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Experimental Study on the Treatment of H_2S and NH_3 in Hospital Sewage Based on Composite Biological Filter Tower

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Abstract:

In the study, the H_2S and NH_3 of common foul gases in hospital sewage were treated by the combination of the bio-trickling filter and the biofilter. The results showed that when the temperature was 25℃, air input was 1.0m^3/h, aerated concentration of H_2S was 10~50mg/m^3 and NH_3 was 10~20mg/m^3, spray amount of nutrient solution was 5L/h, pH was 6.0~7.0, the residence time was 60s, the removal rate of H_2S and NH_3 reached optimum and the removal rate was 98.1% and 97.8% respectively. The composite biological filter tower was restarted 30 days later and the fourth day's removal rate reached more than 80%, which showed that the resistance to shock loads was stronger. The research also showed that as a result of the microbial growth environment was different, the microbial species in bio-trickling filter and the biofilter were also different. The separation of bacteria and fungi was more beneficial to the growth and reproduction of microorganism, which was also better for the purification of foul gas

***Keywords**: Hospital sewage, Composite biological filter tower, Air pollution, H_2S, NH_3, Biotechnology*

I. INTRODUCTION

The treatment of odor gas was mainly concentrated on the treatment of industrial odor, and had achieved remarkable results [1]. But there were less research on treatment of foul gas in sewage treatment plant and farm [2], and the related research in hospital sewage treatment station was much less [3,4]. The treatment technology of hospital treatment station to deal with the foul gas could not directly copy the odor treatment technology of sewage treatment plant. The size of the hospital sewage treatment station was small, so it was necessary to find a kind of economical and feasible technology. There were many studies on the removal of H_2S and NH_3 by biological method at home and abroad [5,6]. But so far there was little research on H_2S and NH_3 combined treatment with bio-trickling filter and the biofilter [7]. Therefore, on the basis of the previous research [8-15], in this study, a composite biological filter was used to bio-trickling filter and the biofilter deal with the mixed gas containing H_2S and NH_3 and the effects of different

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operating parameters on the treatment effect were researched. The purpose of the study was to find an effective way to treat the H_2S and NH_3 with low concentration in the hospital sewage, which provides a theoretical reference for the application of the technology of hospital sewage deodorant.

II. MATERIALS AND METHODS

2.1 The Establishment and Operation of the Reactor

2.1.1 The establishment of the reactor

The composite biological filter tower was composed of a bio-trickling filter and biofilter. The structure of bio-trickling filter and the biofilter was as follows: height was 1 m, diameter was 30cm, high / low water tank was 40cm×50cm×35cm. The filler of the bio-trickling filter was natural zeolite which was optimized by chemical reagents. The bacteria of which were main microbes, which was proper for the treatment of soluble foul gas. The filler of the biofilter was sawdust which could be degraded by microorganism and it's microbes were main fungus, which was suitable for the treatment of poorly soluble foul gas. Fig. 1 was the schematic of composite biological filter tower system.

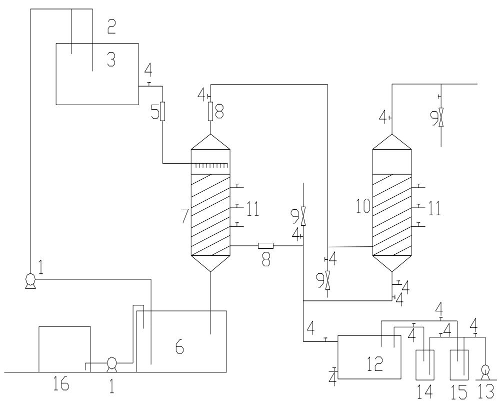

Fig. 1: Schematics of composite biological filter tower system (1. Circulating pump; 2. Content gauge; 3. High water tank; 4. Valve; 5. Glass flowmeter; 6. Low water tank; 7. Bio-trickling filter; 8. Gas flowmeter; 9. Sampling port; 10. Biofilter; 11. Filler sampling port; 12. Foul gas generator; 13. Air compressor; 14. NH_3 reactor; 15. H_2S reactor; 16. Nutrient liquid can.)

