Analysis on the Effect of Spray Liquid Added with Sodium Thiosulfate on the Biological Purification of Formaldehyde Waste Gas

Shen Yan-Ping, Wang Jie, Sun Pei-Shi, Zhang Gen-Lin, and Bi Xiao-Yi

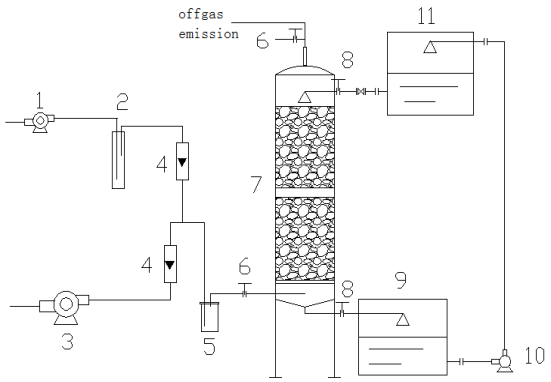
***Abstract*—It aimed to explore the effect of sodium thiosulfate on the removal of formaldehyde by adding sodium thiosulfate to the spray liquid. Experimental results were as follows: formaldehyde in the spray liquid could be removed maximumly when the sodium thiosulfate concentration was 0.05mol/L. When the formaldehyde concentration was 100 ~ 400mg/m3, with the increase of formaldehyde concentration, the group added with sodium thiosulfate had the highest removal efficiency of 99.8% and the highest biochemical removal amount of 13mg/(L ħ); When spray liquid flow was within the range of 5 ~ 20L/h, the effect of spray liquid flow on the formaldehyde removal was little, and the maximal removal efficiency of sodium thiosulfate was 99.5%, with maximal biochemical removal up to 7.85mg/(L ħ); When gas flow was in the experimental range of 0.05 ~ 0.25m3/h, and sodium thiosulfate removal efficiency of group with sodium thiosulfate was 99.6% ~ 99.9%, the biochemical removal amount increased with the increase of gas flow, and was higher than that in the blank control group. Pseudomonas, Methylobacillus, comamonas, Hyphomicrobium, Methylophilus, methylogenic lis and Cupriavidus were seen as the dominant microbial in sodium thiosulfate group. Adding appropriate amount of sodium thiosulfate in the spray fluid could remove formaldehyde in it effectively, promote the removal of biotrickling filter on formaldehyde emissions, so as to provide experimental evidence for the feasibility of sodium thiosulfate on biotrickling filter in the removal of formaldehyde in the future.**

***Index Terms*—Biotrickling filter, biochemical removal, formaldehyde removal efficiency, sodium thiosulfate;**

I. Introduction

Formaldehyde is a colorless, toxic, and strongly pungent odour, soluble in water [1]. Formaldehyde is usually found in aqueous solution, and 35 ~ 40 % of the formaldehyde solution is formalin [2], [3].When the temperature is low, the liquid phase formaldehyde is easy to be turbidity to form a tri-polyformaldehyde polymer. Formaldehyde is volatile mainly in the form of tri-formaldehyde, formaldehyde in the air will gradually oxidize to formic acid. The main harm of formaldehyde is embodied in three aspects: (1) stimulation: stimulation to mucous membrane of the skin effect. formaldehyde is toxic substances that can combined with proteins of virgin pulp, inhalation of high concentration of respiratory tract will be severely stimulus at the same time with edema, eyes sting, headache. (2) sensitization: the skin directly accepts formaldehyde can cause allergic dermatitis, color spot, necrosis, and formaldehyde can cause bronchial asthma. (3) mutagenic effect: high of formaldehyde concentration is a genotoxic substance, and in animal experiments [4], [5], high of formaldehyde concentration can cause nasopharyngeal tumor [6]. At present, formaldehyde is mainly used in the following aspects: (1) synthetic urea formaldehyde resin [7] and phenolic resin [8] in wood industry. (2) the production of fabrics in the textile industry, mainly through the addition of formaldehyde in order to achieve anti-wrinkle, anti-shrinkage, flame retardant effect or to maintain the durability of printing and dyeing [9], [10]. (3) formalin, which has antiseptic and antiseptic properties, and can be used to soak biological specimens and sterilize seeds. (4) the preservative properties of formaldehyde are used in the food industry, and food products such as aquatic products are added [11], [12].

Formaldehyde has great harm to the ecological environment and human health, and it has to attract people's attention. In order to minimize the damage of formaldehyde, researchers at home and abroad are looking for ways to degrade formaldehyde pollutants. Formaldehyde purification treatment technology mainly includes: the physical and chemical adsorption, chemical neutralization processing technology, photocatalysis oxidation treatment technology, nanometer materials catalytic oxidation technology and biotrickling filter processing technology, etc. [13]-[18]. Among them, the biotrickling filter is proved to be the most effective and feasible.



