AIR HANDLING AND SCRUBBER RETROFITS OPTIMIZE ODOR CONTROL

A new air handling and odor exhaust design and a redo of the two stage odor scrubber system have been effective in controlling fugitive and point source emissions at an in-vessel biosolids composting facility. Part II

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A COMPREHENSIVE odor control program was undertaken at the Schenectady, New York in-vessel biosolids composting facility in 1991. In June, 1992, the plant, which utilizes the American Bio Tech (ABT) system, was brought back on line after being shut down since January, 1991. The changes at the plant were done as part of a five year contract between the City of Schenectady and Professional Services Group (PSG) of Houston to maintain and operate both the wastewater treatment plant and the composting facility.

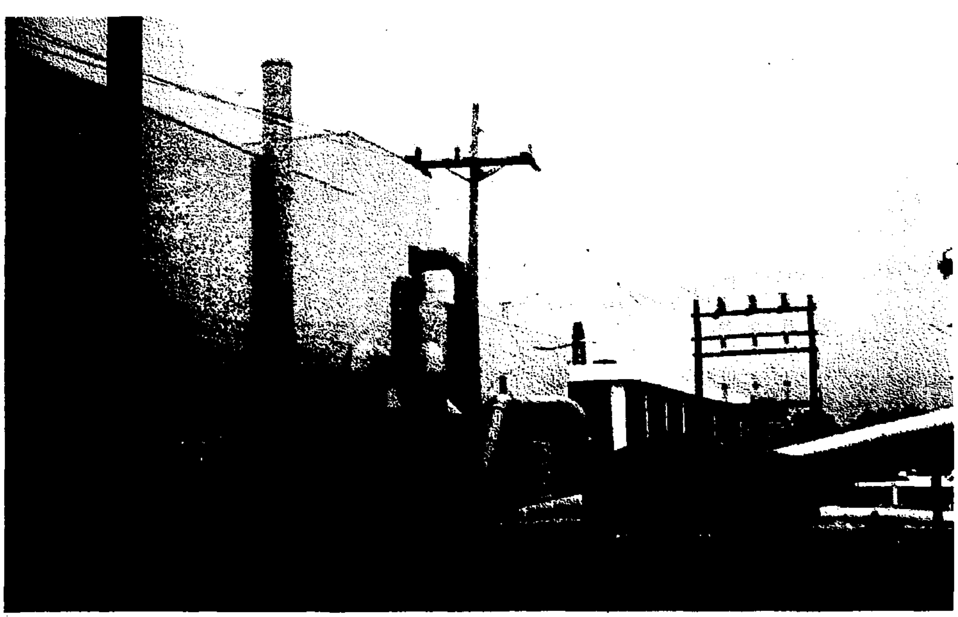
Part I of this article, which appeared in the February, 1993 issue of *BioCycle*, discussed several process modifications and equipment changes made at the ABT in-vessel compost facility to reduce and control odors. The article detailed the elimination of both odorous fugitive emissions from the compost reactors and odorous area emissions from unstable compost product. It also described the distribution program for the finished compost products. Part II describes the design and installation of a compost facility air handling/odor exhaust system and the retrofit of the existing odor scrubber system. These were designed to reduce and control odors from fugitive emissions from the compost facility and point-source emissions from the odor scrubber stack. Part II also discusses the public relations program developed to rebuild confidence in the operation of the compost facility without the discharge and detection of offensive, noxious odors. An interesting element of the PSG contract is that funds can be withheld from the company's monthly fee if satisfactory odor control levels are not being achieved.

The ABT design concept for in-vessel odor control relied upon biofiltration, recirculation, dispersion and dilution. Positive and negative aeration using the patented Air-Lance™ system was provided to eliminate odor dispersion outside the compost mass, assuming that all noxious gases and offensive odors would be captured within the compost mass and treated prior to discharge into the atmosphere. The negative ventilation pressures and high rates of process air exchange within the vessels were designed to provide biofiltration treatment of all potential odors. The discharge duct of the exhaust fans was designed to recirculate biofiltered process air from the reactors back to the reactors via the inlet of the supply fans. Roof exhausters also were installed to disperse biofiltered process air and diluted compost building air to the outside with the assumption that sufficient atmospheric dilution would prevent any detection of odors.

ODOR CONTROL CHRONOLOGY

Immediately upon start-up of the ABT compost facility in July, 1987, there were numerous foul compost odor "incidents" onsite and many complaints by residents living near the plant. The design odor control strategy was failing and no contingency using external odor control equipment was included in the original design and installation of the system. Offensive odors persisted and the pressure mounted by the nearby neighborhood residents on city management to correct the problems or shut down the facility. The NIMBY (Not In My Backyard!) scenario became quickly and firmly established. The first of numerous plant shutdowns for repairs and odor control system improvements occurred in January, 1988.