2.1.2 Sludge domestication

The excessive carbon source of nutrients and adequate supply of other nutrients which was necessary for microbial growth and metabolism were added into the activated sludge which came from sewage treatment plant in Chengdu, and then the microorganism was cultured in it, which made the microorganism reproduce rapidly and provided more microbial strains for the later stage. The study found that nutrients m(C): m(N): m(P)=100:5:1 was most suitable for microbial growth and reproduction. This experiment used glucose as nutrient for the growth and reproduction of microorganism, and the proportion was as

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follows: glucose was 100g/L, urea was 10g/L, KH_2PO_4 was 10g/L. The nutrient was added once a day and then carried on the aeration about 20 hours, and then static set about 4 hours and discharged the supernatant, and recycled above operation.

The domestication of sludge was gradually completed by replacing the glucose nutrient solution with the foul gas as the nutrient needed by the microorganism. In this experiment, the aim was achieved by adding sodium sulfide and ammonia water with high concentration [16].

2.1.3 Biofilm formation of sludge

The domesticated activated sludge mixture was sprayed from the top of the biological filtration tower, and then flowed through the filler's surface. The mixed liquid was accumulated at the bottom of the tower and then transported to the top of the tower with a certain flow rate, and then the mixed liquid was sprayed. The mixed liquid was used circularly to complete the process of biofilm formation [17].

2.2 Analysis Method

H_2S was determined by methylene blue spectrophotometry (GB/T16489-96), and NH_3 was determined by the Na's reagent colorimetric method (GB/T14668-93). The temperature and pH value were measured by CPM253-MR0005 analyzer. The gas flow was measured by LZJ-6 type glass rotor flow meter. The microorganism was observed by high power microscope [18].

In the experiment, in determining the effective number of digits, the rules were "Rounding down for 4 and up for 6 and deliberation for 5, Rounding up for 5 followed by digits other than 0. In case of 5 followed by 0, rounding down if the digit before 5 was even and up if it was odd". To modify the values of the behind, the standard deviation method was used to make a choice of the measured data [19]. The formula was as follows:

$$\left|\frac{A-B\text{（except}A\text{）}}{C\text{（except}A\text{）}}\right| \geq 3 \tag{1}$$

A: questionable value; B: average value; C: standard deviation.

Mathematical expression of standard deviation was:

$$S=\sqrt{\frac{\sum(X_i-\bar{x})}{n-1}} \text{ (in the experiment, n=2 or 3)} \tag{2}$$

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III. RESULTS AND DISCUSSION

3.1 Results of Study on Composite Biofilter Optimal Conditions

3.1.1 Effects of gas flow on the removal efficiency of H_2S and NH_3

When the spray amount of nutrient solution was 5L/h, aerated concentration of H_2S was 10~50mg/m^3 and NH_3 was 10~20mg/m^3, the results were shown in Fig. 2 and Fig. 3.

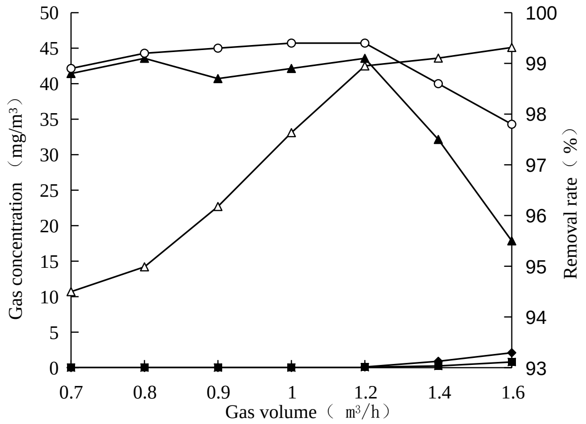

Fig. 2: The effects of gas flow on the removal efficiency of H_2S (△-gas concentration; ◆-Outgassing Concentration of trickling filter; ■-Outgassing Concentration of filter tower; ▲-Removal efficiency of trickling filter; O-Total removal rate)

