Waste Management xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Lab-scale evaluation of aerated burial concept for treatment and emergency disposal of infectious animal carcasses

Jacek A. Koziel [a,b,c,*], Heekwon Ahn [d], Thomas D. Glanville [a], Timothy S. Frana [e], J. (Hans) van Leeuwen [b,a,c], Lam T. Nguyen [a]

[a] Department of Agricultural and Biosystems Engineering, Iowa State University, Ames, IA 50011, USA
[b] Department of Civil, Construction and Environmental Engineering, Iowa State University, Ames, IA 50011, USA
[c] Department of Food Science and Human Nutrition, Iowa State University, Iowa State University, Ames, IA 50011, USA
[d] Department of Animal Biosystems Science, Chungnam National University, Daejeon, Republic of Korea
[e] Department of Veterinary Diagnostic and Production Animal Medicine, Iowa State University, Ames, IA, USA

ARTICLE INFO

Article history:
Received 29 December 2017
Revised 1 March 2018
Accepted 5 March 2018
Available online xxxx

Keywords:
Emergency disposal
Infectious animal carcasses
Aerated burial
Salmonella
MRSA
Odor mitigation

ABSTRACT

Nearly 55,000 outbreaks of animal disease were reported to the World Animal Health Information Database between 2005 and 2016. To suppress the spread of disease, large numbers of animal mortalities often must be disposed of quickly and are frequently buried on the farm where they were raised. While this method of emergency disposal is fast and relatively inexpensive, it also can have undesirable and lasting impacts (slow decay, concerns about groundwater contamination, pathogens re-emergence, and odor). Following the 2010 foot-and-mouth disease outbreak, the Republic of Korea's National Institute of Animal Science funded research on selected burial alternatives or modifications believed to have potential to reduce undesirable impacts of burial. One such modification involves the injection of air into the liquid degradation products from the 60–70% water from decomposing carcasses in lined burial trenches. Prior to prototype development in the field, a laboratory-scale study of aerated decomposition (AeD) of poultry carcasses was conducted to quantify improvements in time of carcass decomposition, reduction of potential groundwater pollutants in the liquid products of decomposition (since trench liners may ultimately leak), and reduction of odorous VOCs emitted during decomposition. Headspace gases also were monitored to determine the potential for using gaseous biomarkers in the aerated burial trench exhaust stream to monitor completion of the decomposition. Results of the lab-scale experiments show that the mass of chicken carcasses was reduced by 95.0 ± 0.9% within 3 months at mesophilic temperatures (vs. negligible reduction via mesophilic anaerobic digestion typical of trench burial) with concomitant reduction of biochemical oxygen demand (BOD; 99%), volatile suspended solids (VSS; 99%), total suspended solids (TSS; 99%), and total ammonia nitrogen (TAN; 98%) in the liquid digestate. At week #7 BOD and TSS in digestate met the U.S. EPA standards for treated wastewater discharge to surface water. *Salmonella* and *Staphylococcus* were inactivated by the AeD process after week #1 and #3, respectively. Five gaseous biomarkers: pyrimidine; *p*-cresol; phenol; dimethyl disulfide; and dimethyl trisulfide; were identified and correlated with digestate quality. Phenol was the best predictor of TAN (R = 0.96), BOD (R = 0.92), and dissolved oxygen (DO) (R = −0.91). Phenol was also the best predictor populations of *Salmonella* (R = 0.95) and aerobes (R = 0.88). *P*-cresol was the best predictor for anaerobes (R = 0.88). The off-gas from AeD will require biofiltration or other odor control measures for a much shorter time than anaerobic decomposition. The lab-scale studies indicate that AeD burial has the potential to make burial a faster, safer, and more environmentally friendly method for emergency disposal and treatment of infectious animal carcasses and that this method should be further developed via prototype-scale field studies.

* Corresponding author at: Dept. of Agricultural & Biosystems Engineering, 4350 Elings Hall, Iowa State University, Ames, IA 50011, USA.
E-mail addresses: koziel@iastate.edu (J.A. Koziel), hkahn@cnu.ac.kr (H. Ahn), timfrana@gmail.com (T.S. Frana), leeuwen@iastate.edu (J. (Hans) van Leeuwen).

https://doi.org/10.1016/j.wasman.2018.03.009
0956-053X/

Please cite this article in press as: Koziel, J.A., et al. Lab-scale evaluation of aerated burial concept for treatment and emergency disposal of infectious animal carcasses. Waste Management (2018), https://doi.org/10.1016/j.wasman.2018.03.009

1. Introduction

1.1. Outbreaks of diseases and emergency animal mortality management – A global concern

Animal disease outbreaks and associated emergency mortality management issues are a global concern. The World Organization for Animal Health (OIE) Database (WAHIS Interface, 2017) shows that nearly 55,000 cases involving 116 diseases were reported during the period 2007–2016. Epidemiologically significant events between 2005 and 2016 are summarized in Fig. S1, Supplementary Material. The disease type, timing, location, and the number of cases were highly variable from year to year, but the overall trend of total cases is slowly rising, emphasizing the need for preparedness and effective emergency disposal methods. Nearly 70% of these cases were reported in Europe, followed by 15% in Asia, 11% in Africa, 5% in Americas, and 1% in Oceania. The Republic of Korea alone, reported as many as 941 cases constituting ~2% of world's total. In 2010 approximately 3.5 million animals were culled and buried at ~4580 burial sites during a Foot-and-Mouth (FMD) outbreak in the Republic of Korea (Park et al., 2013). Managing emergency carcass disposal requires special care and urgency compared with routine daily non-disease-related disposal of relatively small numbers of carcasses via burial, incineration, composting, rendering, lactic acid fermentation, alkaline hydrolysis, or anaerobic digestion (AnD) (NABC, 2004).

