ODOR CONTROL FACILITIES ADDITIONS AND MODIFICATIONS AT REGIONAL COMPOST FACILITY IN HICKORY, NC

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INTRODUCTION

Background

In 1982, the Cities of Hickory, Newton and Conover, and Catawba County, North Carolina formed a Consortium to provide centralized facilities for the disposal of their combined municipal wastewater biosolids. At the time, these local governments were primarily land applying their wastewater biosolids. Recognizing potential problems with their current biosolids disposal methods, rising environmental regulations and potential legal liabilities, these local governments began to discuss and pursue other options for biosolids management and disposal. In anticipation of future growth, the Consortium combined their resources and efforts to construct a regional biosolids composting facility that would meet each participating member's needs.

This innovative approach to an environmental problem using composting by cooperation, provided a viable method for managing and disposing of biosolids in a safe and beneficial way. Composting was selected because of its aerobic process and biological methods of operation, as well as the numerous beneficial uses of the end product as a soil amendment and conditioner. The in-vessel composting technology was also selected because of its endorsements by regulatory agencies through support funding of U.S. EPA Innovative/Alternative (I/A) Technology Grant.

As a result, the project was designed between 1984 and 1986 and construction was inititated in 1987 and completed in July, 1990. A twenty dry ton per day (20 DT/dy) in-vessel facility was constructed for $7.7 million using the Ashbrook-Simon-Hartley (A-S-H) Tunnel Reactor technology. Approximately $5.4 million of this project was funded by the awarding of an I/A Technology Grant in July, 1986. The remaining local funding was based upon the projected percent contributions of biosolids by the respective Consortium members.

Existing Facilities

The Regional Compost Facility (RCF) is built on a 15-acre site in Newton at an equidistant location for all Consortium members. The RCF is comprised of liquid storage, dewatering, composting, product storage, odor control, and effluent pretreatment facilities as shown in the site plan (Figure 1). Municipal liquid biosolids are hauled in tanker trucks to the receiving station and desposited into four underground storage tanks. Various liquid biosolids from four different wastewater treatment plants are blended together in the liquid storage tanks to provide a more consistent biosolids before being pumped to the dewatering facilities.

The mixed liquid biosolids are initially pumped to a blend tank, where wood amendments can be added to increase the feed solids content prior to polymer addition and dewatering. The wood amendment is stored in a silo and conveyed to the dewatering room using screw conveyors. The liquid biosolids are dewatered using two 2-meter belt filter presses. Additional wood amendment is added to the amended cake solids and mixed mechanically into an in-feed compost mixture and transported by drag-flight conveyors to one of four parallel in-vessel Tunnel Reactors. The liquid filtrate, scrubber systems blowdowns, and facility wash waters are directed and processed in a biological pretreatment system. The partially treated effluent is discharged to the Town of Newton's wastewater treatment for final disposal.

REGIONAL COMPOST FACILITY

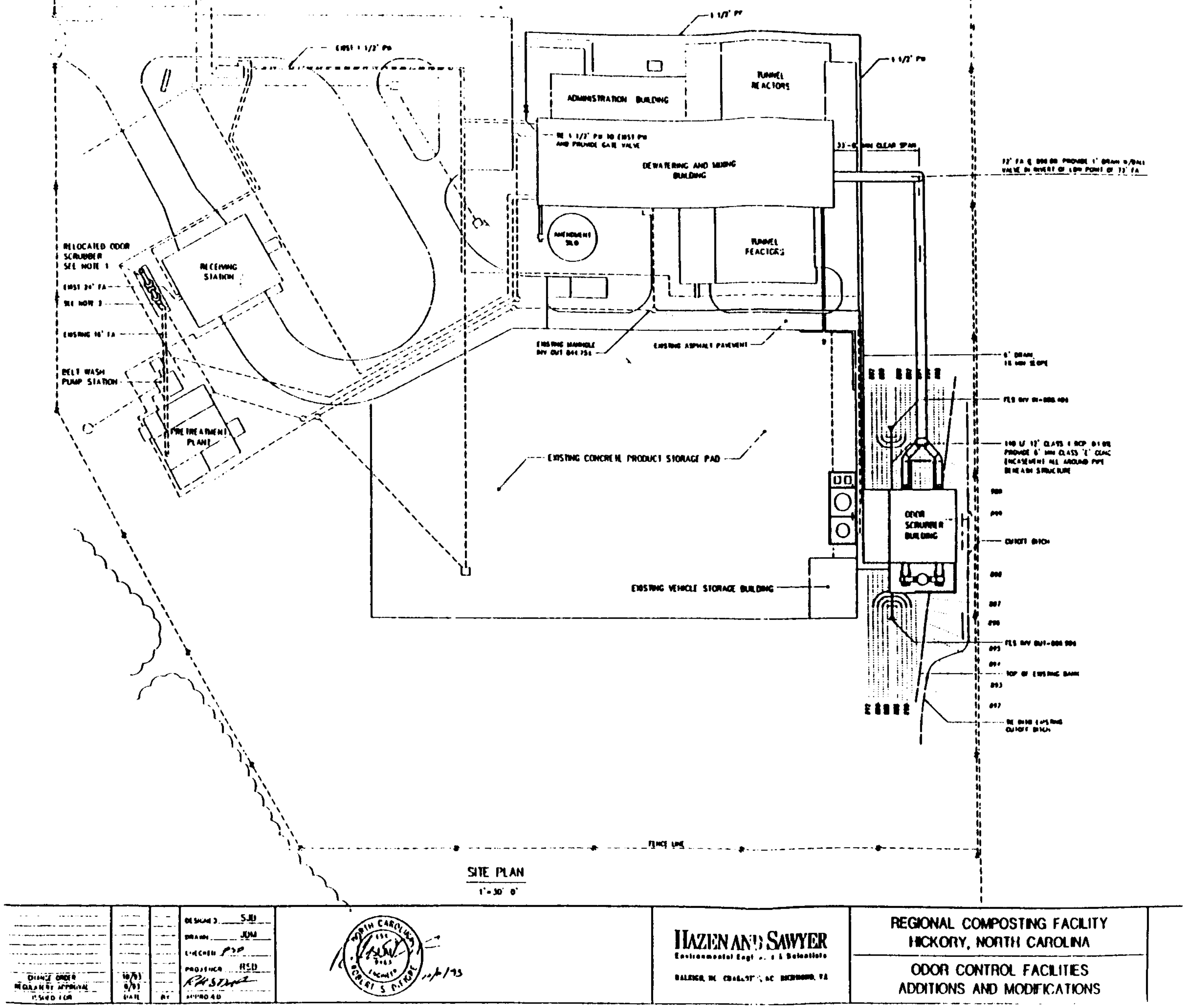

FIGURE 1

These Tunnel Reactors are shaped like a shoe box and were sized at the design capacity loading of 20.0 DT/dy to provide a minimum of 14 days of solids retention time for the compost mixture, prior to discharge. The in-feed compost mixture is fed into the end of each reactor and moves horizontally to the out-feed discharge using a hydraulic push system, which creates a plug flow displacement of the compost material. The out-feed compost can either be recycled back to the mixing equipment for further processing or discharged by a belt conveyor to a concrete cure pad. This pad was sized to allow for product storage and gentle aeration during a 14 to 30 day curing process.