During the spring of 1988, a single stage Beverly Pacific (BP) vertical wet scrubber (5 by 10 ft) was installed as an external odor control device to treat the biofiltered air from the compost reactor exhaust fans. Accordingly, the scrubber was sized at an air flow rate of 14,000 cfm, but this treatment capacity was reduced significantly because the once-through scrubbant liquid sump system was undersized, preventing the



Composting facility in Schenectady, New York uses two-stage packed tower chemical scrubbing system.

proper supply of fresh scrubber chemicals and flooding the packing. The scrubber used sulfuric acid as the scrubbing solution to primarily remove ammonia-nitrogen. A proprietary odor control chemical, DeAmine™, also was added to the inlet of the scrubber, to aid in its performance.

With the scrubber system installed and operational, the compost plant was restarted in the summer of 1988. Despite the new odor scrubber and use of DeAmine™, the odor problems worsened. In January, 1989, another packed tower chemical scrubber manufacturer was brought to the compost site to demonstrate its odor control system using a two stage pilot system. The testing objective was to assess the difficulties of odor removal from the existing BP scrubber and identify any additional treatment units required. The removal efficiency of the pilot scrubber system was gauged by an odor panel made up of the residents from the neighborhood adjacent to the compost facility. The panelists had all registered complaints about foul and offensive odors from the compost facility. The performance of the pilot scrubbers was described in terms of odor concentration and odor removal efficiency.

The week-long pilot test showed an average odor removal efficiency of 88 percent in the odor concentration of dilution to threshold (D/T) ratio. (See sidebar for explanation.) The inlet odor concentrations ranged from 925 to 5550 D/T and were reduced to an outlet range of 110 to 630 D/T. These outlet odor concentrations were too high and shortly after the pilot testing, the compost facility was shut down. Other in-vessel compost facilities and state regulators in the Northeast use outlet odor concentration limits from scrubbing systems between 75 and 100 D/T as being acceptable for atmospheric discharge.

Since the BP scrubber would remain in place, the city hired a second odor science consultant in late summer of 1989 to conduct an odor removal study on this scrubber. To accommodate the test, the compost facility was temporarily placed back into operation on a limited scale. The BP scrubber was analyzed by dynamic olfactometry and a gas chromotagraphy/mass spectrometry (GC/MS) odorgram. The tests indicated that the BP scrubber was ineffective in removing compost odors for all of the scrubbant solutions tested, which included water, sulfuric acid, sodium hypochlorite, and DeAmine™. The evaluation showed no odor removal efficiency, with scrubber inlet and outlet D/T levels remaining at 870. The GC/MS odorgram data showed that the most offensive and pervasive odorous compound was dimethyl disulfide (DMDS). The study concluded that the single stage scrubber was insufficient in providing effective compost odor control. In response to the continued neighborhood odor complaints, the compost facility was immediately shutdown in the fall of 1989.

The original compost reactor and building ventilation system did not provide sufficient air exchange of fresh air.

Based on the ineffectiveness of the original BP odor scrubber system and the results of the two stage packed tower system tested on a pilot scale, a new odor control system was designed in the fall of 1989 and installed in the spring of 1990. A two stage, 10-feet vertical packed tower wet chemical scrubber system, sized at 21,100 cfm, was supplied by the Duall Division of Met-Pro Corporation. The two packed towers were operated in series, with both units using an aqueous solution of sodium hypochlorite as the scrubbing liquid.

The same odor science consultants were retained by the city in the summer of 1990 to conduct another set of odor tests on the Duall scrubbers. During the testing, the inlet and outlet odor levels averaged 660 D/T and 150 D/T, respectively, for an overall odor removal efficiency of 77 percent. The odor at the outlet of the new scrubbing system showed a presence of "compost" odor. Based upon these results, the scrubber manufacturer was required to make modifications to the system to affect the air flow rate and chemistry. Detention time in the scrubbers was increased by changing the induced draft fan, which decreased the volume of treated air from 21,100 cfm to 13,000 cfm. The first stage scrubbing chemistry was modified from a hypochlorite (bleach) addition to sulfuric acid addition to remove ammonia-nitrogen. Sodium hydroxide (caustic) also was added with the bleach in the second stage, as suggested by the scrubber manufacturer, to increase the absorption and oxidation of hydrogen sulfide and other odorous sulfur compounds.

Based upon these scrubber changes, the city retained a third odor science consultant to conduct yet another odor panel in the fall of 1990. The results of this odor testing showed a high odor removal efficiency of 96 percent with inlet and outlet ED_{50} values of 558 and 21, respectively.

Despite the work of specialists and consultants, years of testing, and numerous changes to the control system, the offensive and pervasive compost odors were not effectively being controlled or reduced. Severe odor incidents persisted and to eliminate

Greatest production of odorous steam and fugitive emissions occurred in the third floor reactor area.

Table 1. Compost Facility Air Handling/Odor Exhausting Criteria.

Building Area	*Facility Volume cu ft.*	*Ventilation ac/hr*	*Odor Exhaust cfm*
Compost Reactors (Third Floor)	133,000	11.3	25,000
Screw Parking (Second Floor)	81,800	4.0	5,500
Conveyor Tunnel (First Floor)	52,600	8.0	7,000
Mixing/Recycle (Ground Floor)	85,830	6.0	8,600
TOTAL	353,230		46,100

any further impact on neighborhood residents, city officials directed the long-term shutdown of the compost facility.