1.2. Pros and cons of burial for animal mortalities disposal

Burial is the most common disposal method worldwide and is likely to remain that way (NABC, 2004). Regulatory & governmental agencies and the general public understand it and generally approve (NABC, 2004). Burial requires no specialized equipment. High-capacity excavators are available nearly everywhere. The risk of spreading disease via air is reduced because carcasses are not transported (assuming burial on the farm), and pathogens are quickly sequestered beneath a soil filter. However, because burials are often completed in haste, they can cause: chemical and microbial contamination in the groundwater around burial pits due to the poor site selection and improper construction (Kim and Kim, 2012); odor complaints (Kasper et al., 2012); declining property values; and disruption of long-term land use plans (Brglez and Hahn, 2008).

Burial is not simple even if the necessary steps are taken to avoid the problems above. These steps are time-consuming (evaluating local geologic/hydrologic hazards, and/or trucking contaminated carcasses long distances to specially constructed landfills) yet they must be accomplished quickly when thousands of carcasses need to be managed. When done in haste, offensive odor release, slow carcass decomposition (angering farmers because land used for burial remains out of production much longer than anticipated), and widespread public concern over possible leakage of the burial sites and contamination of groundwater, can occur.

1.3. Need for improved in-trench burial approaches

While emergency disposal by burial is fast and relatively inexpensive, it also can have undesirable and lasting impacts. An example is the 2010 outbreak of FMD in the Republic of Korea in which nearly 3.5 million cattle and swine were buried on 4580 farms. While this solved the immediate bio-security concerns, it spawned a variety of unanticipated problems. Carcass decay within anoxic burial trenches was slower than anticipated, angering farmers who were barred by the government from reusing valuable burial sites until carcasses were fully decomposed. In some instances buried carcasses were subsequently exhumed and disposed of via more rapid on-site composting. Surrounding communities also were impacted. Foul odors were emitted from some burial sites, and hasty burial, without regard for local geology, raised public fear of groundwater contamination.

Following the 2010 FMD outbreak, the National Institute of Animal Science (NIAS) of the Korean Rural Development Administration embarked on a comprehensive scientific evaluation of improved methods for emergency management of diseased carcasses. One method of interest was to use aeration in conjunction with in-trench burial. In this proposed method, carcasses would be buried in trenches lined with plastic or other impermeable sheeting and equipped with aeration tubing (perforated PVC or similar small diameter pipe, embedded in gravel to reduce impact during trench loading and to prevent plugging of perforations), creating a temporary underground aerated treatment vessel. This could possibly (i) speed carcass decay (thus, reducing the time land is taken out of production), (ii) reduce odor emissions (by oxidizing odorous volatile organic compounds (VOCs) into less offensive compounds), (iii) inactivate pathogens, and (iv) produce a treated liquid digestate that is less likely to pollute groundwater, in the event that the plastic trench liner fails over time. This method is analogous to the plastic-wrapped swine mortality composting procedure tested by Glanville et al. (2016) that was designed to reduce emissions of odor, leachate, and pathogens while creating a gas flow regime that could be monitored (for biomarker VOCs) to track process progress. Because on-farm burial is one of most commonly-used disposal methods used worldwide, the proposed aerated burial-AeD hybrid concept could become a useful animal disposal alternative for adoption by animal health professionals, emergency responders, and policymakers.

1.4. Aerobic digestion as a part of 'aerated burial hybrid' emergency disposal technology

Aerobic carcass degradation carried out in small underground vessels was reported as a novel technology that provides an effective option for storing and pretreating of animal (sheep) carcasses prior to final disposal in the UK (Williams et al., 2009). It was shown that high numbers of bacteria *Salmonella enterica* (serotypes Senftenberg and Poona), *Enterococcus faecalis*, *Campylobacter jejuni* and *coli*, and *Escherichia coli* O157) in sheep carcasses were inactivated in the digestate within 3 months of AeD (Gwyther et al., 2012). Combining aeration with burial raises questions that have not been researched. These include: (i) acceleration of whole carcass decomposition during treatment; (ii) adherence of the treated digestate to U.S. EPA effluent guidelines (in case in-trench liner ruptures, the digestate needs to be pumped out, or the site needs to be decommissioned); (iii) minimally-invasive and biosecure means for process monitoring; and (iv) ability to inactivate pathogens.

1.5. Gaseous biomarkers of process completion

VOCs can be used as biomarkers of process completion in potentially infectious environments. Previous research has shown that selected VOCs such as pyrimidine, dimethyl disulfide (DMDS), and dimethyl trisulfide (DMTS) can be detected and quantified in a complex matrix of gases produced by decaying swine mortalities in a biosecure composting process (Akdeniz et al., 2009, 2010a, 2010b). The presence of these gasses was successfully used to biosecurely monitor process completion without the need to dig into the compost pile. It is hypothesized that the same VOCs could be used to monitor degradation of poultry carcasses, but this has yet to be verified.

Please cite this article in press as: Koziel, J.A., et al. Lab-scale evaluation of aerated burial concept for treatment and emergency disposal of infectious animal carcasses. Waste Management (2018), https://doi.org/10.1016/j.wasman.2018.03.009