Odor Control Problems

Two odor control systems were installed to treat foul and odorous air produced at the RCF. Both odor control systems consisted of a two-stage packed-tower wet chemical scrubbers with an induced draft fan and exhaust stack. These odor scrubbers were designed to treat ammonia in the first stage using sulfuric acid and treat hydrogen sulfide in the second stage using sodium hypochlorite and caustic. This odor scrubbing treatment scheme was consistent with the odor control measures used at other operating in-vessel composting facilities.

A 9,500 cfm scrubber system was designed to exhaust odorous gases from the Dewatering Room and the vacuum blowers which exhaust foul process air from the Tunnel Reactors. A 4,000 cfm system was installed to handle the sludge receiving and storage facilities and the pretreatment plant. Various process areas in the Compost Building, including mixers, conveyors, tunnel push pits, biosolids/amendment bin, and compost recycle bin were not exhausted to the larger system. These odor control facilities represented the best available control technology (BACT) at the time of their installation.

When composting operations were initiated at the RCF in May, 1990, odor problems were experienced and numerous complaints were being received from nearby residents and businesses. There were numerous sources of odors from fugitive emissions, point-source emissions, and area emissions at the RCF. The point-source emissions from the odor scrubber stacks were identified as a significant contributor to the odor problems. These scrubbers were not adequately sized for the types and quantities of odorous compounds being generated at the RCF. As a result, significant "bleed-through" of odorous compounds and "carry-over" of burnt scrubbant chemicals were continuously discharged up the exhaust stacks, which resulted in offensive odors. Another significant contributor to the odor problems were the fugitivie emissions of untreated high itensity and pervasive odorous compounds being ventilated directly into the atmosphere through roof exhaust fans in the Compost Building. This practice was used by plant personnel in attempts to improve the working conditions by reducing the levels of foul odors inside the facilities and personnel areas. Area emissions of odors also ocuurred from the on-site cure pad storage of finished product.

These odor problems necessitated a voluntary shutdown of the RCF by the Consortium in August, 1990 to make improvements in the odor control facilities. Odor control modifications included covering of the pretreatment plant, reducing the volume of odorous air inside the Compost Building by installing an interior wall to isolate the-process and personnel areas, adding some duct to scrub foul air directly from certain pieces of equipment, i.e. mixers, conveyors, sludge/amendment storage and compost recycle bins, and eliminating the storage of compost on-site at the outdoor cure pad.

These modifications were completed in January, 1991 and the plant was restarted. Odor problems still persisted and odor complaints continued. By this time, the residential and business community had become very sensitized and communicated their intolerance of virtually no odors from the compost plant. Additionally, the Air Quality Section of the North Carolina Division of Environmental Management (NCDEM) directed that corrective actions be taken to ensure essentially zero emissions of odors from the RCF. Consequently, the Consortuim elected to shut down the RCF in February, 1991 until a comprehensive and radical new approach could be taken to fully correct all odor problems.

In March, 1992, the Consortium's consultants, Hazen and Sawyer Engineers, at the Consortium's request, prepared the "Regional Composting Facility Innovative/Alternative Technology Failure Report", which evaluated the odor problems and proposed a mist scrubber system for additions and modifications to the odor control facilities at the RCF. At that time, mist-type odor scrubbers were considered to be the BACT. However, the long term operating experience with mist scrubbers at several other in-vessel composting facilities showed continued problems with odors and complaints as a result of erratic control, odor bleed-through, chemical carryover into the exhaust, high capital costs, and equipment deterioration. Thus, it became apparent that a new approach needed to be investigated and an alternative odor control plan implemented at the RCF to achieve a fully productive and desired level of operation.

ODOR CONTROL SYSTEM ADDITIONS & MODIFICATIONS

Comprehensive Approach to Odor Control Plan

A comprehensive approach and numerous changes in the existing odor control facilities were initiated by the Consortium in December, 1992. Professional Services Group, Inc., (PSG) submitted a proposal in November, 1992 for a comprehensive compost odor control program which fully addressed all fugitive, point-source, and areas emissions from the RCF. PSG's approach included numerous compost process and system equipment improvements, modifications to the existing odor control facilities and the addition of a new comprehensive odor control system, which are described in detail herein.

The Consortium hired PSG to provide full contract operations, maintenance, and management services (OM&M) to correct the odor problems that had plagued the RCF. PSG's proposed comprehensive compost odor management program provided for specific solutions to each source of odor. Additional elements of this odor reduction, control, and management program which are not presented herein include specific process control strategies, routine neighborhood and business community communication, public relations, and finished compost product marketing and distribution.

This comprehensive approach to compost odor control, implemented at the RCF was based upon PSG's success in reducing and controlling biosolids and compost odors at the 18.5 MGD wastewater treatment plant and 15.0 DT/dy in-vessel compost facility in Schenectady, New York. Chronic odors, mechanical breakdowns and process failures had also shutdown the $7.5 million in-vessel compost facility in Schenectady. In less than one years time, all of these problems were fully corrected. Odors are being successfully reduced and controlled at the composting facility, since it was restarted by PSG in June, 1992. Since that time, more than 60,000 cubic yards of high organic compost has been produced without offensive odors, marketed and distributed to a variety of beneficial uses in New York.

Consortium members visited PSG's project in Schenectady during the fall of 1992 and they decided to implement this odor reduction and control program at the RCF. This approach would include a fresh air ventilation, foul air exhaust, and multi-stage packed-bed chemical wet scrubbing system. During the site visit to Schenectady, Consortium members observed the PSG designed odor control system, which used an innovative configuration of packed-bed scrubbers and an agressive mode of chemical oxidation to control and treat the very pervasive organic sulfide odors. The Consortium also validated the effectiveness of this odor control operation by visiting with several of the residents who live in a neighborhood adjacent to the Schenectady in-vessel biosolids composting facility.

Based upon this operating experience with in-vessel composting and odor control success in Schenectady, a similar system for the RCF was proposed by PSG and accepted after thorough review by the Consortium, Hazen and Sawyer, and PWT Waste Solutions, Inc. (formerly A-S-H). The I/A Report was amended to recommend packed-bed wet scrubbing and the additional odor control system components for the RCF. The cost to construct the additions and modifications of the required odor control facilities would be $1.4 million with $0.9 million received from an I/A Technology Replacement Grant.

Odorous Compounds Characterized

Most large in-vessel composting facilities have been plagued with odor related problems identical in nature to Hickory, North Carolina and Schenectady, New York. Extensive research has been performed by the operators of these facilities to identify the odorous compounds generated at biosolids composting facilities. Operational experience with odor problems coupled with this testing and research, have led to the identification of the problematic odorous compounds and the advancement of technology to treat and remove these odors.

