Biofiltration of Air Streams Contaminated Hydrogen Sulfide : Performance Evaluation of Different Carriers

Gwi-Taek Jeong[1], Gwang-Yeon Lee[4], Kyoung-Min Lee[1],
Jin-Myoung Cha[5], Yung-il Joe[6], Don-Hee Park[1,2,3]
[1]School of Biological Science and Technology,
[2]Faculty of Applied Chemical Engineering,
[3]Institute of Bioindustrial Technology, Chonnam National University,
Gwangju, 500-757, Korea
[4]Dept. Ophthalmic Optics, Dong-A College, Jeonnam, 526-872, Korea
[5]B & E Tech Co. Ltd., Jeonnam, 519-831, Korea
[6]Dept. of Chemical Engineering, Yonsei University, Seoul 120-749, Korea
TEL: +82-62-530-1841, FAX: +82-62-530-1909

Abstract

The objective of this study was to develop a removal process by which H_2S could be biologically removed from the odoriferous gases generated in the waste food recycling process. In order to develop this process we were first required to select a proper biofilter support protocol. When the selected biofilter equipment was then tested using a synthetic odoriferous gas containing 600 ppm of H_2S, we noted a maximal removal rate of 658 g-H_2S/m^3·hr, using polypropylene fibrils as supporting materials. Under identical experimental conditions, we obtained a value of 411.2 g-H_2S/m^3·hr, using polyurethane as a support material. We also conducted a trial in which volcanic stone was utilized as a support material, and in this trial, we logged a maximal 105.1 g-H_2S/m^3·hr removal rate. As the result of our experiments, we concluded that polypropylene fibrils constituted the ideal material for the removal of H_2S gas via biological treatment.

Introduction

The volatile organic compounds (VOCs) and sulfur compounds can be controlled by a host of chemical, physical, and biological techniques, including incineration,

adsorption, chemical scrubbing, bioscrubbing, and biofiltration. Within the past two decades, biological treatment processes, including bioscrubbers, trickling beds, and biofilters have been employed in the successful control of VOCs and odors. Biofiltration has been shown by several researchers to be effective with regard to the removal of alcohols, toluene, phenol, ketones, hydrogen sulfide, petroleum fuel vapors, and other VOCs. Recently, the simultaneous treatment of one or more VOCs via biofiltration has been demonstrated. Many industrial emissions contain mixtures of VOCs, which may exhibit different physical and chemical characteristics, which affect the degree to which biological treatments prove effective in their removal. The packing material within the biofilter functions as a carrier of microbes, nutrients, and water. The performance of the biofilter remains highly dependent on the nature of the carrier, which is also referred to as the support or packing material, or the filter bed. Many different packing material types have been used in this system, including natural materials, inert compounds, and mixtures of both. The packing material must possess a number of characteristics in order to ensure the maximum performance of the biofilter. These characteristics include: a high specific surface area for gas contact; high immobilization of microbes; high water-retaining capacity; air permeability; easy removal of deodorization waste, and low cost. In addition, the carrier must be highly durable, with no clogging/blocking or pressure drops in the packed bed occurring during operation. Currently, a variety of carriers are in use which satisfy these characteristics. The objective of this research, then, was to select an appropriate packing material, and to determine the effectiveness of H_2S in biofilters that had been packed with three different packing materials. Our experimental results are focused on the performance of the carrier of the biofilter operating under transient operating conditions during the start-up period, and following a set of step changes in the biofilter inlet loads.

Materials and Methods

The biofilter was inoculated with a microbial consortium, composed primarily of three microbes (*Pseudomonas* sp. TKC, *Pseudomonas* sp. AKC, and *Geotrichum* sp. MKC) which had been isolated from industrial contaminated fields and *Thiobacillus*

sp. IW. The nutrients for the growth and maintenance of the microbes in the biofilter were supplied with a Minimal Salt Medium (MSM) solution, which contained KH_2PO_4 1.50 g/L, Na_2HPO_4 6.00 g/L, $(NH_4)_2SO_4$ 3.00 g/L, $MgSO_4$ 0.05 g/L, $CaCl_2$ 0.01 g/L, and this medium was adjusted to pH 7.0.

