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# Environmental Impacts & Bio-security of Composting for Emergency Disposal of Livestock Mortalities

Thomas D. Glanville  
*Iowa State University, tglanvil@iastate.edu*

Heekwon Ahn  
*Iowa State University*

Thomas L. Richard  
*Iowa State University*

Jay D. Harmon  
*Iowa State University, jharmon@iastate.edu*

Donald L. Reynolds  
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# Environmental Impacts & Bio-security of Composting for Emergency Disposal of Livestock Mortalities

## **Abstract**

Carcass degradation rate, environmental impacts, and bio-security of windrow-type composting test units were monitored in replicated seasonal trials to assess the feasibility of using composting for emergency disposal of cattle and other large livestock carcasses. Internal temperatures were highest in test units constructed with corn silage. Test units constructed with ground cornstalks or straw and manure were generally 10-20 °C cooler. O<sub>2</sub> concentrations in the core of ground cornstalk test units typically exceeded 15%, while those in corn silage and straw/manure test units were in the 5-10% range during the initial weeks of the trials. Despite differences in core temperature and O<sub>2</sub> concentration, soft tissue degradation rates were the same in all test units, taking 4-6 months in units constructed during warm weather, and 8-10 months during cold-weather. It is believed that the less favorable (lower) temperatures in the cornstalks may have been offset by significantly higher O<sub>2</sub> concentrations which favor rapid aerobic decomposition. Thirty to 45 cm of cover material proved effective in absorbing and retaining odorous gases and leachate. Odors samples collected from the surface of the mortality composting piles typically had low threshold values (< 1500) that differed little from odors emitted by stockpiles of the cover material alone. Leachate volumes were <2% of the precipitation falling on the test units, and preliminary analyses of 1.2 m soil cores show only slight increases in total C and N concentrations in the top 45 cm. Biosecurity tests indicated that pathogens were effectively retained and inactivated: vaccine strains of two avian viruses were inactivated in <21 days; and <2% of sentinel poultry located near the test units exhibited an immune system response to these viruses.

## **Keywords**

animal carcass, mortality, disposal, composting, biosecurity, environment

## **Disciplines**

Bioresource and Agricultural Engineering | Veterinary Medicine

## **Comments**

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## **Authors**

Thomas D. Glanville, Heekwon Ahn, Thomas L. Richard, Jay D. Harmon, Donald L. Reynolds, and Sevinc Akinc



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## **Environmental Impacts & Bio-security of Composting for Emergency Disposal of Livestock Mortalities**

### **T.D. Glanville**

Department of Agricultural & Biosystems Engineering, 201 Davidson Hall, ISU, Ames, Iowa 50011, (tglanvil@iastate.edu)

### **H. K. Ahn**

Dept. of Agricultural & Biosystems Engineering, 100 Davidson Hall, Iowa State University, Ames, Iowa 50011 (hkahn@iastate.edu)

### **T.L. Richard**

Dept. of Ag. & Biological Engineering, Pennsylvania State University, University Park, PA 16802-1909

### **J.D. Harmon**

Dept. of Agricultural & Biosystems Engineering, 202 Davidson Hall, Iowa State University, Ames, Iowa 50011 (jharmon@iastate.edu)

### **D.L. Reynolds**

Dept. of Veterinary Microbiology & Preventive Medicine, 2520 Veterinary Medicine, Iowa State University, Ames, Iowa 50011 (dlr@iastate.edu)

### **S. Akinc**

Dept. of Veterinary Microbiology & Preventive Medicine, 2520 Veterinary Medicine, Iowa State University, Ames, Iowa 50011 (sakinc@iastate.edu)

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## Project Background & Objectives

Poultry and livestock populations in Iowa are among the largest of any state in the U.S. (15,800,000 pigs [#1 in U.S.]; 3,400,000 cattle & calves [# 8]; and 50,000,000 laying hens [#1]). In the event of a disease outbreak or agro-terrorism incident, herd or flock depopulation would pose serious environmental problems. The small number of rendering plants serving the state would be overwhelmed, shallow groundwater and other environmental restrictions make 40% of Iowa poorly suited for mass burial, and incineration is considered unacceptable due to its potential to cause serious air pollution. Anticipating these issues, the Iowa Department of Natural Resources (IDNR) commissioned a three-year study by Iowa State University (ISU) to evaluate the possibility of using composting for emergency disposal of large quantities of livestock or poultry carcasses. Project objectives are to: develop on-farm composting procedures that could be rapidly implemented in an emergency; and evaluate the rate and extent of carcass decomposition, environmental impacts, and bio-security of the proposed procedures.

## Literature Review

Following large scale poultry or livestock losses caused by disease rapid depopulation, immediate containment of carcasses, and application of heat or other disinfecting agents to control pathogen populations, are necessary to minimize undesirable environmental (air and water) impacts and disease transmission (Daggupaty and Sellers, 1990; Kitching, 1998; Sellers and Daggupaty, 1990). During the foot-and-mouth disease outbreak in Great Britain in 2001, incineration and mass burial were the primary disposal options. Subsequent reports commissioned by the British government, however, emphasized the need for improved animal mortality disposal strategies (The Royal Society, 2002; European Commission, 2002).

