Manure Management on Commercial Layer Operations

Environmental Concerns

Control of ammonia volatilization in poultry houses is a major concern for the poultry industry (Timmons and Harter-Dennis, 2011). Ammonia (NH_3) is the **major pollutant gas** associated with poultry production operations. Bird feces contain uric acid that can be rapidly converted to NH_3 in the presence of appropriate microbes (Xin et al., 2011). Ammonia emission is environmentally important because it contributes to the acidification of soil and water and increases nitrogen deposition in ecosystems (Liang et al., 2005).

Excessive NH_3 in poultry houses is detrimental to bird performance and welfare. Ammonia generation is largely influenced by nitrogen (N) content in the manure. How that manure is managed in laying hen houses can greatly influence NH_3 emission. **High-rise (HR) and manure-belt (MB) houses** are the two most common housing styles in the egg industry in the U.S. In HR houses, solid **manure is stored in the lower level of the building** for perhaps a year before removal (Liang et al., 2005). Manure in MB houses **drops onto a belt beneath each row of cages** and is removed daily or perhaps weekly.

Ammonia's threat to air quality is not the poultry industry's only environmental challenge. There is growing concern that land application of manure may pollute both surface and groundwater. Water quality may also be at risk if **manure application is mishandled**.

In addition, widespread use of antibiotics in animal husbandry has resulted in much **concern over antibiotic resistance genes** (ARGs). Conventional manure management practices do not completely remove ARGs, resulting in their release to soil and water environments when manure is land applied.

It is critical that producers follow best management practices related to storage and land application of manure to protect not only the environment but also their way of life.

Ammonia Concerns

The common **NH_3 level recommended for U.S. poultry houses is 25 ppm or less** (UEP, 2017). Serious consequences can result from elevated levels of atmospheric NH_3 in poultry houses, including:

- reduced feed intake and growth rate (Carlile, 1984; Charles and Payne, 1966a; Deaton et al., 1984)
- decreased egg production (Charles and Payne, 1966b)
- damage to the respiratory tract (Nagaraja et al., 1983)
- increased air sacculitis (Oyetunde et al., 1978)
- increase in *Mycoplasma gallisepticum* (Sato et al., 1973)
- increase in keratoconjunctivitis (Faddoul and Ringrose, 1950)
- increase in Newcastle disease susceptibility (Anderson et al., 1964)

Ammonia is an environmental concern because it can enhance acid rain (Xin et al., 2011). Once ammonia is emitted to the environment, it can contribute to the formation of fine particulate matter ($PM_{2.5}$) that may cause respiratory illness in humans (Fierro, 2000) and contribute to problematic environmental issues, such as an increase in atmospheric haze (ApSimon et al., 1987; NRC, 2003). Based on the sum of nitrogen from manure, eggs, and carcasses, approximately **40 percent of feed N input can be lost** to the atmosphere as NH_3 (Patterson and Lorenz, 1996). Typical nitrogen losses between excretion and land application for poultry manure stored in deep pits is 25 to 50 percent (MWPS, 1985).

Liang et al (2005) reported NH_3 emission for HR houses in Iowa and Pennsylvania reached **317 grams NH_3 per hen per year** (0.87 gram NH_3 per hen per day) for hens fed a standard industry diet and **296 grams NH_3 per hen per year** (0.81 gram NH_3 per hen per day) for hens fed a diet with 1 percent lower crude protein. Ammonia concentrations and emission rates of **MB houses were lower** than those of HR houses. The frequency of manure removal in MB houses affects NH_3 concentration and emission rate. Semi-weekly removal emitted 74 percent more NH_3 than daily removal.

In addition to NH_3, **poultry operations can also be a source of greenhouse gases** (GHGs), although **poultry's contributions are much less than those of ruminant animals**. The GHGs of greatest concern are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The danger to the atmosphere (the global warming potential or GWP) of a GHG is determined by an index that is used to compare a specific gas to a reference gas (usually CO_2) in terms of its ability to trap outgoing thermal infrared radiation (Xin et al., 2011). **Methane and nitrous oxide have a global warming potential of 23 and 296 times that of carbon dioxide**, respectively, making them important in any discussion on climate change, even though their concentrations in the atmosphere are less than 1/100 of that of CO_2 (IPPC, 2007).

