BIOFILTER TESTING USING COMPOSTING FOR STYRENE AND METHYL ETHYL KETONE EMISSIONS

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ABSTRACT

This project is a technology demonstration to establish the biofilter technique as a cost-effective method to remove airborne volatile organic compounds (VOCs). The system was designed to remove mainly styrene from the airstream from the Pipe Assembly Building at Augusta Fiberglass Coatings in Blackville, South Carolina. The biofilter was also proved capable of removing methyl ethyl ketone (MEK). Results from the demonstration have shown that the effluent generally remaining below 7 ppm of styrene. The average styrene influent is 200 ppm. The project has demonstrated a reliable and inexpensive method for removing low levels of VOCs. Chicken compost was used as a source of nutrients and microbial growth.

INTRODUCTION

Several technologies are currently being used to reduce VOC emissions. These technologies include vapor scrubbing, thermal oxidation, catalytic oxidation, carbon adsorption, UV oxidation, corona destruction reactors, plasma technologies devices, and biofiltration. The first four are the mature technologies that have been proven effective at reducing VOC air emissions. The latter are newer technologies that are still being tested as to their effectiveness. The technique described and discussed here is a field-pilot biofiltration demonstration used to reduce styrene, methylene chloride and MEK air emissions. Compost matrix was used as a source of nutrients and bacterial growth.

Biofiltration can be widely applied to control VOC emissions from industrial and commercial sources, wastewater treatment plants and soil and groundwater remediation operations. Biofiltration is an air pollution control technology that cleans contaminated air as it passes through one or more beds of a selected medium. VOCs are transported from the gas phase to the biofilm on the compost matrix and degraded to CO_2 and H_2O by the microorganisms in the biofilm. Cost analyses have shown that biotreatment of industrial waste gases containing VOCs is potentially 2 to 10 times less expensive than thermal oxidation or catalytic oxidation, 10 to 40 times less expensive than adsorption to activated carbon and 4 times less expensive than traditional scrubbing (Salemink, R., 1991 and Dharmovaram, S., 1991). Furthermore, vapor scrubbing and carbon adsorption techniques require further processing of volatile organic carbons to oxidize them to CO_2 and water.

The objectives of the pilot demonstration described here are:

- To measure the biodegradation rate of compost microorganisms stimulated by styrene to determine the efficiency of the process.
- To determine the major parameters that effect the biofiltration system and the consequences of long-term shut down of the fiberglass manufacturing process.

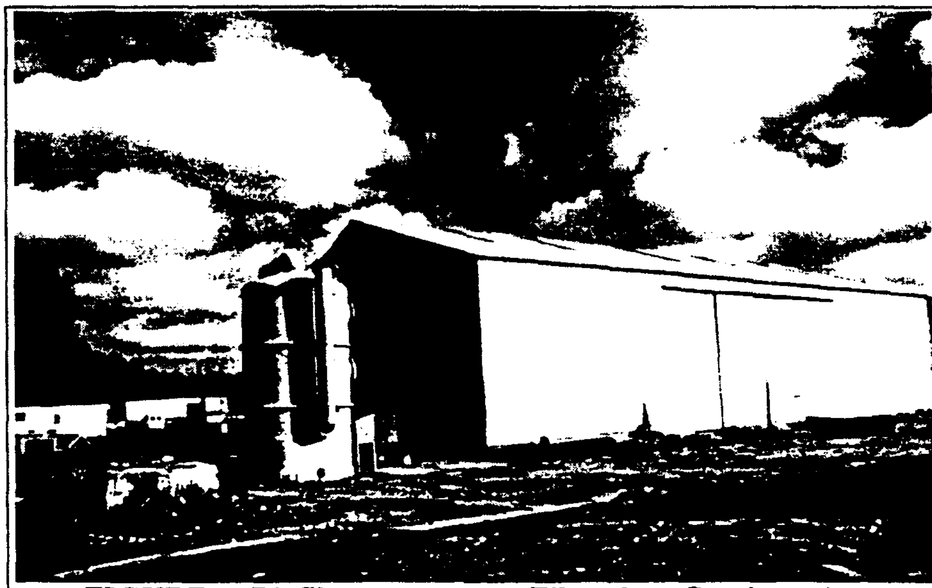

FIGURE 1: Biofilter at Augusta Fiberglass Coatings site.