Operation and construction of biofilter

The biofilter was constructed from a transparent acryl tube, with an inner diameter of 9.4 cm, and a bed length of 25 cm. A pore plate was installed in the bed of the support carrier. The biofilter was operated at a temperature of 25~35℃. Inlet gas was introduced into the bottom of the biofilter, and then was allowed to pass out the upper portion of the biofilter. Exhaust gases were emitted after the passing through of a NaOH absorption solution for the removal of residues. In order to supply the necessary nutrients to the microorganisms, we periodically fed the system with a nutrient solution, using a peristatic pump. We also sprayed water into the system, in order to protect the biofilter bed from drying at the upper nozzle of reactors. Water was sprayed at 2-4 hour intervals. The inlet gas was prepared via the mixing of H_2S with the air-flow, and the inlet concentration and amount were controlled via MFC and a flow meter. Samples were collected from the upper and bottom portions of the assembly, as well as each of the sampling ports of the biofilter, then analyzed. Gas samples were collected from the inlet and outlet streams, and axially along the length of the biofilter. In this study, we applied hydrogen sulfide to the biofilter system. The EBCT of the biofilter was controlled to 60-5 seconds, in order to facilitate the growth of a biofilm, and then the inlet loading was also controlled. To prepare the biofilter packing material, we used polyurethane (PU), polypropylene fibrils (PP fibrils), and volcanic stone (VS) as carriers in our experiments. The biofilter was inoculated with a microbial consortium, which was enriched as was described in a previous report.

Hydrogen sulfide gas was collected at both the inlet and the outlet of the biofilter system. At a concentration of H_2S below 50 ppm, we used a hydrogen sulfide detector. At a concentration greater than 50 ppm, we used a gas detector. Also, gas chromatography was applied to the detection of H_2S in the inlet/outlet streams.

Results and Discussion

Removal of H_2S to inlet concentration

The degree to which odoriferous compounds were emitted from the system was determined to vary with the physical and chemical properties of the compounds. Thus, these odoriferous gases can be controlled and modulated via chemical, physical, or biological techniques. In particular, gases with a high concentration and a low flow rate could be adequately and economically treated via both physical and chemical processes. However, the treatment of low concentration and high flow rate gases via physical/chemical process was also associated with a sharp increase in cost.

The removal characteristics and yields of the tested H_2S gases were observed with the use of several different packing materials within separate biofilter systems (Fig. 1). The H_2S removal efficiency was clearly higher when using PP fibrils as a packing material than when using polyurethane or volcanic stone, under conditions of constant flow and varying inlet concentrations. The H_2S elimination capacity of the system with different carriers is compared in Fig. 1. According to our results, further research into H_2S removal will be conducted using PP fibrils as a packing material.

Removal of H_2S to inlet load

The maximum elimination capacity of a biofilter is referred to as the maximum load, which the system can sustain without any inhibition of microbial activity. This variable is expressed by the same units as is inlet load. These parameters are different under different operation conditions, as well as different types of biofilter packing materials. These parameters, then, were also used as key factors in the design of an optimal biofilter. In this paper, in order to determine H_2S removal characteristics according to changes in the inlet flow rate (changes in retention time), we created biofilters using different packing materials, and also ensured a constant H_2S concentration in the inlet stream, while incrementally changing the flow rate in the inlet stream. According to our results (Fig. 1), the maximum elimination capacity was set to above 95% removal efficiency, as shown by the

graph of maximum inlet load vs. elimination capacity. In accordance with this concept, the PP fibrils remained in a non-saturated condition at an inlet load of above 400 $g/m^3 \cdot hr$, but the other packing materials had long since become saturated at such conditions. In order to compare the removal efficiency of several packing materials in the biofilters, H_2S gas was introduced into the biofilter at a concentration of 250 ppm, via an incremental change in the flow of the inlet stream, at a 0–60 sec retention time for each packing material.

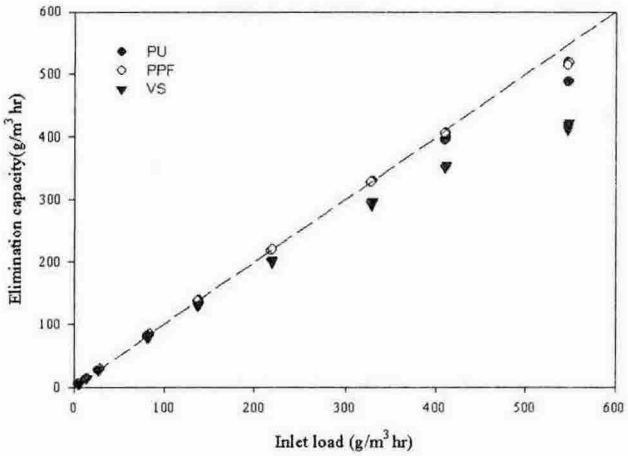

Fig. 1. Inlet load vs. elimination capacity of H_2S at varying media.

