Odor-Control System for In-Vessel Composting of Food Processing Waste

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Abstract

"In-vessel" composting allows more rigorous temperature control than conventional open-air or covered-windrow methods, and with the application of specific bacterial cultures it can stabilize many kinds of biodegradable waste in approximately 100 hours. However, in-vessel composting of keratinous wastes releases high levels of ammonia and other odorous compounds.

A two-stage odor-control process using chemical scrubbing and biofiltration was pilot tested and scaled up to a fully integrated system, which now treats the exhaust from a 10,000-ton/year in-vessel composting facility for poultry processing waste (mainly feathers) in the United Kingdom.

Compact scrubbers using high-capacity packing media protect the biofilter by fully humidifying the air and removing dust and ammonia. Odor levels as high as 1,000,000 OU_E/m^3 (including up to 300 ppm_v of ammonia) are reduced to approximately 350 OU_E/m^3.

The compost product complies with the U.K.'s BSI PAS 100 [1] standard, and the ammonium sulfate byproduct from chemical scrubbing is recycled to nearby farms for use as fertilizer.

Introduction

UK and EU regulations [2,3] have been revised so that since mid-2003 it is no longer possible to dispose of waste animal products in landfills. This has promoted interest in the use of compositing to recycle such waste in the UK.

In the vicinity of Hereford, England, numerous chicken producers must dispose of feathers removed during processing. Now that the feathers can no longer be landfilled, the alternatives are rendering (which is expensive) and composting. Aerobic composting of feathers in open conditions emits high levels of odor, especially if the feathers are “turned” to enhance aeration. Without regular turning, composting can take 3 to 4 weeks. In order to capture and treat the odors generated during composting some form of containment is preferable.

Bioganix Ltd., a waste recovery company based in Leominster, England, was approved by the DEFRA State Veterinary Service to operate a composting plant to process all Category 3 wastes as defined by the Animal By Products Regulations (2003), including catering waste.

Bioganix has researched, developed and operated an “in vessel” composting system that complies with EU regulations for animal by-products, former foodstuffs, and catering wastes. Its research led to the construction of a 1,000-ton-per-month in-vessel composting plant using revolving-drum technology. It is currently operating with waste feathers as the main feedstock, but it has also successfully processed source-separated municipal solid waste and green waste. Although the Leominster plant is operated as a pilot to refine and develop the process and technique, it has consistently been processing 50 tons of waste material every day for 3 years.

The in-vessel process must faster than conventional composting, but rapid decomposition of feathers results in rapid odor generation. Feathers are composed of keratin, a polymer of amino acids. Microbial breakdown of keratin produces large amounts of ammonia and also some organic sulfur compounds. So an odor-control system had to be developed along with the composting system.

Composting Process

Waste materials (mostly chicken feathers and green waste) are shredded and blended to form a pre-mix, which is allowed to stand for between 24 and 48 hours before loading into the composting vessels by a wheeled shovel. The composting vessels are large, slowly rotating steel drums that tumble the mixture and aerate it.

Figure 1. Installation of Rotary Composter

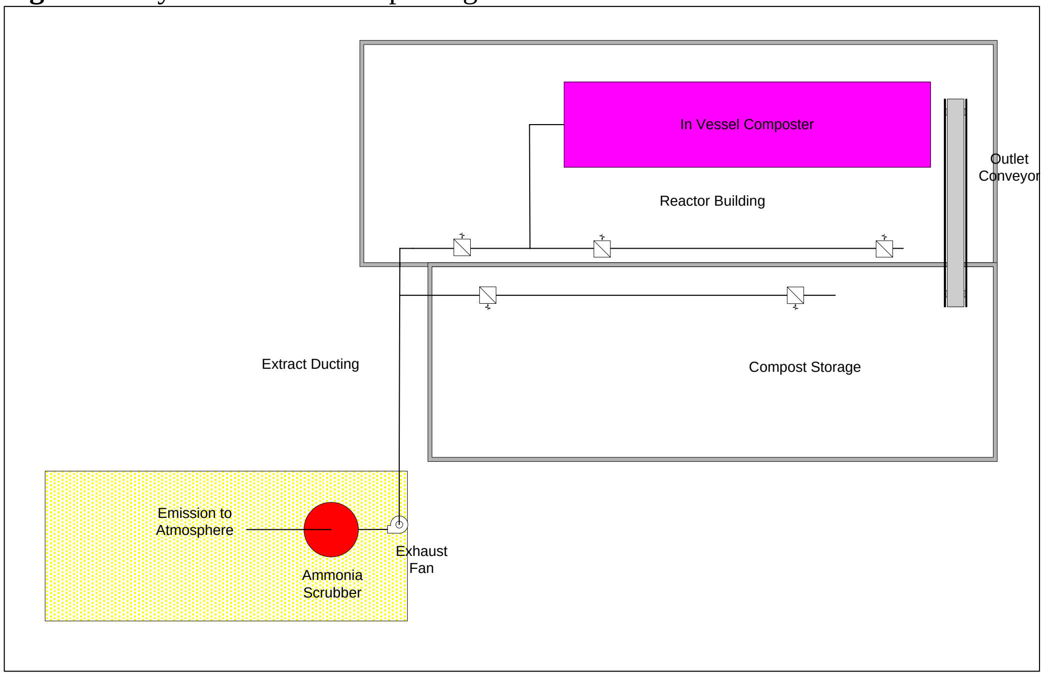
Each day some pre-mix is loaded into each drum, and some compost is drawn off the end of the vessel. Average retention time is 2 to 4 days. The compost is screened to below 12 mm in size, with the oversize fraction being returned for reprocessing. Screened compost is loaded to a batch treatment vessel where the temperature is allowed to rise to over 70°C for at least one hour. The material may then be conveyed to the maturation area where it is stored in bunkers with under-floor air ducts. Air is blown through the compost to continue the composting process, with periodic turning by a wheeled loading shovel, during an average maturation period of 6 weeks. There are markets for partially matured compost, so some of the product is shipped without further maturation. The remainder is matured for 6 to 14 weeks in the space available.

