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Performance of Biofilter for the Removal of Hydrogen Sulphide Odour

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ABSTRACT: Laboratory scale experiments were performed to evaluate the feasibility of biofilters for the removal of H_2S from wastewater treatment plant waste air. The effects of changes in air flow rate and contaminant concentration on biofilter performance treating H_2S odours were also assessed. Compost was used as media in biofilter. The study was carried out in six different phases, by increasing H_2S concentrations gradually. In the first phase only humidified air was supplied to acclimatize and develop the biofilm, within the biofilter conditions. In the second phase, inlet H_2S concentration was kept up to 10 ppm with the humidified air, H_2S removal efficiency was very high around 98%. It was concluded that the biofilter, used in the study, was more efficient (>95% removal efficiency) for low contaminant concentrations (up to 30 ppm). However, as the concentration of H_2S was increased to 50 ppm the removal efficiency decreased to 85%. The study results showed that biofilter could withstand longer starvation period and required less time to recover to its full efficiency. The effect of operating parameter such as moisture content was also assessed. The study revealed that the compost biofilter may be successfully adopted for various industrial operations where a reduction in emissions of H_2S is required.

Key words: Biofilter, Hydrogen sulfide, Compost, Aerobic sludge, Air pollutant

INTRODUCTION

Hydrogen sulfide (H_2S), one of the most common compounds found in wastewater treatment applications, is highly odorous and toxic (Zarook *et al.*, 2003). Till date wastewater treatment plants lack odor control units and hence the operators are exposed to higher levels of hydrogen sulphide. Odor emission can cause serious health hazards and annoyance in the neighborhood of the emission source (Stuetz and Franz, 2001). The potential of the active carbons as efficient and economical means of removing mixture of aromatic hydrocarbon contaminants from water was indicated by the complete removal of objectionable odor from contaminated water samples containing 35.1348 mg/cm^3 benzene and 34.8534 mg/cm^3 Toluene, which are known carcinogens (Lori *et al.*, 2008). In densely populated areas, odour becomes increasingly a matter of serious concerns. The removal of malodorous reduced sulfur emission has been traditionally accomplished using physical or chemical methods, such as vapor scrubbing, incineration or adsorption. However, these control technologies are usually uneconomical if large flow rate and low contaminant concentrations characterize the waste air stream (Wani, 1998).

Biofilteration, a relatively new application of biotechnology in environmental engineering utilizes the efficiency of microorganism to degrade the pollutants. Biofilter is more effective, economical, and environmentally friendly process than conventional methods (Zarook *et al.*, 2003).

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Biofilters provide significant reduction of overall odor emissions including volatile organic compounds (VOC's) emissions. It is a simple technology with minimum moving parts and low energy requirements. Cold winter temperatures do not affect biofilter performance. To sustain high efficiency, parameters such as moisture content, nutrient concentration, pH, inlet air relative humidity and temperature should be controlled.

Todd *et al.,* (1996) worked with the pilot and bench scale biofilters treating H_2S (ppm level) and specific VOC's (ppb levels) using granular activated carbon and yard waste compost as a filter media. They achieved 99% removal of H_2S, 53 to 98% removal of hydrocarbon, 37 to 95% removal of aldehyde and ketones, and 0 to 85% removal of chlorinated compounds. Wani *et al.,* (1998, and 1999) studied the performance of biofilters using different filter media, like compost/ perlite (4:1), hog-fuel/perlite (4:1) and compost/ hog-fuel/perlite (2:2:1). It was concluded that compos and hog-fuel showed best results with H_2S removal efficiencies of over 99%. Further they concluded that the effect of starvation was not significant in case of compost and hog-fuel filter and the effect of presence of organo- metallic compounds in wastewater did not affect the performance of biofilter. Pagella *et al*., (2000) examined the performance of a two stage biofilter using ferric solution as an absorbent. In first stage H_2S was absorbed in a ferric solution and in the second stage ferrous ion in the solution was oxidized by the biological action. Morales *et al.*, (2003) investigated the effect of drying on biofilter performance, and found that excess water reduced the biofilter porosity, that resulted in the formation of anaerobic zones, increasing pressure drop, and the leaching of biomass and nutrients. Sagastume *et al*., (2003) studied the affect of changes in physical properties like moisture content, pressure drop and sulphate accumulation on the performance of biofilter. They concluded that routine washing of the compost and compost mixing effectively mitigated SO_4^{2-} accumulation and kept the compost at adequate moisture content approximate 50%. San, H.K. *et al.,* (2005) investigated the effect of nutrients on the performance of biofilter treating Methyl Isoamyl Ketone (MIAK). They concluded that a nutrient ratio of COD: N:P = 200:4:1 was sufficient for the removal of MAIK from the polluted air. Morgan *et al.,* (2005) studied the effects of mixing, in the filter media of compost biofilter on the H_2S removal efficiency. They concluded that H_2S removal efficiency decreased over time, from 100%to 90% but when bed mixing was carried out, the removal efficiency remained constant, close to 100%, and moisture content and sulfate accumulation were better controlled at 50% and at 12mg S-SO_4/g dry media respectively.