Poultry and livestock operations are unique facilities. Production and emission of gases and particulate matter depend on a series of complex physical, chemical, and biological processes. Emission rate is influenced by a variety of factors that include diet composition and conversion efficiencies, manure handling practices, and environmental conditions (Xin et al., 2011). Diet composition and the efficiency of its conversion to eggs affect the quantity and physical and chemical properties of layer manure; as do handling practices and environmental conditions (Xin et al., 2011).

Dietary modification offers an **effective means to lower NH_3 emissions** by reducing excessive nitrogen excretion or manure pH without adversely affecting egg production (Xin et al., 2011). Including high-fiber ingredients (e.g., DDGS, wheat mids, soybean hulls) in laying hen diets can lower ammonia emission from manure with no adverse effect on egg production (Roberts et al., 2007a, b). A nutritionally balanced diet with 1 percent lower-than-standard crude protein content can lead to roughly a **10 percent decrease in annual NH_3 emission** while maintaining hen performance (Liang et al., 2005).

Repeated applications of poultry manure to cropland have the potential to improve soil health characteristics such as soil organic matter and soil fertility (Lin et al., 2018). However, manure applications to cropland have not always resulted in improved soil health indicators (Clark et al., 2017), partially because of difficulties in assessing soil health in short-term studies because of the complex and dynamic nature of soil nitrogen and organic matter. While agronomic benefits are well established, the environmental impacts of poultry manure management have primarily focused on water quality (Harmel et al., 2009; Vervoort et al., 1998).

Effects on Water Quality

Lorimor and Xin (1999) monitored four commercial HR layer houses in Iowa for a year to determine manure production and nutrient concentration characteristics. Manure production was **10.5 tons per 1,000 birds per year** at an average moisture content of 41 percent on an "as is" basis. When manure production was combined with nutrient concentrations, the measured nutrient production was shown to be **385-867-551 (N-P_2O_5-K_2O) pounds per 1,000 birds per year**. The manure **handling system was found to play a significant role** in manure moisture content. Manure that was allowed to stay on boards beneath the cages for a period before being moved to storage was significantly drier than manure that dropped directly into storage.

There is concern that land application of manure will pollute both ground and surface water. This has led to increasing demands for more precise manure handling practices to prevent environmental damage resulting from overapplication of manure nutrients. Hen manure is an excellent organic fertilizer, but it does have the disadvantage of a **low nitrogen to phosphorus (N:P) ratio**. Adding to the problem is that **plants require approximately eight times more N than P**. Therefore, if poultry manure is applied based on N needs of the crop (as it often is), P is overapplied (Sims et al., 2000; Hoover et al., 2019). This can result in increased soil P levels and lead to P runoff (Pote et al., 1996). P concentrations in runoff water can be high after poultry manure application, even when soil test P levels are low (Edwards and Daniel, 1992, 1993; Moore et al., 2000).

Eutrophication is the **biggest water quality problem** facing U.S. surface waters (EPA, 1996). Eutrophication can lead to algal blooms and fish kills (resulting from oxygen deprivation) in lakes and rivers. Algal blooms can threaten municipal water systems with taste and odor issues. Phosphorus runoff from hen manure can contribute to eutrophication in freshwater systems (Schindler, 1977).

Best management practices to reduce phosphorus runoff from poultry manure application include:

- proper nutrient management planning (DeLaune et al., 2004; Edwards and Daniel, 1992, 1993)
- buffer strips (Chaubey et al., 1993)
- dietary modifications to lower phosphorus content of diets using phytase enzymes (Plumstead et al., 2007)
- chemical precipitation of P in manure using compounds such as alum (Moore et al., 2000; Moore and Edwards, 2007; Wilson, 2004)

If mishandled, **nitrogen can also be an environmental threat**. Runoff nitrogen from manure and atmospheric ammonia can contribute to eutrophication. Nitrate leaching into groundwater is another potential water quality threat. Nitrate leaching from hen manure is dependent on application rate and is recommended to be below 5 tons per acre. You can keep application rates below this threshold by using best management practices and a phosphorus index to determine application rate.

