EFFECT OF H_2S AND AIR FLOW RATES ON PURE AND CONSORTIUM CULTURE OF SULFIDE OXIDIZING BACTERIA BIOFILTRATION FOR H_2S REMOVAL

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ABSTRACT: A novel biofiltration system using granular activated carbon (GAC) as a carrier for sulfide oxidizing bacteria immobilization achieves a good performance of H_2S removal. The effect of H_2S and air flow rates were investigated using pure culture (*Alcaligene faecalis* T 307) and consortium culture. The results showed that H_2S flow rate of 15-35 L/h into pure and consortium culture biofiltrations had the little influence on performance of H_2S removal. Moreover, air flow rate of 5.83 L/h supplied into pure and consortium culture reactors gave the complete H_2S removal (0 ppm of H_2S concentration). Finally, the results showed that consortium culture was better performance than pure culture for H_2S removal using biofiltration in acid condition.

Keywords: Biofiltration; Hydrogen sulfide; *Alcaligene faecalis* T307; Consortium; Granular activated carbon;

INTRODUCTION: Hydrogen sulfide is extremely toxic to living organisms and plants. At a level of 0–5 ppm in the air, it can be detected easily. Levels greater than 10 ppm, can affect human health, while levels more than 600 ppm can cause death[1]. Physicochemical methods for H_2S removal have relatively high energy requirements or high chemical and disposal cost. Biological treatment by biofiltration has been proposed as a convenient alternative for treating gaseous emissions containing hydrogen sulfide and reduced sulfur compounds.

Biofiltration[2] is a process in which air containing pollutants is passed through a bed of moist, porous material in order to remove the pollutants. This technology, based on microbiological degradation of compounds from a gas stream, is considered to be an attractive alternative when compared to chemical and physical treatment[3]. Nevertheless, using biofiltration for hydrogen sulfide control showed the technical merits and economics and found that total annual costs for the biofiltration system were 46% lower than an activated carbon system and 40% less than a chemical scrubber [4].

It has been reported that various used microorganism in H_2S biofiltration as sulfide oxidizing bacteria (SOB), including *Thiobacillus*, *Xanthomonas* and *Pseudomonas* have great potential to metabolize H_2S effectively for its low acid production and fast oxidation rate[5-8]. Most researches studied H_2S removal using pure culture immobilized on carrier[5-9]. Even if pure culture inoculation has drawn great attention because it can shorten the start-up time and increase the removal efficiencies[10] but there are limitations on employing pure cultures for industrial application to remove H_2S using biofiltration. Therefore, some researches used consortium culture from compost[11] and wastewater from treatment plant sludge to removal H_2S [12-13], there are still a lot of microbial diversity in different sources but consortium shown require at least three weeks for acclimation[11-13]. In addition, there is no study in the reported about the performance comparison of biofiltrarion inoculated with pure and consortium culture for biofiltration removal of H_2S. Moreover, the degradation of H_2S by microorganisms is affected by various environmental factors[14]. Biofiltration for H_2S removal is also affected by input flow rate consisted of H_2S and air for this case. Therefore, maintenance of H_2S biofiltration conditions suitable for microbial activity is essential for successful biofiltration operations. Despite a large number of publications on biofiltration, further report on the effect of H_2S and air flow rates is needed. The objectives of this research is to

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study the effect of biofiltration system using granular activated carbon (GAC) as solid support for pure and consortium culture to treat a gaseous stream on H_2S gas and air flow rate.

MATERIALS AND METHODS: Organism cultivation and medium preparation

Pure culture stain of sulfide oxidizing bacterium used in this research was *Alcaligene faecalis* T307, which was isolated from the concentrated latex wastewater and was effective H_2S removal in wastewater from previously experiments. The optimal pH and temperature range at 7 and 25-35 ^0C, respectively. This strain was maintained on medium A agar slant (1.5% w/v of agar) and transferred to fresh slants every 2 months. The composition of the medium A contained the following (per liter) : 2.0 g KH_2PO_4, 2.0 g K_2HPO_4, 0.4 g NH_4Cl, 0.2 g $MgCl_2.6H_2O$, 0.01 g $FeSO_4.7H_2O$, 8.0 g $Na_2S_2O_3.5H_2O$ and 1.0 g Yeast extract[15]. The final pH of the medium was adjust to 7 using 2 N NaOH to the medium.

Consortium culture of sulfide oxidizing bacteria was stimulated from influent wastewater of the sulfate reduction rector of concentrated latex industry with 2.21 g sulfur supplement under aerobic for 3 days. After stimulation process for about 3 days, the bacteria seeds were ready for inoculating onto GAC.