Chung *et al.,* (2001) conducted experiments on biotreatment of various ratios of H_2S and NH_3 gas mixtures using the biofilters, packed with co-immobilized cells (*Arthrobacter oxydans* CH8 for NH_3 and *Pseudomonas putida* CH11 for H_2S). The results showed that H_2S removal of the biofilter was significantly affected by high inlet concentrations of H_2S and NH_3. As high H_2S concentration was an inhibitory substrate for the growth of heterotrophic sulfur-oxidizing bacteria, the activity of H_2S oxidation was thus inhibited.In the case of high NH_3 concentration, the poor H_2S removal efficiency was attributed to the acidification of the biofilter. Shojaosadati and Elyasi (1999) successfully conducted experiments on the removal of hydrogen sulphide from the contaminated air by a pilot scale compost biofilter. Sludge from the leather industry was inoculated into spent mushroom compost and was mixed with grounded snail shell. More than 99% of H_2S was removed from H_2S loaded air. The optimum pH for this operation ranged from 6 to 7. Ho *et al.,* (2008) conducted experiments using a biofilter packed with granular activated carbon (GAC) to eliminate volatile-sulfur compounds (VSC) emitted from solid–liquid separation tank in swine wastewater treatment system. Hydrogen sulfide, methanethiol, dimethyl disulfide, and dimethyl sulfide were effectively reduced to 96–100% at gas residence times of 13–30 s. Kim *et al.,* (2008) investigated the removal of hydrogen sulphide in a lab scale biofilter packed with biomedia, encapsulated by sodium alginate and polyvinyl alcohol (PVA). The immobilized cell biofilter required no separate acclimatization period and showed high removal efficiencies (99%) within the first few days of experiments. Jin Y *et al.,*

(2007) worked on the co-treatment of inorganic sulfur compounds and VOCs in bio-trickling filters.

The results showed that, after adaptation, the elimination capacity of methanol could reach around 236 g m^{-3} h^{-1} with the simultaneous complete removal (100%) of 12 ppm H_2S when the empty bed residence time is 24 s.The aim of this work was to evaluate the feasibility of compost biofilter for sequential removal of H_2S using activated sludge of paper industry.

