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Hydrogen Sulphide Removal Using a Novel Biofilter Media

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***Abstract*—**Air emissions from waste treatment plants often consist of a combination of Volatile Organic Compounds (VOCs) and odors. Hydrogen sulfide is one of the major odorous gases present in the waste emissions coming from municipal wastewater treatment facilities. Hydrogen sulfide (H_2S) is odorous, highly toxic and flammable. Exposure to lower concentrations can result in eye irritation, a sore throat and cough, shortness of breath, and fluid in the lungs. Biofiltration has become a widely accepted technology for treating air streams containing H_2S. When compared with other non-biological technologies, biofilter is more cost-effective for treating large volumes of air containing low concentrations of biodegradable compounds. Optimization of biofilter media is essential for many reasons such as: providing a higher surface area for biofilm growth, low pressure drop, physical stability, and good moisture retention. In this work, a novel biofilter media is developed and tested at a pumping station of a municipality located in the United Arab Emirates (UAE). The media is found to be very effective (>99%) in removing H_2S concentrations that are expected in pumping stations under steady state and shock loading conditions.

***Keywords*—**biofilter media, hydrogen sulphide, pumping station, biofiltration

I. INTRODUCTION

AIR emissions from waste treatment plants often consist of a combination of Volatile Organic Compounds (VOCs) and odors. Odors are inorganic or organic compounds. Volatile chemicals are often present at higher concentrations than odors, but may or may not have any odors associated with them. The major problem with emission of volatile chemicals is the detrimental impact on the environment and adverse human health effects. While several U.S. EPA regulations govern the emission of hazardous volatile chemicals in the ambient air and in the workplace, odor emissions are often a major nuisance to the plant workers and surrounding communities**.**

Hydrogen sulfide is one of the major non-organic gases that are present in the waste air emitted from municipal industries[1]. Hydrogen sulfide is odorous, highly toxic and flammable. It is heavier than air so it tends to accumulate at the bottom of poorly ventilated spaces. Hydrogen sulfide can poison several different systems in the body, although the nervous system is most affected. Exposure to lower concentrations can result in eye irritation, a sore throat and cough, shortness of breath, and fluid in the lungs. Long-term, low-level exposure may result in fatigue, loss of appetite, headaches, irritability, poor memory, and dizziness. At 150-250 ppm, the olfactory nerve is paralyzed after a few inhalations, and the sense of smell disappears. Concentrations over 1000 ppm cause immediate collapse with loss of breathing.

Biofiltration has become a widely accepted technology for treating air streams containing odorous compounds. Biofiltration is also effective for treating air streams containing biodegradable VOCs. There are three equipment variations of the biofilter technology: biofilters, bioscrubbers, and biotrickling filters [2]. Of these, biofilters are the most popular and widely used at municipal industries. In the case of biofilters and bio-trickling filters, microorganisms are immobilized on support materials or media. When compared with other non-biological technologies, biofilters are more cost-effective for treating large volumes of air containing low concentrations of biodegradable compounds. The main components of biofilters are an air distribution system, the media and a means for the control of moisture in the media and nutrients.

Optimization of packing media is essential for many reasons such as: providing a higher surface area for biofilm growth, low pressure drop, long term physical stability, and good moisture retention. If the particles of the packing media are too fine, bed compaction occurs, causing high pressure drop and clogging. The moisture content of the media is also an important parameter for bacteria growth and survival. Typical organic media (i.e. compost) contains 40–80% water by weight. Water is essential for both biofilm survival and microbial activity. Thus, the amount of water in the biofilter is one of the most important parameters for efficient biodegradation activity and high biofilter performance[3]. It is essential that the inlet waste gas be saturated with water vapor and the relative humidity should be greater than 90% so that the water will not evaporate from the media. Biofilters are also equipped with water sprays to add water to the media bed. Moisture content should be suitable in the packing media. And excess of water prevents oxygen transfer and causes anaerobic zones. Organic packing media also contains nutrients that facilitate growth of microorganisms. Most biofiltration processes are aerobic, employing heterotrophic microbes which are effective in removing H_2S for a wide range of potential applications with respect to pH 4.0–8.0[3]. The pH in a biofilter may also change during operation. In some cases, the pH has to be regulated using buffer substances mixed with the packing material or using alkaline or acid solutions[2]. Temperature

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control is very essential. Thus temperature range for biofilter performance is approximate between 15-40°C.