For all continuous experiments, the Thiosulfate mineral medium was used for humid and nutrient supply to biofiltration. The composition of medium contained the following (gram per liter) : 2.0 g KH_2PO_4, 2.0 g K_2HPO_4, 0.4 g NH_4Cl, 0.2 g $MgCl_2.6H_2O$, 0.01 g $FeSO_4.7H_2O$ and 8.0 g $Na_2S_2O_3.5H_2O$ [16]. The final pH was adjusted to 7 by using 1 N NaOH.

Cell immobilization procedure

A. faecalis T307 was grown in 1 L medium A for 3 days and then harvested by centrifugation (8000 rpm for 10 min). Then the cell pellet was put into a 5L plastic tank containing 3L medium. At the same time, 500 g GAC was added to be mixed with the above solution for microbial attachment and cultivation. During the cultivation period, medium was exchanged every 3 days until the cell number of *A. faecalis* T307 was estimated about 4.0×10^8 cfu/g dry GAC by the traditional plate-counting method. After 15 days, the GAC in the tank was then transferred into the biofiltration.

Consortium of sulfide oxidizing bacteria were stimulated for growth in concentrated latex wastewater with 2.21 g sulfur supplement under aerobic conditions for 3 days. The precipitate was then put into a 5 L plastic tank containing 3 L sterile concentrated latex wastewater. At the same time, 500 g GAC was added and mixed with the above solution for microbial attachment. During the cultivation period, sterile concentrated latex wastewater was transformed with new sterile concentrated latex wastewater every 3 days until the cell number of microorganisms reaching about 4.0×10^8 cfu/g dry GAC by the traditional plate-counting method. After 15 days, the GAC in the tank was then transferred into the biofiltration system.

Apparatus and H_2S removal for continuous operation

Figure 1 shown a schematic diagram of the GAC biofiltration designed to remove H_2S emission and this system were performed in two laboratory-scale biofiltrations. Each biofiltration was made of stainless steel, with 0.055 m inner diameter and 0.6 m height (a working volume of 1 L). Two biofiltrations were packed with different type of microorganisms. The packed bed volume of biofiltration was 40 cm or 0.67 L (about 400 g weight of GAC). Firstly, air from compressor was passed through an air filter (pore size of 0.2 μm) to leach nonessential impurities and the air flow rate was controlled by the mass flow meter. Then, the air was passed through a humidification bottle that contains the Thiosulfate mineral medium for humidification and for providing nutrient to biofiltration. Humid air was then mixed with H_2S gas, which was generated from a PVC pipe (0.05 m ID and 0.6 m length). The flow rate of H_2S gas was controlled by mass flowmeter. The Inlet mixture gas was fed to the top of biofiltration at a constant flow rate. Biofiltration were operated at room temperature throughout all the experimental runs.

Analytical method

Inlet and outlet H_2S gas concentration of biofiltration was analyzed by Cadmium sulfide method[17]. In additional, GAC samples were regularly taken out from

biofiltration for further identification. The 0.5 g GAC collected was mixed with 10 mL distilled water and was vortexed for 2 min. Then, the solution was determined for pH, total sulfur and sulfate using pH meter, gravimetric method[18] and turbiditymetric method[19], respectively.

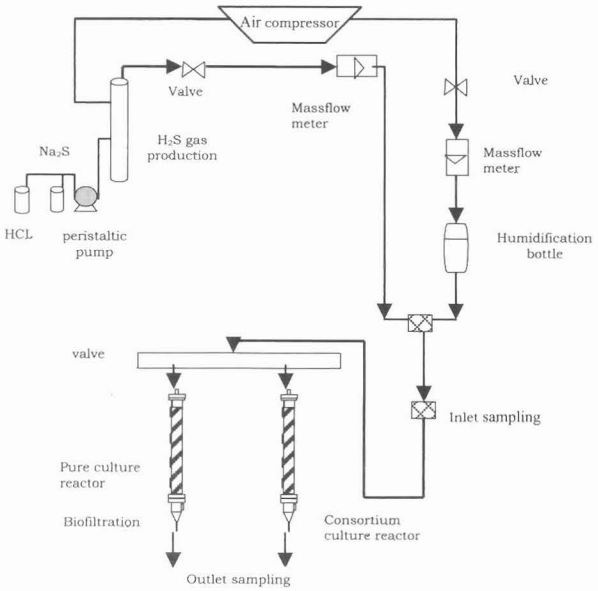


Fig. 1 Laboratory-scale experimental biofiltration system.

