Removal of hydrogen sulfide using upflow and downflow biofilters

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ABSTRACT

The objective of this study was to determine the efficiency of different types of biofilters for hydrogen sulfide removal. The study consisted of two parts. The first part compared the hydrogen sulfide removal efficiency among four different biofilter media comprising compost, bamboo fluff soil, lava rock and activated carbon. The test columns were filled with each of the filter media together with coconut shell fiber to increase void as well as nutrient and microorganism seed. All four biofilters were subjected to empty bed residence time of 45, 60 and 75 seconds and hydrogen sulfide concentration ranged from 50 – 300 ppm. The experiment was run at room temperature (26-33 °C), while the filter moisture was controlled between 60-70%. The measured parameters included gas flowrate, inlet and outlet gas concentration, pressure drop, temperature, moisture, pH, microorganism count, organic matter contents and sulfate contents. The results showed that the compost media could achieve the removal efficiency of 100% with gas inlet concentration of 300 ppm when the height of filter was 1 meter and empty bed residence time was 45 seconds. However, other filter media needed height of filter more than 1.25 meter. Compost, bamboo fluff soil, lava rock and activated carbon achieved the maximum elimination capacity of 122, 111, 72 and 108 g/m^3-hr, respectively. The compost was found to be the best biofilter medium and was used in the second part of the study to examine the influence of gas flow direction by comparing the removal efficiencies between upflow and downflow biofilters. This study varied the empty bed residence times of 25, 50 and 75 seconds and hydrogen sulfide concentration was fixed at 300 ppm while other conditions remained as before. It was found that both biofilters could still achieve 100% removal efficiency with residence time as low as 25 seconds if the filter depth was increased to 1.5 meter. The downflow biofilter had removal efficiency similar to upflow biofilter, but slightly less when the filter depth was 1 meter and the empty bed residence time was only 25 seconds.

1 INTRODUCTION

Hydrogen sulfide gas is harmful to health. It is highly odorous and highly toxic. The gas can be found in industrial area and wastewater treatment plant. Hydrogen sulfide gas from industry come from industrial processes such as oil refinery, food processing, and pulp industry for example. The concentrations of hydrogen sulfide from the mentioned industrial processes are in the range of 5-70 ppm and can be as high as 300 ppm (Barona *et al*., 2004). U.S.A. and Thailand limit allowable concentration of hydrogen sulfide gas at 20 ppm and maximum concentration averaging 10 minutes at 50 ppm (OSHA, 2005).

Control of hydrogen sulfide gas can be achieved by activated carbon adsorption, ozone oxidation and incineration (Ying *et al*., 1996). Presently, there is an interest in using biofilter to treat hydrogen sulfide gas. The method has an advantage over physical and chemical treatment because there is little maintenance and low operating cost while yielding high treatment efficiency. Past research works show that the preferred filter media are compost, peat and soil (Hartlikainen *et al*., 2001; Bohn and Bohn, 1988). It was also observed that lowering retention time led to lower efficiency and lower treatment capacity (Elias and Barona, 2002). Operation of the system over a long period caused a drop in pH of the media and lower treatment efficiency (Oyarzun *et al.*, 2003). The optimum moisture content of the media is around 60%, humidity of air should be higher than 98% and pH of the media should be in the range of 6-8 (Devinny *et al*., 1999).

This research has an objective to study the efficiency of biofilter in removing hydrogen sulfide gas and determine suitable filter media and optimum operating conditions comparing upflow and downflow biofilter.

2 MATERIALS AND METHODS

The experiment used a laboratory scale biofilter made from acrylic column diameter 0.054 meter, 2.00 meters high, filled with media 1.50 meter with total volume of 3.43 liters (Figure 1). Other accessory equipment included hydrogen sulfide gas generator and air humidifier. The experiment compared four filter media, which were compost, bamboo fluff, lava rock and activated carbon. Additional media were bio-sludge from municipal wastewater treatment plant served as microorganism seeds, chicken manure served as nutrients, and coconut shell to increase void. The mixing ratio for main filter media : coconut shell : manure : sludge were 60 : 20 : 10 : 10 by volume. The physical properties of the media are shown in Table 1.