A recent literature[4-6] on biofiltration of H_2S indicates that there is a growing need for development of this technology. The objective of this work is to develop a novel biofilter media, and to obtain removal performance data in a field condition. This work describes media manufacturing, construction of a pilot biofilter column and H_2S removal performance at a pumping station of a municipality located in the United Arab Emirates (UAE).

II. EXPERIMENTAL APPROACH

Biofilter Media Preparation

A specific construction material used for building high rise structures is found to be a good source for biofilter media base. Construction blocks were cut and made into hollow cylindrical particles. The surface area of the particle is increased by having an opening at the centre of the cylindrical piece of the particle. The base material is subsequently coated with nutrients and microbes. Different samples of the coated media were prepared and analyzed. The mixing ratios of the nutrients were adjusted accordingly so that the desired amount of nutrients was coated to the base media, while at the same time the binding was strong. Figure 1 shows a picture of a base material particle before any coatings.

Fig. 1. Base Material of the Media Particle

Pilot Biofilter Set-up

A mobile pilot biofilter unit was constructed and installed at a pumping station located in UAE for field experiments. The unit consists of the followings: biofilter column, humidifier, diaphragm pump, gas compressor, rotameter, OdaLog, trolley and manometers. OdaLog (App-Tek International Pty Ltd, Australia) is specifically designed for the wastewater industry to accurately measure H_2S from sewerage pumping stations and other facilities. At the bottom of the column a disperser was attached to get uniform distribution of the incoming humidified air. Air was pre-humidified by passing it through a water tank. The column was packed with the media described above. The schematic of the biofiltration system set up in the laboratory is shown below in Figure 2, and the photograph of the unit is shown in Figure 3.