RESULTS: Effect of H_2S flow rate

Effect of H_2S flow rate on two biofiltration performances was investigated at various flow rates of 15, 25 and 35 L/h. Inlet H_2S concentration was fixed at 200 ppm according to optimum condition from previous study[20]and the air flow rate was maintained at 0.75 L/h. Concentrations of inlet and outlet H_2S from two biofiltrations were analyzed everyday for 21 days. It was found that outlet H_2S concentrations of pure and consortium culture reactors were less than 3 and 2 ppm, respectively (Shown in Figure 2). From this results showed that the H_2S removal performances were not significantly different at various H_2S flow rates. Nevertheless, the certain of H_2S concentration outlet observed here at varied H_2S flow rate (15-35 L/h) can be explained by the microorganisms which adapted themselves to the new environment at the slow diffusion of H_2S gas[21].

The metabolic products on GAC biofiltration were investigated. pH values, sulfur and sulfate concentrations were measured and showed in Table 1. The results showed that the pH values of GAC in pure and consortium culture reactors were 2.40 to 1.94 and 2.60 to 2.04, respectively. The results of pH values of GAC in two bilfiltrations were low and had the little variation. Moreover, the sulfate concentrations of GAC in pure and consortium culture reactors increased from 1.64 to 3.10 g/L and 1.36 to 2.66 g/L, respectively. Finally, the sulfur concentration of GAC in pure and consortium culture reactors increased from 3.86 to 4.04 g/L and 3.60 to 3.80 g/L, respectively. From this results showed that sulfide oxidizing bacteria is the key microorganisms for H_2S removal, which related to bacteria population, and can oxidize H_2S or element sulfur (S^0) for energy and produce sulfuric acid. The oxidation of H_2S occurs in two main stages and the first oxidation step results in the formation of element sulfur. Here H_2S is used as electron donors by the microorganism. When the supply of H_2S has been depleted, additional energy can be obtained from oxidation of sulfur to sulfate. The final product of oxidation in most case is sulfate [22].

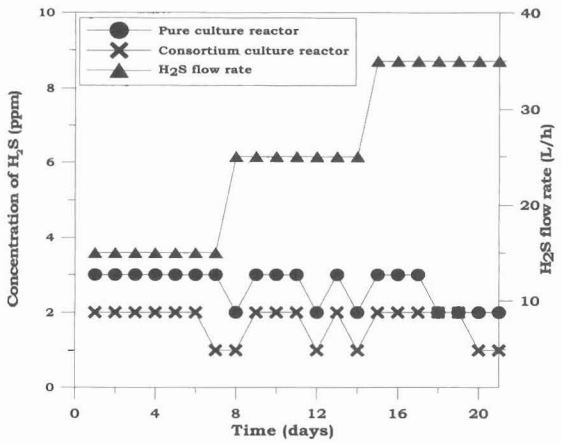


Fig. 2 Outlet concentration of H_2S in two biofiltrations at various H_2S flow rates.

Effect of air flow rate

Effect of air flow rate on the performance of two biofiltrations was investigated at changing air flow rates of 0.75, 1.34 and 5.83 L/h. The inlet H_2S concentration and H_2S flow rate were set at 200 ppm and 35 L/h, respectively. Concentrations of inlet and outlet H_2S from two biofiltrations were analyzed everyday for 21 days. The results showed that outlet H_2S concentrations of pure and consortium culture rectors were less than 3 and 1 ppm, respectively (shown in Figure 3). From this results showed that H_2S removal for two biofiltrations increased with the increasing

air flow rate. The complete H_2S removal (0 ppm of outlet concentration) was found in two bilofiltrations at 5.83 L/h of air flow rate. So, the complete hydrogen sulfide removal can occur when the oxygen is sufficient for the oxidation reaction. The activity of immobilized bacteria on GAC may be enhanced when air flow rate increased. Generally, sulfuric acid is the end-product of H_2S oxidation when the oxygen is implied. However, elemental sulfur may become the end product when the oxygen is consumed and apparently decreased [23]. Oxygen is the key parameter that controls the level of oxidation [24]. Insufficient oxygen may cause a shift in the proportion of the end-products and prevent complete removal of H_2S. Therefore, the metabolic products on GAC biofiltration at 5.83 of air flow rate were investigated. The pH values sulfur and sulfate concentrations were measured and showed in Table 1. The results showed that the pH values of GAC in consortium reactor decreased from 1.90 to 1.42, respectively. Then, the sulfate concentrations of GAC in consortium culture reactor increased from 2.66 to 5.50 g/L but sulfur concentrations of GAC in consortium culture reactor insignificantly increased from 3.80 to 4.02 g/L due to complete oxidation (high air flow rate) led to transformation of H_2S to sulfate instead of sulfur production from the partial oxidation by oxygen limitation (low air flow rate).

