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Odor Removal in Air by Four-Stage Biofilter

Mohammad Reza Massoudinejad[2,4]; Amir Adibzadeh[1]; Simin Mirshafieean[2]; Ehsan Aghayani[2]; Siyavosh Payandehazad[3]

[1] Department of Environmental Health. Faculty of Health, International Branch, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[2]Department of Environmental Health, Faculty of Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[3]Department of Electrical & computer Engineering, faculty of Electrical and Computer Engineering (ECE), Shahid Behehshti University, Tehran, Iran
[4]Safety Promotion and Injury Prevention Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran

ABSTRACT

Biofilteration is one of the major treatments for odor control. Hydrogen sulfide is the important pollutants that cause odor in industries. In this study, a four-stage biofilter was developed to treat odor based hydrogen sulfide from air in bench scale. The objectives were to evaluate the performance and effectiveness of the four-stage biofilter to treat odor based hydrogen sulfide. 4 columns designed with 40 centimeters in height and 15 centimeters in diameter which set up as series and was filled up with % 75 porosity compost to 27.5 centimeter in height. The system efficiency got in the beginning of the first contact at end of the first day of sampling to get more than 90 percent. The results show that biological systems in the biofilter have not clogged due to absence of filamentous bacteria. In order to achieve high efficiency, used of a mixer with low round and stirred into compost or at least two-thirds of the volume of compost to be replaced every three months. With consideration to low cost compost compared with traditional chemical methods, this method can applied as one of the best methods with high efficiency, low cost, easy control and maintenance.
KEYWORDS: air pollution; biofilteration; hydrogen sulfide; compost; biological elimination.

INTRODUCTION

Odor has the detrimental impact on the environment and adverse human health effect and control of odor has become one of the main research topics [1]. Many developed countries have relevant laws to control the odor gases [2]. Hydrogen sulfide is the important pollutants that cause odor in industries. This gas is one of the most important environmental contaminants that into the environment by refineries. Several methods has been proposed for removing these compounds from chimney of the plants, this methods including desulphurization of crude oil, which is very expensive and has a complexity technical know. Desulphurization in this technology can proceed be uses of cuts through distillation and produce material such as kerosene and gas oil [3]. The most important methods used for removal odor are including use of active carbon adsorption, incineration, catalytic oxidation, wet oxidation, humid scrubbers and oxidation heat method [4, 5]. Often these methods have been too expensive and production polluted byproduct and these problems cause that developing hydrogen sulfide removal methods limited in industries [6, 7]. Nowadays, biological treatment methods has attracted experts, because this methods has many advantages including low cost, low energy requirement, no need to use chemicals and no to produce contaminated byproduct [8,9]. Among all the biological technologies, biofiltration is one of the most successful techniques [10, 11]. The reaction mechanism in the biofilter is similar to the biofilms and proceeding in three-step. Outset, chemical in the gas phase passes through the biofilm from the space between gas and the solid bed environment, then the chemicals that exist in biofilms pervade into the community of microorganisms. Finally, the microorganisms gain the energy requirement from chemical oxidation as the primary substrate or cometabolism [12, 13]. In this process, pervade and use nutrients such as nitrogen, phosphorus, sulfur and oxygen occur simultaneously, while the air passing between the environment and biofilms [14]. Maximum polluted materials removal can be occurring if properly designed and conducted biofilter. The polluted materials convert to water, salt, and the biomass [15]. Gaseous compounds via release in flow gas leaving the biofilter. The salt and biomass increases lead to increases thickness of bed surface and reduce the space for passing flow gas [16]. The incorrect design causes gradually increase the pressure drop and

Corresponding Author: Amir Adibzadeh, Department of Environmental Health. Faculty of Health, International Branch, Shahid Beheshti University of Medical Sciences, Tehran, Iran. Tel: (+98)2182482492 E-mail: adibzadeh_251@yahoo.com