MATERIALS & METHODS

The experiments were conducted in two identical bench scale columns used as, biofilter and humidification column. The columns were constructed from transparent, rigid Plexiglas tubing, with an inner diameter of 14 cm, (5.5 inch) height 60 cm. (24 inch). Biofilter shown in Fig.1 was packed with the compost as a filter media up to a height of 35 cm. The filter bed was divided into equal sections leaving 3 cm plenum in between the sections. The packed biofilter in the section was supported by Plexiglas perforated plate, covered by PVC net. There were three ports for sampling the air stream and pressure. The individual sampling ports were identified as inlet, middle and outlet ports. The humidification column was sealed at the top and bottom by clear Plexiglas cover plates and the biofilter was closed at the top by Plexiglas cover with the help of rubber tube, so that top cover can be removed to replace the filter material and to clean the filter before and after use. The compressed air was supplied from a laboratory compressor. The air flow rate was manually controlled by glob valve. The inlet gas stream was conditioned by humidification to saturation. Humidification column was used to add water vapors to saturate the air, as the house air had less than 25% relative humidity at room temperature and pressure. Humidification was controlled by sparking the air, through temperature controlled water, maintaining the water at about 5 ^{o}C above room temperature by using immersion heater. A metered flow of H_2S (12 vol% balance N_2) from compressed gas cylinder was injected in the saturated air stream before entering in to the biofilter column. The flow rate of H_2S gas was controlled by a Teflon gas flow meter, 3mm Teflon tubing was used to carry the H_2S from gas cylinder to the humidified air pipe, while all the gas lines were of 9mm diameter PVC pipes. The up flow direction in the biofilter was chosen because it avoids the compaction of the filter bed.Compost was used as biofilter media, possessing inherently diversified microbial communities, mainly composed of yard waste and animal manures. Biofilter media material was analyzed for its characteristics using standard methods for soil analysis and results are summarized in Table 1.

The sulphur oxidising microorganisms present in the biofilter were acclimatized by supplementing with buffer solution prepared as per Table 2. In the biofilter 100ml nutrient solution was spread

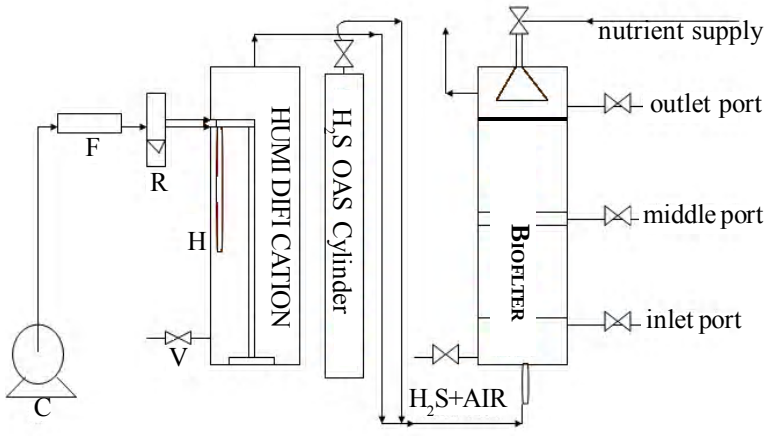

Fig. 1. Schematic diagram of experimental setup

Table 1. Characteristics of biofilter media

Parameter	Value
pH	7.5
Porosity	46%
Moisture Content (w/w)	48%
Bulk Density (g/mL)	0.35
Average Particle Size using sieve analysis (mm)	Percentage
> 3.35	0.50
3.35 – 2.36	4.20
2.36 – 2.00	5.33
2.00 – 1.70	2.89
1.70 – 1.00	39.05
1.00 – 0.85	17.60
0.85 – 0.60	18.20
0.60 – 0.355	11.55
< 0.355	0.68
Total	100

Table 2. Composition of micro and macro nutrients

Salt	Value (mg)
KH_2PO_4	2000
K_2HPO_4	2000
$MgSO_4.7H_2O$	1000
$NaNO_3$	400
NH_4Cl	400
$MgCl_2.7H_2O$	200
$CaCl_2$	50
H_3BO_3	75
$CoCl_2.6H_2O$	50
$(NH_4)_6Mo_7O_{24}.4H_2O$	10
$MnCl_2$	10
$NiCl_2$	10
$CuCl_2$	10

over the filter bed through the shower mounted at the top of the column after every week. To maintain the constant pH conditions of the filter bed, 100 ml of buffer solution of KH_2PO_4 and K_2HPO_4 of 0.1 M concentration was added while packing the filter bed.The concentration of H_2S in gas phase was measured by Jerome meter, which operates on the following principle.