The experiment consisted of 2 stages. The first experiment employed an upflow filter to compare different filter media and study optimum operating conditions. The second experiment compared an upflow filter to a downflow filter using the most suitable filter media and maximum load (Table 2). The experiments were conducted at room temperature (26-33 °C), control air humidity between 70-80%, and varied hydrogen sulfide concentration between 50-300 ppm and retention time between 25-75 seconds.

Parameters to be investigated include Empty Bed Residence Time - EBRT, Mass loading, Removal efficiency, and Elimination capacity. List of measuring instruments are shown in Table 3.

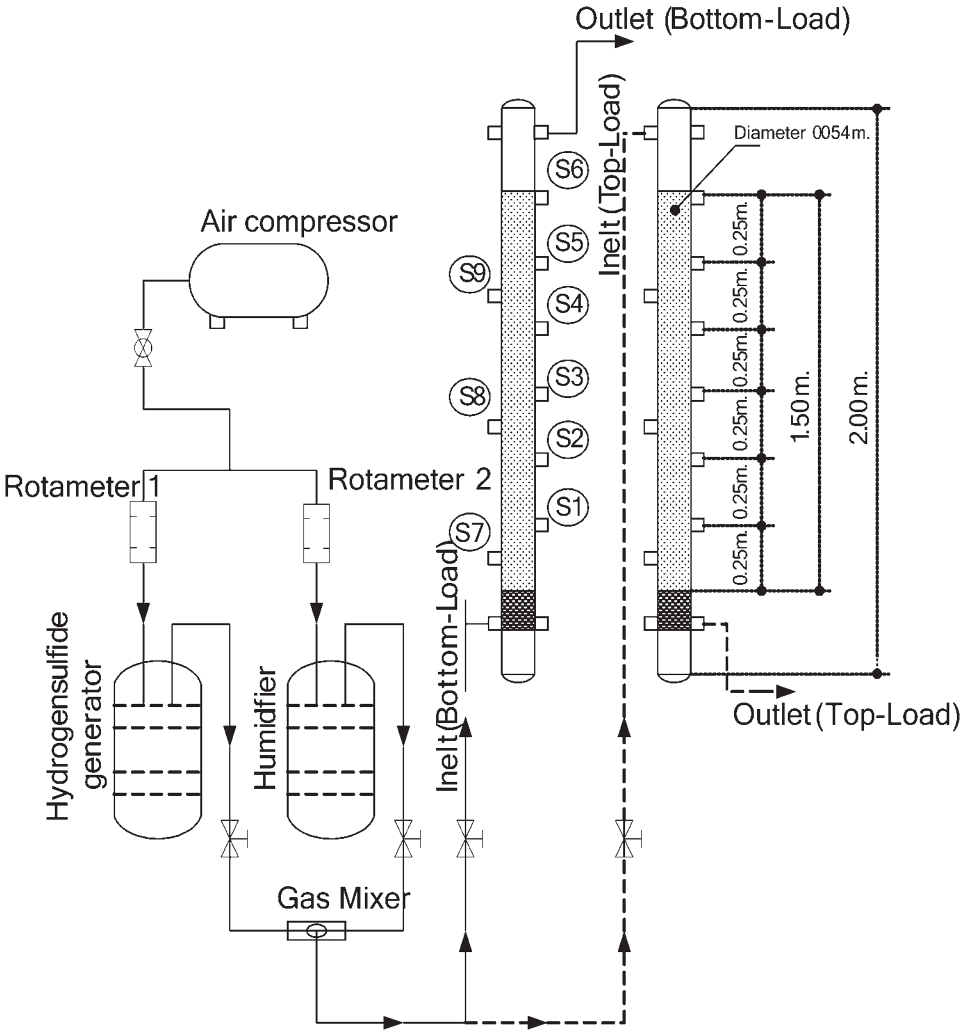


Figure 1. Diagram of biofilter apparatus experimental setup.