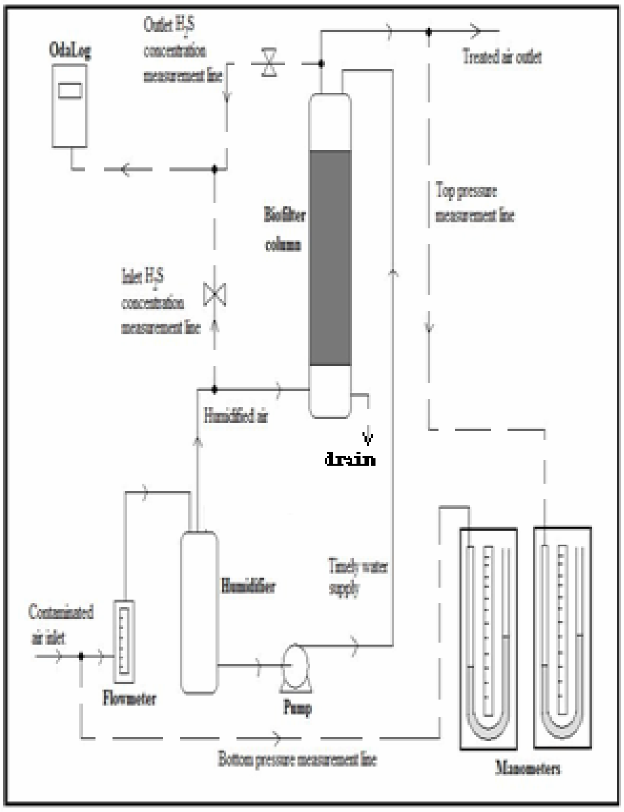

Fig. 2. Schematic of a biofiltration system

Fig. 3. Photograph of the biofiltration system set-up in the laboratory

III. RESULTS AND DISCUSSION

Media Particle Characteristics

Dimensions of the packing material were taken in the laboratory. To have an average size, volume and surface area of the material, a sample of 30 particles was selected. The length and the outer diameter of the packing material were measured by a Vernier caliper to the precision of 2 decimal places. The mean length, inner diameter, outer diameter, surface area and volume of the particles were found to be 2.13±0.18 cm, 0.72±0.04cm, 1.72 ±0.02cm, 20.10±1.54cm^2 and 4.08± 0.43 cm^3, respectively. Since the material is very porous, actual surface area will be much higher. Figure 4 shows the variations of the particle volumes.

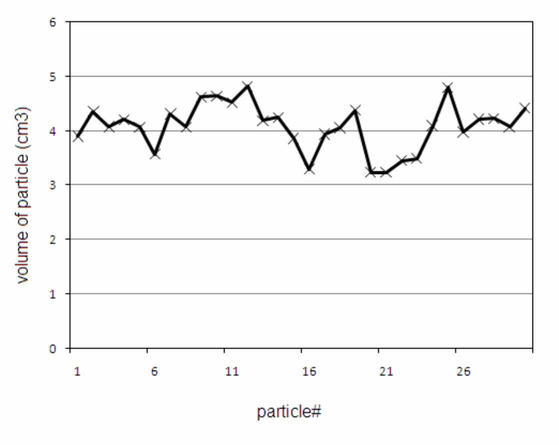

Fig. 4. Volume Variations of the Media Particle Size

Apart from measuring the size of the packing material, void fraction and porosity of the base material were also determined in the laboratory. The void faction was estimated to be 0.57. The pore volume was roughly estimated by the amount of water that filled the pore space. The porosity was estimated to be 0.0175. Not all the pores in the media were filled with water, hence leading to a very low porosity value. For an accurate measurement, a BET surface area method can be employed[1].

Field Testing of the Media

The mobile pilot biofilter was set up at a pumping station of a municipality in UAE. Performance data were collected at different empty bed residence times (EBRT), which is defined as the ratio of the volume of media to the volumetric air flow rate. A calibration curve of EBRT versus flow rate was constructed for easy readings of EBRT values, as shown in Figure 5.

The Empty Bed Residence Time (EBRT) was set to 60 sec, 45 sec and 30 sec by operating under corresponding flow rates of 8 L/min, 11 L/min and 16.5 L/min respectively. At each EBRT, the inlet and outlet concentrations were obtained for at least one week before changing the EBRT to the next value.

Figure 6 shows a set of start-up data taken at 60 sec. EBRT. The lower outlet concentrations at the initial period may be attributed to the acclimatization of the media. Despite the fluctuations in the inlet H_2S concentrations, the biofilter media showed almost 100% removal at 60 second EBRT. Figure 7 and 8 shows removal of H_2S at 45 and 30 seconds EBRTs, respectively.

