiency of the Venturi−bubbling reactor only decreased from 99.89% to 94.52%.

The analysis found that the absorption efficiency continued to decrease with the increase in gas velocity for the venturi reactor. The lowest absorption efficiency was only 35.62%, a more than 50% decrease from the efficiency under optimum operating conditions. It was because the absorption performance of the venturi reactor was influenced by the amount of absorbent solution induced, atomization rate, and droplet size. The droplet diameter increased and the atomization rate decreased with increasing inlet gas flow rate. Both significantly deteriorated the overall mass transfer in the ring system self-priming venturi reactor used in the experiments. The amount

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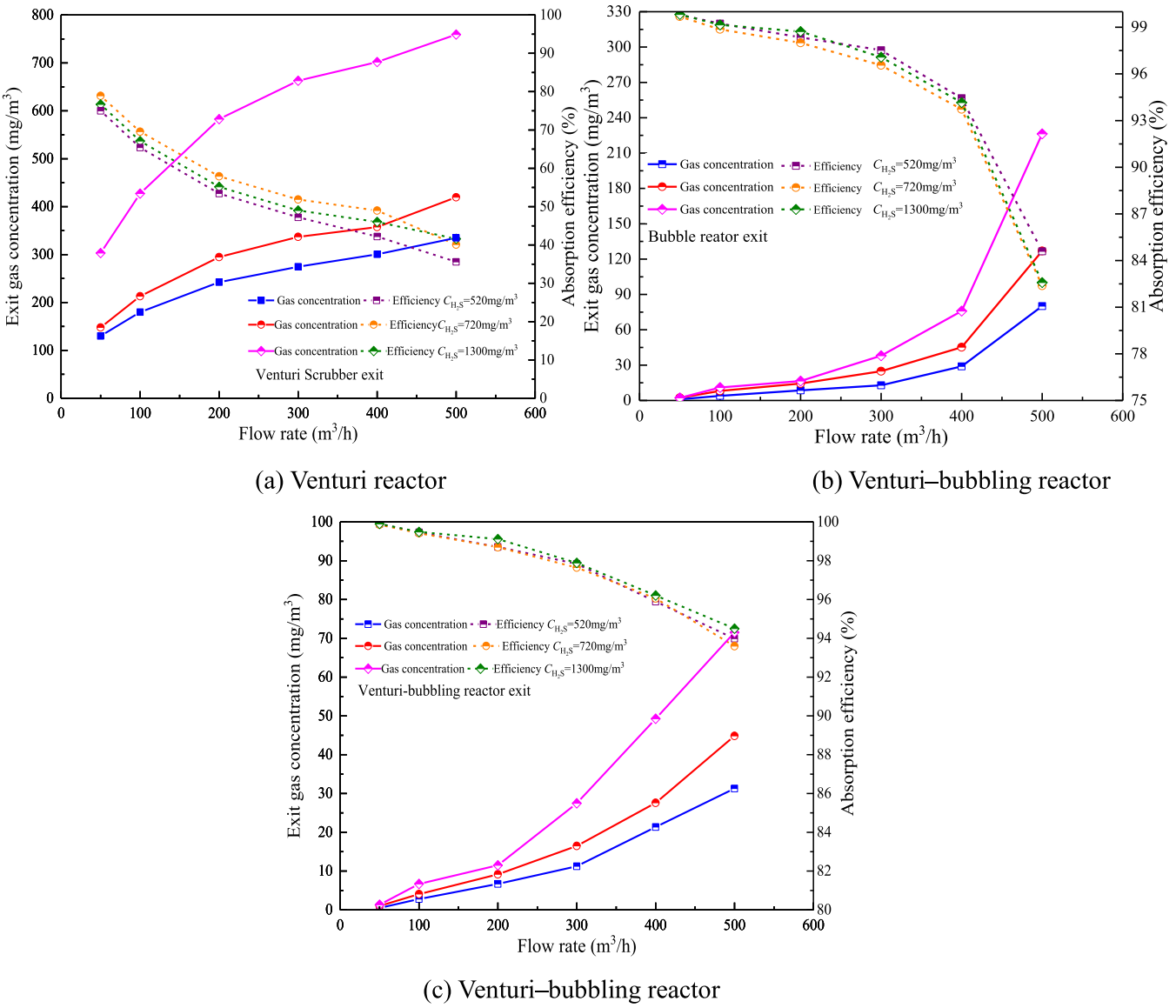