- To determine the efficiency of the biofilter process when it is compared with other air emission reduction technologies.

SITE DESCRIPTION

Augusta Fiberglass Coatings (AFC) is a commercial fiberglass production facility located in an industrial zone outside the city of Blackville, South Carolina. The site is comprised of approximately 168 acres of land and includes 15 production buildings, an administrative structure, and several storage buildings. The biofilter, Figure 1, has been constructed alongside the Pipe Assembling Building (PAB), a 60 ft. by 100 ft. (18m x 30m) building used to complete the construction of smaller specialty fiberglass items. AFC has complied with air emissions regulations, and mass balance calculations show styrene, methylene chloride and methyl ethyl ketone emissions at the PAB of 1.142 lb/hr (518 g/hr), 0.347 lb/hr (157 g/hr), and 0.095 lb/hr (43 g/hr), respectively.

TREATABILITY STUDY: SET-UP AND RESULTS

A treatability study was conducted to optimize biofilter medium composition and styrene removal efficiency. Samples of the PAB exhaust were collected for VOC analyses using hand-held portable pumps and absorbent tubes; laboratory analyses of these samples show that styrene is the major VOC emission from the PAB. Based on these results, the biofilter treatability study was configured using only styrene as the VOC influent.

The dimensions of the treatability bioreactor were 6 inches (15.2 cm) diameter with a 4-foot (121.9-cm) bed height. The styrene inlet flow rate varied from 0.5 to 2 scfm. The selected medium that presented best removal efficiency was chicken compost and granular activated carbon (GAC) in a 2:1 ratio. Removal efficiencies using flow rate of 2 scfm are listed in Table 1. Different loading methods were used for each run in order to check percentage removal of varying influent styrene concentrations.

Table 1: Styrene Removal Pilot Experiment, 8/19/96 to 9/17/96

Influent (Relative ppb)	Effluent (Relative ppb)	% Removal
125200	4400	96.46
421250	1192	99.72
913520	50	99.99
203000	1700	99.16
130000	174	99.92
147700	0	100.00
2700	127	95.30
1141100	16840	98.52
354400	58870	83.39
410400	52240	87.27
877600	121800	86.12
1194000	214720	82.02

PROJECT DESIGN AND DESCRIPTION

The process flow diagram for the biofiltration system in operation at AFC is illustrated in Figure 2. The biofiltration system consists of the following major sub-systems / equipment and components:

1. Blower System (B);
2. Steam Generating Boiler (S) and Humidifier(H);
3. Bio-Filter Vessel (F);
4. Utility Supply System;
5. Instrumentation and Control System, and
6. Influent and Effluent Gas Analyzer System.

The biofilter system was placed on a reinforced concrete foundation and was connected to the PAB with poly vinyl chloride (PVC) piping. The air pump (B) is a positive displacement

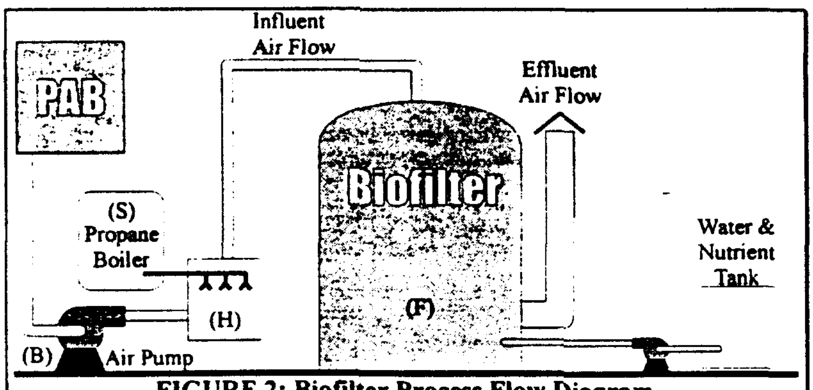

FIGURE 2: Biofilter Process Flow Diagram

blower that, with silencers, exhausts the building air stream through the biofilter tank. The blower system operates at approximately 1,000 scfm, resulting in a water column pressure drop across the biofilter bed in the range of 20" to 30". The biofilter system includes a propane fired boiler (S) providing steam to heat and humidify the influent air stream, and an automatic moisture system providing water and/or nutrients to the compost biofilter medium via a series of spray nozzles in the tank. The average relative humidities (RH) of the air entering the biofilter bed is 38% and averages 85% leaving the biofilter.

