DESIGN AND CASE STUDY OF THE ODOR CONTROL SYSTEM FOR THE ROCKLAND COUNTY COCOMPOSTING FACILITY

Michael Del Vecchio,
Envirogen, Inc.
4100 Quakerbridge Road
Lawrenceville, N.J. 08648

Ronald Delo, Rockland County Solid Waste Management Authority
Fred Gaines, Envirogen, Inc.
Robert Loudon, Envirogen, Inc

ABSTRACT

The Rockland County Solid Waste Management Authority contracted to design, construct and operate a 100 ton per day bio-solids co-composting facility for the County in Hilburn, New York. As part of this project, a complete odor control system, which included an enclosed biofilter, was to be constructed. In September 1997 an order was placed for the odor control system to treat the odors generated by the composting operation. Based on the design parameters as put forth by the Authority, the system has some unique features when compared with a simple biofilter installation:

Parameter:	Value	Units
System Capacity	82,000	cfm.
Ammonia Loading	40, (125)	ppmv average (ppmv maximum)
Hydrogen Sulfide Loading	360,(1)	ppbv average (ppmv maximum)
Methyl Mercaptan Loading	65, (100)	ppbv average (ppbv maximum)
Odor Loading	400, (800)	d/t average (d/t maximum)
Removal Efficiency (within above parameters)		
Ammonia	99	%
Hydrogen Sulfide	95	%
Methyl Mercaptan	80	%
Odor	94	%
System Inlet Temperature	55 - 100	^{o}F

The major differences from simple installations were

1. The inlet air temperature which could go down to 55 degrees F.
2. Variable airflow, whereby the plant would be run at 82,000 cfm during normal working hours, Monday thru Friday and during off-hours or on weekends the system would run at 50,000 cfm.

KEYWORDS

Odor, odor control, biofilter, biofiltration, bio-solids, co-composting, Ammonia, Hydrogen Sulfide, Methyl Mercaptan, Dimethyl Disulfide, Dimethyl Sulfide.

INTRODUCTION

Construction of the overall co-composting plant was begun in March of 1998 and completed by January of 1999. The facility then began a shakedown period followed by a twelve-week acceptance test period. During this acceptance test period, three major test events were scheduled but based on information discussed in this paper, four were conducted for the odor control system. The operating data from these tests as well as additional testing will be discussed in detail in later sections. The plant is currently in full operation, which includes the odor control system. This full operation is the handling of approximately 85 tons per day of bio-solids, which accounts for all of the bio-solids generated by the five POTWs within Rockland County. These bio-solids are a mixture of secondary bio-solids, primary bio-solids and anaerobically digested bio-solids.

The co-composting portion of the plant consists of an enclosed facility including bio-solids receiving and amendment mixing; composting via agitated bin composting and aerated curing. Air is feed into the building via fans at either end of the building which pre-heat the incoming air if needed. The air is then drawn into the composting area by the compost aeration fans and pushed through the bio-solids in the bins. The air is collected in two vents above the composting area and drawn into the odor control system by the exhaust blowers.

The odor control system consists of the following equipment:

- Two (2) air inlet Preheater Fans
- Two 41,000 cfm Exhaust Blowers (operating in parallel) to collect the emissions.
  Each blower is capable of 50,000 cfm. Each blower is electrically paired with a Preheater Fan.
- Two 50,000 cfm packed humidifier / scrubbers (operating in parallel) to pre-treat the emissions.
- Two Circulating pumps for the humidifier / scrubbers.
  The above equipment is arranged in two independent trains, each consisting of a blower, and a scrubber with its circulating pump.
- One 4-compartment Enclosed Biofilter to treat the emissions.
  Each compartment measuring approximately 20' x 66', containing organic and inorganic media. Media was piled 5.3' high. Contact time is 19 seconds at 82,000 cfm and 32 seconds at 50,000 cfm.
- Ancillary equipment includes:
  Acid, caustic and nutrient Chemical feeds.
  Waste Neutralization System
  Instruments and Controls.