FUGITIVE AND POINT-SOURCE EMISSIONS

The original compost reactor and building ventilation system did not provide sufficient air exchanges of fresh air, resulting in concentration of odorous gases and unsafe work conditions. At an overall compost facility ventilation rate of less than three air changes per hour (ac/hr), positive pressure conditions prevailed, creating a condition for fugitive emissions of compost odors. Despite the enclosed vessels, the thin fiberglass exterior wall of the ABT compost facility did not provide insulation or a seal from escaping odors. Numerous leaks in the compost building allowed the high intensity nitrogen compounds (ammonia and amines), and the very pervasive organic sulfur compounds (dimethyl sulfide, dimethyl disulfide, and mercaptans) from the reactors and materials movement areas to escape into the atmosphere untreated. These compounds have very low odor thresholds and can be detected by the human nose despite millions of dilution in the atmosphere. This was the case in Schenectady, where the offensive compost odors were being detected regularly off the plant site by nearby neighborhood residents.

Operational and process control problems with the existing scrubber system also contributed to the compost odors. Point source emissions of compost or chemical odors from the exhaust stack of the two stage scrubbing system were caused by several factors. First, the cyclic operation between positive and negative aeration using the AirLance™ system caused large swings in the odor loadings to the scrubber system, loss in system control, and subsequent "bleed through" of DMS/DMDS up the exhaust stack. Second, the unprotected, outside installation of the scrubbers caused freezing problems in the wintertime, which affected process control and odor treatment performance. Third, the use of sodium hydroxide created scaling and eventual packing plugging problems in the second stage scrubber, lowering its treatment efficiency and requiring shutdowns for acid bath cleaning. Lastly, intermittent failures with the scrubber systems' injectors and pumps and the instrumentation (pH and oxidation reduction potential (ORP) sensors) resulted in unstable scrubber operations and point source emissions of compost or chemical odors from the exhaust stack.

PSG's plan for correcting these odorous emissions was based upon the characterization and identification of the specific, high intensity, and pervasive compost odors which would require collection and treatment. During the initial four month full plant operation under the PSG contract and period of process testing (October 1991 through January 1992), the sources of odorous steam which created fugitive emissions from the compost facility and point source emissions from the scrubber system were carefully evaluated. The specific levels of air handling/odor exhausting and scrubbing treatment needed to eliminate these sources of odors and prevent them from being discharged directly into the atmosphere untreated were determined.

An objective was established to capture, collect and treat all odors from the process reactors and within the compost building to nondetectable levels. The goal was set in response to the high probability that the very intense and pervasive compost odors would be readily detected in the neighborhood, even after millions of dilutions with ambient air, if they were not fully captured and carefully treated.

AIR HANDLING/ODOR EXHAUSTING DESIGN

A 46,100 cfm air handling and odor exhausting duct system was installed that prevents odorous steam from escaping as fugitive emissions from within the compost facility. The entire Schenectady compost plant, including the annexed administration office, is now sealed and operating under negative pressure. No fugitive compost odors are being emitted directly into the atmosphere untreated. The installed air handling system exhausts odorous steam from various strategic locations — the compost reactors, screw parking, conveyor tunnel, and mixing/recycle area — via two air plenums to parallel trains of two stage scrubbing treatment systems. The exhausted odors are treated to nondetectable levels before they are discharged up two 52 foot high stacks into the atmosphere.

The air handling system achieves an average ventilation rate within the compost facility of 7.8 building air changes per hour (ac/hr). It uses two different ventilation techniques according to the design criteria summarized in Table 1. During the four month full plant operation, the production of odorous steam was identified and its removal simulated by smoke bomb testing. This information was utilized to design and install the air handling/exhausting system. A description of the primary areas serviced are described below.

Compost Reactor Area: The greatest production of odorous steam and fugitive emissions of odors occurred in the headspace of the third floor compost reactor area. At the original design exhaust rate of 8,000 cfm (3.6 ac/hr), this area became filled with a thick, dense *fog* of odorous steam and resulted in fugitive emissions of concentrated and untreated odors. The fog was measured using Draeger tubes and contained concentrations of ammonia-nitrogen (NH_3-N) and dimethyl sulfide (DMS) as high as 160 ppm and 2.5 ppm, respectively. Given their respective odor threshold concentrations of 0.0037 ppm and 0.0001 ppm, it was critical that these odors be fully captured and treated to nondetectable levels. These requirements became further magnified by PSG's change in operation to a completely positive aeration mode, which resulted in the continuous liberation of odorous steam from the reactors into the headspace of the third floor. The increased release of moisture resulted in higher concentrations of odors, which have been measured to be as high as NH_3-N = 300 ppm and DMS = 15 ppm.