Fig. 2 shows the H_2S removal efficiency and elimination capacity using different packing materials. When using the polyurethane and PP fibrils, decreases in the retention time did not greatly affect H_2S removal efficiency, whereas, when using the volcanic stone as a packing material, the H_2S removal efficiency decreased abruptly. At an H_2S inlet concentration of 600 ppm, with the set changes in the inlet flow rate, and different packing materials, polyurethane, PP fibril, and volcanic stone, we determined a maximum elimination capacity of 411.2 $g\text{-}H_2S/m^3 \cdot hr$, 658 $g\text{-}H_2S/m^3 \cdot hr$, and 105.1 $g\text{-}H_2S/m^3 \cdot hr$, respectively. With regard to our comparison of different packing materials at 10 seconds of retention time, the polyurethane and PP fibrils were found to remove the malodorous gases completely. However, the volcanic stone demonstrated a removal efficiency of only 90%. These results also reflect the fact that the specific surface area, which bears

great import with regard to the attachment and growth of microbes growth, was far higher in the PP fibrils than in the polyurethane or the volcanic stone. In conclusion, the PP fibrils clearly possessed several advantages as a packing material, as compared to polyurethane or volcanic stone. The PP fibrils exhibit a high adsorption ability, excellent physical/chemical removal efficiency, and high endurance with regard to shock load. Also, the fact that the PP fibrils cannot be degraded by microbes results in a long life-time for the system, and a low pressure drop results from the high permeability of the material.

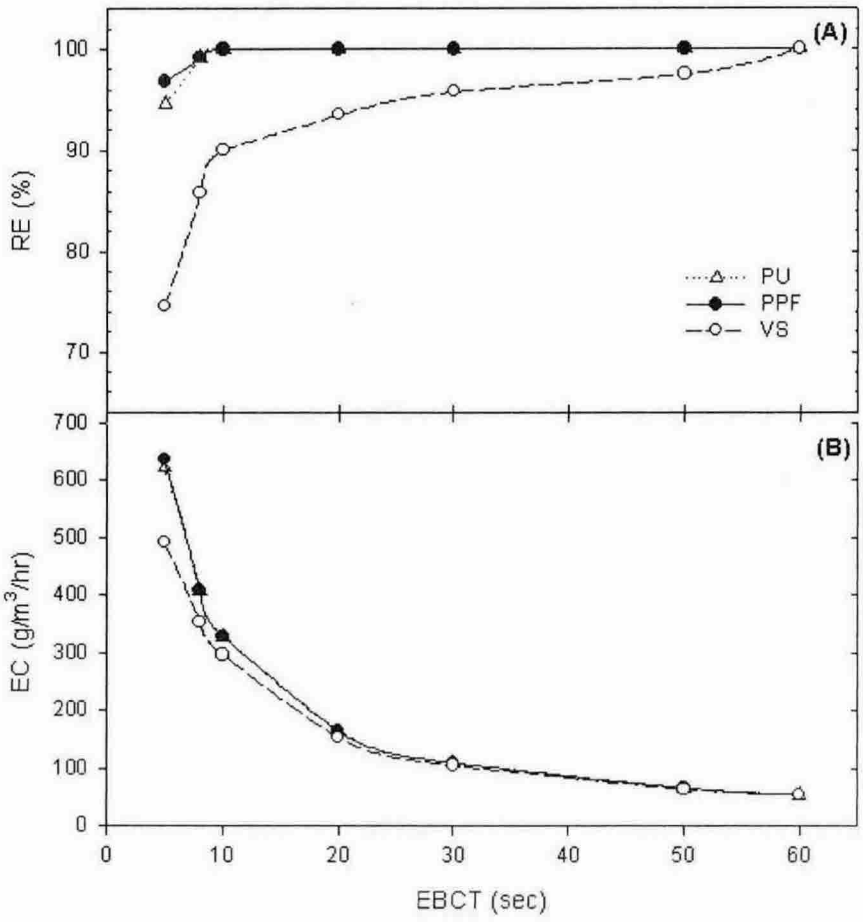

Fig. 2. Changes in removal efficiency and elimination capacity with changes in inlet loading.

(A) Removal efficiency, (B) Elimination capacity.

Acknowledgments

This research was financially supported by the Program for the Training of Graduate Students in Regional Innovation, which was conducted by the Ministry of Commerce Industry and Energy of the Korean Government.

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