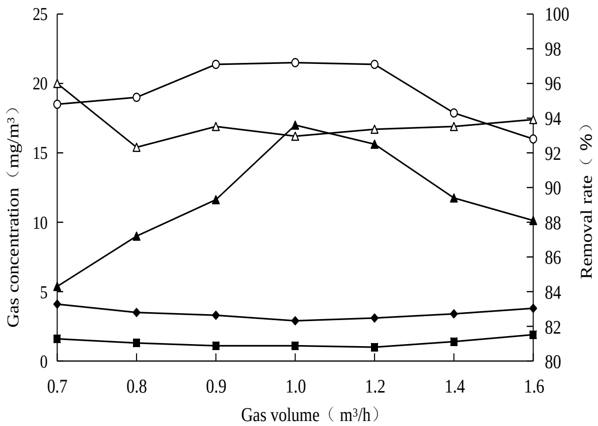

Fig. 3: The effects of gas flow on the removal efficiency of NH_3 (△-gas concentration; ◆-Outgassing Concentration of trickling filter; ■-Outgassing Concentration of filter tower; ▲-Removal efficiency of trickling filter; O-Total removal rate)

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The figures showed that when the amount of gas was $1.0m^3/h$, the removal efficiency reached the best, and the removal rate of H_2S and NH_3 reached 99.4% and 97.8% respectively. It could be seen from Fig.2 and Fig.3 that increasing gas flow and gas flow rate was favorable to the mass transfer process of H_2S from gas phase to liquid phase. The mass transfer of bio-trickling filter mainly occurred on the liquid membrane of the filler's surface. Thus to get good purification effect, there should be a good and large gas-liquid contact interface between two phase fluid. However, the removal rate began to show a downward trend when the gas flow over $1.0m^3/h$.

3.1.2 Effects of gas concentration on the removal efficiency of H_2S and NH_3

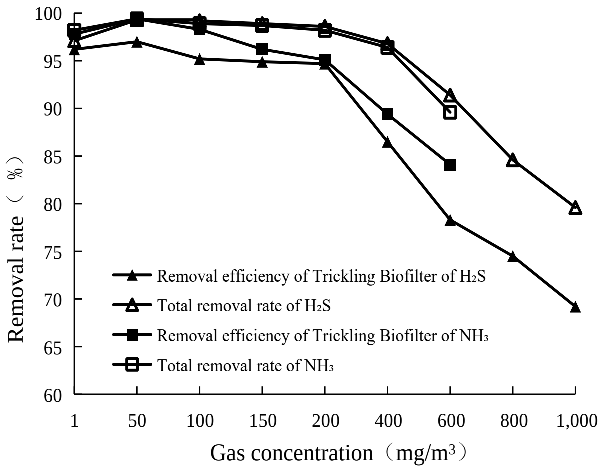

Fig. 4: The effects of gas concentration on the removal efficiency of H_2S and NH_3

When the gas flow was $1.0m^3/h$, spray amount of nutrient solution was 5L/h, the study investigated the effects on removal efficiency of H_2S and NH_3 with the concentration of NH_3 was $1\sim400mg/m^3$ and H_2S was $1\sim1000mg/m^3$. The results were shown in Fig. 4. When the concentration of $H_2S<54mg/m^3$ and the concentration of $NH_3<52mg/m^3$, the removal rate increased with the increase of the concentration. With the increasing of concentration, the removal rate of H_2S and NH_3 was stable, and the removal rates were in the range of 96% ~ 100% and 98% ~ 100% respectively. However, when the concentration of H_2S and NH_3 respectively exceeded 200 mg/m^3 and 100 mg/m^3, the removal rate decreased rapidly.

3.1.3 Effects of the spray amount of nutrient solution on the removal efficiency of H_2S and NH_3

When the gas flow was $1.0m^3/h$, aerated concentration of H_2S and NH_3 respectively was $10\sim50mg/m^3$ and $10\sim20mg/m^3$, the study investigated the effects of the spray amount of nutrient solution on the removal efficiency. The results were shown in Fig. 5. When the spray amount of nutrient solution was 5L/h, the removal effect reached the best. At this time, the total removal rates of H_2S and NH_3 respectively were 98.78% and 98.8%. There was a lowest water content in the treatment of foul gas by the composite biological filter tower, which makes the biofilter has a certain humidity. In fact, it was mainly related to the air input flow, humidity, temperature and the state of their own environment. Therefore, a proper spray

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amount of nutrient solution could ensure the necessary living environment of microorganism and maintain a high metabolic activity so that the reactor could maintain a high removal efficiency [20].

