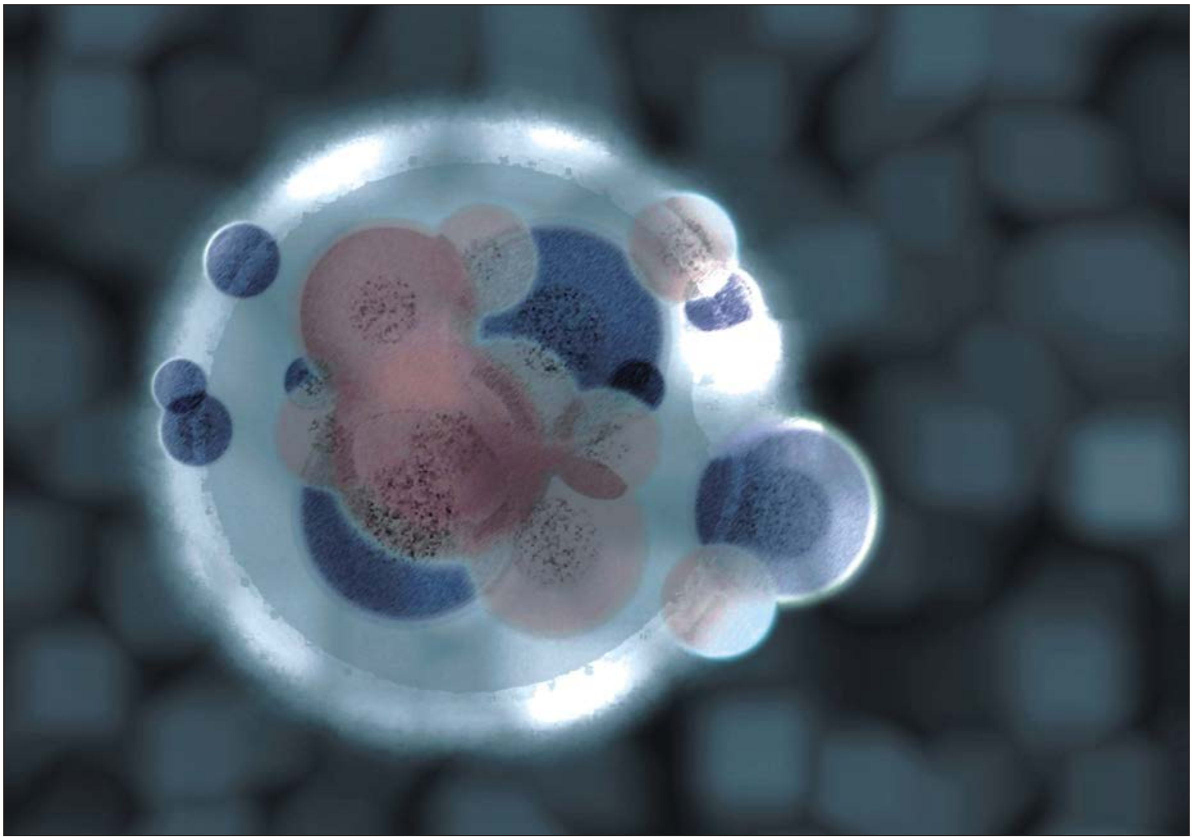

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Biotechnology Advances in Treatment of Air Streams Containing H_2S

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Abstract: Odor control is a severe problem common to most wastewater operations particularly significant at urban treatment plants, gas and oil refineries, paper and pulp industries, etc. The most commonly reported odorous compound in POTW off-gases is hydrogen sulfide (H_2S) which has a very low odor threshold. These odorous emissions can cause a nuisance to adjacent populations and contribute significantly to atmospheric pollution. Waste gases have traditionally been treated using physicochemical processes, such as scrubbing, adsorption, condensation and oxidation, however biological treatment of waste gasses has gain support as an effective and economical option in the past few decades. Some studies have been done on biological systems to control of waste air containing H_2S, although no review on these systems have been reported in the literature. This study reviews available data regarding the performance of biological systems to treat off-gases containing H_2S.