The biofilter vessel is a fiberglass tank, 18 ft. high by 9 ft. diameter (5.5 m x 2.7 m), that was designed and manufactured by AFC. Analyses of the compost indicated a high percentage of nitrogen and phosphorus and a neutral pH. The selected GAC is a particle size of 5 to 10 mesh and, once mixed with the compost, is in two layers 4-feet (1.22 m) thick in the biofilter. The Instrumentation and Control System provides data on humidity and temperature. The system controls the steam and water injection into the biofilter, and measures the humidity and temperature of the influent and effluent air flow.

A Bruel and Kjaer Model 1302 Infrared Photoacoustic Spectrometer (IRS) gas analyzer was used to analyze the influent and effluent concentrations of VOCs. The IRS was calibrated for styrene, methylene chloride, MEK, carbon dioxide, and water vapor, with a full set of measurements recorded every 30 minutes. Analyses of the effluent carbon dioxide concentrations provided the aerobic respiration rate of the microbial population. The biofilter system was totally automated to the point that trips to the site were made primarily to download data from the gas analyzer. The IRS was used to monitor styrene, MEK, and methylene chloride oxidation.

RESULTS

Figure 3 is a chart of the IRS analyzer data showing styrene levels in and out of the biofilter for a normal week of operations at AFC. This chart shows styrene levels peaking at 200 ppm on the biofilter inlet and an outlet concentration that generally remains below 7 ppm. Styrene levels in the influent vary considerably due to the variations in the amount of work being performed in the building, but the effluent styrene levels remain consistently low.

The inlet concentrations of methylene chloride and MEK have been negligible and the performance of the biofilter has been addressed only in terms of styrene removal efficiency.