Research indicates that composting can be effective in inactivating common pathogens associated with poultry and livestock carcasses and manure. In lab scale studies avian influenza, avian adenovirus, Newcastle disease, and infectious bursal disease viruses were inactivated after passing through a two-stage bin composting process (Senne et al., 1994). Composting procedures studied by Murphy (1990) destroyed *Salmonella enteritidis*, *S typhimurium*, *S seftenberg*, *Listeria monocytogenes*, *Pasteurella multocida*, and *Aspergillus fumigatus*. In North Carolina studies, mean total coliform counts of more than 300,000 organisms per gram of dry turkey litter solids were reduced to 22,000 during the 1st stage of a three-stage turkey carcass composting process, and to 4,000 and 300 organisms in the second and third stages respectively (Carter, 1993). Swine carcass composting research in North Carolina produced composting temperatures (60 - 70 °C) of sufficient duration to destroy or greatly reduce *Salmonella*, pseudorabies virus, and *Erysipelas rhusiopathiae* (Morrow et al., 1995). Similar work in Michigan showed that viable *Salmonella cholerasuis* could not be detected in the carcasses of experimentally-infected pigs after 7 days, and *Actinobacillus pleuropneumoniae* were inactivated within 35 days (Rozeboom and Siera, 1996, Siera, 1995). Forshell and Ekesbo (1993) reported that composting of cattle manure inactivated *Salmonella dublin*, *S seftenberg*, and *S typhimurium* in less than 7 days while the same organisms survived 183 to 214 days in uncomposted manure. Similarly, *S seftenberg* and *S typhimurium* survived less than 7 days in composted sow manure, and a heat-resistant strain of *S typhimurium* experimentally added to cage layer manure was rapidly destroyed when compost temperatures exceeded 60 C (deGraft-Hanson et al., 1990).

In addition to the biosecurity studies cited above, widespread use of composting to treat pathogen-containing wastes in industry and agriculture also attests to its effectiveness in

controlling infectious agents. It is a USEPA-approved method for reducing *Salmonella*, enteric viruses, and helminth ova in sewage sludge-based products marketed to the public as soil conditioners (Haug, 1993; Farrell, 1993), and the Natural Resources Conservation Service (NRCS) and many states support the use of composting to degrade and heat-treat poultry and livestock carcasses and manure prior to land application.

Despite its favorable track record, composting has rarely been used for emergency disposal of carcasses known to be infected with a contagious disease. The Canadian Food Inspection Service, however, recently reported successful use of passively aerated windrows for disposal of poultry carcasses during an outbreak of highly pathogenic avian influenza in British Columbia in 2004 (Stepushyn, 2004; Spencer, et. al. 2004).

## **Study Design & Procedures**

### ***Experimental Design***

Field trials were conducted in full-scale (6m X 5.5m X 2.1m) windrow-type test units constructed and instrumented as shown in Figure 1. Each unit contained four 450 kg cattle carcasses placed on a 60-cm thick absorptive base layer of corn silage, ground cornstalks, or ground straw. These materials were selected because they would typically be available in large quantities on most livestock operations. Carcasses were covered with a minimum of 30-45 cm of the same material used in the base layer (Note: to evaluate the feasibility of simultaneous disposal of infected manure, a 15-cm layer of scraped feedlot manure was placed over carcasses composted in test units constructed with straw). To evaluate the impacts of adverse weather conditions, field trials were repeated during hot/dry (summer); cold (winter); and cool/wet (spring) seasons. Seasonal trials using ground cornstalks or corn silage were replicated three times; straw/manure seasonal trials were replicated twice.

### ***Operation***

Since the study was designed to evaluate the performance of composting procedures that could be used with diseased carcasses that might pose a high biosecurity risk, test units were not turned. In some instances, cover material was added to prevent carcass exposure as test units settled.

### ***Monitoring***

Internal temperatures were recorded at two-minute intervals at 20 locations within three conceptual zones in each test unit (core -4 sensors; carcass surface - 12 sensors, and outer envelope - 4 sensors). O<sub>2</sub> concentrations were measured every 10 days at 2 locations within the same conceptual zones. Carcass degradation was visually observed and photographed at irregular intervals by temporarily excavating portions of selected test units.