Key words: Waste air treatment, odor, biotechnology, hydrogen sulfide

INTRODUCTION

There are more than 50000 publicly owned treatment works in the worldwide and emission of objectionable odors from these facilities is a major problem[1]. Apart from low concentration of volatile sulfur compounds in waste gases, it is received special attention due to their low or threshold value (PPb_v range), high toxicity and potential corrosive effect[2]. Air discharges from wastewater treatment works, gas and oil refinery, pulp paper industry and other facilities contain hydrogen sulfide, organic sulfide and various volatile organic compounds[3,4]. As these sulfur compounds are strongly odorous, they contribute to the nuisance and hence, are commonly the object of complaint. Hydrogen sulfide (H_2S) is the principal sulfur compound causing odor nuisance at concentration as low as about 8 PPb_v[5]. Hydrogen sulfide is a toxic, colorless, flammable, liquefied gas with characteristic rotten egg that can undergo number of oxidation reactions so that oxidation products depend on the nature of the oxidizing agent[6,7]. It has a great potential to irritate eyes and injure the human central nervous system. Also, excess amount of hydrogen sulfide is detrimental to the environment as it contributes to greenhouse effect and acid rain[8]. Therefore, the control and treatment of waste gases containing H_2S emissions is essential to protect public health and welfare as well to mitigate vegetation and material damage problem[4,8].

H_2S control technologies: A range of technology is available to treat odorous air stream, such as chemical scrubber, incineration, adsorption, condensation and currently biodegradation (bio-filter, bio-trickling filter and bio-scrubber)[4,9-11]. Selection of particular technology or combination of technologies depend on such factors such as site characteristics including operation and maintenance, treatment efficiency, airflow rate, contaminant loading and characteristics and strength of odorous air streams[11,12]. Biological treatment of contaminated air is an emerging technology for air pollution control. The use of biotechnology for waste air treatment has grown dramatically because of its ability to destroy the pollutants rather than simply transfer them from the gas to the liquid phase. Three major types of bioreactor that currently dominate waste gas biotreatment are biofilters, biotrickling filters and bioscrubbers[10]. In addition of these three most widely used technologies, other alternatives have been proposed, such as external loop air lift bioreactor, a spiral bioreactor, membrane bioreactor and activated sludge[11-13]. Although physical and chemical techniques may effectively remove the H_2S from polluted air stream, the requirement of chemical addition and replacement resulted in high operation cost[14-16].

Biofilter: H_2S is degraded as the contaminated air passes through a bed of naturally occurring microorganisms

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Table 1: Summary of biofilter for odour treatment[10]

Advantages	Disadvantages
• Simple, flexible design, low capital cost • Suitable for treating high volume of low concentration sulphurous odorants • 99% removal efficiency in streams containing aldehyds, organic acids, sulphur dioxide, nitrous oxides, and hydrogen sulphide • 90% removal of methane, propane, and isobutene • Compounds with air/water partition higher than 10 can be treated in recirculating biofilter because the residence time 30-60 S and specific surface area (300-100m^2/m^3) are both high	• Design of criteria still developing • large land area required • Media requires regular replacement • Accumulating of acidic metabolic on biofilm • Dissolution of gas into liquid is the rate- limiting step, so long EBCT is required • Control of operation is limited, as there is no liquid phase involved • Accumulation of metabolites on the biofilm can affect micro organisms

Table 2: Summary of trickling biofilter for odour treatment[10,17]

Advantages	Disadvantages
• Simple and flexible design • Low capital and O and M costs • Can treat H_2S up to 500 ppm • Acidification slower in nitrifying filters and with calcareous filter media	• Design of criteria still developing • large land area required • Media requires regular replacement • Only about 60% H_2S removal efficiency • Increased structure maintenance • accumulation of excess biomass in the media bed can cause pressure loss, resulting in performance fall-off or requiring control techniques witch compromise long term performance

Table 3: Summary of bioscrubber for odour treatment[10]