Figure 3. Effect of gas flow rate on H_2S absorption performance.

of absorbent solution induced increased with the increase in inlet gas flow rate; it first increased and then remained constant. Also, the droplet diameter and the atomization rate increased so that the absorption performance of the venturi reactor decreased rapidly with increasing gas volume when the absorbent solution diversion reached a bottleneck.

Further analysis also revealed that, on the one hand, the increase in gas flow rate intensified the liquid tumbling inside the absorption solution, increased the gas−liquid interface, accelerated the diffusion of low-concentration gas-phase components into the liquid-phase components, and promoted gas−liquid contact mass transfer in the bubbling reactor. However, the increase in gas flow rate decreased the residence time of the gas in the absorption solution, which reduced the gas−liquid mass transfer. Therefore, coupling the venturi and bubbling reactors did not significantly reduce the mass transfer performance of the bubbling reactor. However, as the absorption performance of the venturi reactor decreased significantly, the overall performance showed a significant increase in the concentration of the H_2S gas leaving the reactor with an increasing inlet gas flow rate.

Figure 4 reveals the effect of submersion height on the absorption performance of leaked H_2S. The submersion height influenced the amount of absorption solution induced by the venturi reactor, atomization rate, and residence time of H_2S gas. If the submersion height was too low, then the stable operation of the venturi and bubbling reactors was not favored. When the submersion height was too high, the absorption resistance increased. In an environmental emergency, the gas could not pass through the absorption solution bed and a discontinuous upwelling of liquid occurred, deteriorating the mass transfer. The static pressure head of the fan used in the experiment was 30 kPa. Therefore, the submergence height of the bubbling reactor was chosen to be between 300 to 900 mm, and the venturi reactor was installed 200 mm higher than the bubbling reactor, with a submergence height of 100−700 mm. As shown in the graph, the outlet concentration of H_2S gas decreased with increasing submersion height and subsequently reached a stable level. After the inlet height approached 600 mm, the overall absorption efficiency of the venturi−bubbling reactor remained constant and the absorption efficiency exceeded 97%. At submersion heights below

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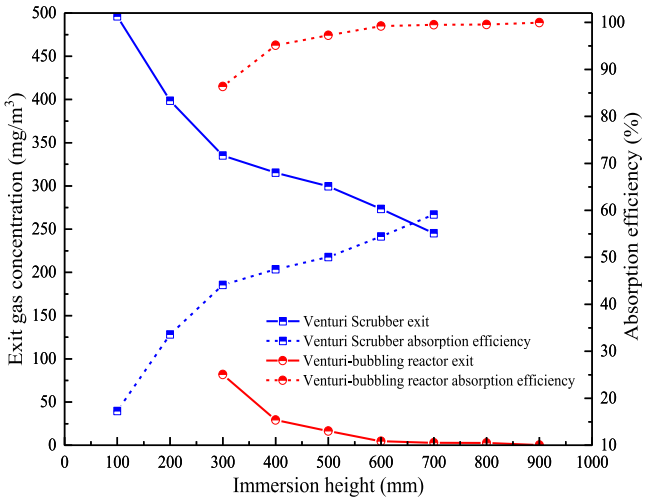

Figure 4. Effect of immersion height on H_2S absorption performance.

400 mm, the outlet gas concentration exceeded the emergency discharge standard. The mass transfer performance deteriorated significantly after that, leading to the need to critically monitor the change in submersion height during the experimental and practical applications.

