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Challenges and Benefits of Managing and Utilizing Poultry Litter Inside and Outside the Broiler House

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Introduction

Commercial poultry production is a primary income stream for many small family farms throughout the southeastern United States, especially in hilly and mountainous regions where soils have historically been low in fertility. Livestock (beef cattle) operations provide a supplemental income source to many poultry producers. These are complimentary enterprises because poultry litter contains significant quantities of essential plant nutrients and is commonly used as a surface-applied fertilizer for perennial pastures and hay meadows. The variable nutrient composition of litter is a challenge and occurs because of the variety of birds reared (broilers, breeders, layers or turkeys), source and thickness of initial bedding material used (e.g., rice hulls, wood shavings, straw, sawdust, peanut hulls and other agricultural residues), frequency of cleanouts, and the management, handling and storage of the litter (Bolan et al., 2010; Ashworth et al., 2020). Litter management (both inside and outside the poultry house) is an increasingly important issue for Tennessee farmers, state and federal agencies, the poultry industry and the general public. While new and innovative methods of utilizing litter continue to evolve, land application remains the most sustainable option (Sharpley et al., 2009).

For many acres of land previously considered marginal for agricultural production, poultry litter applications have greatly increased forage and beef outputs (Pote et al., 2003). However, the land-applied surface **spreading of poultry litter has raised water quality concerns** in some areas. For example, several studies (e.g., Giddens and Barnett, 1980; Westerman et al., 1983; McLeod and Hegg, 1984; Edwards and Daniel, 1993; Shreve et al., 1995) have shown that nutrients and coliforms can be leached from surface-applied litter by heavy rainfall and transported from the field in surface runoff. Long-term land application of poultry litter results in an accumulation of mineral nutrients and trace metals in soil (Daigh et al., 2009); soil phosphorus runoff in particular has the potential to impair surface and groundwater quality (Sharpe et al., 2004; Bolan et al., 2010; McMullen et al., 2014). Indeed, research confirms that nutrients can be leached from surface-applied litter by heavy rainfall and transported from the field in surface runoff (Edwards and Daniel, 1993; Shreve et al., 1995). Land application of litter in many intensive poultry production regions is being closely scrutinized regarding short- and long-term environmental impacts, especially as it relates to phosphorus runoff and its potential role in eutrophication, the enrichment of plant nutrients in surface water that results in algae blooms. In poultry-dense production regions such as the Eucha-Spavinaw and Illinois River Watersheds in northwest Arkansas/northeast Oklahoma, this has led to the implementation of stringent regulatory measures for nutrient management and land application of manure (Sharpley et al., 2009). In addition, the soluble phosphorus pool in poultry litter is problematic because increases in water extractable phosphorus (WEP) in litter increase dissolved P in runoff (Eghball et al., 2002; Vadas et al., 2004; Haggard et al., 2005).

As a result, even though poultry litter has numerous benefits as a soil amendment when handled correctly, poultry growers face several challenges that occur both **inside and outside of the poultry house regarding the management and utilization of litter**. The accumulation of large amounts of waste material in localized areas, especially manure and litter, generated by intensive production practices is a concern for producers (Bolan et al., 2010). Poultry litter is prevalent in intensive poultry production regions like northwest Arkansas and Delmarva, the peninsula encompassing Delaware and parts of Maryland and Virginia, where soil phosphorus concentrations greatly exceed crop nutrient requirements. It is estimated that nearly 14 million tons of broiler litter is produced annually just from broiler production units in the United States (Ashworth et al., 2020). Large-scale concentration of litter may pose disposal and pollution problems unless environmentally and economically sustainable management practices or novel beneficial reuse technologies are developed (Power and Dick, 2000; Kelleher et al., 2002; Sharpley et al., 2007).