Advantages	Disadvantages
• Is more easily controlled because the pH, temperature, nutrient balance and removal of metabolic products can be modify in the scrubbing liquid • Removal of the products of pollutant degradation by washout, thus avoiding inhabitation of the biomass • Easy control of the liquid composition, so very controllable unit process • Acclimation capacity of the biomass provide efficient degradation of the	• Can remove only highly soluble contaminants with an air/water partition coefficient of less than 0.01 • Biomass growth has to be controlled to increase gas treatment efficiency • controlled inputs of nutrients in the liquid phase required for efficient pollutants degradation

Table 4: Performance of hydrogen sulfide removing biofilters in the literature authors

Authors	R (%)	C (mg m^{-3})	EC (g^{-3} h)	Notes
Bonnin *et al.*[19]	99	---	240	Peat
Bonnin *et al.*[19]	99	---	1440-1680	Mearl
Brennan *et al.*[20]	99	83	8.3	Peat/bench scale
Cho *et al.*[21]	---	---	590	Peat
Cho *et al.*[22]	---	---	1200	Peat
Cho *et al.*[23]	---	---	340	Peat
Chung *et al.*[24]	95	60 (ppm)		Immobilized Bacteria
Chung *et al.*[25]	>90	---	---	Immobilized Hetrotrophic Bacteria
Ergas *et al.*[26]	99.99	28	420	Compost/bench scale
Hirai *et al.*[27]	---	---	610	Peat
Kowal *et al.*[28]	100	---	200-12000	Dry activated sludge
Luo *et al.*[29]	29.7-99.9	143100-890000 (OU m^{-3})	---	Different media
Malhautier *et al.*[30]	80	---	680	Granulated sludge
Mcnevin *et al.*[31]	99	32	10	Peat/pilot scale
Mcnevin *et al.*[32]	---	0.0308	2.4	Compost, bark mulch
Nicolai *et al.*[33]	67.5-83.2	---	<150 OU m^{-3}S	Compost and wood chips mixture
Park *et al.*[34]	>95	3.2-5.5	---	Porous ceramic
Pinjing *et al.*[35]	>98	200-1300	6500	Immobilized cell beads
Shojaosadati *et al.*[36]	99	154	22	Compost/bench scale
Yang and Allen[37]	99.9	369	3120	Compost/bench scale
Zhang *et al.*[38]	---	---	730	Peat
Zhang *et al.*[38]	---	---	360	Peat

R: Removal efficiency C: Concentration EC: Elimination capacity

immobilized on a support media. H_2S in air stream provide a source of energy for the biomass, while the bulk media is used to supply the nutrients to the biofilm. Common types of biofilter (close or opened) are indicated in Fig. 1 and 2[10]. Characteristics of this system are summarized in Table 1[11].

Biotrickling filter: The odour laden air stream is passed over a microbial consortium immobilized on support media with a high surface area. Water recirculation maintains humidity in the media bed and allows nutrient supply. Odorants dissolve into the liquid phase and are degraded by the biofilm present. Biotrickling filter media can be

Table 5: Performance of Hydrogen sulfide removal in biotrickling filter

Authors	R (%)	EC (g m^{-3} h)	EBCT (S)	Notes
Deshusses *et al.*[5]	99	20	36	Bench scale
Guey *et al.*[41]	90	3420	---	Bench scale
Kraukman *et al.*[42]	---	100	-	Bench scale
Lating *et al.*[43]	85-98	500-6500	---	Bench scale
Lawrence[44]	97	---	7	Full scale
Lawrence *et al.*[45]	99	---	3	Pilot scale
Lin *et al.*[46]	99	40	<5	Bench scale
Lw *et al.*[47]	95	---	5-30	Pilot scale
Tanji *et al.*[48]	95	590	---	Bench scale