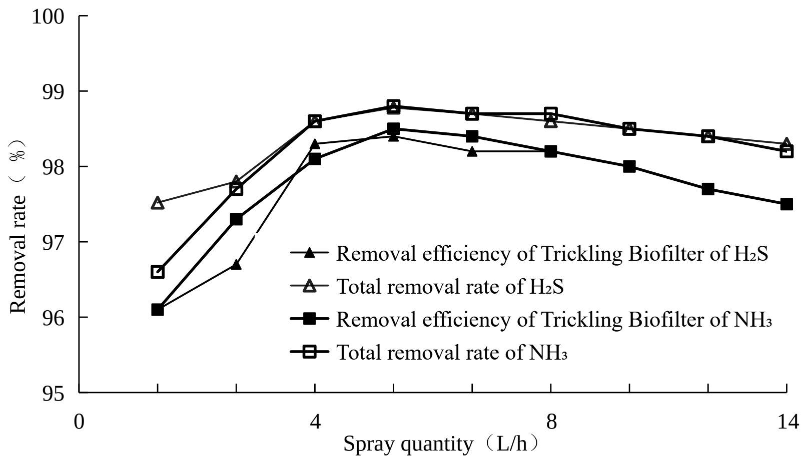

Fig. 5: The effects of the amount of nutrient solution spray on the removal efficiency of H_2S and NH_3

Effects of height of packing layer on the removal efficiency of H_2S and NH_3

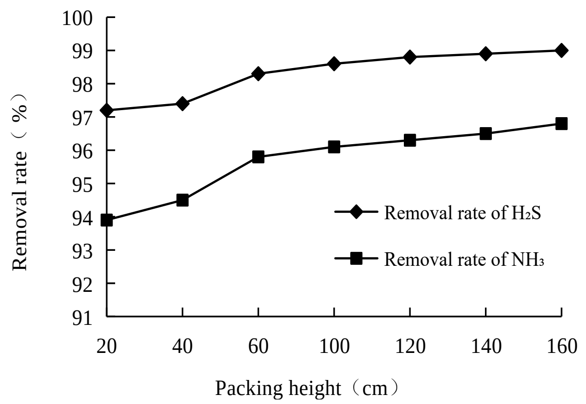

Fig. 6: The effects of height of packing layer on the removal efficiency of H_2S and NH_3.

When the gas flow was 1.0m^3/h, circulating flow was 5L/h, changed the filling height followed by 20cm, 40cm, 60cm, 80cm, 100cm, 140cm, 160cm, and then got the concentration of NH_3 and H_2S. The results were shown in Fig. 6. When the height of packing layer in the range of 20 ~ 60cm, the removal rate of gas increased gradually. When the packing layer height reached 60cm, the removal efficiency tended to be stable. In other words, at this time, the purification effect of fillers reached the best. Thus, 60cm was the best height for the bio-trickling filter and the biofilter to remove NH_3 and H_2S. Therefore, the optimum height of the composite biological filter tower was 120cm.

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3.1.4 Effects of pH on the removal efficiency of H_2S and NH_3

In the condition of temperature was 25℃, gas flow was 1 m^3/h, the spray amount of nutrient solution was 5L/h, the concentration of input H_2S was in the range of 0~500mg/m^3, the concentration of input NH_3 was in the range of 0~500mg/m^3, putting H_2S and NH_3 into the system simultaneously to investigate the effects of pH value on the removal efficiency of NH_3 and H_2S. The results were shown in Fig.7. It showed that the optimal range of pH value was 6.0~7.0 in the case of that NH_3 and H_2S was treated simultaneously. When the pH value was too large, the removal rates of NH_3 and H_2S were both reduced significantly. The optimal pH value of H_2S oxidation bacteria growth was between the neutrality and the partial acidity, but the optimal pH value of NH_3 degrading bacteria was in the neutral conditions. Therefore, it's bad for the remove of H_2S with the pH value was too low, and it was also bad for the remove of NH_3 and H_2S with the pH value was too high.