therefore decreases gas removal efficiency [17]. The most significant biofilter development activities in industrial is removed odor causing compounds (hydrogen sulfide), other sulfur compounds (mercaptans) and nitrogen-containing compounds (ammonia) [18]. From 1934, biological elimination of volatile inorganic compounds is used by biological filter in scale laboratory. According implemented studies, determined that used method is capable after reaching to stable condition afforded about 90% elimination efficiency for a few to 200 gram per cubic meter per hour polluted [19]. Organic bed biofilters is used more for biological purification volatile inorganic compounds. Microbial species of thiobacillus and hyphomicrobium are very good decomposers for sulfur removal in the biofilter [20]. Volatile organic compounds are treatment by specialized microorganisms, too. These compounds are including aromatic and aliphatic pollutants [21]. Furthermore, many studies executed on the removal of certain pollutants with high stability in the air such as alcohols, ketones, Alkenes, methane and chlorinated compounds by biofilters remarkably successful [22]. Also, several studies accomplished for removal hydrogen sulfide used by biofilter. Guillermo and colleagues in 2005 used coconut shell filling for bed column [7]. Oyarzun and arancibia in 2003 by used the biofilter acquired to removal efficiency of hydrogen sulfide about 100%. In that study with increasing the inlet concentration acid, hydrogen sulfide removal efficiencies decreased [22]. Ramirez and Gomez (2009) used the total amount of biomass immobilized on the carrier. They estimated optimal values of the operating variables including pH, surface velocity and sulfate concentration [23]. In another study, Rattanapan and Boonsawang, (2008) was investigated performance of sulfide oxidizing bacterium immobilized on GAC (biofilter A) and GAC without cell immobilization (biofilter B) systems [24]. Also Baquerizo *et al*., (2005) reached to 90 percent hydrogen sulfide removal efficiency by use of coconut shell filling in bed column [3]. According to research on a column full of the seashell with inoculation an acclimated Thiobacillus thioparus bacterium, determined removal efficiency 90 percent of polluted gas [19]. Most researchers have used compost microbial consortium for purification [25]. With used of these complex bacterial germs in the process, removal efficiency 90% has been reported [23]. In this study, special compost for cultivation button mushroom was used for breeding microbial mass in order to remove odor based hydrogen sulfide.

MATERIALS AND METHODS

This project was done in the Faculty of Health laboratory at Shahid Behehshti University. Four-stage Biofilter columns were made of Plexiglas. Height of each column was 40 cm that until height to 27.5 cm full of compost with 75 percent porosity. Above each column 4 input pipes have been fitted. These pipes used for air injection, polluted gas injection, measurement output sample from each column, and injection of nutrients and medium. 4 columns installed in series. In order to creation steady flow of incoming polluted gas was created pore diameter of 5 mm at the bottom of each column. The number of created pores in the bottom of each column was 20 and the inner diameter of each column was 150 mm. In order to protect peoples against probable effluence of gas at the outlet, after each column installed active carbon column and scrubbers containing iron chloride, and finally was placed a flame. In order to move polluted gas in biofilter column have been used air compressor with working pressure 6 to 8 bars and 150 L capacity. Output air compressor flow rate was controlled by a needle valve, as well as, in order to prevent of entering the oil into the columns, fiberglass filter (50 cm length and 10 cm diameter) sited in direction the air exhausted. An aluminum reservoir (320 mm diameter and 310 mm height) used for produce odorous hydrogen sulfide gas. This tank was equipped with an analog pressure gage and a stainless steel needle valve (0.4 inches diameter). For the gas production, the amount of 350 g of sodium sulfide was solved in 2 L of distilled water and this solution was mixed in 300 ml phosphoric acid. Reaction was implemented in the closed environment and gas was produced.

$$3Na_2S + 2\,H_3PO_4 \longrightarrow 2Na_3PO_4 + 3\,H_2S \uparrow$$

Input and output gas concentration rate in each column measured as mg m^{-3} with gas sensors made by Micropac Plus factory. Environmental humidity controlled used of digital psychrometer made by Danfouse factory in Germany with precision $\pm$ 0.01. For environmental temperature control system used a digital thermometer made by Sumone factory Korea with precision $\pm$ 1. Different components of pilot demonstrated in figure 1.

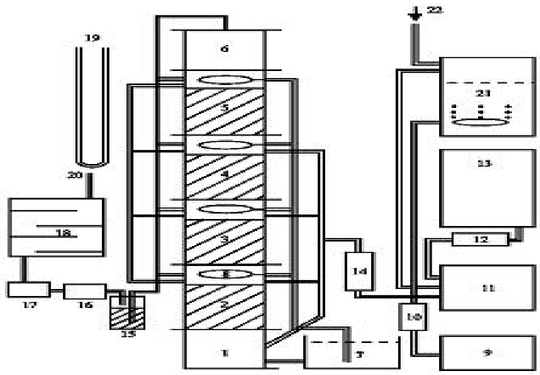

Figure.1: Different components of pilot

1. Leachate collecting tank, 2. Bed filled with compost, 3. Bed filled with compost, 4. Bed filled with compost, 5. Bed filled with compost, 6. Location collect gas output, 7. Water for irrigation beds, 8. Watering-pot, 9. Dry air compressor, 10. Fiberglass filter, 11. Mixing tank, 12. H_2S gas adjustment, 13. Reservoir Production H_2S, 14. Flow meter, 15. Stuck humidity, 16 - determine the device H_2S mg m^{-3}, 17. Vacuum pump, 18. Adsorbent, 19. Manometer, 20. Out flow clean air, 21. Electric heater, 22. Inflow water.