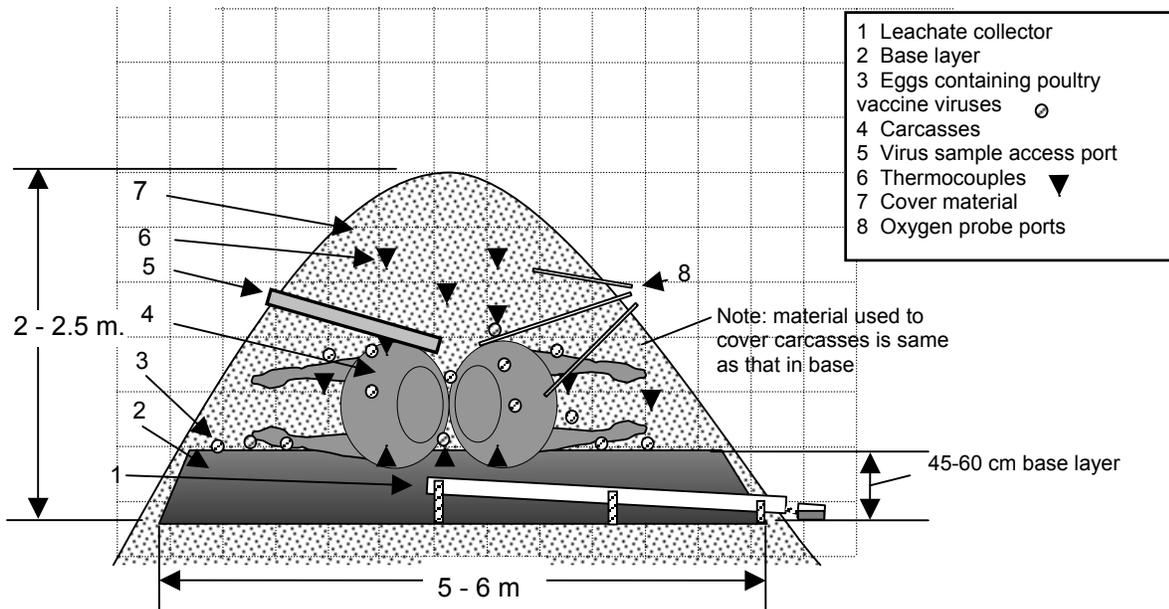


Figure 1. Cross section of field research test units for emergency cattle carcass composting study.

Air quality impacts were assessed by comparing weekly air samples collected from the surface of the mortality composting test units, and from stockpiles of cover material, during the first 4-5 weeks following construction. Sample threshold odor levels were determined in the ISU Ag Engineering Department olfactometry laboratory using experienced odor panelists and following standard dilution procedures.

Soil and water pollution potential was quantified by measuring the volume of leachate collected in PVC sampling tubes installed at the base of the test units, and by testing the leachate for NH<sub>4</sub>-N, total solids, and total organic carbon (TOC). Soil cores (4 cm diameter X 1.2 m long) collected before and after carcass composting also are tested for Total C, Total N, NH<sub>4</sub>-N, NO<sub>3</sub>-N, and Cl.

Biosecurity evaluation procedures were designed to evaluate both virus survival time, and the ability of composting units to retain viruses. Survival was assessed by placing vaccine strains of two poultry viruses (Newcastle Disease Virus, and avian encephalomyelitis) into the composting piles at the time of construction, and by periodically withdrawing samples of the viral material and testing them for viability. Virus retention was assessed by contaminating the carcass exteriors with the same vaccine viruses, and by placing pathogen-free sentinel poultry in cages (warm weather trials only) near the piles. Weekly blood samples drawn from the birds during the first 2-3 months of the trial were tested for antibodies to determine if any birds had been exposed to the viruses.

## **Preliminary Project Results** (project to be completed in September, 2005)

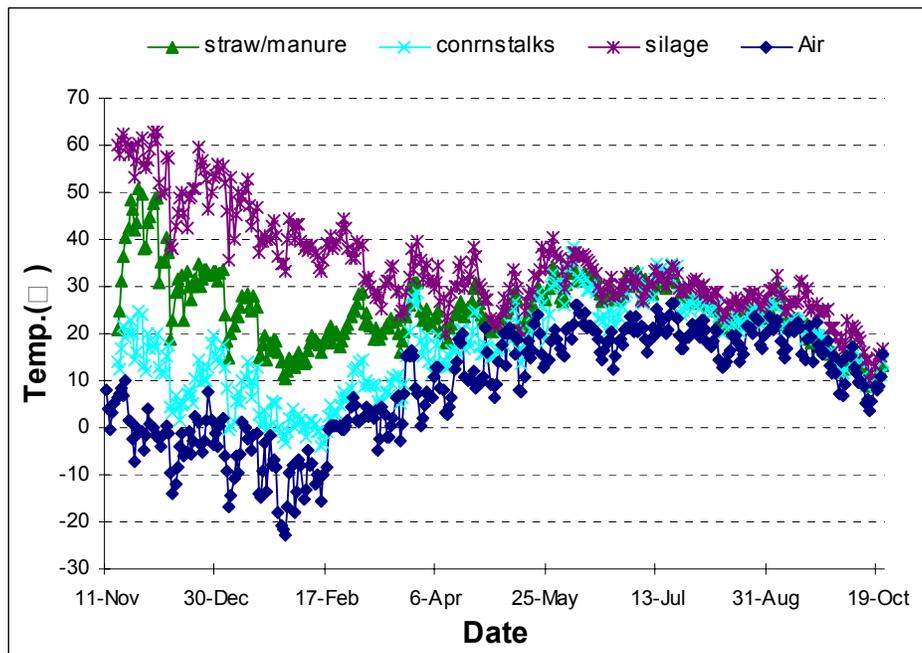
### ***Carcass Decomposition Rate***

A total of 49,000 kg of cattle carcasses have been composted during the project. Temporary excavation of small sections of the test units show that internal organs and soft tissues (but not skeletal remains) are generally fully decayed in 4-6 months during warm weather, and in 8-10 months during cold weather. Periodic turning would generally be expected to reduce these

decay times but, as noted earlier, test units were not turned so as to observe the performance of emergency procedures that were selected to minimize biosecurity risks.