ODOR CONTROL SYSTEM DESCRIPTION & OPERATING PHILOSPHY

The system starts at the air collection vents and ducts over the composting and curing areas of the building and the control of the plant Pre-heater fans. Air is drawn through this ducting to two the Odor Control Exhaust Blowers. These duct sections also contain instrumentation to measure airflow, pressure and temperature. The system remains as two independent trains, consisting of blower, scrubber and circulating pump until the ducts exit the building and enter the common biofilter inlet.

The Pre-heater Fans and Odor Control Exhaust Blowers have variable frequency controlled motors to control their speeds in order to maintain a preset airflow. The Pre-heaters are used seasonally, and when not in use, air will enter the building through wall mounted louvers.

The Scrubbers are packed tower chambers with recirculating water and a reservoir at the bottom. Pumps (one for each) draw water from the scrubber sump and pass it through a centrifugal solids separator and a fine mesh strainer to remove solids before returning it to the scrubber. Within the scrubber, the water contacts the air within the packing and increases the relative humidity of the air entering the biofilter to nearly 100%. The circulating water is provided with an acid injection system to control the pH. During cold weather, the pH set point can be automatically lowered, to have the unit perform as an acidic ammonia scrubber. This eliminates the need to treat the ammonia in the biofilter when the lower temperatures slow down the biological activity. Normally, the system will use minimal acid during warm temperatures and will revert to a full acid scrubber during cold temperatures while always maintaining a 99% destruction efficiency for ammonia

The BIOFILTER consists of three major sections: 1) a concrete inlet distribution tunnel, 2) the covered Biofilter media section and 3) a concrete outlet collection tunnel and exhaust stack.

The Biofilter media section is divided into four independent sections or “chambers”. Individual chambers can be isolated via slide dampers (in the inlet / outlet tunnels) for inspection or maintenance. Each chamber contains the packing on which the biomass grows and a layer of inert material, which aids in final humidification of the incoming air. Air flows up through the media from a distribution chamber below and out under the covers to the outlet collection tunnel.

Each chamber is provided with a dual irrigation system; one is at the top of the packing to moisten it and periodically replenish the nutrients required by the biomass. The other system is located between the packing and the inert layer. This replenishes the water stripped away by the incoming air and assures complete humidification (100%) of the air entering the biologically active area of the biofilter. A computer controlled timing sequence regulates the irrigation systems. This lower irrigation system is also outfitted with caustic injection. During cold weather, the pH of the lower irrigation water can be raised to have the inert layer perform as a caustic sulfur scrubber. This would reduce the need to treat the sulfur in the biofilter when the lower temperatures slowed down the biological activity. This caustic water is added to the inert layer without affecting the biofilter packing above (Patent Pending). Treated air is then forced through the biofilter by the fans and exits through the exhaust stack, 60 feet above grade.

The final complication to the entire design was the siting of the plant. The plant sits on a mountaintop within a high lighting strike area. The entire facility has a self-contained generator, which comes on at loss of power. An independent control scenario was included to allow the odor control system to switch to generator power, operate on a reduced capacity while on the generator by shutting down some equipment, and returning to normal upon the return of normal power.

OPERATIONAL TESTS

During the acceptance test period, testing was done to show compliance with the following:

- Attainment of no detectable odor at or beyond the property line, attributed to the composting operation.
- Inlet and Outlet Ammonia concentrations with a removal efficiency of 99%
- Inlet and Outlet Odor concentrations with a removal efficiency of 94%
- Inlet and Outlet Hydrogen Sulfide concentrations with a removal efficiency of 95%
- Inlet and Outlet Methyl Mercaptan concentrations with a removal efficiency of 80%

During each testing event, two samples were taken at the peak airflow rate of 82,000 cfm. It is during this period, that the plant was expected to be at peak emission rate, which coincided with composting activities, and produced the greatest odor. The composting activities included receipt of bio-solids, mixing of bio-solids with amendment and bin agitation. Also, two samples were taken at the lower airflow rate of 50,000 cfm. These samples were to show emissions during the plant 's unoccupied condition when no activities except bin aeration were occurring.