EBCT: Empty Bed Contact Time

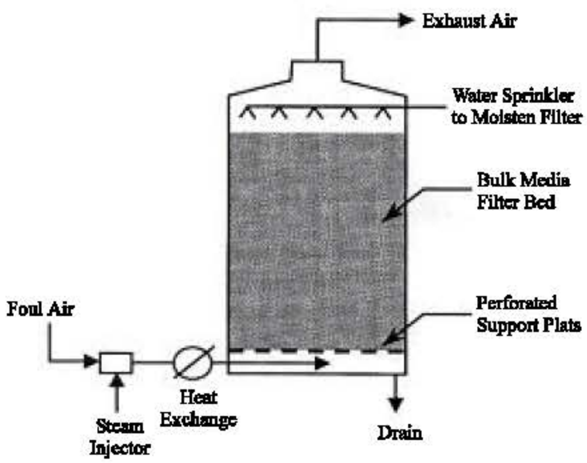

Fig. 1: Packed media biofilter[10]

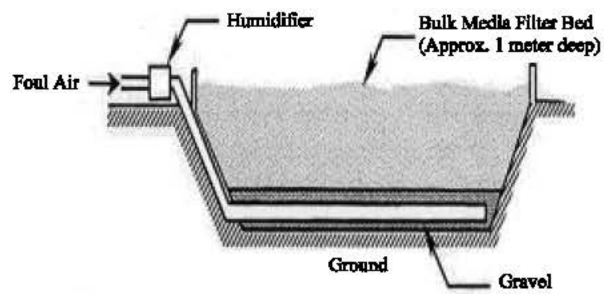

Fig. 2: Open soil biofilter[10]

ceramic or plastic structures, activated carbon, clite or mixture of materials. A sample of bio trickling filter is shown in Fig 3. Table 2 summarize the specifications of biotrickling filters[10,17].

Bioscrubber: In biscrubber pollutants are absorbed into the aqueous phase and then biologically degraded (Fig 4). Table 3 shows the advantages and disadvantages of the bioscrubber process. Bioscrubbing has several advantages over the other biological methods[10]. The process is more easily controlled because the pH, temperature, nutrients balanced and removal of the metabolic products can be altered in the recirculated liquid of the reactor[4] .

Membrane bioreactor: In membrane bioreactors the gaseous pollutants are transferred from the gas to the liquid through a membrane. In this process two membrane types of dense and hydrophobic microprous are used. Two forms of biomass may be also used in membrane bioreactor: biofilm and suspended growth culture[10].

Activated sludge process: Activated sludge is another biological process used for treatment of contaminated air.

In this process, contaminants are removed by absorption, adsorption or condensation followed by biodegradation[18].

Performance data on H_2S bio-degradation: Industries especially in Iran face difficult choices in complying with increasingly stringent air pollution regulations. Although wet scrubber is a proved method for removal of gaseous pollutant[5,10], relatively little is known on treatment of off-gases that contain H_2S, in Iran.

Among biological techniques, many studies have investigated the removal of H_2S in biofilters. Summarized results have indicated in Table 4. In spite of high H_2S removal efficiency, the most important defect of biofilter is accumulation of sulfate from oxidation of H_2S that often cause a decrease of the performance in the long term runs[11,14,15,39,40]. Table 5 shows the summarized results of biotrickling filter performance for H_2S removal in literature. Nishimura *et al.*[49] studied removal of H_2S in a full scale bioscrubber at a wastewater treatment plant and results showed more than 99% removal efficiency when treating 2000 ppm$_v$ of H_2S in 4 m^{3}h^{-1} air flow rate. H_2S and VFA removal from foul air investigated by Li *et al.*[41] in a fibrous bed bioreactor. The experimental results demonstrated that the efficiency of 97.8% for H_2S was achieved.