1.Air pump 2.Formaldehyde bottle 3.Fan 4.Gas flow controller 5. Mixing gas bottle 6.Gas sampling point 7.Packing absorption tower 8. Liquid sampling point 9.Low groove 10.Circulating water pump 11.High groove
Fig. 1. Flow chart of biotrickling filter.

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This project by biotrickling filter processing formaldehyde emission technology as the research object, In view of the difficulty that biotrickling filter couldn't purify formaldehyde exhaust gas effectively [19], [20], appropriate amount of sodium thiosulfate was used as spray liquid in the paper to study the effect of biotrickling filter on the purification of formaldehyde.

II. Experiment Equipment and Methods

Two packing towers were used in this experiment, and the two tower structures were identical as shown in Fig. 1. Tower 1 was a blank group, no sodium thiosulfate was added in the spray. Tower 2 was the experimental group, and 0.05M (mol/L) of sodium thiosulfate was added in the spray. The experimental device was a glass tube with an inner diameter of 85 mm, with a diameter of 10 mm as a filler. The height of the packed tower was 950 mm, with two floors up and down, 500 mm upper and 450 mm lower. The total volume of packing is 5.1dm3.

The experiment adopts the gas-liquid countercurrent operation [21]. The liquid was the spray liquid containing nitrogen and phosphorus nutrients, which was poured down from the top trough to the lower trough from top to bottom, and then the water pump was pumped back to the high tank for recycling. Gas was to use the pump into the gas bottle containing 38% formalin, cheerily make formaldehyde from the bottom into the packed tower with the spray liquid after combination, from the bottom up contact with the wetting of biofilm to be purged, final purification standard of the gas was removed from the top tube.

The experiment was carried out at room temperature and under normal pressure. In the experimental process, the gas phase formaldehyde was mainly collected by the QC-2A atmosphere sampler,and the liquid phase formaldehyde was collected from spray liquid. The collected gas phase and liquid phase formaldehyde samples were determined by acetyl acetone colorimetry [22]-[25], and 722 visible spectrophotometer analysis and test, which the test wavelength was 413mm.

III. Results and Discussion

A. Effect of the Formaldehyde Concentration

The gas concentration of biofilm packed tower was an important parameter to determine the operation load of biotrickling filter. Experimental conditions, gas flow rate of 0.15 m3/h, spray liquid rate of 10 L/h, formaldehyde concentration in 100 mg/L ~ 400 mg/L range change, and the effect of formaldehyde concentration on formaldehyde removal efficiency and biochemical removal of formaldehyde emission was studied. The results were shown in Fig. 2 and Fig. 3.

The results were shown in Fig.2. The formaldehyde concentration was 100 ~ 400 mg/m3, sodium thiosulfate group was better than blank group in overall removal efficiency, blank group and sodium thiosulfate group were maintained at a higher level in formaldehyde removal efficiency. With the increase of formaldehyde import concentration, the removal efficiency of formaldehyde first increases and then decreases. When the concentration of formaldehyde in the blank group was 225mg/L, the removal efficiency was 99.6%. The removal efficiency of sodium sulphate group was 99.8%.

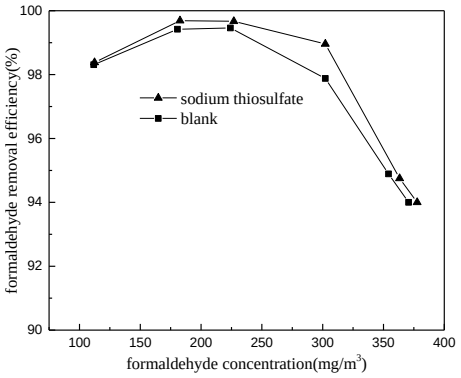

Fig. 2. Effect of formaldehyde concentration on formaldehyde removal efficiency.

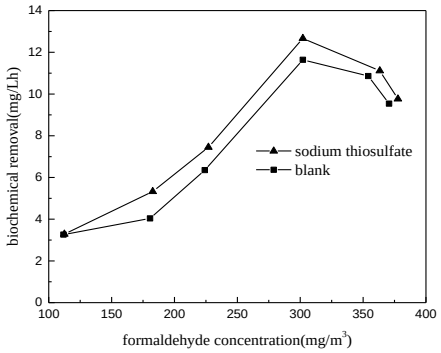

Fig. 3. Effect of formaldehyde concentration on formaldehyde biochemical removal.