Samples of the inlet and outlet gases were collected simultaneously in Tedlar bags (EPA Reference Method 18, evacuated canister method). Draeger detector tubes were used to measure Ammonia levels in air evacuated from the bags. The odor levels were measured through olfactometric analyses conducted in accordance with ASTM E679-91: Standard Practice for the Determination of Odor and Test Thresholds by a Forced-Choice Ascending Concentration Series of Limits. Sulfur compounds were measured using a gas chromatograph with a chemiluminescence detector.

Measurements of system inlet airflow, temperature, humidity and scrubber pH were also performed concurrently with sampling events.

Beyond the required testing outlined above, continuous measurement of inlet VOCs were conducted during the twelve-week period via a Flame Ionization Detector. Near the end of the acceptance test period, some outlet measurements were taken with the same instrument. Additionally, one series of samples was collected and measurements taken via EPA methods TO-14, Full Scan and TO-11.

PERFORMANCE – GENERAL

Based upon these analyses it was noted that the inlet odor concentrations were far above the expected maximums (See Figures 2 & 3) and the removal efficiencies indicated that the system was operating below expectations (See Figure 8). There were anomalies with the Sulfur compound data in that the outlet concentrations were higher, in some cases, than the inlet (See Figures 4 - 7).

Based on this initial testing, an investigation was conducted to determine why the system had lower than expected performance. With the higher odor concentration, it was assumed that the media loading was at a much higher rate than expected. Subsequent testing of media samples showed a complete lack of the nutrient Phosphorus.

Prior to the next test, the following plan was put into action:

- Nutrient addition was initiated to the media in the form of Monosodium Phosphate.
- An additional round of performance testing was added (a fourth round) to the original three tests
- A more detailed sulfur analysis would be conducted on future tests.

Following the addition of nutrient, a subsequent media test was conducted and showed a residual of phosphorus. The additional performance test was then scheduled and executed on April 27.

The second test still showed high inlet concentrations of odor but was within expected removal efficiencies of 94%. Ammonia removal was also within required efficiency. Both Methyl Mercaptan and Hydrogen Sulfide at times still exhibited the anomalies of higher outlet concentration than inlet. With the additional sulfur compound data taken during the test, this was now determined to be due to interactions with other compounds. In particular Dimethyl Disulfide, which exists at a very high concentration in the inlet compared to all other sulfur compounds (See Figures 4 & 6). For the purpose of the remaining testing, it was recommended that rather than looking at individual sulfur compounds that they be looked at grouped as Total Reduced Sulfur compounds.

The remaining two rounds of testing (May 11 & June 1) showed similar, yet improving results as compared to the April 27 testing.

VOC analysis done during the test period showed a general trend of 20 ppmv average in the inlet to the odor control system. Peaks at times were seen as high as 200 ppmv at the inlet. The data shown was an average of readings taken during the four test dates (See Figure 10).

PERFORMANCE – AMMONIA

Review of the data from the first test on April 8 showed good system removal at lower airflow but the removal did not meet expected removal efficiency at the higher airflow. Based on the system design, most of the ammonia is removed in the scrubber prior to entry into the biofilter. On the April 8 test the scrubbers were operated at a pH of less than 4. This left a residual of 1 to 1.5 ppmv of ammonia after the scrubber and entering the biofilter (See Figure 9). This residual ammonia was not being removed in the biofilter. The small amount of ammonia in the system outlet was enough to fail the required removal efficiency at high airflow.

Once the nutrients present in the media were checked and the need for phosphorus addition was discovered, it was felt the need for nitrogen provided by the ammonia would also rise as microbial activity increased.

During the subsequent tests, the pH in the scrubbers was raised in an effort to allow more ammonia into the biofilter for use as a nutrient. By the last test the pH had been raised to 6.25 allowing 15 ppmv of ammonia into the biofilter (See Figure 9) while retaining non detect on the outlet of biofilter and therefore the system efficiencies were attained (See Figure 8).

