

DEVELOPMENT OF A BIOFILTER MEDIA FOR REMOVAL OF HYDROGEN SULPHIDE

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ABSTRACT

Industrial facilities emit pollutant air that contains volatile organic compounds (VOCs) and reduced sulphur compounds (RSCs) which are nuisance, corrosive to materials and dangerous to health. In recent years, biofiltration has replaced numerous conventional processes (i.e. adsorption) due to its more effective, economical and environmental benefits. Thus, increasingly industrial facility operators are adopting biofilters for removal of air pollutants. Biofiltration takes place in bioreactors that are packed with media particles. On these media particles micro-organisms form biofilms where biological oxidation takes place. The new biofilter media developed in this study consists of a base material, hydrophobic coatings, nutrients and binding agents. In this contribution, method of development, evaluation and performance of this new bioreactor media are discussed.

KEYWORDS: bioreactor, media, air pollution control, biofiltration, hydrogen sulphide.

INTRODUCTION

It is well known that numerous municipal and industrial operations including wastewater treatment, food processing, petrochemical, pulp and paper manufacturing, rendering, and composting processes produce Hydrogen Sulphide (H_2S). H_2S is a highly odorous, toxic and corrosive air contaminant that can cause adverse health effects. The maximum safe exposure limit to H_2S gas is approximately 10 ppm; however, the gas detection threshold is approximately 0.47 ppb. Given the exposure limit and the fact that even small quantities can be detected, there are strict regulations in effect for controlling the emission of H_2S in many regions of the world.

In recent years, biofiltration has replaced numerous conventional processes due to its more effective, economical and environmental benefits. Prior to the development of biofilters, conventional treatment methods used to remove H_2S from air streams, relied on processes such as activated carbon adsorption, chemical oxidation, and incineration. These conventional systems have drawbacks such as high equipment cost, high disposal cost, chemical requirements, and a high energy cost. A biofilter system uses media such as peat, wood bark, soil, compost, coated ceramic particles, synthetic media, or a combination of these materials upon which microbial populations grow as thin biofilms. As a contaminated air stream passes through the biofilter, air contaminants such as H_2S are transported to the biofilms where they are biodegraded.

Laboratory and field studies have shown that biofiltration of H_2S is feasible, however there have been few problems reported due to the formation of acidic intermediate products (Allen and Yang, 1992), sulphur deposits on the media (Yang and Allen, 1994; Chung *et al.*, 1996), and slow rates of H_2S degradation (Shareefdeen *et al.*, 2002) which results in large media volume requirements for full-scale systems. Shareefdeen *et al.* (2003), in another study, reported H_2S removal performance of a synthetic biofilter media (EU Patent No. 0 497 214 B1). Although this media has better structural and biological properties, it still has a few

problems as discussed above. Thus, there is a need for an improved and efficient way to remove H₂S from the air. The objective of this work was to develop an improved biofilter media for removal of H₂S. In this work, method of media manufacturing, evaluation and performance of this new bioreactor media are presented.

EXPERIMENTAL METHODS

Media Manufacturing

The media developed in this study consists of a hydrophilic nucleus, hydrophobic coatings, bonding agents, metallic powder, micro-organisms, nutrients and acid. The nucleus of the media is made of expanded porous aggregate particles which are moistened prior to crushing and screened. The pre-screened porous hydrophilic nuclei are then mixed with water and the hydrophobic coating (i.e. activated carbon). The hydrophobic coating includes a bonding agent (i.e. cement), which holds the nucleus and the coating together. The coating also includes a metallic (i.e. iron) powder. The powdered iron aids in the formation of iron sulfide (FeS) and serves to speed up the biological oxidation of H₂S. In order to provide a source of micro-organisms and nutrients, the biofilter media also includes a carbon source which is often peat, compost or a coarse wood material. The process of adding the hydrophobic coating to the hydrophilic nucleus includes an acidification step. Acidification of the coating using phosphoric acid (H₃PO₄) increases both the porosity and the buffering properties of the finished biofilter media. Further details of manufacturing process are described in the US Patent Pub. No. 2205/0084949 A1.

Biofiltration experiments

Several batches of the media were produced and tested. Media performance data were obtained from pilot biofilters (see Figure 1) which were used in the synthetic media evaluation study (Shareefdeen *et al.*, 2003). For biofilter experiments, H₂S gas was regulated and supplied via high precision Teflon™ flow meters (Cole Parmer, IL) into the air inlet line. Concentrations were measured using ODALOG (Detection Instruments Co., AZ) and airflow rates, using inline air flow meters (RMC-121, ITM Instruments, ON, Canada). Controlling the moisture content of the biofilter media is important for effective removal of H₂S. The moisture in the hydrophilic nucleus of the media supports metabolic activity throughout the surface area and aids in keeping the biofilter media from drying out. The moisture content of the biofilter media is controlled by humidification and surface irrigation. In full biofilter scale systems, humidification may be done by pre-scrubbers, pneumatic sprays, steam addition or other technology (Shareefdeen and Herner, 2005).