### Temperature

Corn silage consistently produced the highest internal temperatures and sustained them for the longest time (Figure 2). Internal temperatures in test units constructed with ground cornstalks were often 10-30 °C (even more during cold weather) cooler than those in silage test units, particularly during the initial weeks following construction when the cornstalks were very dry. Temperatures in test units constructed with ground straw and manure were normally higher than in cornstalks, but lower than in the corn silage. As carcass decay was completed, temperatures in all three materials approached external air temperatures signaling that readily degradable organics were no longer available to fuel microbial heat production.



**Figure 2. Daily average external (air) and internal temperatures (at carcass surface) for test units constructed in November of 2003.**

From a biosecurity standpoint corn silage appears to offer the best option for pathogen inactivation. Not only are internal temperatures much higher within the silage (particularly during cold weather), but these temperatures also are attained quickly. The rate of temperature rise may be important since some research suggests that, given sufficient time, successive generations of bacteria develop the ability to produce shock proteins which help to protect them from temperature stresses.

Contrary to expectations, higher temperatures within the silage test units did not result in noticeably shorter carcass decay times than those observed in the much cooler cornstalks. The reasons for this are yet to be confirmed, but it is speculated that the less favorable temperatures in the cornstalks may have been offset by significantly higher O<sub>2</sub> concentrations (see following section) which favor rapid aerobic decomposition of organic materials.

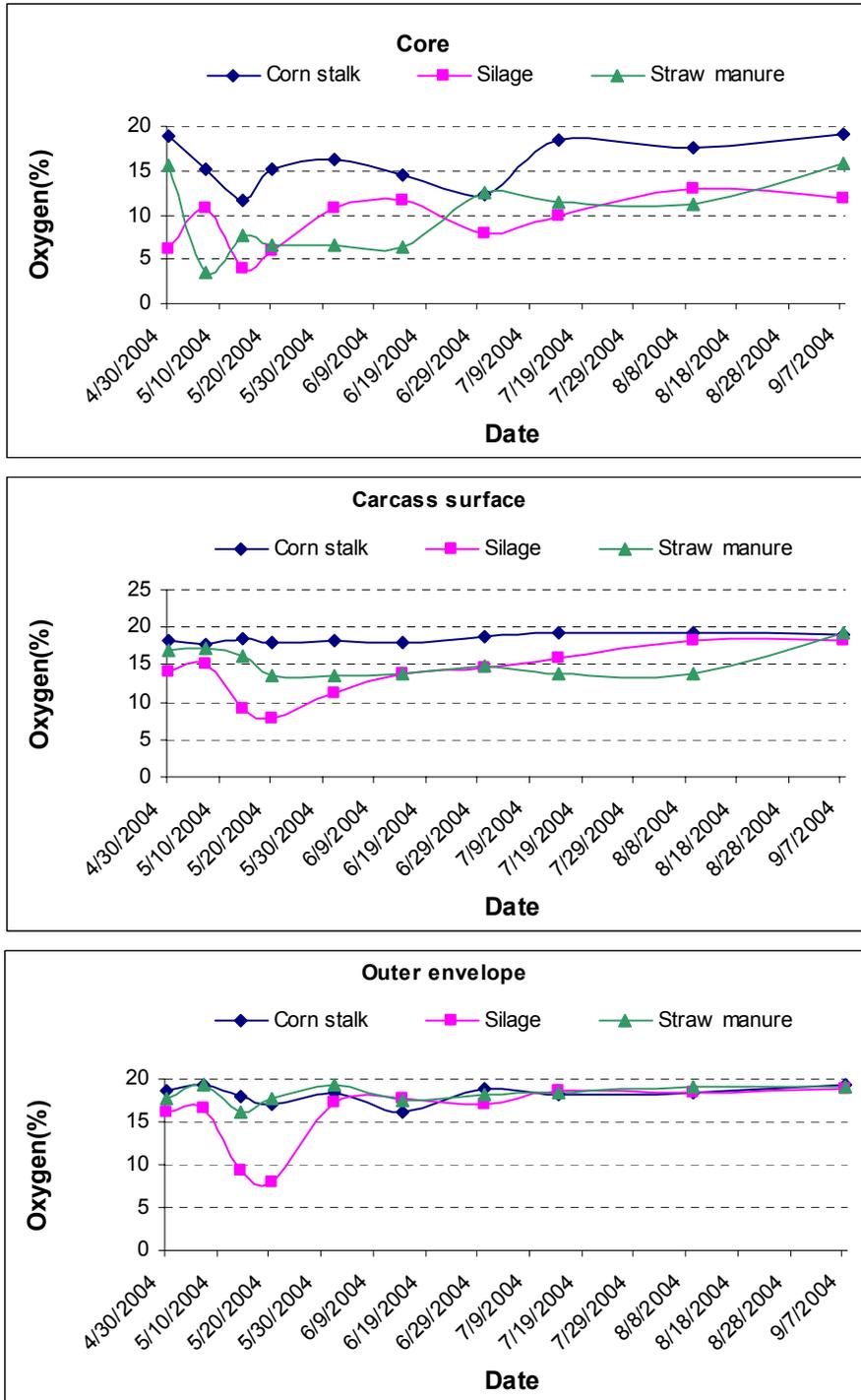


Figure 3. Bi-weekly oxygen concentrations in core, carcass surface, and outer envelope zones of test units constructed in April, 2004.