PERFORMANCE – SULFUR COMPOUNDS

A review of the analytical data for Methyl Mercaptan (MM), indicated wide swings in the removal efficiency of MM when viewed as a single compound. Upon further review of all the sulfur compounds entering the system, it was concluded that one cannot just evaluate removal of MM alone in the presence of Dimethyl Disulfide (DMDS) and Dimethyl Sulfide (DMS). As shown in the literature, MM is an intermediate in the DMDS and DMS oxidative pathways, as shown below (Smith and Kelly, 1988a; Smith and Kelly, 1988b; Kanagawa and Kelly, 1986; De Bont *et al.*, 1981; Suylen *et al.*, 1986) (also see attached Figure 4 from Smith and Kelly, 1988b).

DMDS (CH_3-S-S-CH_3) ⇒ 2 **MM** (2 CH_3SH) ⇒ 2 $\mathbf{H_2S}$ ⇒ 2 H_2SO_4

\+

2 Formaldehyde (2 HCHO) ⇒ 2 Formate (2 HCOOH) ⇒ 2 CO_2

DMS (CH_3-S-CH_3) ⇒ **MM** + Formaldehyde

MM ⇒ $\mathbf{H_2S}$ + Formaldehyde

2 Formaldehyde ⇒ 2 Formate ⇒ 2 CO_2

H_2S ⇒ H_2SO_4

Thus, although the concentration of MM is generally low in the influent, the much higher concentration of (DMDS + DMS) acts as a reservoir that can produce MM as a transient intermediate in the biofilter (See Figures 4 & 6). (Transient intermediate production is also observed for biofilters treating carbon disulfide (CS_2), as discussed below.)

In our review of the analytical data for hydrogen sulfide (H_2S), we also observed anomalous swings in the removal efficiency of H_2S when viewed as a single compound. Again, this is presumed to be due to the presence of other sulfur-containing compounds in the air. As shown above, H_2S is an intermediate in the DMDS, DMS, and MM oxidative pathways. In addition, as shown below, H_2S is an intermediate product of CS_2 and COS biodegradation (Smith and Kelly, 1988c).

$CS_2 + H_2O \rightarrow COS + \mathbf{H_2S}$

$COS + H_2O \rightarrow CO_2 + \mathbf{H_2S}$

$2\ H_2S + 4\ O_2 \rightarrow 2\ H_2SO_4$

Thus, if the biofilter influent includes DMDS, DMS, MM, CS_2, and/or COS, one can expect production of H_2S as a transient intermediate in the biofilter (See Figures 4 – 7).

The concentrations of MM and H_2S that are measured across the complete Rockland system are a dynamic and potentially variable number that results from both their transient production and destruction within the biofilter. Therefore, there is no reasonable way to measure removal efficiency of these two compounds individually. In our opinion, the best approach is to measure total reduced sulfides, which will encompass all of the important target sulfur compounds and overcome the issue of intermediate production of MM or H_2S from DMDS, DMS, MM, CS_2, and/or COS as discussed above.

* Total Reduced Sulfides = (1 x MM) + (1 x H_2S) + (1 x COS) + (1 x DMS) + (2 x CS_2) + (2 x DMDS)

As you can see from the data (See Figures 4 - 8), the biofilter is performing very well as demonstrated by the removal of total reduced sulfides, especially in the face of the significant sulfur compound loading. As explained above, in the presence of high levels of other reduced sulfides (DMDS, DMS, CS_2, COS), the removal efficiencies of MM and H_2S, as measured against their inlet concentrations, are inaccurate indicators of true removal efficiency of MM, H_2S and total system performance. Therefore, it was conclude that measurement of total reduced sulfides will provide the most reliable ongoing evaluation of system performance for the Rockland County odor control system.

PERFORMANCE – VOC

As stated earlier, VOC concentrations of the inlet generally averaged in the 20 ppmv range. Peaks were also seen exceeding 200 ppmv. A test to determine what compounds made up these VOCs was conducted. The following list of compounds were found present. This list does not include the Organo-sulfur compounds already listed previously:

- Methane
- Acetone
- Formaldehyde
- Acetaldehyde
- Methyl Ethyl Ketone
- Isopentanal
- Ethanol
- N,N-Dimethyl Methanamine
- α-Pinene
- 4-Methylene-1-(1-Methylethyl Cyclohexane)
- Dimethylamine

Some testing was done at the end of the test period to try to determine the reduction efficiency of the system on VOCs. Since there was only one FID unit, for short periods, the sample point was switched from the inlet to the outlet. Based on the data collected during these tests, the inlet VOCs averaging 15 ppmv were reduced to less than 0.5 ppmv in the outlet. From this it was concluded that the VOC reduction averaged greater than 95%

PERFORMANCE – ODOR

Prior to the nutrient addition, efficiency was below than expected. After the nutrient addition, efficiency increased to greater than 95% by the final test (See Figure 8). All three of the tests taken subsequent to the nutrient addition meet or exceeded expected overall odor removal even though the inlet conditions were much higher than expected (See Figures 2 & 3).