The absorption performance of the venturi reactor varied significantly due to the submersion height compared with the smooth variation in the venturi−bubbling reactor. As shown in Figure 4, the absorption efficiency increased substantially from 17.38% to 59.11% when the submersion height was increased from 100 to 700 mm. This was because the submersion height directly affected the amount of liquid released from the venturi reactor. Reducing submersion height also reduced the time for the toxic gas to penetrate the absorber bed and the adequate gas−liquid contact time at the same gas flow rate based on the observations.[25,26] It was reflected in a significant increase in gas concentration at the venturi reactor outlet and a decrease in mass transfer performance.

Figures 5 and 6 show the effect of absorber concentration and pH on the absorption of spilled H_2S, the reaction mechanism of which can be approximated by eqs 2, 3, and 4:

$$H_2S + OH^- = HS^- + H_2O \quad (2)$$

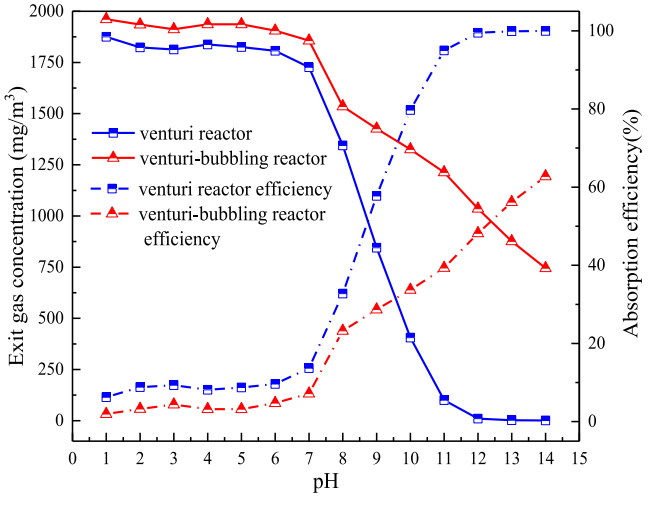

Figure 5. Effect of pH on the absorption performance rate.