Odor-Control System

The Bioganix compositing facility has grown over the past three years, and the odor-control system has had to adapt and grow with it, from a "laboratory" pilot plant to an industrial-scale pilot system.

At first odors were expected to originate only from the building housing the rotary composters and loading and unloading conveyors. A 17,000-m^3/h (10,000-cfm) ventilation system was installed to provide approximately 6 air changes/hour for the building, and the exhaust air was treated in a single-stage packed-bed scrubber to remove ammonia and other basic gases in an acidic scrubbing liquor. A polypropylene knitted mesh pad was used for mist elimination. Inlet concentrations of ammonia to the scrubber were on the order of 300 ppm, and outlet concentrations were less than 1 ppm.

Figure 2. Layout of Initial Composting Plant and Ammonia Scrubber



However, even though ammonia and amine emissions from the plant were effectively curtailed by the scrubber, the odor level was still a nuisance to neighboring properties.

At the same time the scope of composting operations were growing. A reception building was constructed to handle the incoming feathers and carbonaceous (green) waste, increasing the capacity of the compositing facility to 12,000 ton/year of waste.

Figure 3. Reception Building

The reception building acts as a storage facility and is now houses the area where feathers and green waste are mixed. To prevent fugitive emissions to the environment, air is extracted from the building at a rate of 8 changes per hour. The odors emitted include a wide variety of compounds.

A second packed scrubber using oxidizing chemicals was installed to treat exhaust air from the reception building together with the ammonia-free air leaving the original acid scrubber, which contained residual sulfur compounds and other organic vapors. This scrubber was designed to handle 51,000 m^3/h of air using sodium hypochlorite and sodium hydroxide to keep the scrubbing liquor at pH ~9 with an oxidation-reduction potential (ORP) of +650 mV.

When the reception building was brought into operation, however, it was found that air exiting the reception building was contaminated with 50 to 100 ppm of ammonia, which reacted with hypochlorite in the new scrubber to form chloramines. Subjective olfactory assessment tests of the new scrubber with and without hypochlorite addition indicated that hypochlorite was actually exacerbating the perceived odor.

This problem was solved by installing a scrubber to remove ammonia from the reception building exhaust air. Like the composter building exhaust scrubber, this unit recirculates a scrubbing liquor kept at pH ~2.5 by addition of sulfuric acid.

The older scrubber had experienced maintenance problems due to plugging by dust particles in the rotary composter exhaust air. This especially affected the mesh pad used for mist elimination. In order to avoid similar difficulties, the new scrubber was packed with polypropylene Q-PAC, a high-capacity random packing specially designed for resistance to fouling. For the same reason, the mist eliminator in the new scrubber was not a mesh pad but rather a layer of polypropylene NUPAC. (Both packings were supplied by Lantec Products.[4]) The use of high-capacity packing and mist eliminator resulted in lower gas-side pressure drop across this scrubber than for the original unit. The extra fan power required by the scrubber was thus lower, and indeed the scrubber was installed without having to alter the exhaust fan or motor.

