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Potential water quality impacts originating from land burial of cattle carcasses

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HIGHLIGHTS

- We investigated water quality impacts of buried cattle carcass leachate.
- Cattle carcass burial produced leachate containing a variety of organic and inorganic contaminants, including nutrients.
- Steroids and pharmaceuticals were also detected in the leachate at high concentrations relative to other wastewaters.

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ABSTRACT

Among the conventional disposal methods for livestock mortalities, on-farm burial is a preferred method, but the potential water quality impacts of animal carcass burial are not well understood. Typically, on-farm burial pits are constructed without liners and any leachate produced may infiltrate into soil and groundwater. To date, no information is available on temporal trends for contaminants in leachate produced from livestock mortality pits. In our study, we examined the concentrations of conventional contaminants including electrical conductivity, COD, TOC, TKN, TP, and solids, as well as veterinary antimicrobials and steroid hormones in leachate over a period of 20 months. Most of the contaminants were detected in leachate after 50 days of decomposition, reaching a peak concentration at approximately 200 days and declined to baseline levels by 400 days. The estrogen 17β-estradiol and a veterinary antimicrobial, monensin, were observed at maximum concentrations of 20,069 ng/L and 11,980 ng/L, respectively. Estimated mass loading of total steroid hormone and veterinary pharmaceuticals were determined to be 1.84 and 1.01 μg/kg of buried cattle carcass materials, respectively. These data indicate that leachate from carcass burial sites represents a potential source of nutrients, organics, and residues of biologically active micro-contaminants to soil and groundwater.

1. Introduction

1.1. Cattle and calf production

Production of cattle and calves in the United States is approximately 100 million head per year over the past 60 years (USDA/NASS Homepage, 2012) with a reported retail equivalent value of 79 billion dollars in 2011 (USDA/NASS, 2011; USDA/ERS Homepage, 2012). The United States Department of Agriculture reports that since the late 1980s, over 2.2 million mortalities occur in cattle and calf production facilities each year on average (USDA/NASS Homepage, 2012). A 5-year retrospective cohort study (Loneragan et al., 2001) investigated 121 cattle feedlots in the United States and found an approximate annual routine mortality rate of 1.3%, suggesting that over 1 million cattle routine mortalities require disposal each year.

1.2. Animal carcass disposal methods

Conventional disposal for deceased livestock includes burial, composting, rendering, and incineration. Burial and composting are attractive disposal options for cattle mortalities due to the costs and regulatory restrictions on rendering and incineration of cattle carcasses (Code of federal regulations, 2010). On-farm burial is a method preferred by animal producers due to the limited infrastructure requirements and minimal disposal costs (Gwyther et al., 2011).

1.3. Impacts of carcass burial on groundwater

Few studies have documented the impacts of carcass burial on groundwater quality. To date, investigations of groundwater quality impacts due to animal carcass disposal have focused largely on poultry carcass disposal and have investigated only a limited number of routinely-measured contaminants, including nutrients, chloride and fecal pathogens. Increased concentrations of ammonia, nitrate, chloride, and fecal pathogens in groundwater have been observed on farms with poultry carcass disposal pits (Hatzell, 1995; Ritter and

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Chirnside, 1995; Myers et al., 1999). Ritter and Chirnside (1995) found the highest concentrations of ammonia and nitrate adjacent to poultry disposal pits in Delmarva Peninsula. Maximum concentrations of ammonia and nitrate detected at this location were 366 mg N/L and 77.6 mg N/L, respectively and the maximum concentration of chloride was reported to be 209 mg/L. In contrast, Myers et al. (1999) reported 39.7 mg N/L as the highest level of nitrate detected in the monitoring wells while almost all water samples contained ammonia-N less than 0.2 mg N/L. Moreover, only slightly increased nitrate concentrations (i.e. increases of 2 mg N/L from the median nitrate concentration) were found by Hatzell (1995) in west-central Suwannee County in Florida at a location with a chicken carcass disposal pit. No obvious effects of the disposal pit leachate on other water quality characteristics were determined. Variability in the results of nutrients observed from these studies is partially due to variation in local soil texture, background water quality, groundwater flow direction, and water table depth. However, the elevated nitrate levels were all above the drinking water standard of 10 mg N/L. Both Ritter and Chirnside (1995) and Myers et al. (1999) detected fecal pathogens, though at low concentrations (generally <20/100 mL for most samples), in groundwater samples obtained near poultry disposal pits. However, other on site waste disposal practices, such as uncovered litter stockpiles, were thought to have a higher impact on groundwater quality than the pit itself (Hatzell, 1995; Myers et al., 1999). In a related study (Glanville, 2000), groundwater samples were collected and analyzed for routinely-measured contaminants near disposal pits containing 28,400 kg turkey mortalities and 6 swine carcasses. Elevated levels of BOD (230 mg/L), ammonia-N (403 mg/L), TDS (1527 mg/L) and chloride (109 mg/L) were detected in the monitoring wells installed within 1 m of one of the study sites. These values were all significantly greater ($p < 0.05$) than mean background concentrations detected in the control monitoring well measured as 6 mg/L, 0.2 mg/L, 658 mg/L, and 8.6 mg/L, respectively. It also suggested that complete decay in lightly loaded burial trenches with well-drained soils may take two years or more.