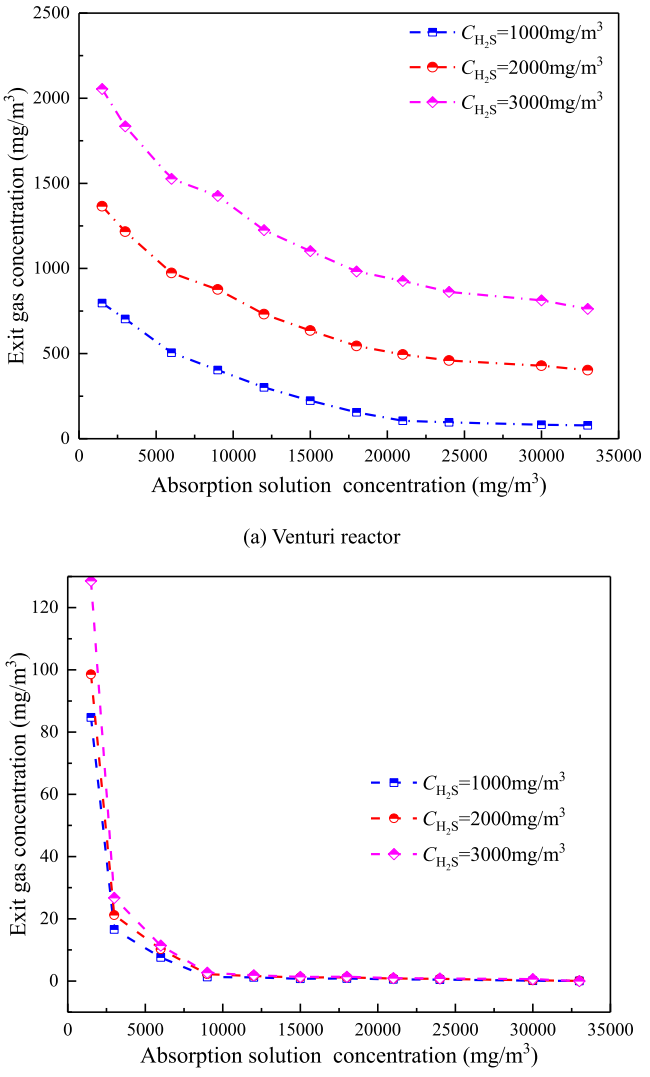

Figure 6. Effect of absorbing solution concentration (Fe^{3+}) on the absorption performance rate.

$$2Fe^{3+} + HS^- + OH^- = 2Fe^{2+} + 1/8S_8 \downarrow + H^+ \quad (3)$$

$$2Fe^{2+} + 1/2O_2 + H_2O = 2Fe^{3+} + 2OH^- \quad (4)$$

In the wet oxidation processes, the potassium hydroxide solution is usually used as the activating solution for absorption, Fe^{3+}/ Fe^{2+} as the catalyst, and O_2 as the oxidizing agent.[20] Although pH does not influence the overall reaction process, it significantly affects the capture and dissolution of H_2S gas. As shown in Figure 5, the absorbent solution hardly reacted with the H_2S gas at a solution pH below 7. Notably, the alkalinity of the absorbent solution played a decisive role in the first step of the reaction. When the pH increased to 7−10, the H_2S concentration at the outlets of the venturi and bubbling reactors decreased rapidly with increasing pH. That is, the absorption performance increased significantly. As the pH increased to 11−12, the decreasing trend of the H_2S concentration at the outlets of the venturi and bubbling reactors with increasing pH became slower. When the pH exceeded 13, the H_2S concentration at the outlets of the venturi and bubbling reactors remained unchanged. Then, the pH of the absorption solution increased, and the overall

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ACS Omega 2024, 9, 21260−21269

absorption performance did not change. It indicated that the absorption of toxic gases must occur in an alkaline environment with an optimum pH of 13.

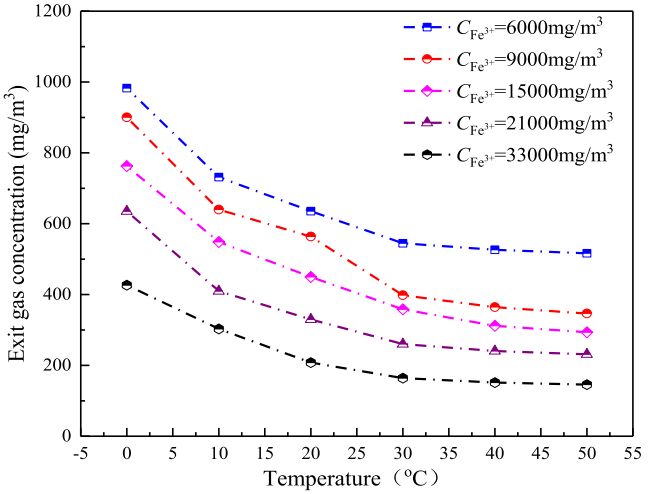
As shown in Figure 6, the H_2S concentration at the outlets of both the venturi reactor and the venturi−bubbling reactor first decreased with the increase in Fe^{3+} concentration and then remained constant; the absorption performance significantly improved for both.

At a Fe^{3+} concentration of 9000 mg/m^3, the venturi−bubbling reactor outlet concentration was always below the emergency emission standard at an inlet H_2S concentration of 3000 mg/m^3, indicating that the increase in absorbent concentration significantly enhanced the absorption performance of the toxic gas. It was also found that the absorption effect hardly changed in the venturi reactor once the Fe^{3+} concentration in the absorption solution increased to 21 000 mg/m^3. For the venturi−bubbling reactor, when the Fe^{3+} concentration in the absorption solution increased to 12 000 mg/m^3, the absorption effect hardly changed with the increase in Fe^{3+} concentration. The absorption performance did not show a continuous improvement with increasing Fe^{3+} in the absorption solution. Instead, there existed optimal parameters that yielded the best absorption performance. However, an increase in Fe^{3+} concentration increased the viscosity of the absorbent solution and the absorption pressure drop of the toxic gas. Therefore, the optimum Fe^{3+} concentration for the emergency disposal process for leaked H_2S was 21 000 mg/m^3.

