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Poultry litter and the environment: Physiochemical properties of litter and soil during successive flock rotations and after remote site deposition☆

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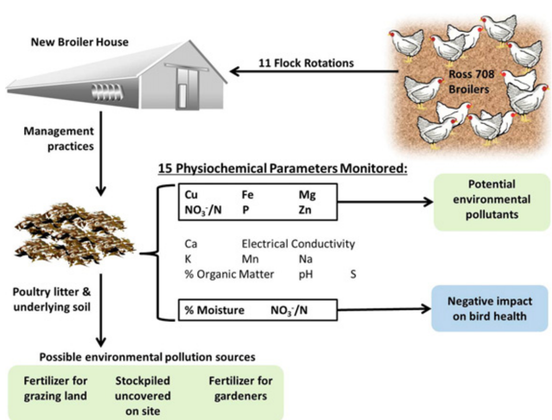
HIGHLIGHTS

- Investigated 15 physiological parameters for first 2.5 y of broiler production.
- Assessed litter and soil before and after 11 flock rotations and stockpiling.
- Evaluated time and management practices on in-house physiochemical parameters.
- Litter clean-out reduces in-house build-up of minerals and heavy metals for birds.
- Proper management may prevent litter leaching of contaminants into the environment.

GRAPHICAL ABSTRACT



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ABSTRACT[1]

The U.S. broiler meat market has grown over the past 16 years and destinations for U.S. broiler meat exports expanded to over 150 countries. This market opportunity has spurred a corresponding increase in industrialized poultry production, which due to the confined space in which high numbers of animals are housed, risks accumulating nutrients and pollutants. The purpose of this research was to determine the level of pollutants within poultry litter and the underlying soil within a production facility; and to explore the impact of spent litter deposition into the environment. The study follows a production facility for the first 2.5 years of production. It monitors the effects of successive flocks and management practices on 15 physiochemical parameters: Ca, Cu, electrical conductivity, Fe, K, Mg, Mn, moisture, Na, NO_3^-/N, organic matter, P, pH, S, and Zn. Litter samples were collected in-house, after clean-outs and during stockpiling. The soil before house placement, after the clean-outs and following litter stockpiling was monitored. Management practices markedly altered the physiochemical profiles of the litter in-house. A canonical discriminant analysis was used to describe the relationship between the parameters and sampling times. The litter profiles grouped into five clusters corresponding to time and management practices. The soil in-house exhibited mean increases in all physiochemical parameters (2–297 fold) except Fe, Mg, %M, and pH. The spent litter was followed after deposition onto a field for use as fertilizer. After 20 weeks,

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[1] COS-# = Clean-out soil sample at # time point; EC = electrical conductivity; M = moisture; OM = organic matter; PCB = Pine chip bedding; PCO = Partial clean-out; TCO = Total Clean-out; S-# = Soil sample at # time point.

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the soil beneath the litter exhibited increases in EC, Cu, K, Na, NO_3^-/N, %OM, P, S and Zn; while %M decreased. Understanding the impacts of industrialized poultry farms on the environment is vital as the cumulative ecological impact of this land usage could be substantial if not properly managed to reduce the risk of potential pollutant infiltration into the environment.

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1. Introduction

A 36% growth in the U.S. broiler production occurred between 1997 and 2012 due to demand in both the domestic and international markets (Davis et al., 2013). In 2014, the U.S. was the world's second-largest broiler meat exporter behind Brazil, accounting for 35% of global poultry meat export market (Davis et al., 2013). The increasing demand for animal products worldwide has resulted in the expansion of concentrated animal feeding operations (CAFO) (Godfray et al., 2010; Güngör, 2013a). Broiler production has increased in an almost linear fashion in developed countries and global poultry meat exports are projected to exceed 10 million MT by 2020 (Mathews and Haley, 2014). The last several decades have seen remarkable increases in the capacity and productivity of poultry feeding operations (Maheshwari, 2013; USDA, 2015a). In the United States, eight states deliver 70% of broiler production (USDA, 2015b). The animal waste management from these CAFO is a major concern in both the developed and developing countries (Sims et al., 2005; Potter et al. 2010). Today's consumers tend to purchase sustainable products, but also want low prices. The problem with sustainability in many situations, such as commercial broiler production, is that it rarely has a finite solution, but often only a "better or worse" outcome. Additionally, producers and the public have radically different frames of reference. The underlying cause and effect relationships related to these problems are complex and highly variable, but the development of practical management practices within the industry that also protect the environment are necessary (Peterson, 2013).