RESULTS AND DISCUTION

Due to the different variables this study including changes the flow of air, moisture, temperature, pollutant gas concentration, as well as correct conclusions and avoid interference effects different variables in purification process tried in a series of tests, one factor had been considered variable and other factors were constant. Consequently optimal conditions were found with this intersection. The amounts input pollutant gas concentrations was measured in 10 weeks in 6 groups of less than 20, between 20-40, 40-60, 60-80, 80-100 and more than 100 mg m^{-3} of compost bed.

Table 1: Changes in the input air flow and gas concentration input and output.

Input air flow Lit min^{-1} / Concentration gas mg m^{-3}	2	3	4	5	6	7	8	9	10	>10
Input	100	128	127	140	139	120	131	120	140	125
Output	11	10	18	34	50	75	99	74	77	59
Input	105	97	89	89	99	94	91	89	100	97
Output	13	9	12	26	45	35	34	48	47	41
Input	81	75	75	75	65	67	76	69	68	74
Output	29	8	10	22	9	24	14	30	30	40
Input	19	53	52	49	46	50	46	49	54	28
Output	4	6	7	10	7	20	19	17	24	13

The highest efficiency during the 10 week for various groups will be explained in the table 1. The highest efficiency of gas removal during 10 weeks of testing and sampling is summarized in Table 2.

Table 2: Changes in the input air flow and Changes physical and hydraulic biofilter column.

Input air flow Lit min^{-1} / Variables measured	2	3	4	5	6	7	8	9	10	>10
Average Temperature	29.8	29.3	29	24.5	28.8	29.7	29.5	31	30.5	31
Average Humidity%	90	90	90	90	90	90	90	90	90	90
Average residence time empty bed	2.651	1.767	1.425	1.06	0.884	0.757	0.663	0.589	0.53	0.482
Average actual residence time of the bed	1.99	1.325	0.994	0.795	0.663	0.568	0.497	0.442	0.398	0.361
Average loading surface	0.114	0.17	0.227	0.284	0.341	0.348	0.455	0.511	0.568	0.625
Average mass loading (volumetric)	0.023	0.038	0.049	0.066	0.075	0.028	0.101	0.107	0.128	0.138
Average elimination capacity	1.832	3.405	4.3	4.6	5.525	4.665	5.483	5.379	6.57	5.351
Average removal efficiency%	79.64	87.75	88.73	79.67	78.49	63.17	61.28	55.66	53.87	43.4

Interventions of the changes in polluted gas concentration and change the carrier gas flow show in figure 2-4.

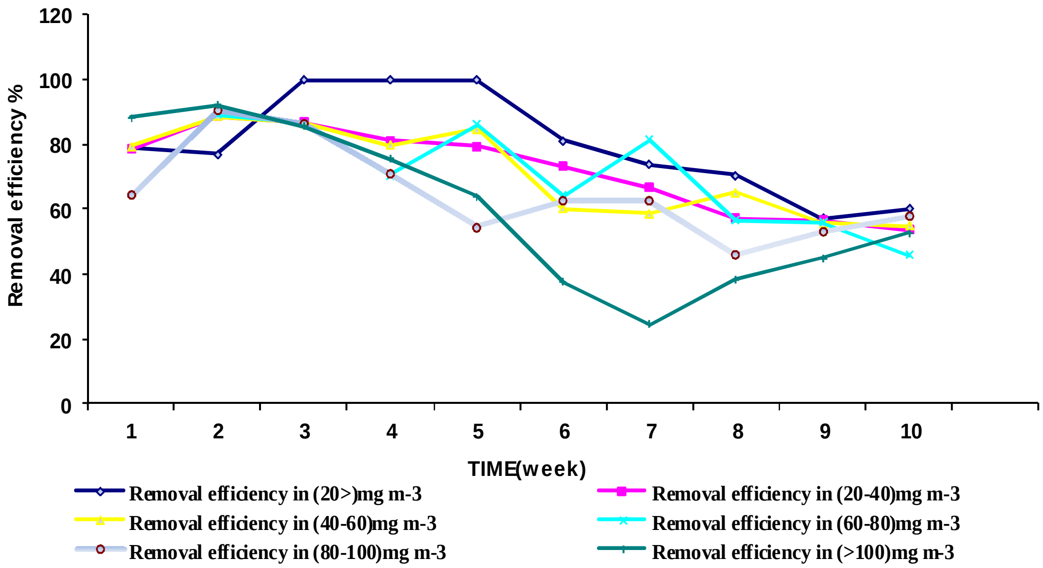

Figure 2: Relationship between time (terms of week) and removal efficiency in the compost bed for polluted gas concentrations of less than 20 to more than 100 mg m^{-3}.