Control of the fog condition required very high rates of ventilation and exhaust. Operating the third floor headspace under negative pressure guaranteed the elimination of fugitive emissions. The measured headspace volume in the third floor area, assuming four full compost reactors, is approximately 133,000 cubic feet. A tapered duct plenum (System A) with 23 exhaust takeoffs and instaduct dampers, spaced every seven feet, was installed along the length of the interior wall of the compost facility, to exhaust odorous steam from the four reactors. Ten wall vents with expanded screens and blastgate dampers were installed on the opposite wall of the compost reactors, spaced every 16 feet, to provide fresh air and cross flow ventilation. A new 25,000 cfm induced draft fan, powered by a 75 hp motor, was installed to exhaust this volume of odorous air from the compost reactor area to the chemical scrubbers.

The cross flow ventilation system achieves an exhaust rate of greater than 11 reactor headspace ac/hr, increasing the capture and treatment of odorous reactor air from 8,000 cfm to 25,000 cfm. The rate of fresh air supply and foul air exhaust has significantly reduced the fog condition and now meets Occupational Safety and Health Administration (OSHA) requirements for human exposure. Through dilution with fresh air, the third floor NH_3-N concentration now averages 30 ppm, which is below the OSHA level of 35 ppm for an eight hour exposure. It also complies with fire protection guidelines for invessel compost facilities by the National Fire Protection Agency (NFPA), which recommends continuous ventilation at 12 ac/hr.

Outfeed Screw Parking Areas: Two slotted ducts remove odorous steam from each of the two areas where the outfeed screws are stored when not in use (i.e. parking areas). These ducts are positioned in parallel over the screws at the ends of the reactor cells. The release of moisture from the bottom of the compost piles creates odorous steam, which gets concentrated in the parking areas when the screws are being returned from operation. These parking areas require negative pressure because of the large cracks in the swinging doors on the outside walls of each end of the compost facility, which enable removal of the screws. The doors provided an easy escape route for untreated emissions from the compost building. An average continuous ventilation and exhaust rate of 4 ac/hr provides negative pressure in these two areas.

The north screw park area is attached to the end of the first floor conveyor tunnel exhaust plenum to remove steam. The south screw area uses an existing ABT exhaust fan and ties into the first floor conveyor tunnel exhaust duct plenum.

Outfeed Conveyor Tunnel Area: The outfeed conveyor, which transports bio cell compost to the cure cells or transports compost product from the cure cells to the screening plant, is located at the bottom of the reactors on the first floor tunnel. The two outfeed screws just described auger compost daily from the bottom of the reactors onto the outfeed conveyor. Operation of this equipment also creates a very intense odor area as a result of the release of steam and moisture. Odor production is intermittent, based upon the actual operation of the screws and conveyor. When operational, the confined space and nonexistent ventilation in the first floor tunnel area, create a heavy fog of concentrated odors.

A push-pull ventilation technique captures the odorous steam and exhausts the foul air by a PVC duct plenum to its own train of packed tower chemical scrubbers. A

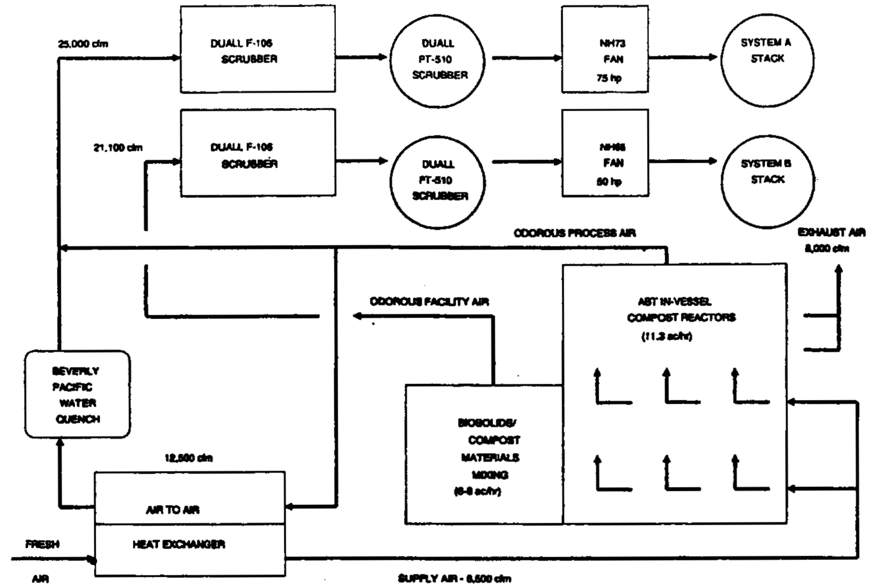
ODOR "MEASUREMENTS" AND ANALYSIS

ODOR, concentration is a dimensionless unit expressed as the dilution to threshold ratio (D/T). This ratio as described by Odor Science & Engineering, is a statistically defined end point in odor analysis that characterizes an odor's "pervasiveness" and "detectability" and determines its detection and recognition thresholds. The D/T value states how many times an odor needs to be diluted to reach the threshold. this value is equivalent to the ED_{50} unit, which also has been used to measure odor quantity.