A thin gold film, in the presence of hydrogen sulfide, undergoes an increase in electrical resistance proportional to the mass of hydrogen sulfide in the sample. When the SAMPLE button is pressed, an internal pump pulls ambient air over the gold film sensor for a precise period. The sensor absorbs the hydrogen sulfide.

The instrument determines the amount absorbed and displays the measured concentration of hydrogen sulfide in ppm. During normal sampling, the ambient air sample is diluted in the flow system at a ratio of 100:1. When sampling in Range 0, (where low levels of hydrogen sulfide are expected) undiluted air samples are drawn across the gold film sensor.

All chemical analysis was carried out as per *Standard Methods* (APHA 1998)

Empty Bed Residence Time and Removal Efficiency

Empty bed residence time (EBRT) and removal efficiency were determine using the relationships between the influent and effluent gas phase concentration, waste air flow rate, and the volume of the biofilter material as follows:

$$\tau = V/Q$$
$$RE = [(C_{in}-C_{out})/C_{in}]*100$$

Where
Q : is the waste air flow rate (m^3h^{-1}),
V: is the volume of filter material (m^3)
C_{in} and C_{out} :are the contaminant concentration in the influent and effluent waste gas stream (ppm_v) (Wani *et al.*, 1998).

RESULTS & DISCUSSION

Activated sludge was taken from Pulp and Paper Mill and acclimatized under aerobic conditions by adding Na_2S, glucose and nutrients for a period of one month.3.5 kg of compost and 0.875 kg of stone pieces (average size 5mm) and 700 ml of acclimatized activated sludge was mixed thoroughly, and packed in the biofilter column. The experiments were conducted in six different phases by varying concentration of H_2S and humidified air flow rate. Inlet H_2S concentration was increased gradually from zero to a maximum of 47 ppm, the variation of H_2S with time is shown in Fig. 2.

In the first phase of the study, the day 1 to day 10 only humidified air was supplied at a flow rate of 1± 0.2 m^3h^{-1} to acclimatize and develop the bio-film, within the biofilter conditions. During this period adequate nutrient were added to the system. The second phase (Fig. 3) of the study, from day 11 to day 18, the inlet H_2S concentration was kept up to 10 ppm, with the humidified air

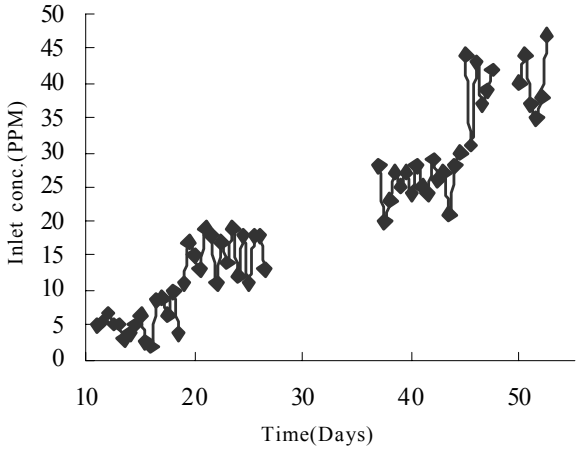

Fig. 2. Variation of H_2S concentration with time35

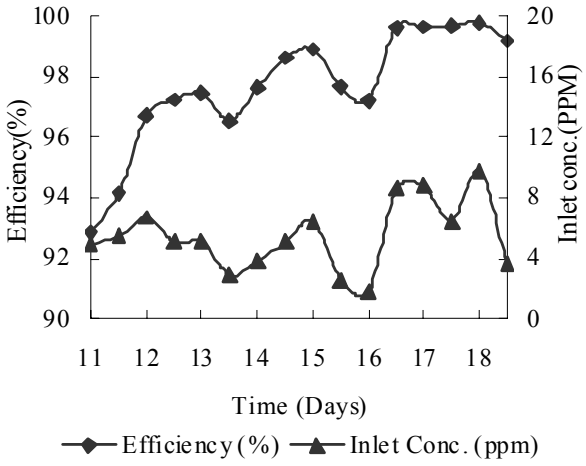

Fig. 3. Variation of H_2S removal efficiency with time under second phase

flow rate was maintained in the range 0.9 to 1.3 m^3h^{-1}. The H-$_2$S removal efficiency was very high around 98% as also reported by Todd *et al.*, (1996). This may be due to adsorption of sulfide on the media surface with subsequent microbial degradation, as reported by Wani *et al.*, (1998).