Figure 4. Q-PAC Scrubber Packing

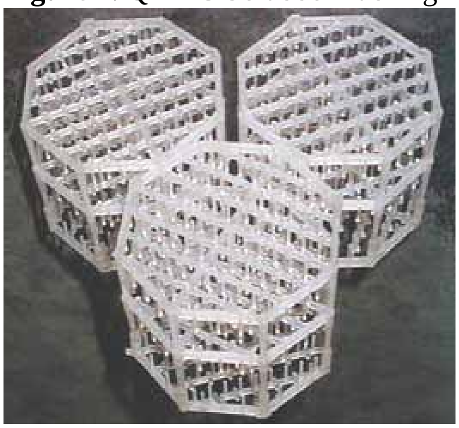


Figure 5. NUPAC for Mist Eliminator

Table 1. Ammonia Scrubber for Reception Building Exhaust Air

Air Flow:	34,000 m³/h (20,000 cfm)
Inlet Ammonia Content:	50 ~ 100 ppm
Scrubbing Liquor:	Water with H_2SO_4 added (pH ~2.5)
Liquid Recirculation Rate:	40 m³/h (176 gpm)
Tower Diameter:	2400 mm (8 ft)
Packing Height:	1500 mm (4.9 ft)
Packing Type:	Q-PAC
Mist Eliminator Height:	450 mm (1.5 ft)
Mist Eliminator Type:	No.2 NUPAC (dry packing)
Removal Efficiency:	99%
Pressure Drop:	3 mbar (0.8 in.WC)

Air pretreated by this scrubber contained less than 1 ppm of ammonia and amines.

Nevertheless, subjective olfactory testing indicated that odors from the plant had been reduced but were still not acceptable to neighboring residents. It was thus thought prudent to install a biofilter after the scrubbers to bring the odor down to an acceptable level. However, it was feared that sodium hypochlorite in the oxidizing scrubber might release chlorine which could reduce microbial action in a biofilter.

A biofilter could be protected from chlorine emissions by a tertiary scrubbing tower using sodium hydroxide, but space and cost considerations made that option unattractive in this case. The oxidizing scrubber was therefore operated using a chlorine dioxide solution in place of sodium hypochlorite. The solution pH was kept at 9.5, and the ORP was controlled by addition of ClO_2 solution. The optimum ORP set point was found to be +150 mV. Olfactory testing indicated that perceived odor levels were reduced using chlorine dioxide, and quantitative measurements showed less than 0.2 ppm of either Cl_2 or ClO_2 in the treated air.

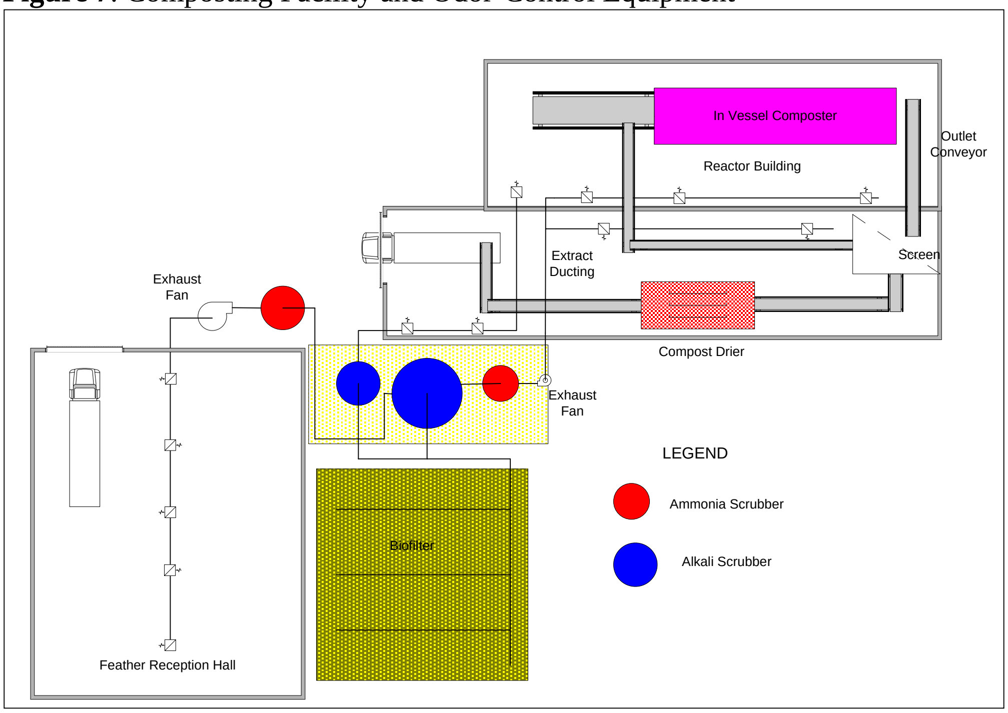
The downstream biofilter was sized for a residence time of approximately 30 sec.