## Oxygen Concentrations

Composting guidelines typically suggest that internal O<sub>2</sub> concentrations of at least 5% are needed for successful composting. As shown in Figure 3, O<sub>2</sub> levels in the central core (between carcasses) generally met this requirement. At the outer surfaces of the carcasses O<sub>2</sub> concentrations were usually higher than in the core, and in the outer envelope of cover material O<sub>2</sub> approached ambient concentrations (21%). Test units constructed with ground cornstalks consistently had the highest O<sub>2</sub> concentrations, while O<sub>2</sub> was generally lowest in corn silage. Even in the core, mean O<sub>2</sub> concentrations in cornstalk test units generally exceeded 15%, and at the outer carcass surface O<sub>2</sub> was only one or two percentage points below those typical of ambient air. These data clearly demonstrate how use of appropriate cover materials (such as ground cornstalks) having high gas permeability can help to maintain desirable internal oxygen concentrations even when piles are not turned.

## Air Quality

Testing of air samples collected from the surface of carcass composting test units showed that 12-18 inches of cover material was generally very effective at absorbing and retaining odorous gases produced during carcass decay. Many of the threshold odor values were less than 500 which is indicative of very low odor. About 25% of samples fell in the 1,000 - 2,000 range which is a typical for odor emitted from a secondary manure lagoon cell. Only two samples exceeded odor threshold values of 2000 (Figure 4). Threshold odor values for samples collected from the surface of cover material stockpiles (no carcasses) were often very similar to the odor intensities emitted from carcass composting windrows constructed with the same material.