Two thresholds are used in the industry to quantify odor concentrations and quantities: detection threshold and recognition threshold. Odorous substances are used to produce a positive odor stimulus upon dilution with odor free air until this detection or recognition endpoint is reached. The detection threshold is defined as the odor concentration at which 50 percent of the panelists identify the odor stimulus as directly compared to odor-free air. The recognition threshold is defined as that minimum concentration at which 50 percent of the panelists can discriminate and describe the odorous stimulus from the odor-free or blank air. Since characterization of the odor requires recognition, rather than detection, the D/T measurement is then expressed in terms of the number of volumes of odorfree air required to reduce one volume of the odorous stimulus to the recognized threshold.

All fugitive emissions from the compost facility have been fully corrected and compost odors no longer escape directly.

Figure 1. Air-to-air heat exchanger.



5 hp fan supplies fresh outside air and pushes it down the 160 foot long tunnel via a tapered duct plenum, located along the floor of the tunnel, underneath the outfeed conveyor. It contains 12 take-offs and instaduct dampers spaced every 15 feet. The exhaust duct plenum is located above the outfeed conveyor along the length of the tunnel. It also contains 12 take-offs and instaduct dampers which are staggered every 15 feet and positioned at a specific angle to pull the odorous steam. The positioning of the exhaust duct and take-offs was determined on the basis of field observations of actual steam movement and smoke bomb testing.

The drop of hot compost from the outfeed conveyor onto another inclined belt conveyor leading to the materials handling/compost mixing area represented a point source of odorous steam production and odors. A canopy hood with hanging curtains was installed at the end of the outfeed conveyor where compost is dropped. The hood increases the exhaust rate at this specific location. Steam at the top of the hood goes into the exhaust duct plenum (System B). The push-pull system achieves 8 ac/hr in the first floor outfeed conveyor tunnel area.

Materials Handling/Compost Mixing Area: The two, 40 cubic yard biosolids storage bins, amendment and biosolids conveyors, mixer accumulator screws, plow-blade mixer, screw conveyor, vertical drag flight conveyor and finished product and compost recycle conveyors are all located in one area, referred to as the materials handling/compost mixing room. This room would contain strong, pungent wood amendment and sludge odors, as well as the offensive compost odors generated during reactor material transfers. A specially designed duct, hoods and canopies were installed to achieve an overall area ventilation and exhaust rate of 6 ac/hr. The exhaust rate within each hood canopy is higher than 6 ac/hr, dependent upon the enclosed volume.

The annexed administration offices, located directly on the other side of the materials handling wall, used to contain severe odors. The concentration of NH_3-N was high enough to cause burning eyes and headaches and the DMS was so strong that it adsorbed to the employees' clothes, skin, and hair. The entire materials handling area now operates in a negative pressure and the odors have been removed and controlled. The odors in the office area have been completely eliminated.

Overall, the 6 to 8 ac/hr in the materials handling, compost mixing, outfeed conveyor, and screw parking areas have increased the treated air flow from 13,000 cfm to 21,100 cfm. All fugitive emissions from the compost facility have been fully corrected and compost odors are no longer escaping directly into the atmosphere.

ODOR SCRUBBER SYSTEM RETROFIT

The compost facility duct system containing the odorous compost compounds is directed to two parallel trains of two stage, packed tower chemical scrubbers (System A and System B). System A treats 25,000 cfm of saturated odorous air from the third floor headspace of the compost reactors (Figure 1). System B treats the 21,100 cfm of odorous air from the outfeed conveyor tunnel, screw parking areas, biosolids storage bins and materials handling/compost mixing areas.

The existing Duall 13,000 cfm chemical wet scrubbers used two 10-ft vertical, counter current, packed towers operated in a two stage series. To maximize the available scrubber treatment capacity, and prevent the additional installation of vertical scrubbers, these units were converted into two parallel second stage scrubbers. New horizontal 6-ft packed tower, cross flow scrubbers have been installed as first stage units. The treatment capacity of each scrubber train system was limited by the 25,000 cfm air flow of each existing vertical packed tower. To provide 25,000 cfm of treatment for System A, a 75 hp induced draft fan and 52 feet high exhaust stack (identical to the existing stack) were installed. System B treatment of 21,100 cfm was limited by the output of the existing 50 hp fan. This fan was upgraded from 13,000 cfm to its maximum output of 21,100 cfm, by changing shievs and pulleys and operating the motor near nameplate amperage. Heated and insulated buildings were constructed around both trains of scrubbers to protect the equipment and ensure proper operating conditions.

The local chemical controllers for the existing two stage scrubber system were replaced with a new programmable logic controller (PLC). The PLC continuously monitors both scrubber trains and automatically adjusts the chemical feed rates according to treatment demand and odor loadings. The program uses proportional integral (PI) control with offset to provide a very responsive and precise automated system. On-line measurement of treatment demand and chemical scrubbant levels are provided by pH and ORP sensors, as well as off-line by plant operators using an amperometric chlorine residual analyzer. Operating and alarm setpoints can be adjusted at the operator interface panel to ensure all compost odors are treated to nondetectable levels. Specific odorous compounds in the air stream are measured by plant operators using Draeger tubes at various stages of the treatment trains to ensure maximum scrubbing efficiency at optimal cost. Fine-tuning of setpoints and controllers is performed to ensure that all point source compost odor emissions are eliminated, prior to discharge from the two exhaust stacks.