Fig. 4 shows the variation of H_2S removal efficiency with time under third phase of the study, from day 19 to day 26.Under this phase the H_2S concentration was increased up to 20 ppm at a variable humidified air flow rate of 0.9 m^3h^{-1} to 1.3m^3h^{-1}. H_2S removal efficiency was greater than 99.6% confirm the results of Kim *et al.*, (2008) and Shojaosadati and Elyasi (1999).The biofilter has shown the highest efficiency under this period of operation.

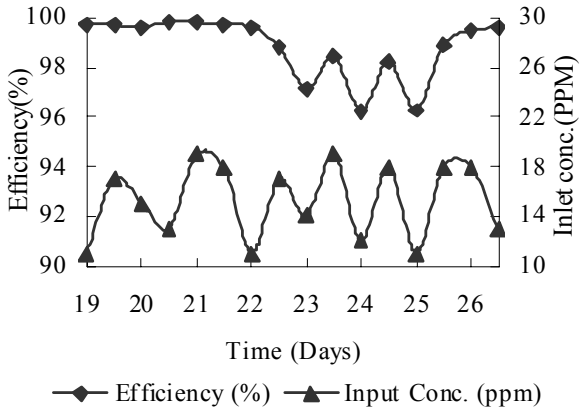

Fig. 4. Variation of H_2S removal efficiency with time under third phase

In the fourth phase of study, between days 27 to day 36, neither humidified air nor H_2S was supplied due to electrical fluctuations and failure of air compressor. As a result compaction and drying of the filter bed was observed. To maintain the microorganisms and proper moisture in the biofilter, air was supplied through the aquarium pump at the constant flow rate of 0.2m^3h^{-1} and water was supplied through shower mounted at the top of the column, about 500 ml per day. This condition helped us in examining the response of biofilter under such situations and to determine the time required to recover to full efficiency. When compressor was repaired, 37th day of operation, contaminated air was supplied as before.

The biofilter rapidly recovered its performance and removal efficiency of >85% was observed within 36 hours. The compaction of biofilter has affected the performance, justifying the results of Marcia *et al.*,(2003).Although H_2S removal efficiency was low in the initial hours after the restart, some biodegradation took place immediately after the process was restarted; indicating the survival of H_2S degrading microorganisms present in the biofilter. However, they were not quite active because of 10 days of starvation confirm the earlier results (Wani *et al.*, 1998). During the fifth phase of the study i.e. from day 37 to day 44, the H_2S concentration was kept up 30 ppm with variable humidified air flow rate. The results are shown in Fig. 5. It is observed that the average removal efficiency for this phase was around 88%.