An assessment by PSG of the various process areas and review of the historical operating experiences at the RCF identified several odor sources (Figure 2). This information indicated that the composting process generated more than two-thirds of the odors at the RCF, with the relative proportions of odorous compounds projected as being very characteristic of the experiences of other in-vessel biosolids composting facilities. Both high intensity nitrogen compounds (ammonia and amines) and very pervasive organic sulfide compounds (dimethyl sulfide, dimethyl disulfide, and methyl mercaptan), as well as other compounds (hydrogen sulfide, chlorine, and chlorinated hydrocarbons) were identified as the dominant odors. These compounds have very low odor thresholds (Table 1) and were being detected regularly as far as a mile away from the RCF despite many millions of dilutions in the atmosphere.

TABLE 1 IN-VESSEL BIOSOLIDS COMPOSTING ODORS		
ODOROUS COMPOUND	CHEMICAL	THRESHOLD (ppm)
Ammonia	NH_3	0.0037
Trimethyl Amine	TMA	0.0002
Hydrogen Sulfide	H_2S	0.0005
Dimethyl Sulfide	DMS	0.001
Dimethyl Disulfide	DMDS	0.001
Methyl Mercaptan	CH_3SH	0.002

Design Criteria of Odor Control Facilities

In December, 1992, the "Team" comprised of the Consortium (Owner), Hazen and Sawyer (Consultant), PWT (Compost System Supplier) and PSG (Operator) initiated a cooperative effort to design and construct an effective odor control system for the RCF. This new system would include a comprehensive fresh air ventilation, foul air capture and exhaust, odor conditioning and wet chemical scrubbing treatment, and treated air discharge.

The Team established the objective to capture, collect, and convey all odors at the various identified sources and treat them to non-detectable (ND) levels prior to discharge to the atmosphere. This stack discharge level would require that more than 99% of all captured and exhausted odors be removed in the scrubbing system. The fundamental goal of the odor control plan recognized that the high intensity and very pervasive odorous compounds generated at the RCF would still be readily detected off-site by nearby residents and businesses, if these odors were not captured and fully treated using continuous monitoring and reliable odor control equipment. Additional criteria in the design of the additions and modifications to the odor control facilities at the RCF included an adequate fresh air ventilation and foul air capture and exhaust system for various process and personnel working areas, as well as a building which encloses the new odor scrubbing equipment.

Retrofit of Existing Odor Scrubbing System

It was determined that the existing two-stage packed-tower wet chemical scrubbing systems were inadequately designed to treat and remove odors from the respective process areas at the RCF. After careful review of the treatment capacities and a thorough evaluation of the structural and mechanical condition of the existing odor scrubbing systems, it was decided to refurbish and relocate the two-stage 9,500 cfm system from the Dewatering and Compost Building to replace the two-stage 4,000 cfm system at the Biosolids Receiving Station and Pretreatment Plant.

The sheet packing media in this scrubber system was replaced with higher treatment efficiency randomn fill packing media. The spray nozzles were upgraded and the spray piping modified to increase mass and heat transfer between the scrubbing solutions and odorous air stream. Baffle plates were installed inside the scrubbers to allow for the addition of mist elimination packing media in the top cone section of each tower. This demisting packing provides impingement of very small water droplets and prevent any carryover of chemicals. Improved on-line instrumentation (pH and ORP sensors) was installed for improved monitoring of scrubbing conditions and precise responses in the chemical feed control system. The chemical solution recirculation pumps were mechanically refurbished to improve their reliability. A modified chemical bulk storage tank arrangement and a retrofitted chemical metering pump system with improved injectors were installed to increase the supply and control of scrubbing chemicals to match the scrubbing demand. Finally, the 10 foot high exhaust stack height was also doubled to 20 feet to improve atmospheric dispersion and minimize downwash conditions of the scrubbed and treated air.