Moreover, the pH values of GAC in pure culture reactor insignificantly decreased from 1.94 to 1.90. Then, the sulfate concentrations of GAC in pure culture reactor decreased from 3.10 to 2.50 g/L but sulfur concentrations of GAC in pure culture reactor increased from 4.04 to 5.58 g/L. It was found that the main product of H_2S oxidation by *A. faecalis* T307 with high air flow rate (high oxygen) was sulfur compound instead of sulfate. It indicated not only the amount of oxygen was supplied but also type of microbial strain affected on type of metabolic products.

Comparison of pure and consortium culture

Comparison of pure and consortium culture was investigated by effect of H_2S and air flow rate on two biofiltrations. The results found that H_2S removal performance in each reactors related pH and sulfate concentration in GAC. Lower pH was originated form the biodegradation of H_2S which produces sulfuric acid. Since there is no biotransformation consuming the acid, the latter will accumulate very fast, and the pH will to the drop point where the microbial ecosystem is inhibited[16]. Higher sulfate concentration originated form the process of H_2S biodegradation which H_2S is used as electron donor by the bacteria[25]. In the experiment, pH in GAC of pure and consortium culture reactors were dropped at 1.90 and 1.42, respectively and sulfate concentration in GAC were increased at 2.50 g/L and 5.50 g/L, respectively after operations. This results showed that consortium culture was lower pH and sulfate but H_2S removal performance was higher than pure culture reactor because the autotrophic *Thiobacillus* group in consortium culture includes both acidophilic bacteria that grow at low pH values[27] but optimum pH of pure culture (*Alcaligenes faecalis* T307) is neutral. Therefore, consortium culture was good performance for H_2S removal using biofiltration in acid condition.

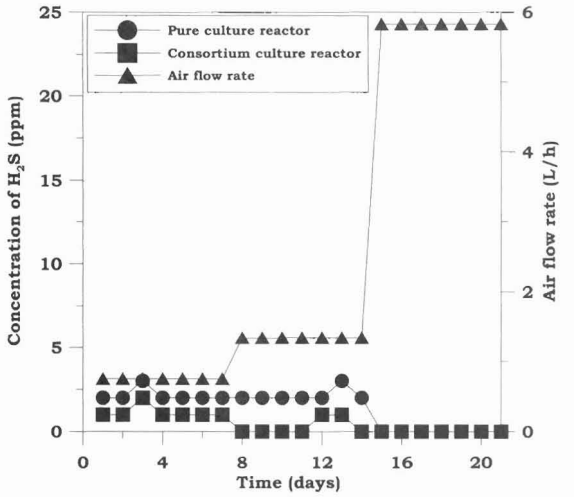


Fig. 3 Outlet concentration of H_2S in different reactors at various air flow rates.

CONCLUSION

The performance of pure (*Alcaligenes faecalis* T307) and consortium culture immobilization on GAC biofiltration showed that the suitable for the treatment of H_2S on various H_2S and air flow rate. Also, it was found that H_2S flow rate of 15-35 L/h into pure and consortium culture reactor had the little influences on H_2S removal, which can be explained by the microorganisms which adapted themselves to the new environment at the slow diffusion of H_2S gas. Moreover, air flow rate into pure

and consortium culture reactors gave the complete H_2S removal (0 ppm of H_2S concentration) at 5.83 L/h due to sufficient oxygen for the oxidation reaction. Finally, the results showed that consortium culture was better performance than pure culture for H_2S removal using biofiltration in acid condition

Table. 1 The pH values, sulfur and sulfate concentrations of two biofiltrations on GAC

Reactors	pH			Sulfur (g/L)			Sulfate (g/L)		
	A	B	C	A	B	C	A	B	C
Pure culture	2.40	1.94	1.90	3.86	4.04	5.58	1.64	3.10	2.50
Consortium culture	2.60	2.04	1.42	3.60	3.80	4.02	1.36	2.66	5.50

Note: A = Before experiment
B = At inlet H_2S concentration of 200 ppm and H_2S gas flow rate of 35 L/h
C = At inlet H_2S concentration of 200 ppm, H_2S gas flow rate of 35 L/h and air flow rate of 5.83 L/h

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