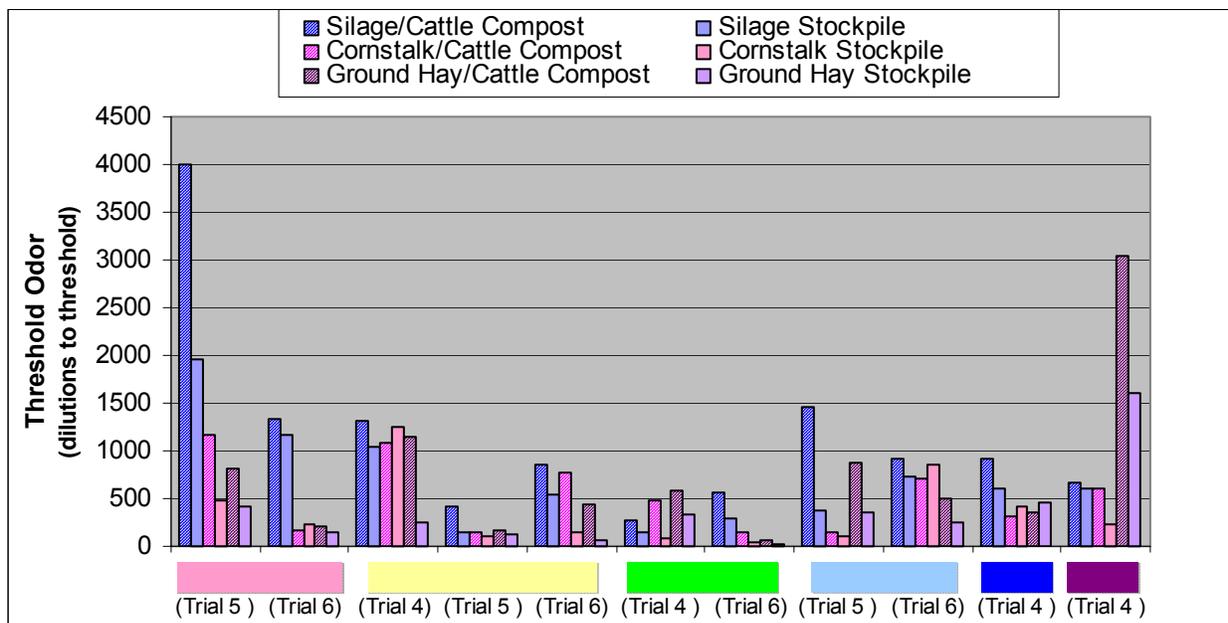


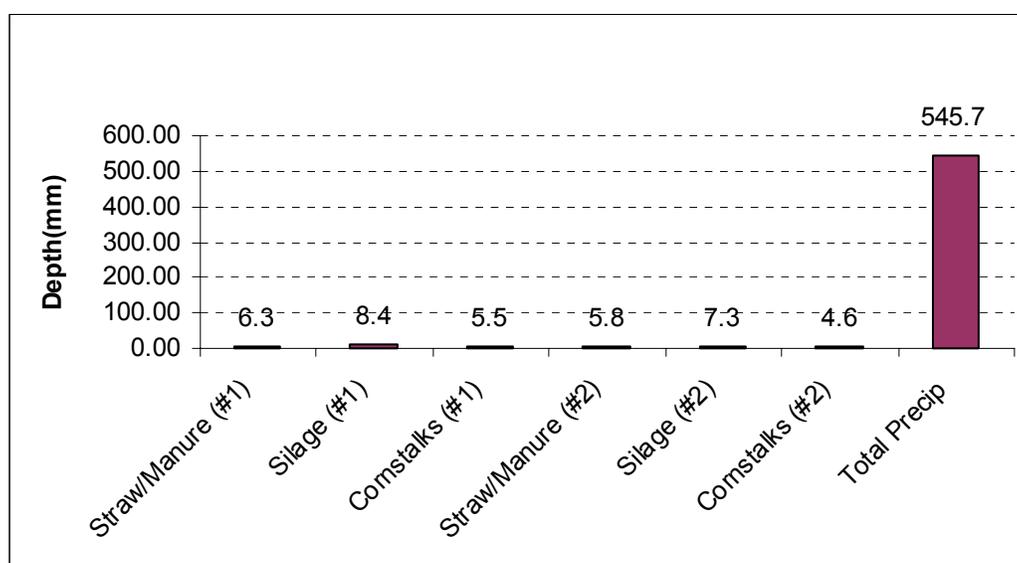
Figure 4. Threshold odor levels for air samples collected from surface of cattle composting test units and comparable cover material stock piles.

## Soil & Water Pollution

Chemical analyses of leachate from carcass composting operations show that this liquid has high pollution potential with mean ammonia concentrations of 2,000 - 4,000 mg/L, total organic carbon (TOC) of 7,000 - 20,000 mg/L, total solids of 12,000 - 50,000 mg/L.

To avoid release of highly contaminated leachate, emergency carcass composting windrows must be constructed with base and cover materials having sufficient water holding capacity to temporarily retain and subsequently evaporate water contributed by seasonal precipitation; water contained within carcasses (about 650 L per 1,000 kg of carcasses), and water released by bio-metabolism of organic matter.

As shown in Figure 5, the cover materials tested were quite successful at retaining and evaporating excess liquid. During a five-month period following their construction in late April of 2004, six test units that received 546 mm of seasonal precipitation released less than 9 mm of leachate.



**Figure 5. Precipitation received during May - September 2004, and total depth of leachate captured at base of cattle composting test units during the same time period.**

Although a substantial fraction of the pre- and post-composting soil cores have yet to be tested, preliminary results from the earliest cornstalk (Figure 6) and silage (Figure 7) trials suggest that, increases in total C and total N are generally not large and, even when statistically significant, are limited to the upper 30-45 cm of soil. As such, these results are in concert with the data showing low leachate volumes being released into the soil, and further suggest that the composting procedures being tested are unlikely to threaten shallow groundwater quality.

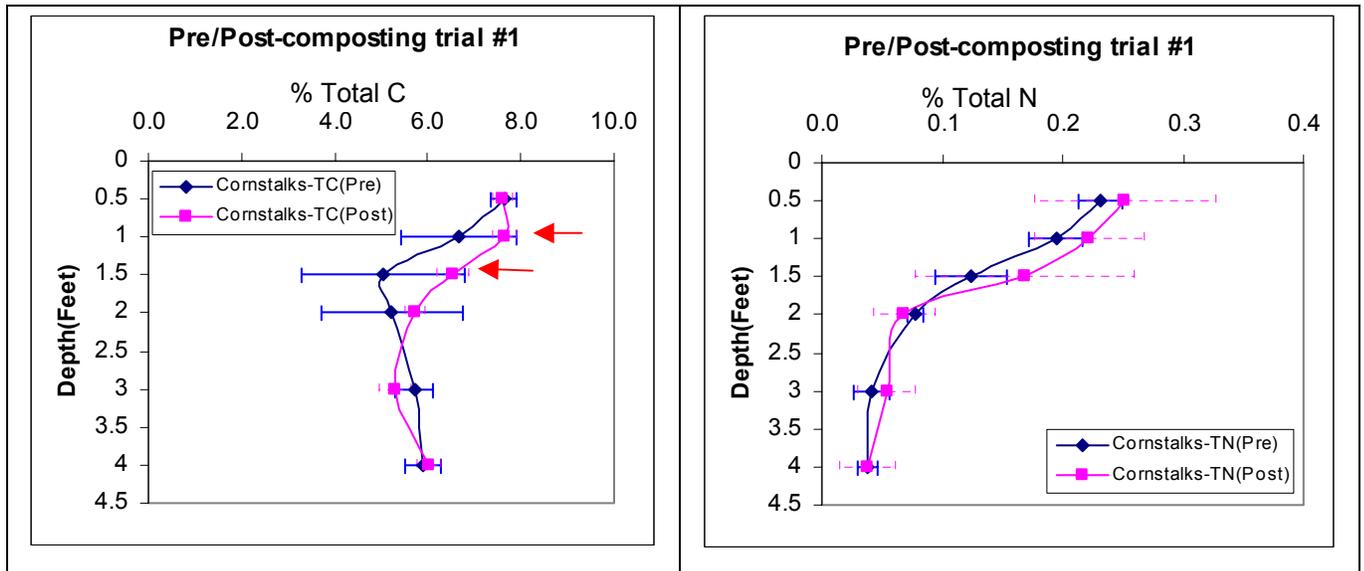


Figure 6. Pre- and post-composting concentrations of total C and N in soils beneath cornstalk test unit in trial #1 (arrows indicate depths at which statistically significant differences were noted).