Intensive livestock farming is one of the fasting growing agricultural sub-sectors, paralleled by an increase in manure production (Yang et al., 2016). The increased nutrient concentration as a result of the manure can be a contributor to environmental issues (Ilea, 2009). In particular, water quality in the USA and around the world is endangered by contamination with excess nutrients, such as NO_3^-/N and P from agricultural runoff (Burow et al., 2010; Feyereisen et al., 2010; He et al., 2012; Güngör, 2013b). Potter et al. (2010) reported that the highest rates of N and P in animal wastes were found in the USA, parts of South America, Western Europe, East Africa, Northern India, Eastern China, and New Zealand. The U.S. Environmental Protection Agency currently views agricultural non-point source contamination of surface waters in the mid-United States as a major threat to various water ecosystems (EPA, 2000). Agricultural use was identified as the most common pollution source for all water systems including ground water (Sims et al., 2005; Wang et al., 2006; EPA, 2012a; Cox et al., 2013).

Today's CAFO often focus exclusively on just producing animals not on the growing crops to feed those animal. This requires less land, but this also results in limited access by a producer to land on which to spread the animal wastes produced by the operation (Maheshwari, 2013). As a result, animal wastes, such as spent poultry litter, can often be stacked and stored uncovered, long-term on site where it may leach, or sold (untreated) to be spread onto crop and grazing lands by local farmers and ranchers or as fertilizer to local gardeners.

Over the last decade, researchers have examined the release of pollutants into surface and groundwater after land application or stockpiling of spent manures. Some of the primary environmental concerns related to poultry litter nutrient emissions into the soil-water systems are eutrophication due to NO_3^-/N or P, water contamination with nitrate, and ecotoxicity due to excessive levels of micronutrients, such as Cu, Zn (Pirani et al., 2006; Toor and Haggard, 2006; Shah et al., 2009; EPA, 2012a; Cadet et al., 2013; Kibet et al., 2013). Mencio et al. (2016) found that nitrate pollution was not just a matter of the concentration of ions, but was also influenced by their effect on biogeochemical processes controlling water-rock interactions. There is much more to learn about the buildup and transfer of contaminants into the environment.

The purpose of this research was to determine the buildup of possible pollutants within poultry litter and soil beneath and how management practices affect retention; as well as, to begin to explore the impact of spent litter deposition into the environment. We examined the changes in 15 physiochemical properties [Ca, Cu, electrical conductivity (EC), Fe, K, Mg, Mn, percent moisture (%M), Na, NO_3^-/N, percent organic matter (%OM), P, pH, S, and Zn] of litter within a dirt-floored broiler house and the pad beneath from the first bedding application within a newly constructed house through 11 consecutive flock rotations (2.5 yrs). We then followed the spent litter to where it was stockpiled (20 weeks) awaiting spreading as a fertilizer and monitored changes to the environment (the soil beneath). We correlated the retention of possible pollutants with management practices (before and after a partial and a total clean-out). Since poultry houses are often built *en masse* placed on top of bare land and can be near water sources and waterways, where leaching can occur, we feel this is an important environmental study. Additionally, spent poultry litter is often stored uncovered, long-term on sites where it may leach, sold as fertilizer to local gardeners, or spread (untreated) onto crop and grazing lands by farmers, ranchers and local gardeners.

2. Materials & methods

2.1. Site description

The construction site of the new dirt-floored broiler production house was open range Post Oak Savannah several miles from another existing broiler production facility in NW Robertson County, Texas (Gould et al., 1960). The broiler facility was a standard tunnel ventilated metal house, 14 m wide (North/South) by 152.4 m in length (East/West) in size placed on 25 cm pad of commercial grade clay-based topsoil (Pad). Water and feed lines ran the length of the house alternating spaced at 1.52, 2.44, 4.57, 6.10, 9.43, 11.56, and 12.48 m from the North to South. The research was conducted over a 2.5 year period, during which 11 flocks (Flks) were grown out over an average of 59 ± 6 days (flock rotations).

2.2. Management Practices

Approximately 32 MT of fresh pine chip bedding (PCB) (15.3 cm) was added to the floor of the house prior to the arrival of the first flock. The Ross® 708 broiler chicken was stocked and fed a corn/soy based ration (see regime in Supplemental Table 1). Each flock had a stocking density of one broiler per 0.1 m^2 (25,800 birds per rotation). After the 7th flock rotation, the producer performed a partial house clean-out (PCO), consisting of the removal of the top caked-layer of hardened manure and 5–8 cm of litter. Fresh PCB (6.4 cm) was then added to the house. A total house clean-out (TCO) was performed after the 9th flock rotation consisting of removal of all litter plus a 1–3 cm of the pad-soil. Fresh PCB (15.3 cm) was added to the house prior the 10th flock. Litter is defined as bedding after use by the birds; and consists of bedding, chicken manure, urine, carrion, feathers,