REGIONAL COMPOST FACILITY
In-Vessel Composting Odors

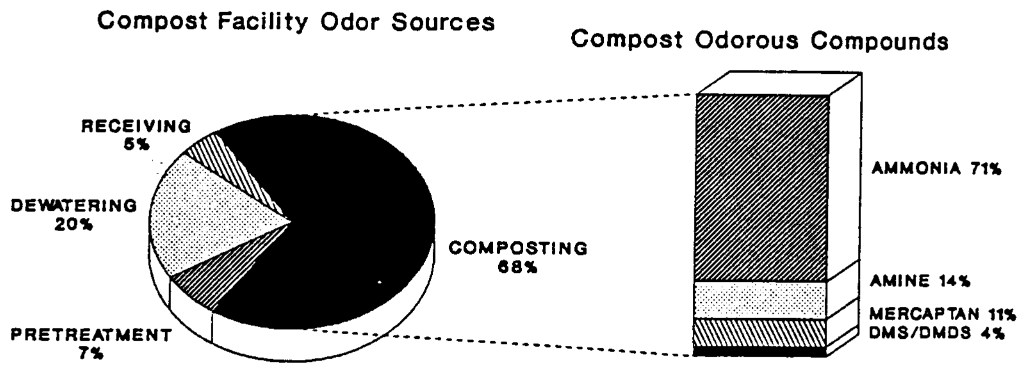

Figure 2

REGIONAL COMPOST FACILITY
In-Vessel Composting System

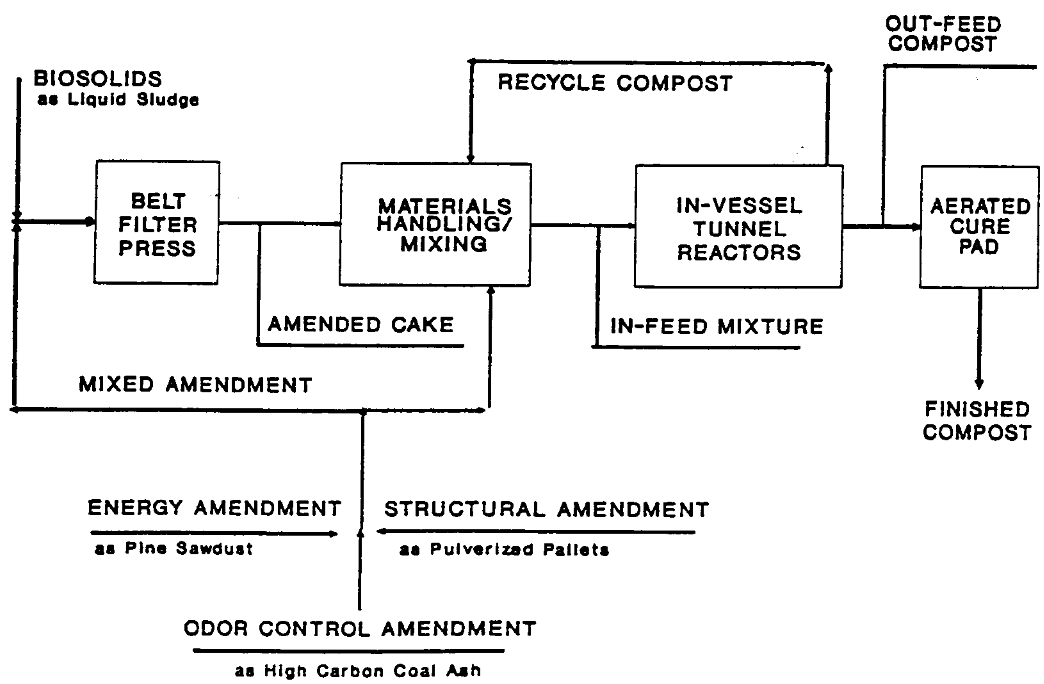

Figure 3

Process Optimization to Mitigate Odors

A high emphasis was placed on mitigating and reducing the production of process odors, which then must be captured, exhausted, and treated in the new odor control system. Operational and equipment improvements were made in several areas of the RCF to optimize the composting process (Figure 3). The areas of focus were amendment and compost process control.. Undesireable operating conditions were identified as the single most significant contributor of offensive odors. These odors were created from fugitive emissions and routine point-source emissions whiched passed through the 9,500 cfm scrubber system either partially or completely untreated.

A new three-component amendment recipe is used at the RCF to provide specific process control aspects to improve operations and mitigate compost odors. The historical use of a very fine and dusty hard wood oak sawdust has been replaced with a more coarse soft wood pine sawdust as the energy amendment. The pine sawdust provides moisture absorption, the available carbon for active composting within the biosmass, and the "free-flowing factor" required for efficient materials handling operations with in-vessel systems.

The pine sawdust amendment is now supplemented with dry, medium particle size pulverized wood pallets to provide moisture control and increased porosity. The pulverized wood serves as the structural amendment by providing the macrostructure and porosity within the compost matrix for achieving aerobic conditions by increasing the oxygen transfer capacity. It also allows for the void spaces needed in-vessel for proper heat release heat, moisture, and odors from the compost product into the reactor headspace, where this odorous fog is captured, exhausted, and treated in the new odor control system.

Historically, this excessive moisture, heat and odors were temporarily trapped within the compost reactors and product and then released as a fugitive emission during reactor unloading and/or as an area emission during compost product storage and handling outside on the curing pad. An upgraded and retrofitted amendment handling system has been installed to process the new wood amendments without the historical plugging and bridging problems. The new equipment now allows the unloading of the wood amendments at the design loading and throughput capacities.

The initial blend of wood amendments which formulates the new amendment recipe is 60% by volume of the soft pine sawdust and 30% of the hard wood pulverized pallets. The remaining 10% by volume of the recipe is comprised of a high carbon coal ash. This ash is a by-product of coal fired power plants and possesses a high level of adsorption capacity as an inert material. The coal ash is used to treat the very offensive odorous organic sulfur compounds (DMS, DMDS, and mercaptans) within the vessel by the process of adsorption.

This odor removal mechanism is similar to the organic matter removal mechanisms used in activated carbon columns or mixed-media water filters. The low solubility properties of these sulfur compounds result in their greater affinity to be adsorbed by the coal ash within the compost matrix and thus the coal ash becomes the odor control component in the amendment recipe. These low odor threshold sulfur compounds become bound in the compost in a non-odorous complexation and do not become liberated or released when the finished product is subjected to materials handling. Equally important, the adsorption of the odorous organic sulfide compounds in the compost significantly reduces these gasses from being discharged into the headspace of the Tunnel Reactors. Therefore, use of high carbon coal ash provides a very powerful method of mitigating the production of foul organic sulfide odors.

Several other process control and operational changes have been made to optimize the composting performance and mitigate the production of odors. All four Tunnel Reactors are now utilized to process the average biosolids loading of 13.5 dry tons per day (DT/dy), based upon a five day per week operation. A "once through" approach is now used, where the four reactors operate in a single pass plug flow manner to achieve a desired solids retention time (SRT) of 21 days. The rate of active composting and curing inside the Tunnel Reactors is maximized using compost recycle to improve the stability and maturity of the finished compost. This higher quality finished compost will correct the historical problems of area emissions of odors from product discharge and outside cure pad storage.

Air Handling/Odor Exhausting Design

The containment of odors and control of fugitive emissions from the Compost Building was a primary odor control challenge at the RCF. The original design of ducted and exhausted air flow of 9,500 cfm was configured to handle 5,200 cfm of process air from the Tunnel Reactors and 4,300 from the Dewatering Room and enclosed equipment in the Materials Handling Room. A 72,000 cfm air handling and odor exhausting system was designed and installed to correct the problems with fugitive emissions of odors by incorporating all of the process areas inside the Compost Building and creating a continuous negative pressure operating condition.

The installed system provides both fresh air ventilation and foul odorous air exhaust at various process locations within the Compost Building (Figure 4) and exhausts the captured odors to the scrubbing treatment system. Exhausting and scrubbing of all process areas inside the Compost Building was necessary to effectively control odors at the RCF. The rate of ventilation from each area was determined by process requirements and level of plant personnel exposure as summarized in Table 2.

TABLE 2
AIR VENTILATION/ODOR EXHAUST DESIGN CRITERIA

PROCESS AREA/LOCATION	VENTILATION (ac/hr)	AIRFLOW (cfm)
Compost Tunnel Reactors	9.0	8,300
Reactor Inlet "Push-pits"	12.0	4,000
Materials Handling Room	12.0	42,850
Biosolids Dewatering Room	14.5	10,050
Biosolids Transfer/Polymer Room	7.5	6,800
AVERAGE/TOTAL	**11.6**	**72,000**

The new air handling and odor exhaust system achieves an average ventilation rate within the Compost Building of 11.6 ac/hr. Two different ventilation and exhaust techniques are used to achieve the design criteria summarized in Table 2. The high temperature odorous gases from the compost Tunnel Reactors were addressed differently than the lower temperature odorous gases from the remaining Compost Building process areas in the new capture and exhaust system.

Compost Tunnel Reactors:

Process odor capture and exhaust was a key aspect of the new odor control system. The treatment capacity of the new odor scrubbing system design was based upon the peak production of offensive odors being generated continuously from the composting process, without any credit being given to odor mitigation from advanced process control.

Fundamental improvements have been made in the air supply and odor exhaust of the Tunnel Reactors. Piping modifications were made to supply fresh outside ambient air to the suction side of the four centrifugal pressure blowers. The use of foul, saturated odorous process air from the Dewatering Room and Materials Handling Room for the pressure aeration blowers is now eliminated. Odorous process air from the vacuum blowers is now exhausted directly into the new polyvinyl chloride (PVC) duct and odor scrubbing system. Negative pressure in the Tunnel Reactors and process air balancing are accomplished with new polypropylene (PP) duct and exhaust ports installed on the in-vessel reactor roofs.