All of the tests included a fence line and neighborhood odor survey. During these surveys, no detectable odor from the composting plant was detected at or beyond the property line. It should be further noted that since the start of the acceptance test to the date of this paper, there have been no odors detected beyond the plant and no odor complaints from the surrounding neighbors. In some instances, odors from other manufacturing facilities in the area were detected at the composting plant as opposed to any odors from the composting process.

SUMMARY & CONCLUSIONS

The measurements taken for odor inlet concentration closely followed the Total Reduced Sulfur concentration and the VOC concentration. Based on the sulfur compounds present, their concentration had a large affect on the VOC concentration. Ammonia, especially as seen during the last test, had much less of an impact on the inlet odor concentrations (See Figures 2 & 3).

Sulfur compounds cannot be tracked as individual compounds due to the interaction of different sulfur compounds and their breakdown in a biofilter. The best available method is to track all sulfur compounds as Total Reduced Sulfur.

Nutrients must be added on a regular basis. It is currently estimated that the addition of Monosodium Phosphate, will be needed approximately every 3 to 6 months.

Based on the data collected, it is possible to attain high removal efficiencies of Ammonia, Sulfur Compounds and VOCs in short retention time within an enclosed biofilter (20 seconds). By controlling the environment of the media and nutrient levels needed for proper microbial growth, the enclosed filter performs as well, if not better than as a standard open biofilter. The advantages of the enclosed unit are the use of less space, (up to 80% less than an open unit), environmental control of the media and greatly reduced influence of weather and temperature on the performance of the biofilter.

ACKNOWLEDGEMENT

The authors would like to thank Mr. John Goodwin of Waste Management/Bio Gro for his cooperation in the collection of information used in this paper.

REFERENCES

De Bont, J.A.M., J.P. van Dijken, and W. Harder. (1981). “Dimethyl sulphoxide and dimethyl sulphide as a carbon, sulfur, and energy source for growth of Hyphomicrobium S.” Journal of General Microbiology, vol. 127, pp. 315-323.

Envirogen, Inc. 1999. “Operating and Instruction Manual, Rockland Odor Control System” vol. 1, sec. 8

Kanagawa, T. and D.P. Kelly. 1986. “Breakdown of dimethyl sulphide by mixed cultures and by Thiobacillus thioparus”. FEMS Microbiology Letters, vol.34, pp. 13-19.

Smith, N.A. and D.P. Kelly. 1988a. “Isolation and physiological characterization of autotrophic sulphur bacteria oxidizing dimethyl disulphide as sole source of energy. “ Journal of General Microbiology, vol.134, pp.1407-1417.

Smith, N.A. and D.P. Kelly. 1988b. “Mechanism of oxidation of dimethyl disulphide by Thiobacillus thioparus Strain E6.” Journal of General Microbiology, vol. 134, 3031-3039.

Smith, N.A. and D.P. Kelly. 1988c. “Oxidation of carbon disulphide as the sole source of energy for the autotrophic growth of Thiobacillus Thioparus Strain TK-m.” Journal of General Microbiology, vol.134, pp.3041-3048.

Suylen, G.M.H., G.C. Stefess, and J.G. Kuenen. 1986. “Chemolithotrophic potential of a Hyphomicrobium species, capable of growth on methylated sulphur compounds. “ Archives of Microbiology vol.146, pp.192-198.

Waste Management of New York, 1998. “Rockland County Co-Composting Facility, Acceptance Test Plan” pp. 18-20

Water Environment Federation, 1995, Biosolids Composting, pp. 57-72