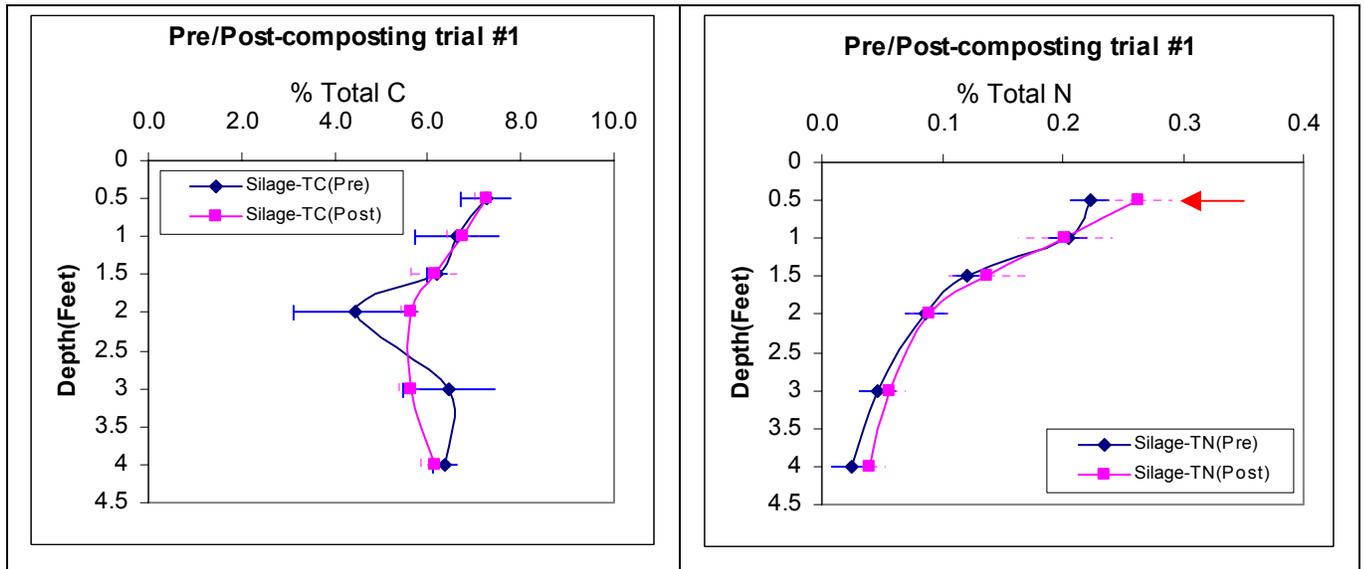


Figure 7. Pre- and post-composting concentrations of total C and N in soils beneath silage test unit in trial #1 (arrows indicate depths at which statistically significant differences were noted).

## Biosecurity

Vaccine strains of Newcastle Disease Virus were inactivated in 7 days or less during warm seasons, and in 21 or fewer days during cold weather (Figure 8). Avian encephalomyelitis was inactivated in 7 days or less (Figure 9). During cold-weather trials, inactivation times in silage test units were often much shorter than in test units constructed with materials like cornstalks and straw which produce and retain less heat. During warm weather, differences in virus inactivation times were less obvious, as were differences in internal temperature.

Composting windrows were effective in retaining viral pathogens. Of 72 specific-pathogen-free sentinel poultry housed near composting test units seeded with vaccine strains of avian viruses, only one bird (1.4%) showed a positive immune system response indicative of a possible release from the carcass composting piles.

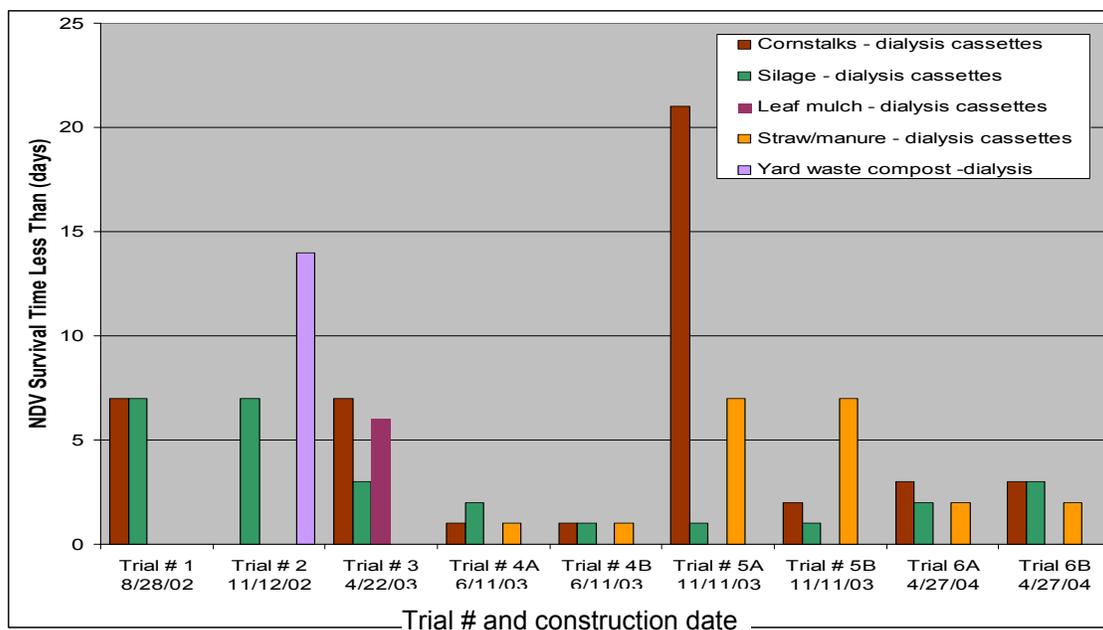


Figure 8. Newcastle disease virus survival in cattle mortality composting test units.