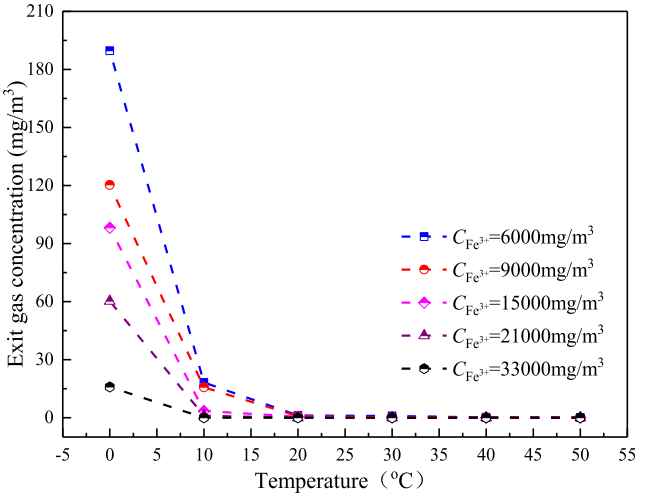
Figure 7 shows the effect of temperature on the H_2S absorption performance. As the decomposition temperature of the chelating agent in the catalyst was 52 °C, the test range was chosen from 0 to 50 °C. The absorption performance first remained constant and then decreased with the decrease in the temperature of the absorption solution. The absorption efficiency started to fall at 10 °C−15 °C, and the absorption efficiency dropped significantly at 0 °C−10 °C. When the ambient temperature approached 0 °C, the absorbent solution could no longer deal effectively with leaked H_2S. Hence, the best working temperature range for H_2S emergency disposal equipment was 15 °C−50 °C, which could also be relaxed to 10 °C−50 °C as appropriate.

If the working ambient temperature is not within this range, then suitable insulation treatment, such as adding cooling equipment and insulation modules, must be included. When applied on a large scale, appropriate increases are required to reduce the concentration of the absorption solution according to the environment. In summer, when the temperature is higher, the concentration of absorption solution can be reduced to save maintenance costs. In winter, when the temperature is low, the concentration of the absorption solution can be increased appropriately during emergencies to improve the handling capacity of the installation.

As the experimental platform used a recyclable Fe^{3+}/Fe^{2+} process, the off-gas from the loading and unloading processes outside the sulfur-containing wastewater treatment plant was used as the gas source for the field performance tests in the experiments. When the gas flow rate was 200 m^3/h, the effect of operating time on the H_2S absorption effect was considered. The actual spill emergency disposal site equipment is generally used for less than 24 h. Therefore, the experiments tested the absorption performance of the equipment under continuous 48 h operation of the experimental platform. As shown in Figure 8, despite fluctuations in the inlet gas concentration (50−3000 mg/m^3), the absorption efficiency of the toxic gas H_2S hardly



(a) Venturi reactor



(b) Venturi–bubbling reactor

Figure 7. Effect of temperature on the absorption performance rate.