Table 1.
Properties of filter media.

Parameters	Compost	Bamboo fluff	Lava rock	Activated Carbon
Particle diameter d_{50} (mm)	0.35	2.00	4.35	1.70
Density (g/cm^3)	0.60	1.15	0.88	0.64
Void (%)	50.04	62.57	59.24	49.98
Moisture content (%)	29.97	6.39	0.71	10.20
pH	8.12	7.82	6.82	9.21

Table 2.
Experimental plan.

Run	Day	Retention time (sec)	Gas flowrate (liter/min)	H_2S concentration (ppm)
Start – up	1 - 20	90	2.29	50
1	21 – 35	75 - 45	2.74 - 4.58	50
	36 – 50	75 - 45	2.74 - 4.58	100
	51 – 65	75 - 45	2.74 - 4.58	200
	66 – 80	75 - 45	2.74 - 4.58	300
2	81 - 95	75 - 25	2.74 - 8.23	300

Table 3.
List of measuring instruments.

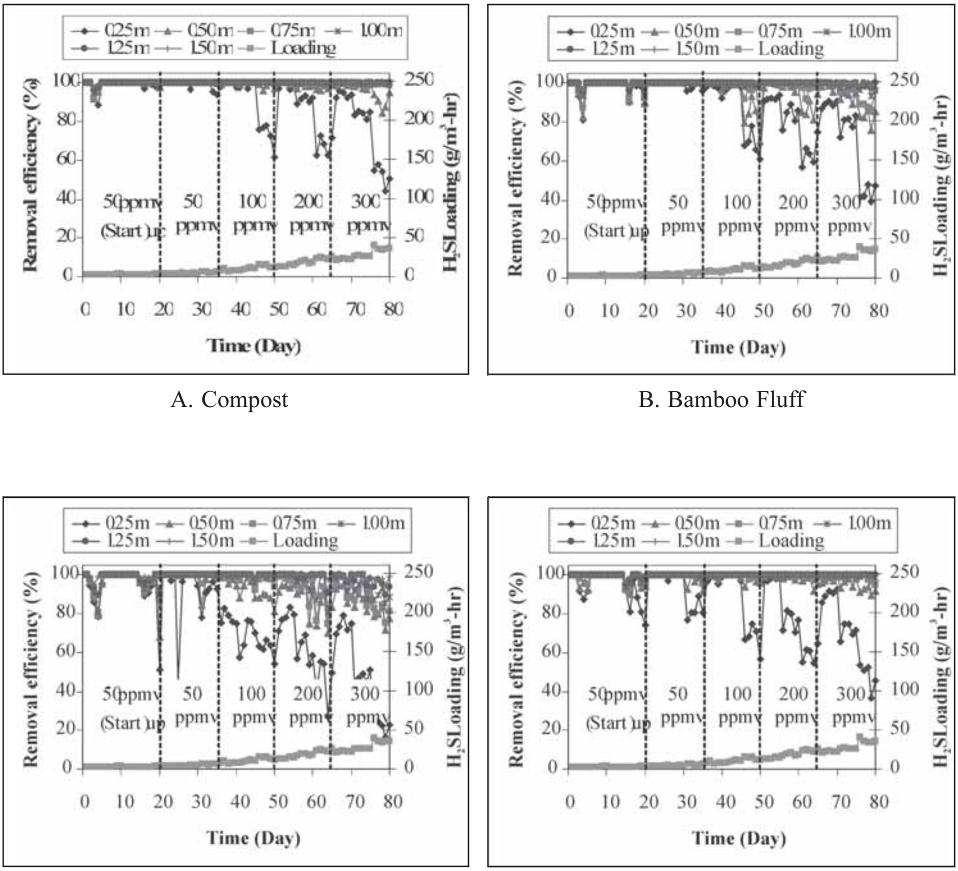
Parameters	Instruments / Model
H_2S concentration	VOCs Analyzer/MiniRAE2000
Pressure drop	Manometer/Dwyer
Relative humidity	Hygrometer/Barigo
Gas flowrate	Rotameter/Dwyer
pH of media	pH meter
Moisture content of media	Moisture meter
Temperature of media	Thermometer