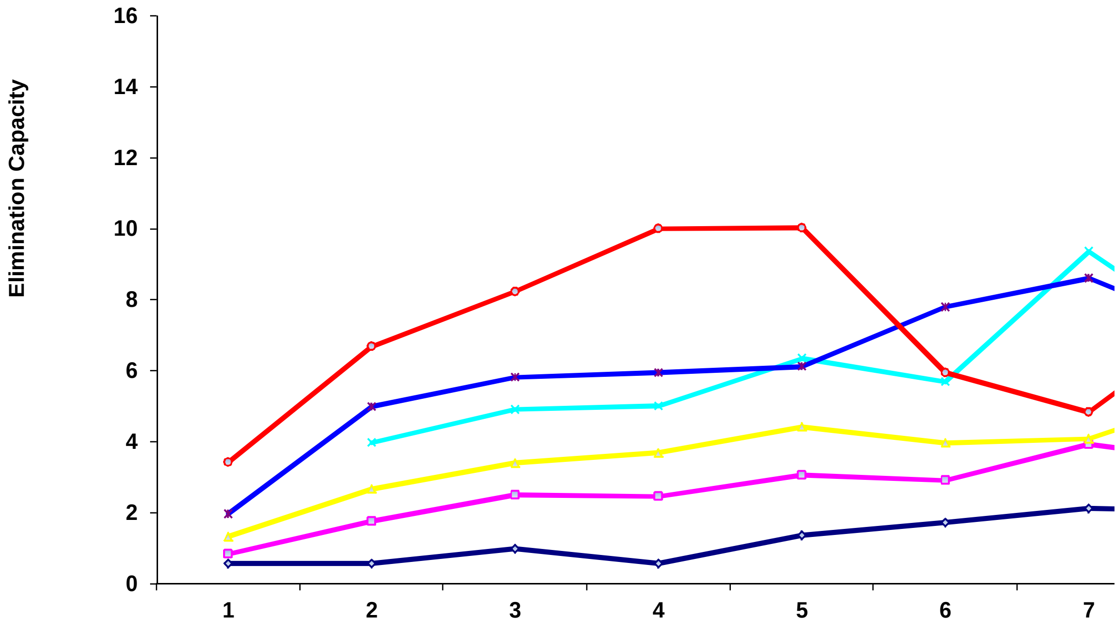

Figure 3: Relationship between time (terms of week) and elimination capacity (EC) in terms of $gr_{microbial\ mass}\ m^{-3}$ per min.

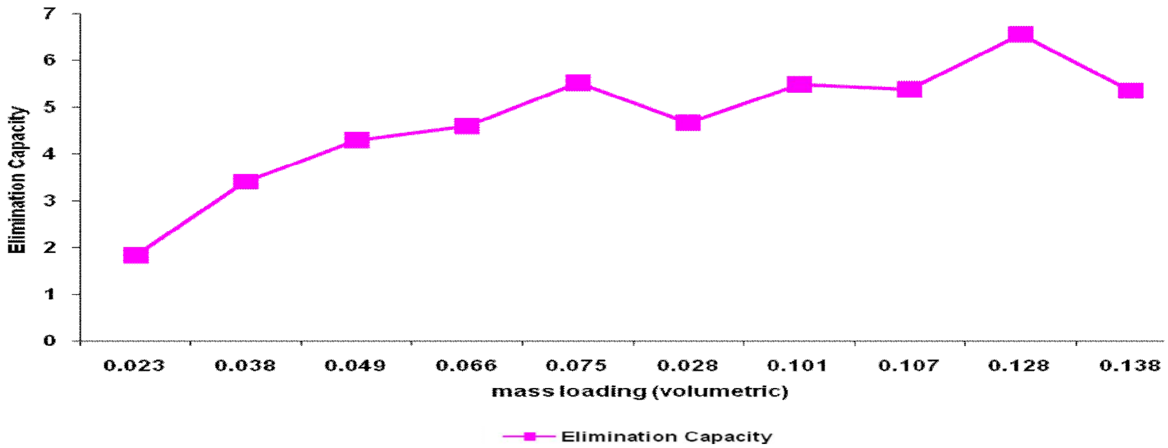

Figure 4: Comparison of mass loading per unit volume (in terms of $gr_{microbial\ mass}$ m^{-3} per min) to elimination capacity.