Figure 6. Biofilter and Scrubbers

The biofilter media is a mixture of wood chips and seashells with a bed depth of approximately 2 meters. To prevent short circuiting at the edges, the filter is contained on three sides by earthen dikes. The air distribution plenum was built using railway sleepers as the structural members, overlaid with polypropylene mesh to prevent the filter medium falling through.

A schematic layout of the plant as at present installed is shown in Figure 7.

Figure 7. Composting Facility and Odor-Control Equipment



Olfactory Testing

The odor-control efficiency of the plant has been tested using the protocols described in BS EN13725.2003: “Air quality - determination and odor concentration by dynamic dilution olfactometry”.

Testing was performed by Silsoe Odour Laboratory, which is accredited by ISO 9001 and by UKAS for this procedure.

Figure 8. Location of Air Sampling Points

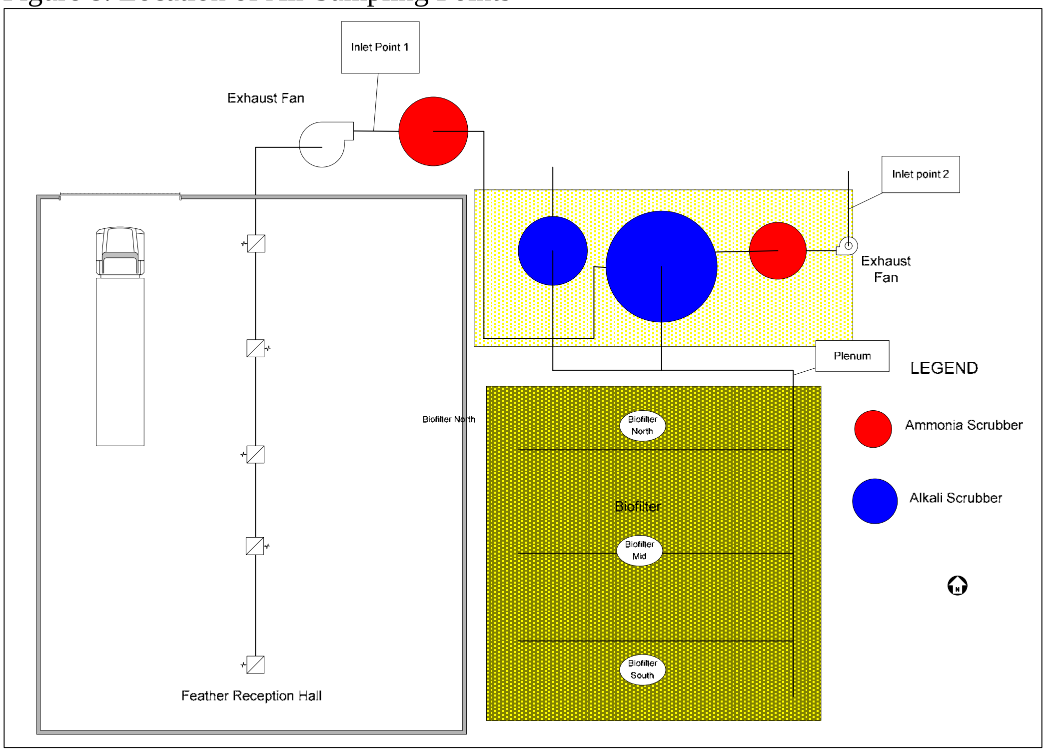


Table 2. Untreated Exhaust Air Quality

	Sample 1 OU_E/m^3	Sample 2 OU_E/m^3	Sample 3 OU_E/m^3	Mean OU_E/m^3
Inlet 1	551,948	379,429	429,425	453,600
Inlet 2	765,005	895,891	1,031,567	897,487

Table 3. Post Scrubber Air Quality

Position	RESULTS OU_E/m^3	Hedonic characterization of the odor by members of the SRI odor panel.
Plenum	41,343	

Table 4. Biofilter Exit Air Quality

Position	RESULTS OU_E/m^3	Hedonic characterization of the odor by members of the SRI odor panel.
Biofilter South	368	
Biofilter Mid	446	
Biofilter North	336	Earthy × 6, Compost × 6
Biofilter South	252	
Biofilter Mid	368	
Biofilter North	229	Earthy × 5, Compost × 5, Sugary × 1
Biofilter Mid	240	
Biofilter Mid	199	Earthy × 5, Compost × 5, Rotten Cabbage × 2, Chicken × 1, Sewage × 1