Each Tunnel Reactor roof now contains along its length, a PP duct header which contains fresh air intake vents and foul process air exhaust ports and instaduct dampers. The headspace sections above the compost inside the Tunnel Reactors is now ventilated at a rate of 12 ac/hr to forcefully remove the heavy fog of odorous steam. The entrapment, buildup, and subsequent "raining" of odorous condensed moisture on the compost is now eliminated, which improves upon its dryness and stability. The PP duct was used for both the Tunnel Reactors and the discharge side of the vacuum blowers due to its ability to handle higher gas temperatures (up to 180 deg. F). The duct and instaduct dampers were sized to ensure a continuous ventilation of the headspace and thereby prevent any fugitive odorous emissions from the Tunnel Reactors independent of the operation of the seven aeration zones.

Compost Building Process Areas:

The various other biosolids and compost process areas inside the Compost Building are also ventilated with fresh air and foul air captured and exhausted to the new odor scrubbing treatment system. These areas were handled with PVC ducts and hoods as shown in Figure 3 to capture the discharges of high intensity odorous emissions from various pieces of equipment, i.e. belt filter presses, mixers, and Tunnel Reactor inlet "push-pits". The odorous gases from these equipment are lower in temperature and concentration than the process air exhausted directly from the Tunnel Reactors. However, to prevent any fugitive emissions of the odorous compounds discharged inside the Compost Building from escaping into the atmosphere untreated, the remaining process areas were included in the air ventilation, capture and exhaust system.

The largest process area in the Compost Building is the Materials Handling Room. To achieve a negative pressure in the room required the ventilation and exhaust of 42,600 cfm of diluted foul air at a rate of 12 ac/hr. A "cross-flow" ventilation system is used where "bird screen" type wall vents were installed on the inboard walls of Tunnel Reactors #2 and #3 to introduce a uniform rate of fresh outside air along the length of the Materials Handling Room. The diluted foul air is exhausted horizontally into a large exhaust duct plenum with instaduct takeoffs on both sides, located in the middle of the Materials Handling Room.

A four-sided rectangular PVC hood with hanging clear plastic strip curtains was also installed over the high intensity discharge of odorous emissions from the out-feed conveyor. This hood removes 250 cfm as a point-source exhaust rate of 12 ac/hr and connects into the large exhaust duct plenum. Hoods were also installed over the Tunnel Reactor inlet "push-pits" to capture occasional tunnel door seal odor leaks. Each three-sided Tunnel Reactor inlet push-pit hood exhausts 1,000 cfm at a ventilation rate of 12 ac/hr. Four-sided PVC hoods with hanging strip curtains were provided over each belt filter press to exhaust high concentration biosolids odors at a unit air flow of 800 cfm and ventilation rate of 12 ac/hr. The Biosolids Dewatering Room exhaust duct system provides an overall ventilation rate of 15 ac/hr at 8,400 cfm.

Additionally, the internal long corridors on the outboard side of Tunnel Reactors #1 and #4 were also filled with odorous steam during periods of in-feed compost loading. This area in the Compost Building was stagnant at an average ventilation rate of 1.5 ach/hr. This low level of ventilation resulted in the escape of untreated odors to the atmosphere through the wall vents, located at the ends of the corridors. A 4,600 cfm push-air fan has been installed at the front end of each outboard Tunnels corridors to provide a "push-pull" ventilation technique at a rate of 10 ac/hr. The high negative pressure achieved in the Tunnel corridors results in fresh air from the end wall vents being mixed with foul air and drawn into the push fans. The diluted foul air is pushed via the fans using a discharge duct containing several uniformly spaced instaduct dampers. The foul air is pushed at a high velocity over the tops of the in-let push pits hoods, where it is captured by instaducts and exhausted into the large duct plenum located in the center of the Materials Handling Room.

Light grey PVC was used in most areas of the new ventilation and exhaust duct system because of its corrosion resistance, durability, and appearance. Some existing extruded dark grey PVC duct was used in the Biosolids Transfer/Polymer Room to connect the Dewatering Room duct with the large plenum in the Materials Handling Room. The exhaust air in this non-process and minimal odorous area within the Compost Building is used to balance the entire duct ventilation and exhaust system, dependent upon the actual process air flow conditions inside the Tunnel Reactors. Varying modes of positive and negative aeration inside the Tunnel Reactors using the pressure and vacuum blowers defines the overall rate of exhaust from the top of the reactors and the corresponding overall system air balancing using fresh air make-up supplied from wall vents in the Biosolids Transfer/Polymer Room.

White PVC duct was used outdoors to prevent ultraviolent degradation of the duct from sunlight exposure. Black PP duct was used for handling all hot gas temperature process air as previuously described for the vacuum blowers and the roofs of the Tunnel Reactors. All of the ducts and hoods were sized to minimize friction losses and provide an average airflow velocity of 2,240 fpm to achieve an overall system static pressure of less than 8"WC at the induced draft fans.

Odor Scrubbing System Configuration

The high concentration process odors and lower concentration general building odors were combined into the large duct plenum at the combined exhaust flow of 72,000 cfm. This foul air is directed to two parallel trains of 36,000 cfm three-stage packed-bed wet chemical scrubbers. The packed-bed chemical scrubbing system uses an innovative close-coupled reactor unit configuration to achieve the highest level of treatment efficiency at the lowest capital and O&M costs. The installed odor control scrubbing system was 40% lower in cost than an alternative 72,000 cfm mist-type scrubbing system.

The parallel trains of three-stage scrubbers consist of horizontal cross-flow and vertical counter-current flow reactors installed in a close-coupled and space efficient configuration. The three-stage scrubber trains are located in one room and the motor control center (MCC), PLC/annuciator panel and chemical metering pump system are installed in a second room of the new Odor Control Building (Figure 5).

The first two scrubber stages are rectangular in shape and required minimal inlet and outlet transition and overhead space and the third stage is a conventional cylindrical tower. The new Odor Control Building fully encloses the first two stage units and 60% of the third-stage vertical units, with special roof penetrations made to accomodate the packed-tower scrubbers and maintain water tight building conditions. The scrubbers and duct inside the building are constructed of light grey PVC and the outside portions of the towers, connecting duct, induced draft fans, and exhaust stack are white PVC.

Table 3 summarizes the design criteria for the Duall scrubber trains. Stages 1 and 2 consist of horizontal cross-flow, packed-bed wet chemical scrubbers. The foul air in the large exhaust header is evenly split into two smaller ducts with the parallel inlet airstreams entering one side of the horizontal scrubbers and exiting out the opposite side. The scrubbing recirculation solution is discharged through spray nozzles pointed perpendicular to the airstream to achieve mass transfer of odors. Horizontal scrubbers were selected for several reasons, including lower unit capital costs, close-coupled spacing, high treatment efficiency, and ease of maintenance access.

The horizontal units are randomnly filled with six feet of 3-1/2" diameter spherical polypropylene packing media. The amount of packing media was determined by the design inlet odor loading conditions and the requirement for removing all odorous compounds to non-detectable levels. A design gas-to-liquid ratio of 80 cfm/gpm was used to determine that 450 gpm of recirculating scrubbing liquid would be necessary to provide the required high level of chemical treatment. The recirculating scrubbing liquid is passed over the packing media to promote mass and heat transfer. Low pressure anti-clog nozzles are used to ensure intimate air to liquid contact and effective wetting of the media for maximum scrubbing efficiency.