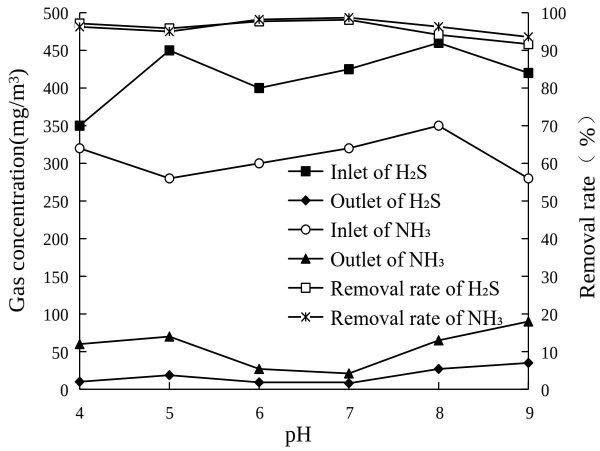

Fig. 7: The effects of pH value on the removal efficiency of H_2S and NH_3

3.1.5 Effects of residence time on the removal efficiency of H_2S and NH_3

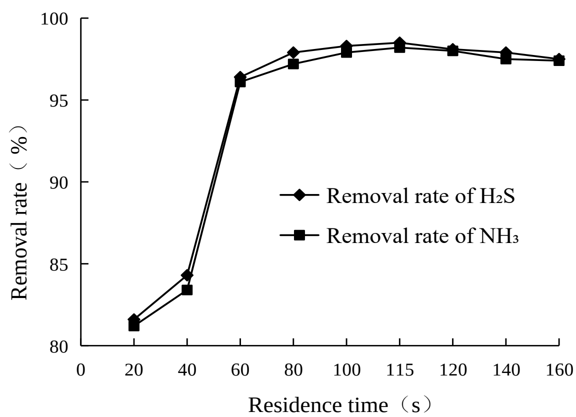

Fig. 8: The effects of residence time on the removal efficiency of H_2S and NH_3

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It could be seen from Fig. 8, when the residence time was 60s, the removal slop of H_2S and NH_3 achieved the maximum value and respectively were 96.4% and 96.1%. As time went by, the removal rate increased with low efficiency. Thus, the most ideal residence time was 60s.

3.2 The Experiment of Anti-Shock Loading

The anti impact load test refers to the reactor did not run in a period time (without H_2S and NH_3 and drop spray liquid), and then observe the purification capacity of reactor with putting H_2S and NH_3 into the system and dropping the spray liquid [21]. It could be drawn from Fig. 9, when the experimental device was started, the removal rate of H_2S was 10.2% and the removal rate of NH_3 was 23.4%, and then both of the removal rate showed a rapid upward trend. 60h later, the removal rate was improved significantly, and the removal rate of H_2S was 52.3% and the removal rate of NH_3 was 67.4%. 100h later, the removal rate of H_2S was 80.2% and the removal rate of NH_3 was 84.5%. In conclusion, the composite biological filter made the purification efficiency more than 80% in 4 days after 30 days of stop working, which showed that its resistance to shock loads was stronger.

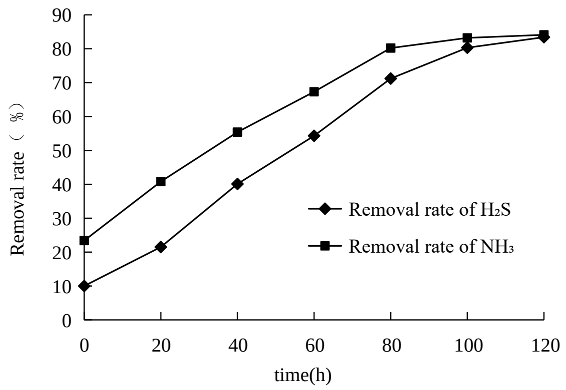

Fig. 9: The effects of the condition that the composite biological filter tower was restarted 30 days later on the removal efficiency of H_2S and NH_3