1.4. Leachate quality from carcass burial pits

Even more limited is information on leachate water quality from animal burial sites. To our knowledge, only two studies have reported data describing the quality of leachate produced from animal burial. MacArthur et al. (2002) reported average leachate concentrations of ammonia-N (3294 mg/L), alkalinity (9400 mg/L), BOD (12,700 mg/L), and COD (20,414 mg/L) on a burial site with food-and-mouth disease mortalities of mixed species. In addition, a total of 4000 m^3 of leachate was generated. A field study investigating leachate quality was conducted with poultry, bovine, and swine carcasses buried in separate pits and isolated from the surroundings with a sealed 40 mil polyethylene liner (Pratt and Fonstad, 2009). Elevated levels of ammonium-N (12,600 mg/L), alkalinity (46,000 mg/L as bicarbonate), chloride (2600 mg/L), sulfate (3600 mg/L), potassium (2300 mg/L), sodium (1800 mg/L), and phosphorus (1500 mg/L), and relatively lesser amount of iron, calcium, and magnesium were present in leachate samples. These data provide important information on the potential for groundwater contamination from animal disposal pit leachate since most of the on-farm mortality pits in the U.S. are unlined. No previous studies have examined the characteristics of naturally produced leachate from animal burial pits.

1.5. Presence of steroid hormones and veterinary pharmaceuticals in wastes from animal production environments

Animals in the United States routinely receive steroid hormone and antibiotic supplements as growth promotants and to prevent disease. Currently, no information is available on the potential for release of these compounds in leachate from animal carcass burial sites. However, these compounds have been detected in wastes from animal production facilities. In a concentrated animal feeding operation (CAFO) with animal manure application located near Lansing, MI, monensin and amprolium were detected frequently ranging from 1 to 189 ng/L and 6 to 288 ng/L in surface water, and 0.004 to 0.5 μg/kg and 0.03 to 0.26 μg/kg in top soils (Song et al., 2010). 13 pharmaceutical compounds and 4 steroid hormones were also detected in lagoon wastewater and adjacent groundwater underlying selected beef cattle and swine CAFOs in Nebraska (Bartelt-Hunt et al., 2011). Among the targeted pharmaceuticals, monensin was detected most frequently and the maximum level was measured as 13,000 ng/L in lagoon wastewater. Detected steroid hormones including estrone, testosterone, 4-androstenedione, and androsterone ranged from 30 to 3600 ng/L in lagoon wastewater and 30 to 390 ng/L in groundwater. These data indicated that steroids and veterinary pharmaceuticals originating from animal production wastewater can infiltrate to shallow groundwater.

1.6. Objective

To better understand the chemical composition of rainfall-produced leachate after burial of cattle carcasses, a two-year field study was performed by burying cattle mortalities in lined pits with a leachate collection system. The objectives of this study were to determine temporal trends in leachate generation and contaminant concentrations in the leachate, including both routinely-measured parameters as well as veterinary pharmaceuticals and steroid hormones.

2. Materials and methods

2.1. Carcass burial pit description

Carcass burial pits were constructed at the University of Nebraska-Lincoln Agricultural Research and Development Center near Mead, Nebraska. The surface area of each disposal pit was approximately 120 m^2 (12 m by 10 m) and depth of the pit was approximately 5 m. Pits were constructed with 1:1 side slope. Details of the pit dimensions are provided in Fig. S1. The pit was lined with a 40-mil PVC liner. A 445 L PVC reservoir was placed beneath the liner and was connected to a perforated HDPE pipe for leachate collection. The leachate collection system and bottom liner were covered by 10 cm gravel and 15 cm structural sand (Fig. S1). Approximately 1400 kg (5 to 7 head) of beef cattle carcasses was placed in each of 3 replicate pits and the pits were backfilled with native soil and compacted with a tapping machine right after the carcasses were placed. Soil compaction was evaluated by soil density test. For each pit, 5 to 6 soil sampling sites were selected and soils were sampled during backfilling at one-inch increments from a depth of 4 inches to 10 inches below the ground surface. Compaction testing was conducted with a nuclear gauge and a confirmation test for density was performed using a sand cone apparatus. The top of each pit was graded at a 20:1 slope to minimize ponding on the pit surface.

2.2. Source of materials

All carcasses were obtained from an operating commercial beef cattle feedlot. Animals at the feedlot received growth promotants as feed additives containing monensin, trenbolone acetate, and estradiol. Additionally, florfenicol, cetiofur, and enrofloxacin were used in the feedlot hospital. Carcasses used in this project were routine mortalities from the hospital and were younger than 30 months of age. Carcasses were placed in the pits one or two days after death.

2.3. Site monitoring and sampling

Local temperature and precipitation data were obtained from a weather station operated by the High Plains Regional Climate Center