The scrubber system configuration has been very effective in eliminating the historical point source emissions of compost odors from the scrubber exhaust stacks. Table 2 summarizes the odor treatment and removal efficiency of the retrofitted odor control system for average and peak inlet odor conditions for the most commonly recognized and targeted compost odors.

Table 2. Packed Tower Odor Scrubbing System Performance.

	Average Odor Conditions			*Peak Odor Conditions*		
Odorous Compound	*Inlet (ppm)*	*Outlet (ppm)*	*Removal (%)*	*Inlet (ppm)*	*Outlet (ppm)*	*Removal (%)*
Ammonia	80	ND	>99.9	300	ND	>99.9
Amines	12	ND	>99.9	20	ND	>99.9
DMS/DMDS	2.1	ND	>99.9	15	0.15	99.0
Mercaptans	1.0	ND	>99.9	2	0.1	95.0
Chlorine	0	0	—	0	0.2	—

ND = Nondetectable

SCRUBBER SYSTEM CONFIGURATION

The wet chemical scrubbing treatment system at the Schenectady facility uses an air-to-air heat exchanger, a water quenching mist tower and two stage packed bed scrubbers, and employs vapor cooling, condensation, acidification, absorption, and oxidation to remove each type of odorous compound.

Air-To-Air Heat Exchanger: System A air temperature averages 140°F, which is approximately 50°F warmer than System B. About 50 percent of this hot air flow (12,500 cfm) is cooled in an aluminum air-to-air heat exchanger (Figure 1). Static pressure levels control and limit the allowable air flow of 12,500 cfm through the air-to-air heat exchanger and mist tower water quench system. Fresh outside air is passed by the hot process air where effective heat transfer occurs. The warmed fresh air is supplied directly to the compost reactors as the single source of process air. Cooling of the foul process air in the heat exchanger removes a small amount of the soluble nitrogen compounds, ammonia and amines (NH_3-N and RNH), found in the odorous stream via condensation. The condensibles, as well as the scrubbers' effluent, are treated in the activated sludge system at the adjacent wastewater treatment plant. Fresh and foul air can bypass the air-to-air heat exchanger to allow for seasonal process flexibility and equipment maintenance.

Mist Tower Water Quench: The cooled air from the air-to-air heat exchanger is pretreated with water in a quench system to solubilize and further remove nitrogen compounds. The original Beverly Pacific packed tower scrubber was retrofitted to a water mist-type cooling tower by removing the packing media from the vessel and installing a tree of low pressure, BETE full cone 120 degree mist nozzles. The mist scrubbing technology was selected because of the water tower's straight pass-through treatment system, which uses secondary effluent water as the scrubbing medium. The removal of the random packed, spherical media significantly reduced the pressure drop across this system and doubled its air flow and scrubbing capacity. The water quench system provides average and peak NH_3-N removals of 60 and 95 percent, respectively. Slide gates in the System A duct also were installed to allow for complete bypass of the mist tower water quench system. Air flows are adjusted for summer and winter operation to control the outlet temperature from the system.

First Stage Treatment: Both System A and B use new Duall (F-106) horizontal cross-flow, packed tower chemical scrubbers for first stage treatment. Horizontal scrubbers were selected for several reasons, including lower cost, spacial restrictions, nearby high voltage retention wires, and odor treatment requirements. Each scrubber unit was designed with six feet of random filled spherical polypropylene packing (3½" diameter Jaeger Tri-Pak). The number of packing units was determined by the design inlet odor loading condition and requirement for removal of the odorous nitrogen compounds to nondetectable levels. The design peak inlet NH_3-N and RNH concentrations to the first stage scrubbers were 400 ppm and 60 ppm, respectively. The minimum concentration removal rate requirement is 99 percent and inlet/outlet sample ports were installed in the duct system to monitor the scrubbers' performance. The first stage treatment performance requirement for removing NH_3-N has been met over the past year by the Duall scrubbers.

A gas-to-liquid ratio of 55 cfm/gpm was used to determine that 435 gpm of recirculation of the scrubbant liquid was needed to provide this high level of chemical treatment. The recirculated scrubbing liquid is passed over the packing media to promote mass and heat transfer. The odorous nitrogen compounds are removed from the air stream into the scrubbant liquid using the mechanisms of absorption, evaporation, and condensation. A spray pattern of low pressure anti-clog BETE 120 degree nozzles are used to ensure intimate air to liquid contact and effective wetting of the packing media for maximum mass transfer and scrubbing efficiency.