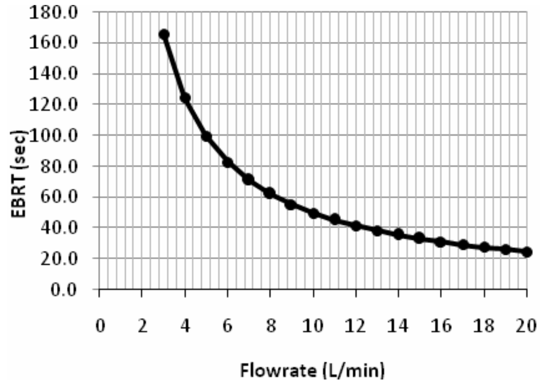

Fig. 5. Empty bed residence time (EBRT) vs. Flow meter readings

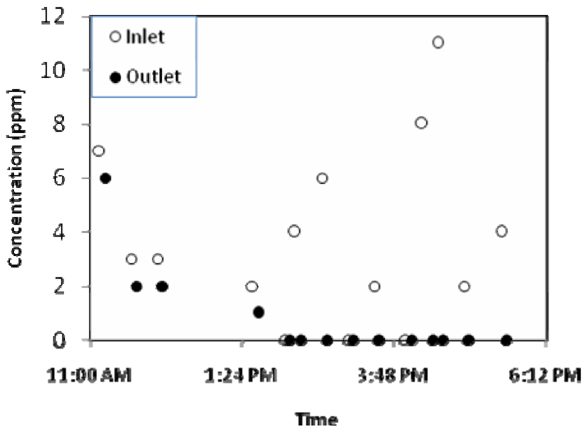

Fig. 6. H_2S concentration versus time at 60 sec. EBRT (October 22, 2009)

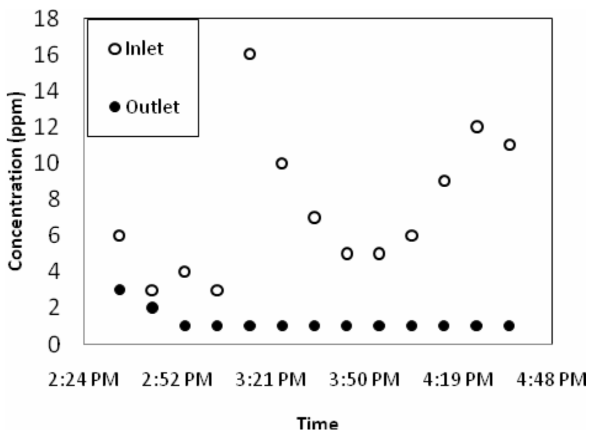

Fig. 7. H_2S concentration versus time at 45 second EBRT (November 11, 2009)

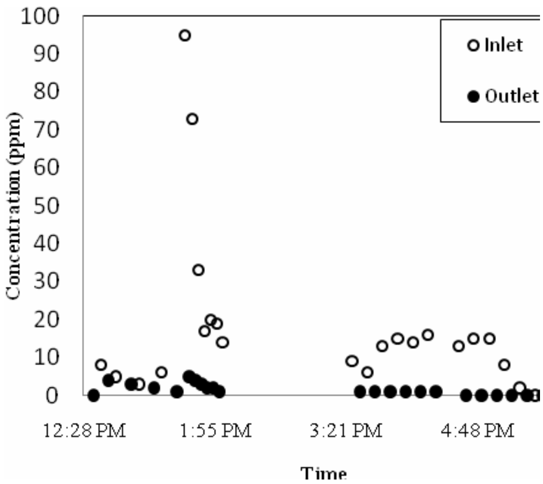

Fig. 8. H_2S concentration versus time at 30 second EBRT (November 5, 2009)

In all cases, Figures 6-8 show that biofilter media is effective in removing H_2S concentrations that are expected in pumping stations. In some days, (refer to Figure 8), peak value of H_2S reached 100 ppm. Regardless, the biofilter media removal efficiency remained over 90% at 30 second EBRT. The inlet H_2S to the biofilter was fluctuating and discontinuous during shut-down on holidays. However, the bacteria showed a consistent performance and recovered quickly after start-up. Thus, the media was able to withstand concentration shock loading conditions. The occasional irrigation of the media removed by products (i.e. sulfuric acid) from the media and media showed consistent performance.

IV. CONCLUSIONS

In conclusion, a novel biofilter media has been developed and tested at a pumping station of a municipality located in the United Arab Emirates (UAE). The media porosity and void fractions were estimated. A mobile pilot biofilter was constructed and packed with the novel media. The media was found to be effective in removing H_2S concentrations that are expected in pumping stations under steady state and shock loading conditions. The biofilter column was placed outside without protection from the sun. As the temperature in UAE can reach above 45^oC in summer, additional consideration should be considered in collecting performance data and also in the design. Based on the performance of the media and analysis of the model, a full scale biofilter system that incorporates this media will be designed. Such a work is in progress and will be presented in our future contribution.

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