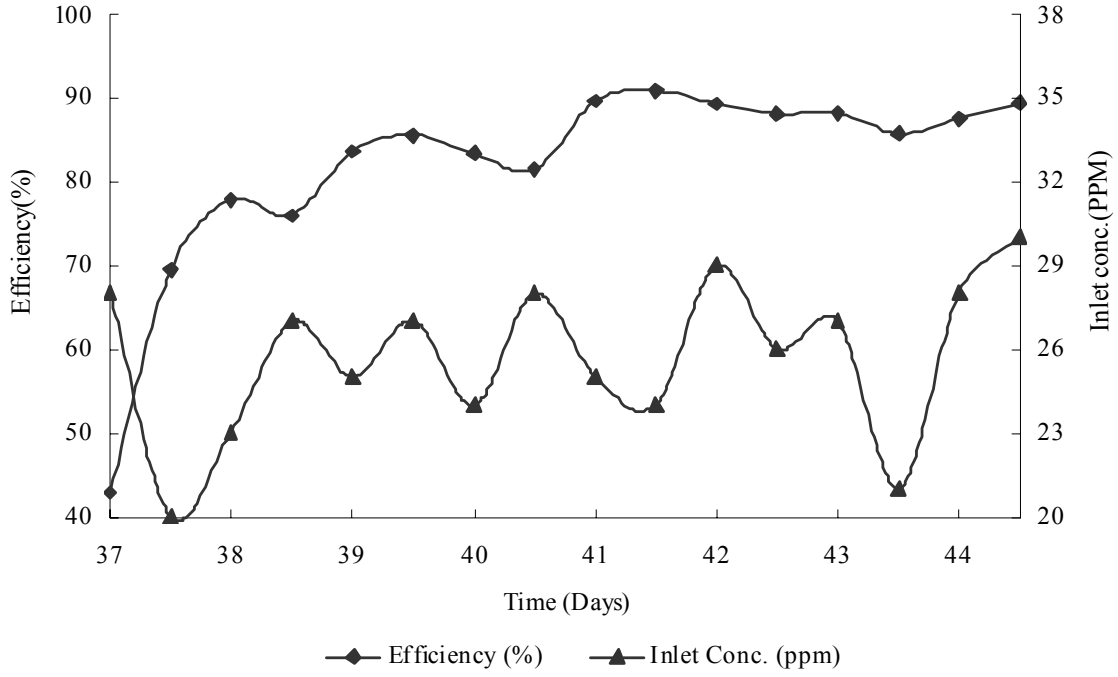

Fig. 5. Variation of H_2S removal efficiency with time under fifth phase

Fig. 6 shows the sixth phase of study i.e. from day 45 to day 52, the H_2S concentration was increased to a maximum 47 ppm with a variable humidified air flow rate from 0.9 to 2.2m^3h^{-1}, the average H_2S removal efficiency was slightly greater than that obtained under fifth phase of the study.

Fig.7 shows the overall H_2S removal efficiency with time for all the phases. There is a break in the curve that is due to power and compressor failure as discussed earlier. It is seen that in initial phases of study the H_2S removal efficiency was nearly 100%. However after the power failure, the maximum H_2S removal efficiency was around 90%.