One foot of 2" diameter mist elimination packing media are installed in the outlet transition of each scrubber to prevent any "carry-over" of moisture as small water droplets to the next treatment stage. The complete removal of moisture between treatment stages is a critical aspect in the success of the three-stage scrubbing trains. Undesireable chemical interactions and corresponding erractic feed control, excessive chemical demands, and reduced odor treatment efficiency are prevented with the mist eliminators.

The third-stage units are vertical counter-current flow packed-tower scrubbers. The air flow from the second stage horizontal scrubber is discharged into the bottom of the third stage unit, travels up the tower and exits the top. The 450 gpm of recirculation scrubbing solution is pumped from the bottom storage reservoir to the spray header nozzles located at the top of the tower. The upward air flow and downward spray of chemical scrubbing solution provides the counter-current scrubbing. The vertical towers are filled with twelve feet of the same scrubbing packing media as the horizontal units and the top cone section is filled with the same type of demisting packing. The higher level of packing media in the vertical towers was required to provide a higher level of detention time in the scrubber to fully treat the very pervasive organic sulfur (DMS & DMDS) compounds. The mist elimination packing also prevents formation of a visible stack exhaust plume from carryover of fine water droplets. A visible exhaust plume from the stack, even if its non-odorous, can be perceived as a discharge of odorous emissions from nearby residents and businesses.

REGIONAL COMPOST FACILITY
Air Ventilation/Odor Exhaust System

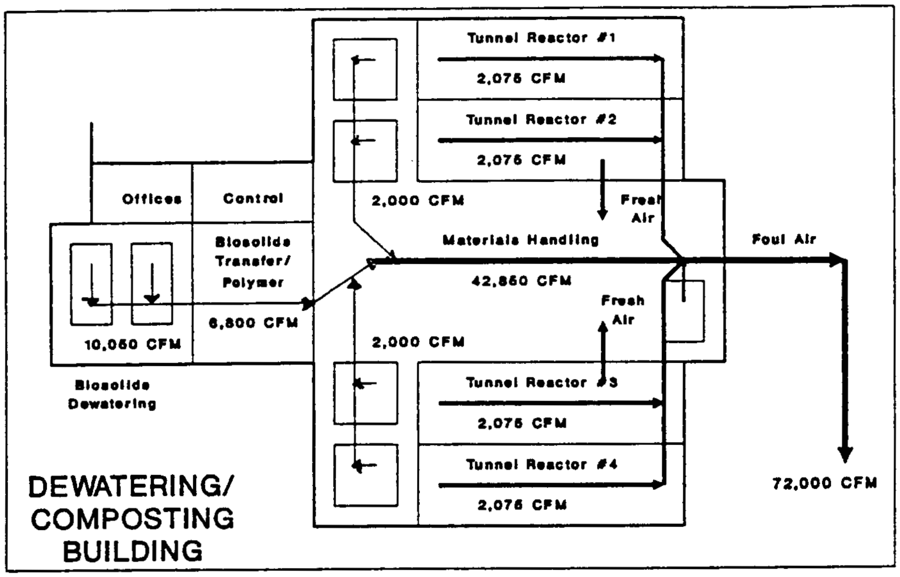

Figure 4

REGIONAL COMPOST FACILITY
Three-Stage Packed-Bed Scrubbing System

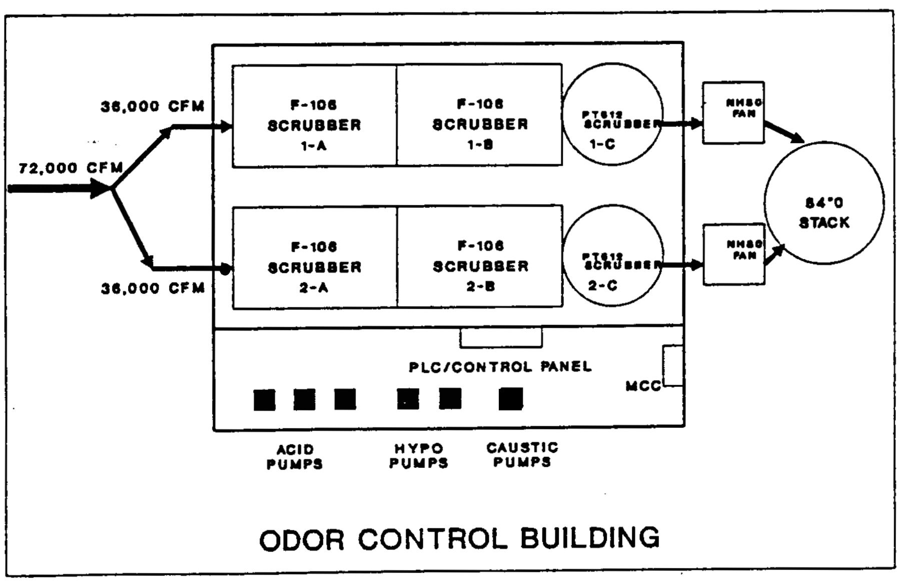

Figure 5

TABLE 3 PACKED-BED SCRUBBER TRAIN DESIGN CRITERIA			
SCRUBBER PARAMETER	STAGE 1	STAGE 2	STAGE 3
Reactor, type	Horizontal	Horizontal	Vertical
Air Flow, direction	Cross-Flow	Cross-Flow	Counter-Current
Packing Media Depth, ft.	6.0	6.0	12.0
Detention Time, sec.	1.0	1.0	3.0
Gas/Liquid Ratio, cfm/gpm	80	80	80
Recirculation Flow, gpm	450	450	450
Chemical Overflow, gpm	3.0	3.0	3.0

The scrubbed air is discharged into a single 50 foot tall exhaust stack. Two induced draft fans pull the air through the exhaust duct system and scrubber trains and push the treated air up the stack for atmospheric discharge. The exhaust stack diameter and height was sized for optimal exit air velocity and upward projection to achieve maximum dispersion. The 50 foot height is also two and half times the roof height of the new Odor Control Building and adjacent Garage Building to prevent downwash conditions of the stack emissions.

Odor Scrubbing System Performance

Table 4 summarizes the projected scrubber inlet concentrations of odorous compounds for the combined Tunnel Reactor process air with Compost Building exhaust air, which were based on actual air flows and in-vessel biosolids composting odor production experience. This information resulted in a six fold concentration dilution (1:6) of the two air streams. The combination of high concentration process odors with low concentration building odors allows for a complete mixture of all compounds to achieve uniform inlet characteristics with fluctuations in loadings minimized. This combined air flow configuration allows for a single treatment mode and operating scheme for the two trains of scrubbers, which maximizes their process control reliability and odor removal efficiency.