3 RESULTS AND DISCUSSION

Comparison of the four types of filter media under variable loading ranging from 3 - 34 g/m^3-hour and retention time between 45-75 seconds showed that for all four filters hydrogen sulfide removal efficiency decreased as the load increased. However, the compost media yielded best efficiency and could still retain 100% efficiency at the media height of 1.00 meter while being subjected to hydrogen sulfide concentration 300 ppm and 45 seconds retention time. On the other hand, other filter media need height of media at least 1.25 meter to achieve the same efficiency (Figure 3).

Maximum elimination capacity and Critical loading of each filter can be derived from the relationship between elimination capacity and loading as shown in Figure 4. The compost filter had highest maximum elimination capacity at 122 g/m^3-hour followed by bamboo fluff, activated carbon and lava rock at 72 g/m^3-hour (Table 4). The compost filter also had highest critical load at 64 g/m^3-hour followed by bamboo fluff, activated carbon and lava rock at 22 g/m^3-hour.

The second experiment was to determine the influence of gas flow direction using compost filter, which was the best filter media and varied retention time between 25-75 seconds and increase the loading to 20 - 60 g/m^3-hour. It was shown that for both filters hydrogen sulfide removal efficiency decreased as the load increased. The downflow filter had removal efficiency similar to upflow filter, but slightly less when the filter depth was only 1.0 meter and the EBRT was only 25 second (Figure 5). However, both filters could still achieve 100% removal efficiency with residence time as low as 25 seconds if the filter depth was increased to 1.50 meter (Figure 6). It can be concluded that the biofilter can be operated using both upflow and downflow configuration and still achieve 100% removal efficiency using a proper loading and adequate filter depth.



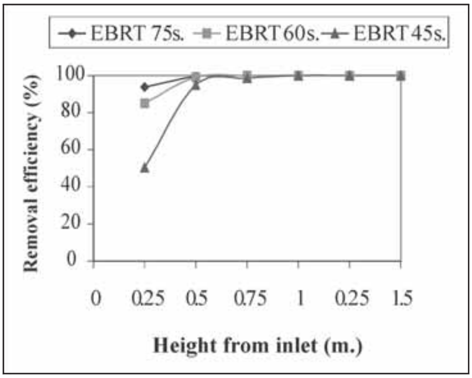
A. Compost

B. Bamboo Fluff

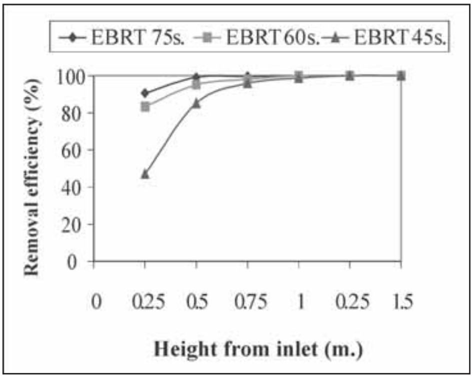
C. Lava Rock

D. Activated Carbon

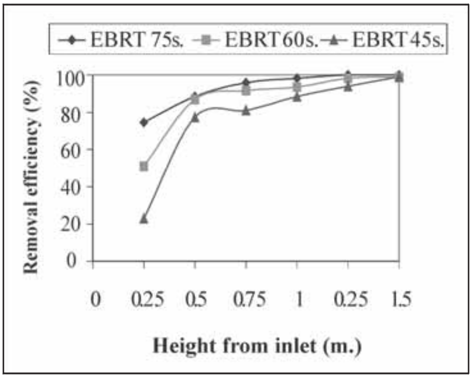
Figure 2. Relationship between removal efficiency and loadings for each filter.