RESULTS AND DISCUSSION

Concentrations of H₂S and operational time were recorded throughout the experiment. The biofilters were operated under steady state and transient conditions. The biofilter media start-up was almost immediate and it took only a day for complete removal of H₂S. Figure 2 shows a typical 8-hr day operation of a biofilter. The graph shows that the new biofilter media removes about 50 ppm of H₂S in 20 second EBRT under steady state conditions. For the same H₂S levels (~ 50 ppm), the media described in the European Patent No. 0497214 B1 and many vendor supplied media products require at least 30 second EBRT for complete removal. Thus, due to a short EBRT time requirements, biofilters can now be made in smaller compact modular units using this improved media to treat larger airflow volumes from a variety of applications that emit H₂S.

In practical applications, concentration and flow variations are more common. Figure 3 shows, typical variations of H₂S concentration levels from a wastewater pumping station. Thus, efficient biofilter should be able to remove H₂S levels under steady state as well as transient conditions. Several transient experiments are carried out to verify efficiency of this new media. Figure 4 shows a typical transient experimental data which demonstrates that new media performance is excellent even under transient conditions.

As the air flows through the biofilter media, contaminants are oxidized by the microorganisms. The acidic-byproducts generated from these metabolic activities were easily removed (washed out) from the media with water, using irrigation at pre-determined intervals

(Shareefdeen *et al.*, 2003). Thus, pH of the media was easily maintained at neutral conditions that provided constant and predictable performance.

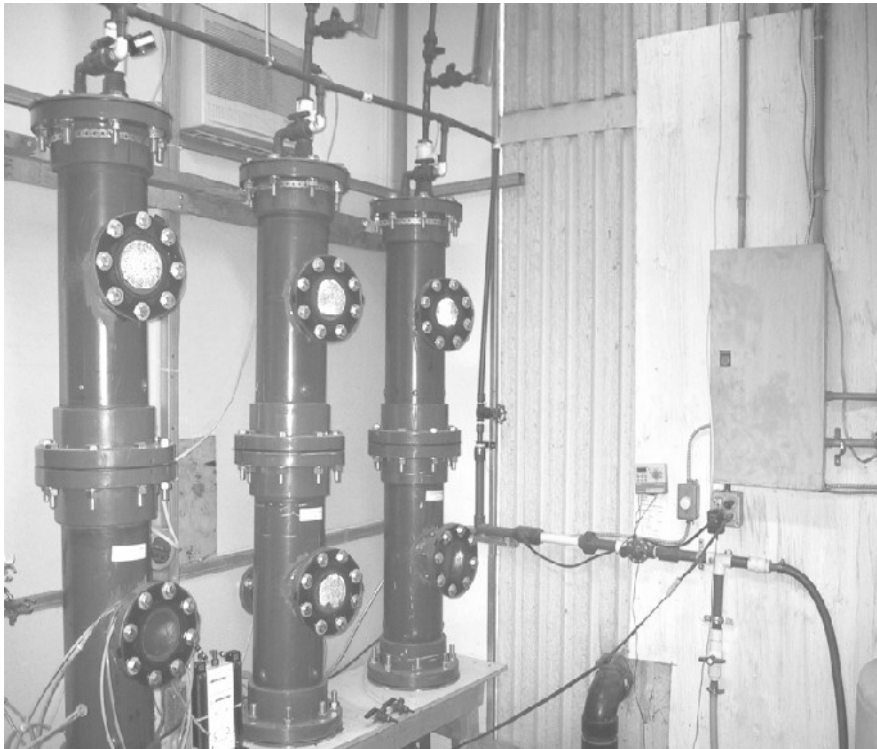


Figure 1. Pilot Scale Laboratory Biofilter Set-Up

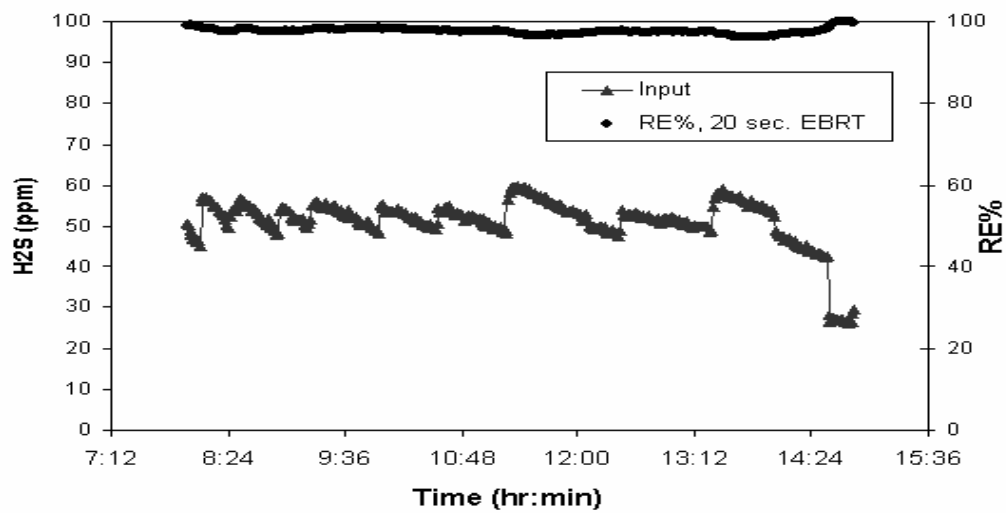


Figure 2. H₂S Performance Data under Steady State at 20 second (EBRT)