Furthermore, the ambient building air temperature cools and preconditions the hot process air to lower the overall combined air flow to an ideal temperature of 80 deg. F for optimal wet chemical scrubbing efficiency. Inlet scrubber gas temperatures above 95 deg. F begin to reduce their treatment performance. Large temperature variances between the recirculating scrubbing solution and the odorous gas stream as a result of high evaporative rates and heat losses will adversely impact the gas to liquid transfer mechanisms and the odor removal rates occurring inside the scrubbers.

TABLE 4 DUCT SYSTEM FOUL AIR CHARACTERISTICS			
FOUL AIR PARAMETER	PROCESS AIR	BUILDING AIR	COMBINED AIR
Exhaust Flow, cfm	12,500	59,500	72,000
Exhaust Velocity, fpm	2,830	2,540	2,590
Temperature, deg. F	145	65	80
Ammonia, ppm	300	50	93
Amines, ppm	60	10	19
Mercaptans, ppm	45	7.5	14
Hydrogen Sulfide, ppm	0	12	10
Organic Sulfides, ppm	15	2	4

The scrubber trains are sized and configured to provide maximum removal of odorous compounds to non-detectable (ND) levels (>99% removal). Enhanced chemical techniques and proven wet scrubbing practices are employed at each stage of the treatment train. Scrubbing mechanisms of odorous gas cooling, condensation, absorption, acidification, and oxidation are efficiently and effectively controlled by continuous monitoring sensors, on-line instrumentation, and automation of chemical feed using a programmable logic controller (PLC). Based upon projected inlet concentration ranges of odorous compounds in the combined airstream, the three-stage scrubbing system is designed to provide a very high level of odor treatment and removal efficiency (Table 5).

TABLE 5 PACKED-BED ODOR SCRUBBING PERFORMANCE DESIGN				
ODOROUS COMPOUND	RANGE (ppm)	INLET (ppm)	OUTLET (ppm)	REMOVAL (%)
Ammonia	0 - 300	93	ND	>99
Amines	0 - 60	19	ND	>99
Mercaptans	0 - 25	14	ND	>99
Hydrogen Sulfide	0 - 20	10	ND	>99
DMS/DMDS	0 - 15	4	ND	>99
Chlorine	NA	0	0.05	>99
Moisture	NA	NA	ND	>99

where ND - non-detectable and NA - non-applicable.

Odor Scrubbing System Flexibility

Perhaps the most unique and innovative aspect of all of the additions and modifications to odor control facilities at the RCF is the high level of flexibility in the operation of the new scrubbing system. As summarized in Table 6, three distinct modes of operation in the treatment schemes of the chemical scrubbers have been designed and configured in the PLC and automated chemical feed system. The ability to automatically adjust the entire scrubbing scheme in response to changing inlet odor conditions, which necessitates an alternate mode of operation is provided. Dynamic and seasonal changes at the RCF may directly impact and alter the projected or actual inlet odor loadings and conditions to the scrubber trains. To ensure that maximum odor removal efficiency is maintained in the most cost effective manner, adjustments in the chemical treatment schemes and operating modes for the scrubbers have been provided.

TABLE 6
CHEMICAL SCRUBBER TREATMENT SCHEMES & OPERATING MODES

TREATMENT MODE OF OPERATION	STAGE 1	STAGE 2	STAGE 3
NORMAL	Cooling	Nitrogen	Sulfur
Scrubbing Chemicals	Water	H_2SO_4	H_2SO_4/NaOCl
Solution pH, s.u.	7.2	3.0	6.7
Solution ORP, mV	N/A	N/A	975
Residual Chlorine, ppm	N/A	N/A	465
CONSERVATIVE	Nitrogen	Sulfur	Sulfur
Scrubbing Chemicals	H_2SO_4	H_2SO_4/NaOCl	NaOH/NaOCl
Solution pH, s.u.	3.0	6.7	10.5
Solution ORP, mV	N/A	975	600
Residual Chlorine, ppm	N/A	435	265
AGGRESSIVE	Nitrogen	Sulfur	Sulfur
Scrubbing Chemicals	H_2SO_4	H_2SO_4/NaOCl	H_2SO_4/NaOCl
Solution pH, s.u.	3.0	6.7	6.7
Solution ORP, mV	N/A	975	975
Residual Chlorine, ppm	N/A	435	435

The odor scrubbing control panel contains switches which changes the treatment mode of operation. These switches allows the chemical feed controllers to be reversed between acidic and alkaline scrubbing solutions and ensures that the PLC continues to receive on-line pH and ORP information from the sensors and then properly automate the chemical feed pump system. A total of fourteen positive displacement chemical-metering pumps are installed to support the three scrubbing schemes, including six sulfuric acid pumps, five hypochlorite pumps, and three caustic pumps.

Normal Operation:

The Normal mode of operation is the standard two-stage chemical treatment scheme used by PSG in the removal of compost odors. The first stage scrubber is used for evaporative cooling of the inlet airstream using water. No chemicals are introduced into this stage, however, due to the high solubility properties of the nitrogen compounds (ammonia and amines), as much as 60% of these odorous compounds will be removed. As the recirculating water passes over the packing media to promote mass and heat transfer, the mechanisms of absorption and condensation will occur and thereby provide a substantial degree of treatment and removal of the nitrogen compounds.

The second stage scrubber completes the nitrogen removal process by the mechanisms of acidification and absorption using a dilute solution of sulfuric acid as the scrubbing liquid. This treatment stage uses an on-line pH sensor to mainain a specific acidic setpoint and automates the acid pumps. The fully wetted and immersed probe inside the scrubber vessel precisely senses an increase in pH, caused by the consumption of sulfuric acid from actual scrubbing demand. The level of sulfuric acid is automatically replentished by the PLC in response to the actual scrubbing demand to maintain the desired setpoint. This ensures that sufficient chemical is available at all times to provide continuous and reliable treatment. The demand based treatment approach with the packed-bed scrubbers prevents the undershoot and overshoot of chemicals.

The acidic setpoint is set at a low enough level to ensure that all nitrogen compounds are completely removed in Stage 2. Any "bleed-through" of ammonia or chemical mist "carry-over" into Stage 3 would create undesirable reaction with chlorine to produce chloramines. The production of chloramines depletes the necessary chlorine levels needed in the third stage and results in erractic oxidation control and excessive chemical consumption. To prevent these undesireable operating conditions, the complete removal of ammonia and moisture must occur in the second stage and is accomplished in the horizontal units using sulfuric acid.

The third stage scrubber provides the absorption and oxidation of the more difficult to treat and very pervasive organic sulfide compounds (DMS/DMDS and Mercaptans) using a chlorine solution. A small amount of sulfuric acid is added to convert the addition of sodium hypochlorite (NaOCl) to hypochlorous acid (HOCl) to maximize the oxidation potential of the scrubbing solution. PSG's operation of this aggressive mode of chemical oxidation in Schenectady has been demonstrated to be very successful in the removal of the organic sulfur compounds. This scrubbing approach using HOCl is considered aggressive, because of its significantly higher oxidation potential and the higher risk of the HOCL converting to chlorine gas at the lower pH operating conditions.