Table 5. Local Ambient Air Quality

Position	RESULTS OU_E/m^3	Hedonic characterization of the odor by members of the SRI odor panel.
Upwind	566	
Main Yard	229	
Receptor Gate / Landscape	793	

Usage of Compost and Byproduct Ammonium Sulfate

The composting facility produces one main grade of compost, which conforms fully to BSI PAS 100. Special markets exist for less mature composts, such as in agriculture for blending with farmyard manures, or in reclamation for blending with hydrocarbon-contaminated soils as part of a remediation process. Compost for these markets is still produced to BSI PAS 100 standards but is not fully matured.

Compost that fails to meet ABPR standards is normally sent back through the system for re-composting and sterilization. If the compost will not achieve the standard it is rejected as unfit for use and ultimately sent off to a landfill or incinerator.

Compost produced at the Bioganix Herefordshire plant is used by a number of the 450 farmer shareholders. The amount of synthetic nitrogen farmers may use is restricted, and the price of those fertilizers rises each year. The compost is high in nitrogen, so it is an ideal organic equivalent, and local demand is currently exceeding supply. The compost has significant sulfur content, which is also attractive to farmers since restriction on atmospheric SO_2 emissions have resulted in less sulfur deposition to the soil, resulting in deficiencies for some crops. The compost helps farmers restore sulfur in the soil to optimum levels.

Some farmers find it beneficial to take compost before it has matured, as it is more reactive, so its nutrients become available to crops sooner.

PAS 100-compliant compost can also be sold to premium markets such as growing medium and landscaping. These markets are at present relatively small. The agricultural market gives the facility a failsafe option.

The 20% ammonium sulfate solution drained from the ammonia scrubbers has been used as a fertilizer for potatoes at a number of local farms.

Having complied with PAS 100, the Leominster compositing facility has management systems in place to facilitate compliance with other standards, as well. Bioganix is working towards certification under standards including:

- ISO 9001 International standard
- ISO 14001 Environmental Management System
- APEX [5] Standard

Such certification will allow Bioganix compost to be marketed to a wider consumer base, and will enable more compost to be sold to higher-priced market segments.

It is worth noting that of the 1 million tons of compost now produced annually in the UK, 13% is distributed without charge and 39% used on site. This means that 52% of current production generates no revenue, only costs. In contrast, Bioganix has found markets for 100% of the compost it currently produces, and has a waiting list of prospective customers.

Conclusion

It is difficult to overemphasize the importance of odor control at waste recycling sites. Waste management sites of any sort are rarely welcomed by local residents, and composting sites can be particularly contentious. Such sites typically receive whatever mixture of waste has been collected, at all times of the year. The inclusion of food processing waste in a green waste stream dramatically increases odor levels. Systems designed for green waste can quickly be overwhelmed by this type of material.

Main composter vessels are fed with fresh air and the exhaust is extracted via a condenser to an odor-control facilities which must treat 2,000 to 5,000 m^3/h of air per composter, depending on the operating temperature and the moisture content of the waste. Air extracted from in-vessel composters is highly odorous and may contain up to 300 ppm of ammonia when the feedstock is largely animal waste.

The odor control system uses two-stage scrubbing towers, using an acidic solution in the first stage to remove over 99% of the ammonia and amines. The air is then treated in a second tower with an alkaline oxidizing solution to remove sulfides, mercaptans, and fatty acids. The treated air is finally “polished” in a biofilter, filled to a depth of 2 meters with a semi-inert organic medium, kept moist by irrigation and colonized by microbes which destroy any remaining odors as the air passes through.

This odor-control system has managed to reduce very high level odors from the worst forms of waste, with high protein content, to virtually undetectable levels. Testing confirms reductions from over 450,000 OU_E/m^3 to below 300 OU_E/m^3 (where most background readings are over 500 OU_E/m^3). This gives a 98^{th} percentile predicted odor level at the Bioganix Leominster site boundary of below 3 OU_E/m^3, which is well within EA H4[6] guidelines.

References

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6. Integrated Pollution Prevention & Control (IPPC), Technical Guidance Note IPPC H4, Environment Agency, October 2002.

Key Words

Composting
Odor control
Multistage scrubber packing
Biofilter
Rotary composter
Food processing waste
Poultry feather compost
Recycling ammonia nitrogen
Ammonium sulfate
Chlorine dioxide