3.3 Analysis of Biological Phase of Composite Biological Filter Tower

According to the difference of gas composition and microbial living environment, such as temperature, humidity, pH value and so on, the microbial populations were also different. It was good for the growth of microorganism to contain the pH value in the range of 7~8. When the pH value in the range of 3~5, it was suitable for the growth of fungus. When the composite biological filter tower was stable, the growth of the bacteria was observed by high power microscope, and the results were shown in Fig. 10: there were main Bacillus subtilis and Vorticella growing on the filler of the biological filter tower. On the biological filtration tower, the mainly microorganism were Aspergillus candidus and Staphylococcus. The result showed that the growth environments of microorganism were different so that the types of microorganism on biological filter tower and biological filtration tower were also different. Culturing bacteria and fungus

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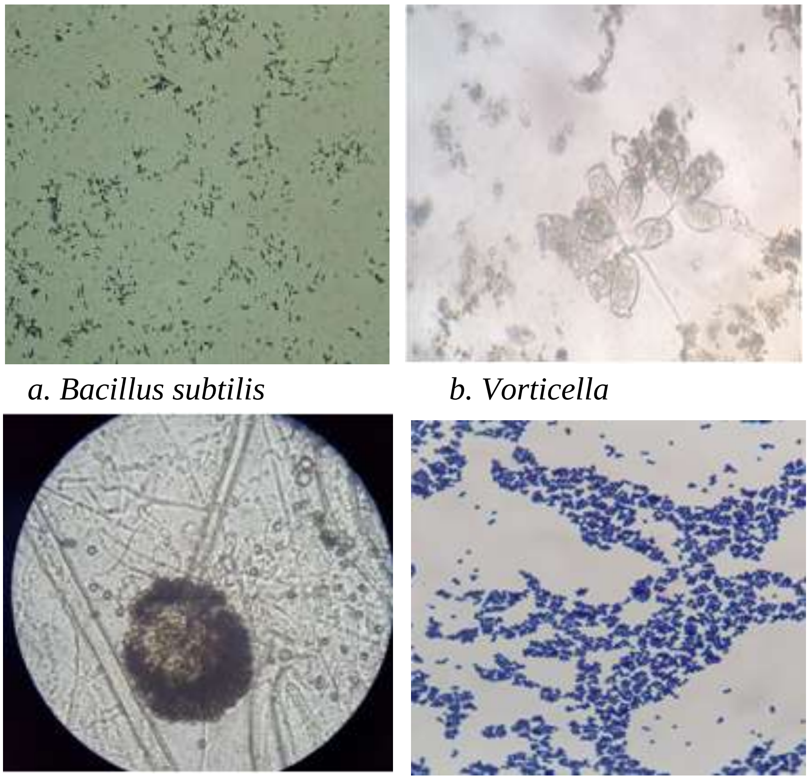
in separation was more beneficial to the growth and reproduction of microorganisms, which was more beneficial for the treatment of foul gas [22].



a. Bacillus subtilis *b. Vorticella* *c. Aspergillus candidus* *d. Staphylococcus*

Fig. 10: Bacteria and fungi in composite biological filter (1000×)

IV. CONCLUSIONS

In this study, it was feasible to use natural zeolite and wood chips as filler for the composite biological filter to purify the foul gas mixture of H_2S and NH_3. In the condition of the temperature was 25℃, air input was 1.0m^3/h, aerated concentration of H_2S was 10~50mg/m^3 and NH_3 was 10~20mg/m^3, the spray amount of nutrient solution was 5L/h, pH value was 6.0~7.0, the residence time was 60s, the removal efficiency reached the best, and the removal rate respectively was 98.1% and 97.8%. The composite biological filter made the purification efficiency more than 80% in 4 days after 30 days of stop working, which showed that its resistance to shock loads was stronger. According to the difference of gas composition and microbial living environment so that the microbial populations were also different. There were mainly Bacillus subtilis and Vorticella growing on the filler of the bio-trickling filter. On the biofilter, the main microorganism were Aspergillus candidus and staphylococcus. Culturing bacteria and fungus in separation was more beneficial to the growth and reproduction of microorganisms, which was more beneficial for the treatment of foul gas.

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