The success of the third stage scrubber in the Normal mode of operation is the interactive control system which stabilizes the complex scrubber chemistry. The PLC is configured to control each chemical feed system with its own on-line sensor and control algorithm. The control of the slightly acidic pH is most critical because of the competing and neutralization effects of the alkaline NaOCl. A small change in solution pH can cause a large change in the chemical balance in the third stage and thus, the pH sensing must be precise with a fine-tuned PLC control algorithm for the sulfuric acid feed. The pH is tightly controlled to prevent the production of chlorine gas. Any liberation of chlorine gas into the airstream from the aggressive mode of oxidation in the third stage scrubbers is removed by the mist eliminaton packing located in the outlet sections of the packed-towers.

The level of HOCl in the scrubbing liquid is independently controlled by the on-line measurement of the oxidation/reduction potential (ORP). Specially designed ORP probes for monitoring high millivolt (mV) values produced by the slightly acidic scrubbing operation were installed. The ORP setpoint is adjusted by the plant operators at the PLC to automatically control the feed rate of the NaOCl pumps and thereby maintain a desired level of total residual chlorine (TRC) in the recirculating scrubbant liquid.

TRC is used as the direct measurement of the remaining level of available chlorine after oxidation of the odorous sulfur compounds. The desired level of TRC in the scrubbing solution is measured off-line by the plant operators using a bench-top colorimetric residual analyzer. The TRC measurement is used as the tuning parameter for adjusting the ORP setpoint, so that this on-line sensor properly controls the level of oxidation. As a result, "bleed-through" of the offensive sulfur compounds from inadequate oxidation or creation of "burnt chemical odors" from excessive oxidation does not occur in the third stage scrubbers.

Conservative Mode:

The Conservative mode of operation of the three-stage scrubbers uses two stages of oxidation to treat and remove the odorous sulfur compounds. In addition to increased oxidation capacity, the third stage is operated in a more conservative mode by using sodium hydroxide (caustic) to prevent any conversion of the NaOCl to HOCl. The caustic creates a very alkaline scrubbing solution, which ensures that hypochlorite ions (OCl^-) predominate and thereby prevents any production and off-gassing of chlorine. The alkaline pH scrubbing solution also improves the absorption of the odorous sulfide compounds by increasing their solubility properties and thereby increases the level of oxidation and mass transfer from the airstream to the scrubbing liquid.

The evaporative cooling of the inlet foul airstream in the first stage is eliminated. The nitrogen removal treatment using acidification and absorption with sulfuric acid is performed in the first stage scrubbers. Complete removal of ammonia and amines is accomplished in the first stage to prevent any adverse impact on the agressive oxidation operation in the second stage scrubbers. The majority of the oxidation of the sulfur compounds is accomplished in the second stage scrubbers using HOCl. The completion of the oxidation process occurs in the third stage scrubbers using NaOH. Any minor chlorine off-gassing in the second stage scrubbers is removed as sodium chloride (NaCl) salts in the third stage scrubbers using the available sodium ions (Na^+) from the caustic solution.

Aggressive Mode:

The Aggressive mode of operation is available if the actual level of inlet odorous sulfur compounds is significantly higher than projected and two stages of high level oxidation is required to fully treat these pervasive odors before discharge. Both the second and third stage scrubbers are operated in the slightly acidic pH range to oxidize the sulfur compounds using the HOCl. This mode of operation is characterized as being aggressive, because of the increased capacity of high level oxidation and the greater risk of off-gassing of chlorine.

Due to the extremely low odor-thresholds of the organic sulfide compounds (DMS and DMDS), the ability to fully oxidize these odors using two stages can be employed. The control of any off-gassing of chlorine relies upon the mist eliminaton packing media installed in the outlet sections of each scrubber unit. This mode of operation also requires that all of the odorous nitrogen compounds be removed in the first stage scrubbers.

CONCLUSION

Additions and Modifications to Odor Control Facilities have been designed and installed at the Regional Compost Facility in Hickory, North Carolina. A comprehensive approach has been taken to identify and correct offensive odor problems, which had required the shutdown of the $7.7 million in-vessel compost facility. Corrective actions were implemented in the areas of compost process control, equipment reliability, operating flexibility, and upgraded odor control system facilities to address fugitive, point-source, and area odor emissions.

The existing two-stage 9,500 cfm packed-tower chemical wet scrubber system was refurbished and relocated from the Dewatering and Compost Building to treat foul air from the Biosolids Receiving Station and Pretreatment Plant. This scrubber system was upgraded with higher treatment efficiency packing media and spray nozzles, addition of mist elimination packing media and improved on-line instrumentation and chemical feed control system. The exhaust stack height was also doubled to improve atmospheric dispersion.

A 72,000 cfm three-stage packed-bed wet chemical scrubbing system was constructed to provide comprehensive fresh air ventilation, foul air capture, and odor exhaust and treatment for the process and building areas. An overall ventilation rate of 12 ac/hr is now achieved, which creates a strong negative pressure inside the Dewatering and Compost Building and results in a work environment during full Tunnel Reactor capacity which meets OSHA standards and NFPA guidelines for in-vessel compost facilities. The high concentration process odors and lower concentration building odors are combined into one large exhaust duct plenum.

The exhausted foul air is split between two parallel trains of three-stage 36,000 cfm packed-bed wet chemical scrubbers and discharged up a common 50 foot tall stack. The inlet odors to the new odor control system are comprised of high intensity nitrogen compounds and very pervasive sulfur compounds. These odorous compounds, as well as others are treated in the scrubbers to non-detectable levels, which requires a concentration removal efficiency of greater than 99%. The scrubber trains can be operated in three different modes of chemistry between the three stages, dependent upon the actual level of inlet odors experienced at the RCF. The scrubbers are monitored continuously by on-line instrumentation and automatically controlled by a PLC with local and remote alarming and annuciation. A substantial portion of the new odor control system is housed in the Odor Control Building for longterm equipment protection and a favorable work environment.

The in-vessel biosolids composting process has also been optimized to reduce and mitigate odors before they are treated in the new odor control system. A new three component amendment recipe is now used to control porosity, oxygen content, moisture, temperature, and odors inside the Tunnel Reactors. Each type of amendment performs a unique and critical function in the composting process to produce a desireable end product with minimal production of odors. A retrofit of the amendment handling equipment was made to ensure the acceptance and suitability of the new amendment recipe. Operating adjustments in the number of Tunnel Reactors placed into service, fresh air supply, level of positive aeration, maximizing rates of active composting and curing in-vessel, and optimization of compost recycle have been implemented to mitigate and reduce the production of process odors and eliminate area emissions of odors from the outside storage of finished compost.

The Team firmly believes that the comprehensive approach taken in the additions and modifications to the odor control facilities at the RCF will result in a successful operation and a longterm beneficial use of the biosolids generated by the Consortium communities. The start-up and full capacity operation of the RCF and the modified and new odor control facilities are planned for January, 1995.

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