Simultaneous wastewater treatment and odor control in an activated sludge process was studied by Hardy *et al.*[50]. Results indicated that the levels of H_2S

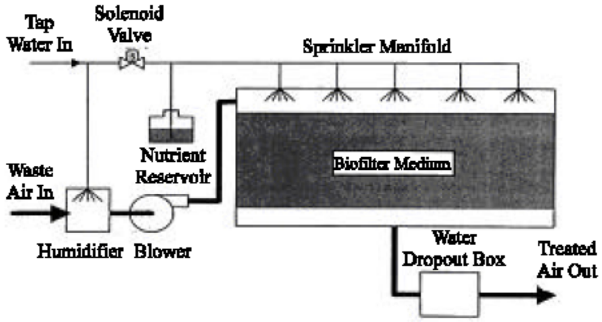

Fig. 3: Trickling biofilter[10]

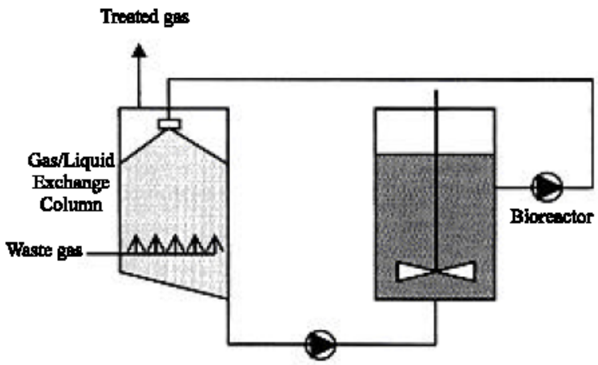

Fig. 4: Bioscrubber[10]

produced by other unit processes on a wastewater treatment plant (approximately 5 ppm_v) can be treated by activated sludge diffusion.

Picot *et al.*[51] investigated the use of biological cover for *in situ* control of gaseous sulfide emissions from an anaerobic pond by a lab scale experiment. The biological cover, consisted of a peat bed floating on the wastewater, caused a reduction of the H_2S emission by 84.6%. The addition of Fe^{+2} and plants to the bed improved the H_2S removal performance to 95.5%. In 1995, Brandy *et al.*[52] studied the removal of H_2S in a bioscrubber in which H_2S removal efficiency of 100% was achieved. Stillwell *et al.*[53] studied the performance of a mixed culture activated sludge process for H_2S removal in which removal efficiency of 83% was achieved. In a same study, Kasakura *et al.*[54] could remove 99% of the H_2S diffused into a mixed culture activated sludge system.

DISCUSSION

At present, among biological treatment processes, biofilters are the most common process studied for odorant abatement. Although, this technique has some limitations such as large size, channeling, media compaction and short-circuiting of air flow, low oxidation rate, tolerating low pollutant concentration and accumulation acidic metabolites (sulfate in H_2S bio-oxidation) on biofilm that causes a decrease in the long run[5,9,10,45].

In trickling biofilter, as the air passes through the media it is collected from inside a dome at the top of filter, the majority for recycling through the bed and a small portion for final treatment. Trickling biofilters (Table 2) represent a method in witch metabolites are washed out from over the biofilm and acidification can be avoided. The major draw back with this system is the problem of transforming the odorous pollutants from the foul air to the liquid phase, but trickling biofilters can still be effective in treatment of gaseous compounds with a air/water partition coefficient of less than 1[55,56].

Bioscrubbing has several advantages over media based filtration (Table 3). This process is more easily controlled because the pH, temperature, Nutrient balance and removal of metabolic products inhibiting oxidation can be altered in scrubbing liquid[11]. Although researches have shown the promise of bioscrubbers for H_2S removal, additional knowledge is needed to determine of influencing operational factors on performance to decline its defects.

Industries and POTWs especially in Iran, face different choices in complying with increasingly stringent air pollution regulations. Although wet scrubber is an approved method for removal of gaseous pollutants, relatively little is known on treatment of off-gases containing H_2S. Data published in literature show that biotechnology is a promising technique to control of the waste concentrations of pollutants especially acidic air streams in relatively low pollutants concentrations. Although for higher odorants such as H_2S, chemical scrubbers still are preferred systems. Also, currently no direct performance comparison on chemical scrubber and bio-scrubber and their sustainability has been reported in the literature. Long term influent and effluent quality data are required in order to study the performance of these two systems. Authors are working on this field, so the results will be published in literature[57].

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