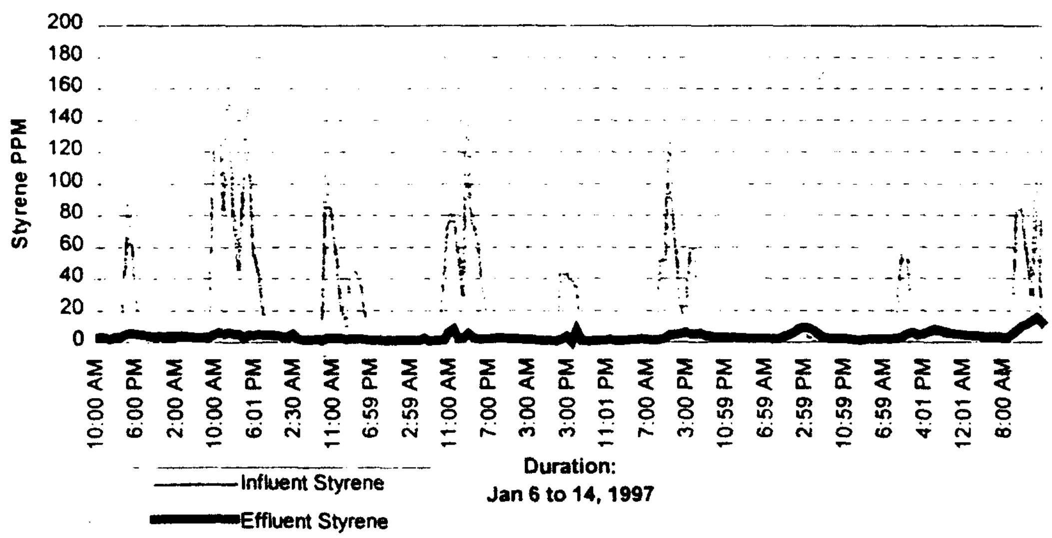

FIGURE 3: Styrene Levels Recorded over a Standard Week at AFC

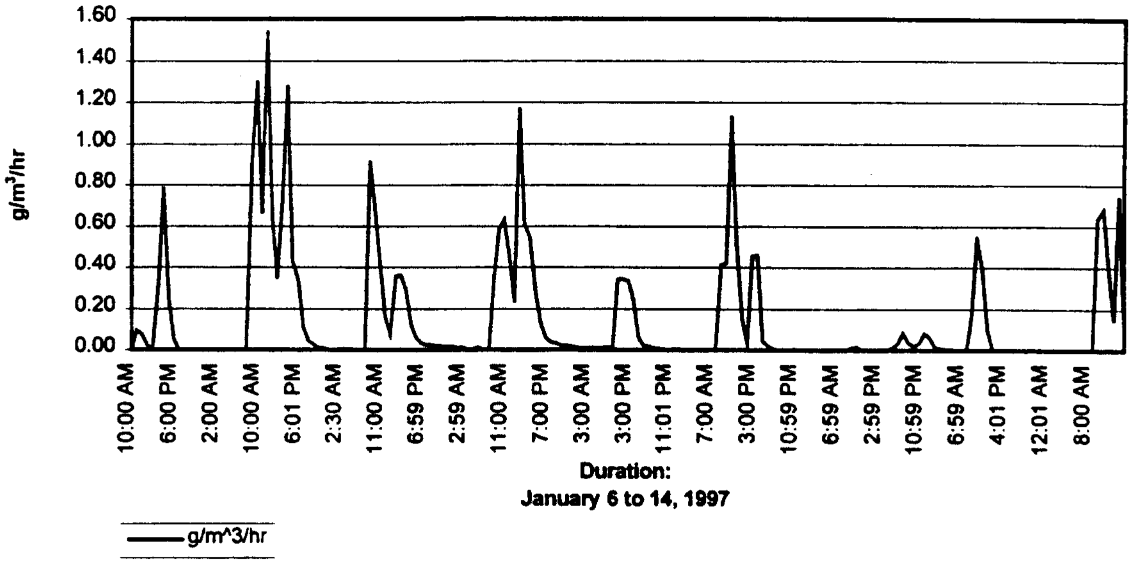

FIGURE 4: Styrene Elimination Rates over the Sample Test Period

Figure 4 reflects the elimination rates of the biofilter bed for styrene using the data plotted in Figure 3. The elimination rates are calculated using the following equation:

$$E_R = (C_{in} - C_{out}) \cdot Q/V$$

Where E_R = elimination rate, $g/m^3/hr$
Q = flow rate, m^3/hr
C_{in} = influent gas phase pollutant concentration, g/m^3
C_{out} = effluent gas phase pollutant concentration, g/m^3
V = volume of the bed material, m^3

CONCLUSIONS AND RECOMMENDATIONS

The results of this field-pilot biofilter demonstration provide strong support for the use of biofilters to treat industrial styrene emissions. The project commenced with contract award in June of 1996, construction was completed in August, and startup of operations in October of 1996. As of mid January 1997, bed acclimation has been accomplished, and significant performance data have been acquired.

Data from the treatability study and the CO_2 effluent concentrations recorded by the IRS for the pilot technology demonstration support the biodegradability of styrene in this demonstration. The efficiency of the process in terms of a calculated biodegradation rate was not determined. Styrene biodegradability has been well documented; intrinsic biodegradation rates from bench-scale biofilter for styrene has been in the range of 9 to 35 μg styrene per hour per mg dry weight (Togna, et al., 1992)

Figures 3 & 4 show that a steady-state effluent concentration was obtained and that acclimation of the bed was reached. It seems that the large fluctuations in the VOC mass loading due to changes in the manufacturing process is not adversely affecting the biofilter performance.

The efficiency of the biofilter process when compared with other air emission reduction technologies was demonstrated in this project. Traditional air pollution control technologies have been known to be too costly and, in some cases, not capable of treating low concentration VOCs. Conversely, biofiltration is both cost-effective and provides treatment of low concentration VOCs.

The demonstration project has proven itself so well that AFC has requested that the biofilter remain in operation at the completion of the demonstration and become a permanent addition to their continuing program of environmental responsibility.

REFERENCES

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