From Fig. 3 results were shown that the blank group, biochemical removal of sodium thiosulfate group almost the same change trend, shows affected by the concentration of the two groups are consistent, biochemical removal of blank group amount up to 11 mg/(L h); Biochemical removal of sodium thiosulfate group was 13mg/(L h).Result analysis shows that with the increase of concentration of formaldehyde, the removal efficiency of formaldehyde have rise after the fall. The main reason was that the chemical reaction rate was relate to initial concentration, and the increase of formaldehyde concentration must increase the positive reaction of the reaction, and promote the biochemical degradation capacity of formaldehyde. But as the concentration of formaldehyde increases, the burden on the microbes was increasing, and the absorption and degradation of formaldehyde in the biotrickling filter are decreased. Finally, the biochemical removal rate of the biotrickling filter was reduced.formaldehyde removal efficiency and biochemical removal of sodium thiosulfate group was batter than blank group, the results confirmed that the sodium thiosulfate of formaldehyde has the very strong removal effect of spray, also verified using sodium thiosulfate strengthening biotrickling filter formaldehyde waste gas purification performance of the new method was feasible.

B. Effect of the Spray Liquid Flow

As formaldehyde was easily soluble in water, spray flow will be a very important operational control condition. The formaldehyde concentration was 200 ~ 250 mg/m^3, gas flow rate was 0.15 m^3/h, spray liquid was set to 5 L/h, 10 L/h, 13 L/h , 16 L/h, 20 L/h, and the effect of spray flow on formaldehyde removal efficiency and biochemical removal of formaldehyde emission was studied. The results were shown in Fig. 4 and Fig. 5.

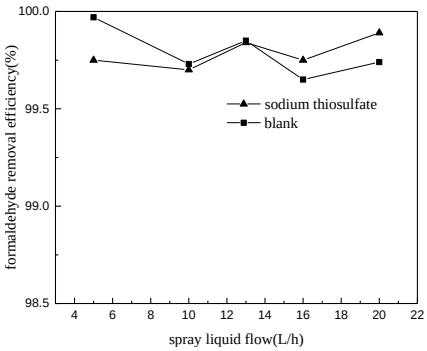

Fig. 4. Effect of spray flow on formaldehyde removal efficiency.

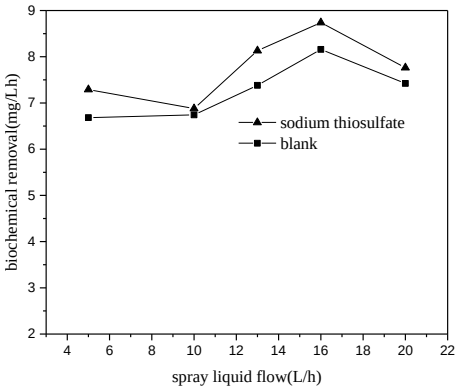

Fig. 5. Effect of spray flow on formaldehyde biochemical removal.

From Fig. 4, the spray liquid flow within the scope of 5 ~ 20 L/h, the removal efficiency of the blank group and sodium thiosulfate group were kept at more than 99.5%. The amount of spray liquid has little effect on the formaldehyde removal efficiency.

The Fig. 5 shows that the spray flow rate increased from 5 to 10 L/h, biochemical removal of the blank group amount remains the same. When the spray flow increased to 16L/h, the amount of formaldehyde biochemical removal increased, reaching 7.8mg/ (L ћ). After that, the spray flow continued to increase to 20L/h, and the amount of formaldehyde biochemical removal decreased.

Sodium thiosulfate group, the flow increased from 5 to 10 L/h, reduced the volume of formaldehyde removal, spray flow rate increases to 16 L/h, the quantity of formaldehyde removal increased and up to 9 mg/(L ћ), traffic continued to increase, biochemical removal amount reduced.

The main function of spray fluid was to moisten the biofilm and provide nutrients to the microflora. The biochemical removal of sodium thiosulfate group was better than that of blank group, which confirmed that sodium thiosulfate had a strong purification effect on formaldehyde in spray liquid. However, when the spray liquid fluid flow reaches a certain amount, the excessive flow will rush to some biofilms, which will reduce the degradation of the microorganisms to formaldehyde. The effect of spray flow on formaldehyde purification was not significant. In summary, sodium thiosulfate promotes the purification of formaldehyde.

C. Effect of the Gas Flow

Since formaldehyde functional bacteria is a good aerobic microorganism, the gas flow of biofilm packed tower is a very important operating control condition. Experimental conditions for the gas phase of formaldehyde concentration in about 200 mg/L ~ 250 mg/L range, spray liquid flow rate of 10 L/h, gas flow were set to 0.05 m3/h, 0.1 m3/h, 0.2 m3/h, 0.3 m3/h, 0.4 m3/h. The effect of gas flow on formaldehyde removal efficiency and biochemical removal of formaldehyde emission was studied. The results were shown in Fig. 6 and Fig. 7.