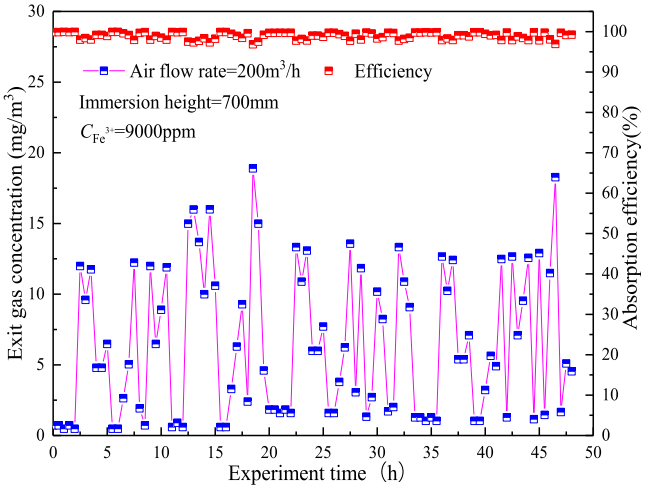


Figure 8. Effect of operating time on the absorption performance rate.

changed significantly during the test time, always being high at 90%. Also, the outlet concentrations were all below the emergency discharge standard. It showed that, on comparing

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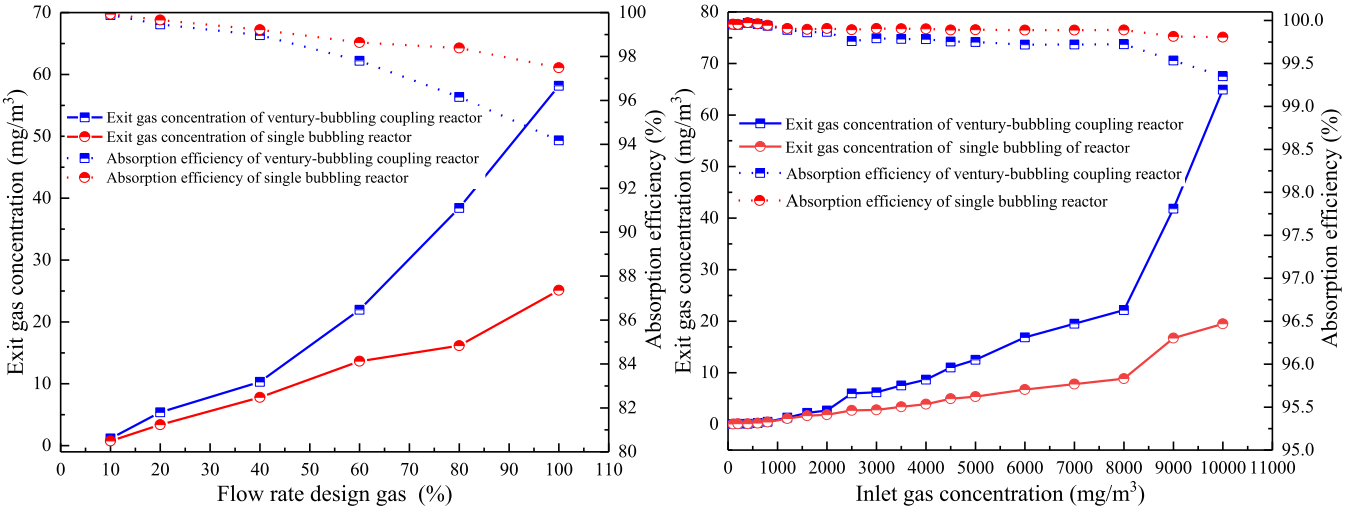
ACS Omega 2024, 9, 21260−21269

(a) Bubble reactor (1000Nm^3/h)
4000mm*1900mm*2600mm

(b) Venturi–bubbling reactor (500Nm^3/h)
1720mm*1720mm*2000mm

Figure 9. Physical diagram of coupling reactor and bubbling reactor.



(a) flow rate on absorption performance

(b) inlet concentration on absorption performance

Figure 10. Absorption performance of different operating parameter.

the developed process and experimental platform with the bubbling reaction process alone, the equipment size was significantly reduced, had good absorption performance over a more extended duration, and fully met the emergency needs of the H_2S leakage site.