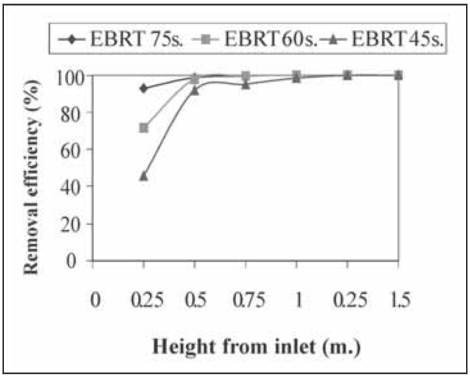
A. Compost



B. Bamboo fluff

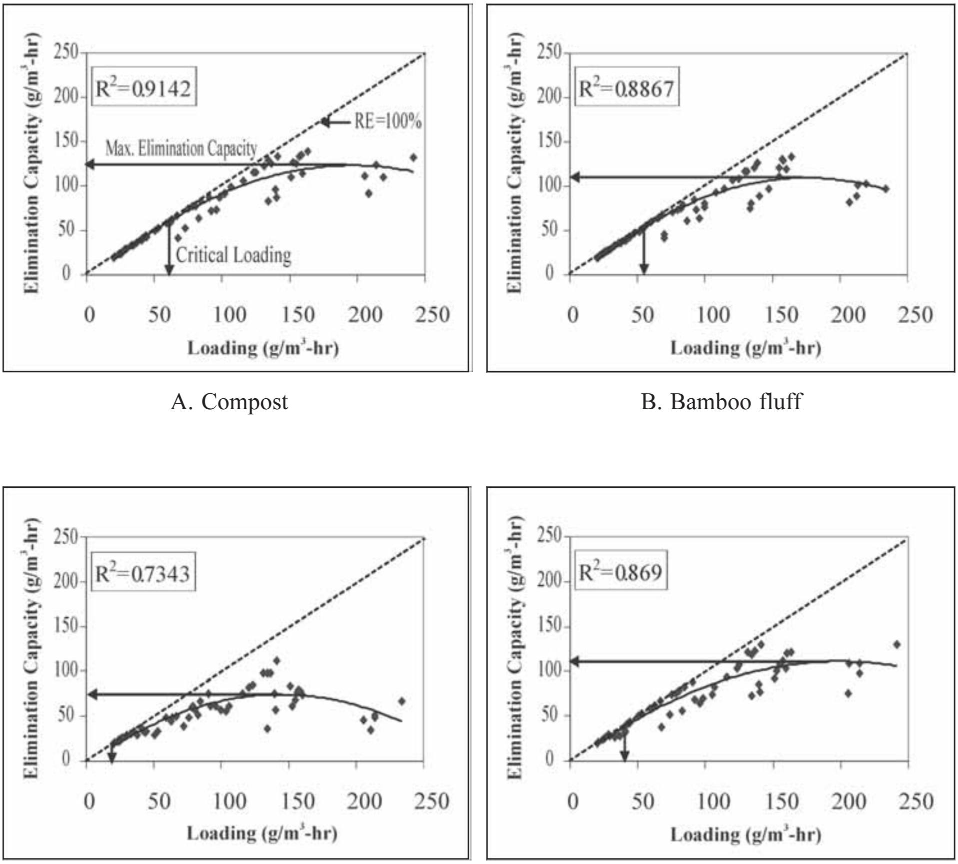


C. Lava Rock



D. Activated Carbon

Figure 3. Relationship between removal efficiency and height of filters at different EBRT for H_2S concentration of 300 ppm.