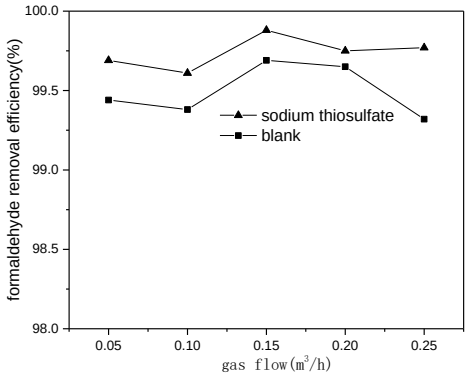

Fig. 6. Effect of gas flow on formaldehyde removal efficiency.

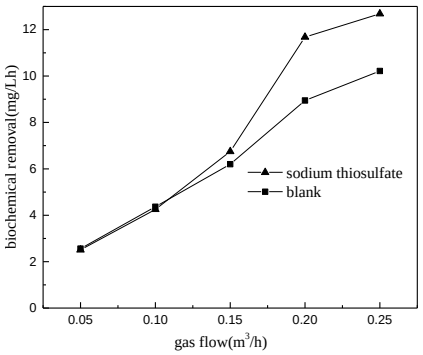

Fig. 7. Effect of gas flow on formaldehyde biochemical removal.

It can be seen from Fig.6. In the range of 0.05 ~ 0.25 m3/h, both the blank group and the sodium sulfate group were maintained at a high level, and the blank group was 99.3% ~ 99.6%. Sodium thiosulfate group was maintained 99.6% ~ 99.9%. Gas flow within the scope of 0.05 to 0.15 m3/h, the blank group and sodium thiosulfate formaldehyde removal efficiency increases, when the gas flow rate is 0.15 m3/h, blank group formaldehyde removal efficiency up to 99.6%, sodium thiosulfate group was 99.9%; The gas flow continued to increase, and the formaldehyde removal efficiency of formaldehyde in the blank group decreased continuously. The gas flow increased to 0.2 m3/h, the formaldehyde removal efficiency of sodium thiosulfate group was 99.7%, and the gas flow continued to increase, and the formaldehyde removal efficiency was still 99.7%.

It can be seen from Fig.7 that the amount of biochemical removal of the blank group and sodium thiosulfate group increases with the increase of gas flow in the range of 0.05 to 0.25 m3/h. Gas flow rate from 0.05 to 0.1 m3/h, the blank

group and sodium thiosulfate removal volume, gas flow within the scope of 0.1 to 0.25 m3/h, and biochemical removal amount higher than the blank group, sodium thiosulfate and sodium thiosulfate effect on gas flow formaldehyde degradation effect is very good.

By experiment result, The two groups showed an increasing trend of biochemical removal. The main reason is that as the gas flow increases, the content of oxygen in the liquid phase increases, which is beneficial to the growth of aerobic dominant population, and the amount of formaldehyde was increased. And, with the increase of gas flow rate, gas liquid mixed degree increase, increasing the mass transfer process of formaldehyde from gas phase into the liquid phase, the reasons of the formaldehyde concentration in liquid phase contac tbetter with biofilm. In the range of 0.1 ~ 0.25 m3/h, the biochemical removal amount of sodium sulphate was higher than that of the blank group, which further proved that sodium thiosulfate had a strong removal effect on liquid phase formaldehyde in spray liquid.

D. Identify the Dominant Microflora Structure

During the suspension of the packing tower, the ceramic particles were taken once every two weeks (Sample three times, named h_{21}、h_{22}、h_{23}), and sent to Shanghai Sangon. The results were shown in Fig. 8.

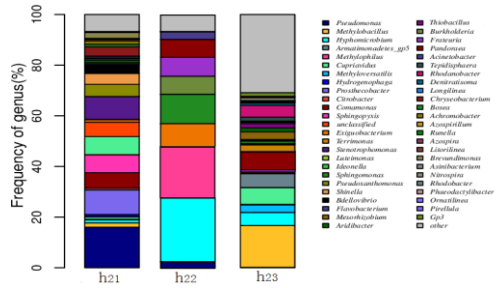

Fig. 8. Species richness at the genus level.

From the Fig. 8, it was concluded that pseudomonas is the most in the h21; In the h22, Hyphomicrobium was highest proportion and the most contentthe, secondly, Methylophilus has a higher proportion; There was more Methylobacillus and little Hyphomicrobium in the h23. From the above, Biotech for a high-throughput 16SrDNA identification. The results were showed that Pseudomonas [21]-[22], Methylobacillu[s] [23]-[25], comamonas, Hyphomicrobium, Methylophilus, methylogeniclis and Cupriavidus were seen as the dominant microbial populations of sodium thiosulfate group from the distribution and content of each sample.

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