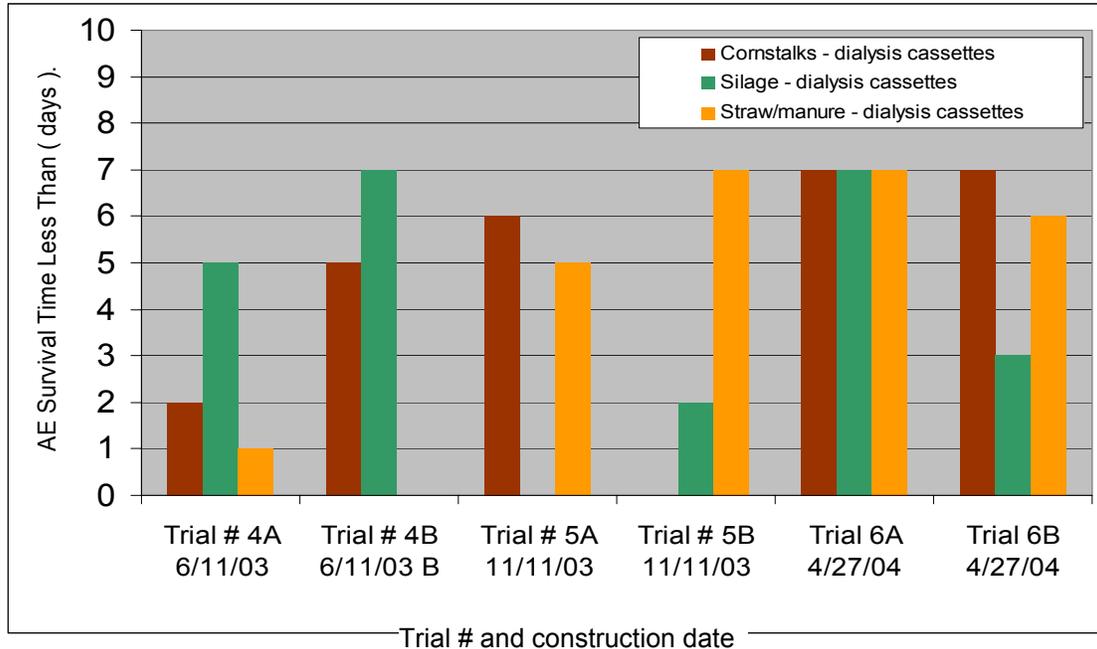


Figure 9. Avian encephalomyelitis survival times in cattle mortality composting test units.

## Conclusions

Monitoring of replicated seasonal windrow-type composting test units has provided significant insights into the feasibility, effectiveness, environmental impacts, and bio-security of emergency mortality composting in open windrows. Corn silage consistently produced the highest internal temperatures and sustained them for the longest time while temperatures in test units constructed with ground cornstalks and straw/manure were often 10-30 °C (even more during cold weather) cooler than those in silage test units. Test units constructed with ground cornstalks exhibited the highest O<sub>2</sub> concentrations, generally exceeding 15% within the core of the pile at all times. Core O<sub>2</sub> concentrations were lower in corn silage and straw/manure test units, dropping into the 5-10% range during the initial weeks of the trials. Despite notable differences in internal temperatures and O<sub>2</sub> concentrations, carcass decomposition rates were essentially the same in all three test materials. Soft tissues (not skeletal remains) associated with 450 kg cattle carcasses were generally fully decayed in 4-6 months during warm weather, and in 8-10 months during cold weather. It is believed that the less favorable (lower) temperatures in the cornstalks may have been offset by significantly higher O<sub>2</sub> concentrations which favor rapid aerobic decomposition of organic materials. Thirty to 45 cm of cover material proved to be effective at absorbing and retaining odorous gases. Air samples collected from the surface of the compost piles typically exhibited threshold odor values of < 1500 and were about the same as threshold values for samples drawn from cover material stockpiles. With less than 2% of the precipitation falling on the test units emerging as leachate at the base, the types and depths of cover materials tested appear capable of temporarily absorbing and subsequently evaporating excess liquid. Low soil pollution potential is further confirmed by relatively small differences in pre- and post-composting concentrations of total C and total N in the soil beneath the test units. Biosecurity data indicate that the compost piles can successfully retain and inactivate viruses. Vaccine strains of Newcastle Disease Virus and avian encephalomyelitis were inactivated in ≤21 days, and < 1.5% of the pathogen-free sentinel poultry stationed at the base of the test units exhibited an immune system response to the test viruses.

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