A. Compost

B. Bamboo fluff

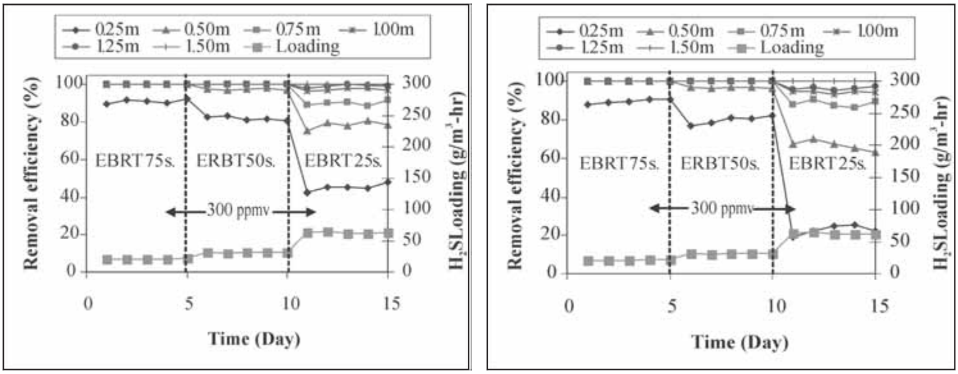
C. Lava rock

D. Activated carbon

Figure 4. Relationship between maximum elimination capacity and critical loading of the four biofilters.

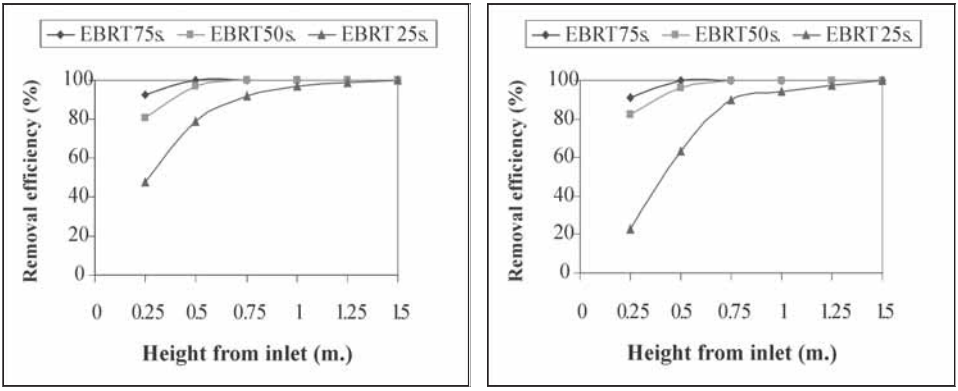
Table 4.
Maximum elimination capacity and critical loading of the four biofilters.

Filter Media	Maximum Elimination Capacity(g/m^3-hour)	Critical Loading (g/m^3-hour)
Compost	122	64
Bamboo fluff	111	58
Lava rock	72	22
Activated carbon	108	44



A. Upflow Filter B. Downflow Filter

Figure 5. Relationship between removal efficiency and loadings of upflow and downflow filters.



A. Upflow Filter B. Downflow Filter

Figure 6. Relationship between removal efficiency and height of filters at different EBRT for upflow and downflow filters for H_2S concentration of 300 ppm.

4 CONCLUSIONS

1. Compost was found to be the most suitable filter media among the four media investigated. It can achieve removal efficiency as high as 100% with moderate filter height.

2. To completely remove H_2S at 300 ppm using residence time of 45 seconds, the compost biofilter needed media height of 1.00 meter only while other filter media including bamboo fluff, lava rock and activated carbon needed media height atleast 1.25 meter.
3. The four filter media which are compost, bamboo fluff, lava rock and activated carbon had maximum elimination capacity of 122, 111, 72 and 10 g/m^3-hour, respectively and critical loading of 64, 58, 22 and 44 g/m^3-hour, respectively.
4. The downflow filters had similar removal efficiency to the upflow filter but slightly less when the filter depth was 1 meter and EBRT was 25 seconds.

5 ACKNOWLEDGEMENTS

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