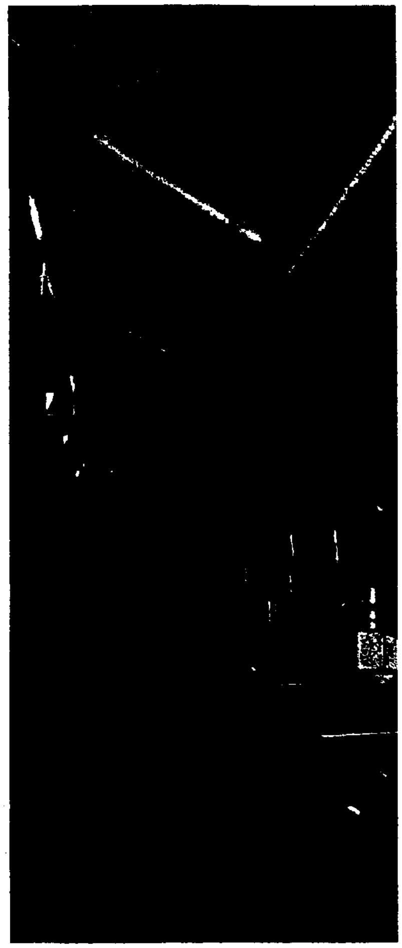
The first stage treatment system is operated at a pH range of 2.0 to 2.6 using a dilute solution of sulfuric acid (H_2SO_4) as the scrubbing liquid. The existing five wire output signal pH probes, which had a long history of problems, were replaced with a new two wire system. The fully wetted and immersed pH probes precisely sense an increase in pH, caused by the consumption of H_2SO_4 from actual scrubbing demand. The level of H_2SO_4 is automatically replenished by the PLC in response to the actual scrubbing demand. The control algorithm maintains the desired pH setpoint of 2.5, thereby ensuring that sufficient H_2SO_4 is available at all times to provide continuous and reliable treatment.

The Duall F-106 scrubbers control rapid changes (spikes) and varying odor loadings by operating continuously in a demand and response mode. Day-to-day operations still cause some fluctuations in odor loadings to the scrubbers, despite the high level of process control at the compost facility.

Since June, 1992, an average H_2SO_4 usage of 30 gpd has been required to provide the high level of treatment efficiency achieved. The chemical cost has been approximately $31 per day at unit costs of $0.67 per 1000 cfm of air scrubbed or $4.15 per dry ton of biosolids composted.

Second Stage Treatment: The original Duall (PT-510) vertical scrubbers, which used caustic and sodium hypochlorite, have been retrofitted to use sulfuric acid and hypochlorous acid (HOCl) to oxidize the more difficult and pervasive organic sulfur compounds (DMS/DMDS and mercaptans) to nondetectable levels. While the countercurrent air/liquid flow for these two scrubbers was maintained, they were converted into second stage units by changing the inlet and outlet duct transitions and close coupling them to the new F-106 horizontal scrubbers. Based upon design peak inlet DMS/DMDS and mercaptan concentrations of 15 ppm and 10 ppm, respectively, the original 10 feet of random packing was sufficient to provide a minimum removal rate for average loading conditions of 99 percent. A mist or moisture removal rate of 99 percent also was set to prevent a plume of visible discharge of chemically treated vapor at the exhaust stacks.

The configuration of the second stage scrubbers controls each chemical feed system with its own on-line sensor and PLC algorithm. The interactive control system stabilizes the complex scrubber chemistry and provides effective treatment of the offensive and pervasive organic sulfur compounds found in the odorous compost exhaust. The second stage scrubbers are operated at a slightly acidic pH range of 6.5 to 6.9 using a small amount of H_2SO_4 (< 5 gpd). This aqueous operating environment converts the alkaline NaOCl to HOCl, which possesses a higher oxidation potential to treat the odorous sulfur compounds to nondetectable levels.



Outfeed conveyor, push-pull exhaust duct plenum.

The level of pH control in the second stage scrubbers is most critical because of the competing and neutralization effect of the NaOCl. A small change in solution pH can cause a large change in the chemical balance of the scrubber system. For this reason, PSG installed a precise pH sensing and fine-tuned PLC control system.

The level of HOCl in the scrubbant liquid is controlled by on-line sensors which measure oxidation reduction potential (ORP). The existing ORP sensors were replaced with new and specially designed units for the slightly acidic solution. Since ORP increases with decreasing pH, and the scrubbers are operated at a much lower pH (6.7 as opposed to 9.25), the new ORP probes were fabricated with a larger measurement range (0 to 2000 millivolts (mv) as opposed to 0 to 1000 mv). The ORP setpoint, which ranges from 950 to 1050 mv, is adjusted by the plant operators at the PLC to control the level of total residual chlorine (TRC) in the recirculating scrubbant liquid.

TRC is a measurement of the remaining level of available chlorine after oxidation of the odorous sulfur compounds. Since System A and B contain different levels of inlet odors, the TRC level in each second stage scrubber is unique. TRC setpoints for System A and System B of 400 ppm and 175 ppm, respectively, are maintained to ensure that proper oxidation and continuous treatment occurs at varying odor loadings. The level of residual chlorine is monitored by plant operators using a bench-top amperometric titrator. Since June, 1992, an average NaOCl usage of 175 gpd has been required to oxidize the odorous sulfur compounds to nondetectable levels. The chemical cost has been approximately $125 per day at unit costs of $2.73 per 1000 cfm of air scrubbed or $15.20 per dry ton of biosolids composted.