Hence, on comparing the venturi and bubbling reactors, it was found that the venturi reactor was more sensitive to the changes in operating parameters. In contrast, the bubbling reactor had better redundancy and satisfied the contingency requirements under more fluctuations in operating parameters, but the equipment was extensive and huge. However, considering the simple structure of the venturi reactor and the lower pressure, it was ideally suited for pilot-scale, or even industrial plant, coarse treatment applications. The integration and coupling of the venturi and bubbling reactors allowed for better absorption performance in a minimum size of equipment.

The absorption performance of the ventury-bubbling coupling reactor was compared with that of the previously designed bubbling reactor through experiments, and the evolution law of absorption by the coupling reactor was analyzed (as shown in Figure 9 and Figure 10).

Figure 9 depicts a physical diagram of both reactors, where the left picture represents the bubbling reactor (4000 × 1900 × 2600 mm^3), and the right picture represents the ventury–bubbling coupling reactor (1720 × 1720 × 2000 mm^3). That is to say, the volume of the coupled reactor accounts for 29.94% of that in the separate bubbling reactor. The absorption

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capacity of both devices to leakage H_2S was tested at 0−100% design gas and 0−10 000 ppm.

As seen from Figure 10, when the inlet concentration is at ERPG-2 emission standard level or below, maximum gas volume for coupled process is about 60% of design value while maximum inlet gas volume is about 90% for single bubbling reactor under same inlet concentration; thus making maximum applicable gas volume for coupled process two-thirds that of larger scale bubbling reactor.

Also, for the same gas volume and concentration range (0−10 000 mg/m^3), both the bubbling reactor and coupling reactor are capable of processing the gas. In Figure 9(a), it can be observed that the outlet concentration of the bubbling reactor is lower than that of the coupling reactor shown in Figure 9(b). The maximum applicable concentration for the coupling reactor is 8000 ppm, whereas for the bubbling reactor it reaches approximately 10 000 ppm, accounting for an approximate difference of 80%, which meant the coupling process can achieve 80% of the performance exhibited by a separate bubble reactor, while occupying merely 29.94% of its volume.

Although the coupled process exhibits lower absorption performance compared to a single bubbling reactor, it offers advantages such as smaller equipment size, maximum gas volume (about 66.67% of the latter), and maximum applicable concentration (80.0% of the latter). Consequently, it achieves higher absorption efficiency with ample gas redundancy, making it more suitable for emergency systems.

4. CONCLUSIONS

In this study, an experimental platform was designed for the absorption of leaked H_2S by the venturi−bubbling reactor on a pilot scale. The effects of critical operating parameters, such as inlet gas flow rate, inlet H_2S concentration, absorption solution submersion height, absorption solution concentration, and solution temperature, on the absorption performance of leaked H_2S were tested. The main findings were as follows:

(1) The concentration of outlet H_2S gas increased with the concentration of inlet H_2S gas and decreased significantly with the increase in gas flow rate. After the inlet concentration was higher than 2000 mg/m^3, the absorption efficiency of the venturi reactor did not change and remained at around 50%, which was only suitable for the coarse treatment of toxic gases.

(2) The absorption performance of the venturi−bubbling reactor for H_2S gas decreased first with the increase in submersion height and then remained stable. After the inlet height approached 600 mm, the overall absorption efficiency of the venturi−bubbling reactor remained constant, with an absorption efficiency of more than 97%.

(3) The best Fe^{3+} concentration for leaked H_2S absorption was 21 000 mg/m^3. The absorption performance was stable at first and then decreased with the increase in the temperature of the absorbent solution, and the best working temperature range was 10 °C−50 °C.

(4) Within the range of fluctuating inlet gas concentrations (50−3000 mg/m^3), the pilot-scale experimental platform had an outlet concentration below the emergency emission standard for 48 h, which could fully satisfy the real emergency needs of the site.

(5) The absorption reactor utilizing the venturi-bubbling coupling process achieves approximately 80% of the performance exhibited by the traditional single bubble process while utilizing only 29.94% of its volume.

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Notes

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