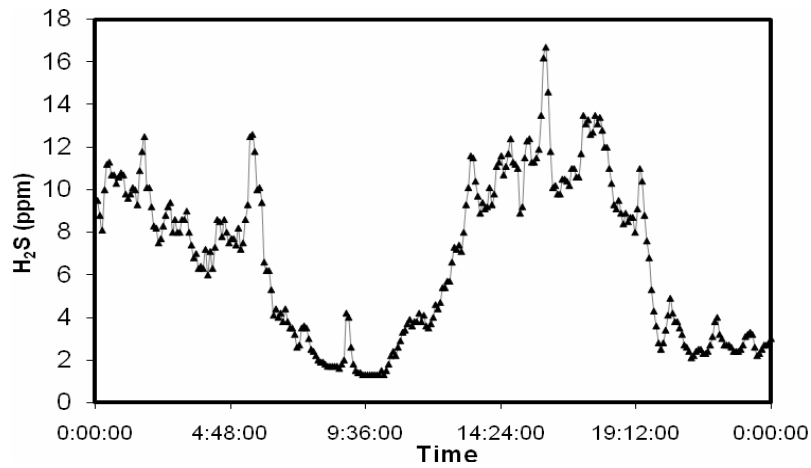


Figure 3. H₂S emissions from a Wastewater Pumping Station (Shareefdeen *et al.*, 2003)

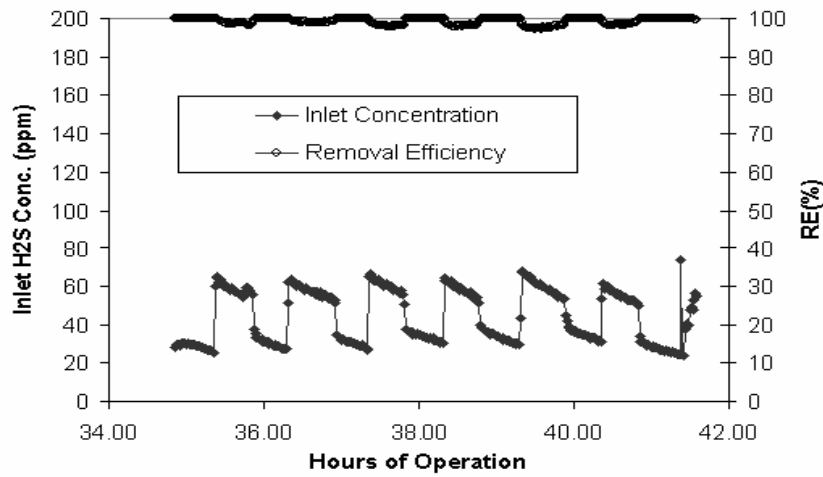


Figure 4. H₂S Performance Data under Transient Conditions

The steady state data collected from this study were compared with biofilter models. Of all the models tested, zero-order diffusion limited model fitted the data best.

The concentration profile for diffusion limited regime is given by,

$$\sqrt{\frac{C_{H_2S,air}}{C_{H_2S,air-inlet}}} = \left\{ 1 - A_S * EBRT \sqrt{\frac{k_0 D}{2m C_{H_2S,air-inlet}}} \right\} \quad (1) \text{ or}$$

$$\sqrt{\frac{C_{H_2S,air}}{C_{H_2S,air-inlet}}} = \left\{ 1 - \alpha_{lump} EBRT \sqrt{\frac{1}{C_{H_2S,air-inlet}}} \right\} \quad (2)$$

where, $\alpha_{lump} = \left\{ A_S * \sqrt{\frac{k_0 D}{2m}} \right\}$

- A_S : biofilm surface area/ volume
- C_{H_2S} : concentration of H₂S in the air

- D: effective diffusion coefficient of H₂S in the biofilm
K₀: zero order rate constant
m: air/biofilm distribution coefficient for H₂S

This model has been validated with steady-state experimental data of this study and the lump parameter value (α_{lump}) was found to be 0.204 when H₂S concentration and EBRT were expressed in ppm and seconds, respectively. This correlation is used to estimate media volumes for several full scale applications.

CONCLUSIONS

In this work, a new improved biofilter media is developed. Media consists of inert hydrophilic base material, hydrophobic coatings, a metallic component, nutrients and binding agents. Performance data using this media under different operating conditions have been collected under a steady state, and transient conditions. The media gives complete H₂S removal (>99%) in 20 second EBRT. This improved media performance was compared with the media described in the European Patent No. 0497214 B1 which requires 30 seconds for the same removal and conditions (i.e. 50 ppm H₂S). Thus, media volume required to accomplish the same removal can be reduced by 1/3. Removal of H₂S in the biofilter followed zero-order diffusion limited kinetics. The design correlation developed in this study can be used in estimating media volume and sizing biofilter systems. This improved media is now patented and used in several H₂S commercial applications.

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