According to the results from table 1 that obtained the analysis of the 65 samples in different conditions during 10 weeks, the best removal efficiency of hydrogen sulfide determined in beginning contact. Also summarized results in table 2 determined to a concentration of contaminated gas that non-significant influences in the process of gas purification. When favorable conditions prepare for microorganisms, removal efficiency will be more than 90 percent. If 90% humidity and temperatures 30° C is provided, removal efficiency will increase due to influence the humidity and heat in the process of growth and proliferation of microbial consortium. To consideration porosity of the compost bed and estimate the gas residence time in the actual bed, this time varied between 0.3 to 2 minutes depending on the carrier gas flow. Results indicate that the best residence actual time in the column is 0.99 min. It became clear during the process; pores in the porous bed of compost are not clogged by bacteria growth and proliferation. This subject examined by measuring the pressure water drop in the biofilter inlet and outlet by a manometer. To calculate the actual residence time in the bed used of the following equation:

$$\tau = \frac{Vf \times \theta}{Q}$$

τ : Actual residential time (min)

Vf: Biofilter volume (m^3)

θ : Porosity or the result of empty bed volume divided the total volume

Q: Air flow intensity (lit min^{-1})

The amount of mass loading per unit volume that include amount of destroyed pollutant mass per volume of bed biofilter on unit time, is determined through the following equation:

EC= Volumetric mass loading $\times$ RE

Average refining capacity by microbial mass = volumetric mass loading $\times$ removal efficiency

$$massloading\ (volumetric) = \frac{Q \times Ci}{Vf}$$

Ci: concentration of the input gas (g m^{-3})

By comparing the results of tables 1 and 2 determine that highest removal efficiency will have achieved as the mass loading rate be about 0.049 (g m^{-3}.min). If refining capacity by the microbial mass was 4.3 g m^{-3} .min, biofilter achieved the best removal efficiency.

CONCLUSIONS

Melvin used the mixed bed of glass wool and compost. Efficiency of their system after 64 days reduced because the space of porous bed was clogged. This seems to use the method of filling such seashell is more appropriate [20]. Oyarzuna used the biofilter reached an efficiency of 100% when fed with 355 ppm H2S and an air flow of 0.030 m3 h-1. With increasing the inlet concentration acid, hydrogen sulfide removal efficiencies decreased and reaching 90 and 60% at 0.070 and 0.030 m3 h-1 respectively. A maximum value was obtained for the elimination capacities of 55 g m3 h-1. Mathematical modeling based on Ottengraf's model enabled a prediction of the performance of the biofilter [22]. Guillermo used coconut shell filling for bed column. They reached 90 percent removal efficiency, the concentration of 280 mg L-1 of hydrogen sulfide during the 40 days [7]. Baquerizo used coconut shell filling for bed column. They reached 90 percent removal efficiency, the concentration of 280 mg L-1 of hydrogen sulfide during the 40 days [3]. Rattanapan used the comparative performance of sulfide oxidizing bacterium immobilized on GAC (biofilter A) and GAC without cell immobilization (biofilter B) systems was studied. It was found that the efficiency of the H2S removal was more than 98% even at high concentrations (200–4000 ppm) and the maximum elimination capacity was about 125 g H2S/m3of GAC/h in the biofilter A. However, the H2S flow rate of 15–35 l/h into both biofilters had little influence on the efficiency of H2S removal [24]. Massoudinejad by use of a column full of the seashell with inoculation an acclimated Thiobacillus thioparus bacteria, determined a removal efficiency 90 percent of polluted gas for gas flow 6 L min-1 with entry polluted gas concentrations lowest than 140mg m-3 after three weeks in environmental condition such as humidity between 77 to 93 percent and temperatures form 20.5 to 30° C [19]. Ramirez used the total amount of biomass immobilized on the carrier was 8.2 ± 1.3 _ 1010 cells/g. The optimal values of the operating variables were: pH between 7.0 and 7.5, surface velocity of 5.9 m/h and sulfate concentration below 5 g/L. The critical EC value was 14.9 g S/m3/h (removal efficiency of 99.8%) and the EC max was 55.0 g S/m3/h (removal efficiency of 79.8%) for an EBRT of 150 s. For loads of 2.89 ± 0.05 and 11.5 ± 0.1 g S/m3/h, the removal efficiency was higher than 99% for an EBRT over 90 s [23]. In a similar investigation that used of ceramic fillers and compost, efficiency has been reported over 90 percent in the removal process [18, 23]. But this type of investigation, after about 2 months due to the accumulation of crystals sulfur on the surface bed, removal rate declined sharply in the column.

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