Packed Tower Chemical Scrubbing Control: The measurements of pH, ORP, and TRC in the packed bed chemical scrubbers monitors the changes in actual scrubbing demand as a function of changing odor loadings. The proper level of chemical reaction is automatically provided between the scrubber liquid and the odorous gas. The Duall packed tower scrubbers do not anticipate odor spikes or operate in a reaction mode to fluctuating odor loads, such as required by mist-type scrubbers. Accordingly, they prevent excessive overshoot and undershoot with the addition of chemicals. The "bleed-through" of offensive compost odors from insufficient oxidation or creation of "burnt chemical odors" from excessive oxidation does not occur in the second stage units. In addition, any overshoot of chlorine does not liberate and discharge dangerous, odorous levels of chlorine gas up the exhaust stacks and into the atmosphere, which is a common and documented problem with mist-type scrubbers. As a result, a third stage dechlorination (removal of gaseous residual chlorine) scrubber is not required in Schenectady.

Mist eliminators, comprised of one inch diameter packing media, were installed in the outlet sections of each F-106 and PT-510 scrubbers. These provide impingement of water droplets and prevent any carryover of chemicals or treated moisture. Scrubbant liquid in the first stage treatment system, which contains ammonia, does not "bleed-through" to the second stage treatment system, where it would exert an erractic chlorine demand (formation of chloramines), reduce oxidation capacity, and adversely impact the oxidation scrubbers' performance.

COST OF SOLUTIONS

Approximately $450,000 was spent in the last year on the new air handling/odor exhaust duct system and retrofitted odor scrubber system. The city's cost for the existing odor scrubbing equipment was approximately $153,000. The total cost for solving the Schenectady compost facility odor problems is less than $1 million. Additional personnel have not been hired to maintain the odor control system. Currently, two plant operators are assigned full time to the compost facility to handle all operations, including the odor control system. Corrective maintenance is handled effectively by the plant maintenance staff, which includes the electrical/instrumentation specialist. The high level of process control, comprehensive approach, and reliable automation have proven to be a significant O&M cost savings in personnel, labor, and materials. The overall unit O&M cost of the Schenectady compost plant with the comprehensive odor control system and process changes describes in Part I of this article, is approximately $185 per dry ton of biosolids composted.

REBUILDING PUBLIC CONFIDENCE

In late June, 1992, the new air handling/odor exhausting and retrofitted scrubber systems were placed into service. During the previous months of compost facility operation and over the six month period of design, installation, and start-up, PSG focused on addressing the NIMBY concerns of the nearby neighborhood residents by rebuilding their confidence about composting. The focus of the public relations program has been that the compost facility can be operated successfully and productively without the discharge and detection of offensive, noxious odors.

The first step towards dealing with the general public where the NIMBY scenario exists is to be sensitive and understanding of people's attitudes and perceptions about the compost plant. The common theme by the general public was that of a cartoon once published in the Schenectady *Gazette*, which showed the compost plant in the background and a skunk pointing towards a facility sign that read, "City of Schenectady Compost Plant — keep us or sell us, you'll always smell us!" To erase this public perception, a comprehensive client and neighbor relations program has been implemented with the citizens of Schenectady and the nearby residents of the Northend Homeowners Association (NHA).

Materials mixing area hood, curtains and exhaust duct.

A newsletter, called the *Communicator*, has been routinely mailed to the 55 NHA residents, mayor, city council members, and local newspaper. The newsletter enables PSG to communicate about the operation and odor control activities at the compost plant. A NHA Hotline was established; calls about the detection of odors are received directly into the project manager's office.

Odor detection reports are completed by PSG personnel for every call received from the NHA and the project manager follows up in some way with each caller. PSG holds a semiannual dinner meeting with the NHA members to report on odor control progress and discuss specific neighborhood concerns. As would be expected, the contractor also meets with the mayor and city council on a regular basis. The most important component of the public relations program is the Odor Control Committee (OCC). The OCC is comprised of five people — three members and two alternates from the NHA, a city councilman, and PSG's project manager. PSG's Northeast regional manager serves as the coordinator. The OCC meets quarterly to report on the progress and effectiveness of the odor control program.

An odor control survey, which includes 10 criteria, subjective questions and various degrees of response, was developed by the OCC and has become Schenectady's odor standard. The survey, which contains no specific technical criteria or analytical limits, is mailed to the 55 NHA members. The collective response by the NHA is forwarded to the three NHA voting members of the OCC. Based upon their findings, these individuals have the responsibility to report on the results of the survey and vote on the authorization to release funds, which are withheld from PSG's monthly fee as an odor control incentive. The use of the questionnaire and survey, coupled with the financial advisory responsibilities of the three voting OCC members, have been an effective way of setting, monitoring, and enforcing odor standards.

To date, the OCC is pleased with the progress the operator has made in meeting its commitment to control, reduce and, where possible, eliminate odors from the operation of the wastewater treatment facilities and compost plant and thereby minimize the impact on the nearby community. The OCC firmly believes that the efforts of odor control are not only vital and important to the neighbors surrounding the treatment plant, but also to the entire city. ■

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