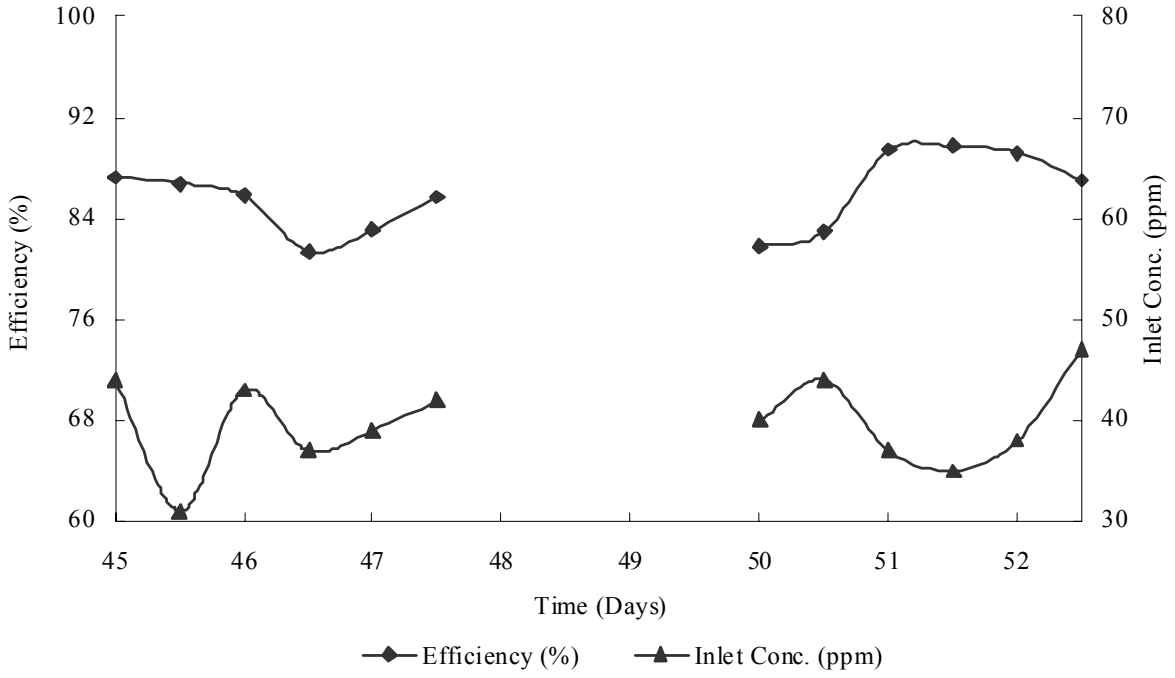

Fig. 6. Variation of H_2S removal efficiency with time under sixth phase

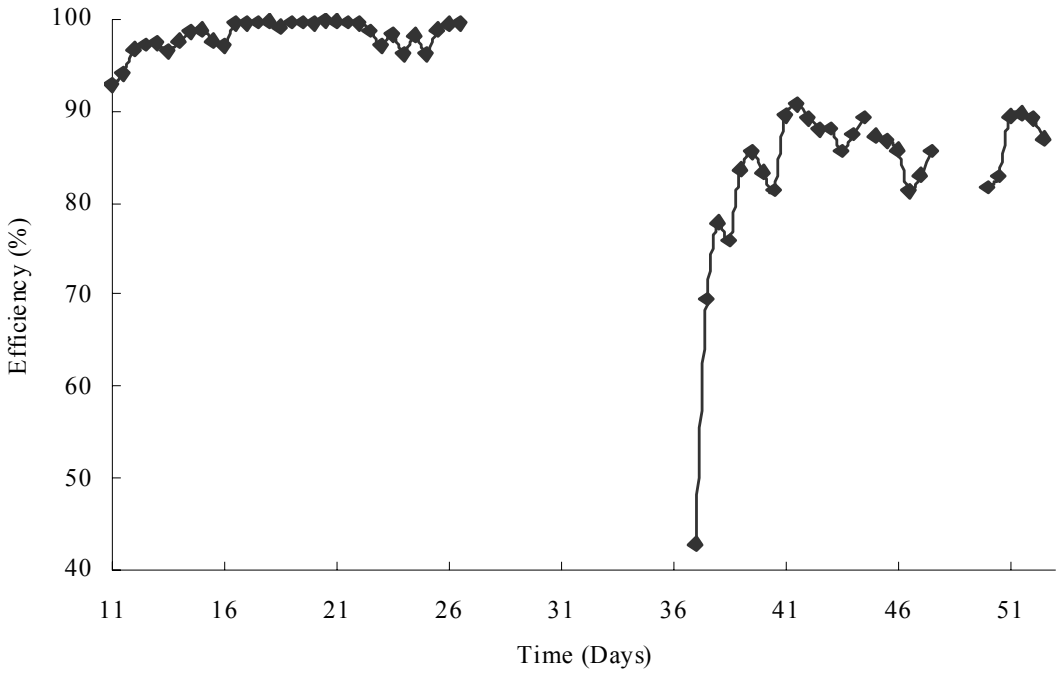

Fig. 7. Variation of Over all H_2S removal efficiency with time

CONCLUSION

The present study was performed to assess the performance of biofilter for the removal of H_2S. It was concluded that the biofilter, used in the study, was more efficient (>95% removal efficiency) for low contaminant concentrations (up to 30 ppm).However, as the concentration of H_2S was increased to 50 ppm the removal efficiency decreased to 85%.The biofilter was able to withstand starvation period and the process recovered well once feeding of H_2S was restarted The re-acclimation time (36 hours) for the biological activity after the starvation period was comparatively shorter than the reported the literature. The results showed that 30 ppm of H_2S concentration required ~20 seconds Empty bed residence time (EBRT) for adopted size of biofilter.

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