Since the 1940s, livestock production practices in North America have evolved from extensive to intensive systems, concentrating animals, nutrients, and their associated microorganisms within limited geographic areas (McAllister and Topp, 2012). Approximately **39 percent of pathogens currently known to infect livestock are also infectious to humans** (Cleaveland et al., 2001). Livestock manure can harbor a wide range of bacterial, viral, and parasitic pathogens that can move from land-applied manure to surface water, leach into groundwater, or contaminate vegetable crops through irrigation (McAllister and Topp, 2012). However, pathogen mobility from intensive and extensive livestock operations is complex, and exposure of adjacent water sources occurs through multiple pathways.

As the global human population approaches 10 billion by 2050, meat and milk production are expected to nearly double (FAO, 2006). More than 1 billion of the population increase is expected to occur in Africa alone (Thornton et al., 2009). In fact, much of this expansion will occur in developing countries already prone to microbial contamination of water. Proper manure **handling is one critical control point required to avoid foodborne illness**. Best livestock management practices can reduce the release of pathogens into the environment.

Both extensive and intensive production systems can threaten surface waters through microbial contamination. Livestock often have **direct access to streams and rivers in extensive systems**, while in intensive systems (as with commercial layers), pathogens most often enter surface water by **runoff from land-applied manure**. This highlights the importance of developing sound manure management practices and a nutrient management plan for your operation.

Many of these practices are simple. Avoid spreading manure in high-risk areas such as steep slopes, bottomlands that are prone to flooding, and fields adjacent to waterways. Consider planting cover crops that inhibit overland water flow and increase soil water-holding capacity. Conservation tillage practices that leave crop residue in the field can reduce runoff and erosion. Buffer strips and set-back distances create a safety zone and help protect streambanks. Soil and manure tests can prevent overapplication of nutrients and loss of these nutrients to the environment through leaching and runoff.

Antibiotic Resistance Genes (ARGs)

Globally, **animal husbandry accounts for over half of all antibiotic use** (Van Boeckel et al., 2017). Much of this antibiotic use in animal husbandry is for **non-therapeutic purposes**, such as promoting growth and preventing disease (Woolhouse and Ward, 2013; Zhu et al., 2017). In recent years, most non-therapeutic use in Europe and the U.S. has been phased out, but **non-therapeutic use is still prevalent** in many parts of the world. This enables bacteria in livestock digestive systems to **acquire and maintain antibiotic resistance genes** (ARGs) and fosters an increase in the relative abundance of resistant populations (Gullberg et al., 2011). When these ARGs propagate to surrounding environments, antibiotic resistance becomes an environmental pollution concern (Rysz and Alvarez, 2004).

Although current **livestock waste treatment technologies are not designed to remove ARGs** specifically, the possible removal of ARGs during waste treatment from concentrated animal feeding operations is an area of interest. Currently, one of the most pressing needs is to **control ARGs at the source by improving management strategies** to reduce the abundance and diversity of ARGs in livestock manure (He et al., 2020). Management changes—including adjusting animal diets to minimize disease occurrence, decreasing human-to-animal interaction, optimizing manure collection methods, increasing frequency of manure collection, and creating confinement areas for sick livestock to reduce the spread of disease—could suppress ARG proliferation and reduce the need for antibiotics (He et al., 2020). In addition, **antibiotic alternatives**, such as antimicrobial peptides, probiotics, prebiotics, essential oils, and enzymes, show promise for selective microbial control.

Summary

While commercial layer manure is an excellent organic fertilizer source, it has a low N:P ratio. If mishandled, excess nutrients can leach into groundwater or run off into surface waters, affecting water quality. Ammonia volatilization may also have a detrimental effect on bird health and the environment if not properly managed. An increase in antibiotic resistance genes is also a possibility if livestock manure is mishandled. While some regions of the world have banned antibiotics for prophylactic use, the practice is still common in many places. Using best management practices and following the nutrient management practices uniquely designed for each livestock operation will lessen environmental concerns associated with poultry and livestock and reduce chances of overapplying manure nutrients.

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