Utilizing Poultry Litter

The application of poultry litter to croplands and hay and pasture fields is a traditional, long-standing and common practice that is shown to improve soil fertility, earthworm and microbial communities as well as soil physical and hydrological properties such as aggregate stability, infiltration rate and hydraulic conductivity (Adeli et al., 2009; Ashworth et al., 2018; He et al., 2019; Feng et al., 2021). As a circular bioeconomy and the increased use and recycling of waste materials gains greater attention, land application of poultry litter to corn and soybeans serves as a prime example of the ultimate circular bioeconomy. In fact, most manure and litter produced by commercial poultry production is currently land-applied to agricultural fields as a high-quality organic fertilizer source, although recent novel litter-based innovative bioconversion techniques have also shown promise in establishing an environmentally sound circular bioeconomy as well (Cheng et al., 2022; Vishwakarma et al., 2022; Kullan et al., 2025).

Often, more litter is produced near commercial poultry production farms than can be sustainably applied to local agricultural fields; therefore, finding alternative uses are vital for the sustainability of the poultry industry (Katuwal et al., 2023). Poultry litter fits well into the circular bioeconomy, which places emphasis on the sustainable use of biological resources through closed-loop systems that rely on reducing, reusing, and recycling biomass. A circular bioeconomy provides ecosystem services that promote sustainable production, use, conservation and regeneration of biological resources and their transformation into food, fiber, materials and energy within ecosystem boundaries (Tabler et al., 2025). The recent global shift toward sustainable development and the transition toward a circular bioeconomy is increasingly recognized as a promising pathway forward, minimizing the use of finite resources, encouraging the use of regenerative practices and preventing loss and waste of valuable agricultural resources (Jurgilevich et al., 2016; Korhonen et al., 2018; Desing et al., 2020; Muscat et al., 2021). Creating such an efficient circular bioeconomy is projected to reach a value of U.S. $7.7 trillion by 2030 (WBCSD, 2019).

Several studies have shown that agricultural wastes such as poultry litter can be converted into value-added products, including biochar which can be used as a pathogen-free soil amendment (Cantrell et al., 2012; Novak et al., 2012; Song and Guo, 2012; Katuwal et al., 2022) that improves and maintains soil fertility, soil quality, water-holding capacity and increase soil carbon sequestration (Chan et al., 2008; Novak et al., 2009). Litter biochar also can remediate contaminates in soil and water (Lima and Marshall, 2005; Guo et al., 2010; Lima et al., 2015). Alternative litter utilization methods also include its use as a biomass energy source via combustion to recover heat and energy (Lynch et al., 2013), the generation of biogas by anaerobic digestion (Beausang et al., 2020; U.S. EPA, 2022) and the generation of electricity (Dagnall et al., 2000), all with lower environmental impact compared to land application of raw poultry litter with respect to pathogens, pollutants and emissions of volatile gases (NH3, N2O, and NO_x gases) (Billen et al., 2015). However, including the cost of mining minerals and fossil fuel consumption in a non-sustainable mineral fertilization scheme may offset some of this lower environmental impact.

Despite the increasing potential of novel bioconversion techniques, land application of poultry litter remains a useful and critical method to recycle essential crop nutrients including nitrogen (N), phosphorus (P) and potassium (K) back to the soil when managed correctly. Still, pollution and nuisance problems will occur if litter is land applied when conditions do not favor agronomic utilization of litter nutrients (Sharpley et al., 1998; Casey et al., 2006; Kaiser et al., 2009). In addition, overall litter production and nutrient content can vary greatly from farm to farm based on house size, bird harvest weight, management practices, number of flocks per year, litter cleanout schedule, etc. To this end, Tabler et al. (2009) estimated litter production at **2.5 lb. of litter per bird harvested or 1.25 tons per 1,000 birds produced** for broilers. While land application remains the **most desirable use for poultry litter**, this waste must often be moved farther and farther from the source (the farm where it was produced) to be applied to agricultural lands that can benefit from P application (Pokhrel and Shober, 2024). As a result, litter is often transported out of the watershed where it initially originated to prevent local and regional overapplication of nutrients, particularly P (Figures 1, 2 and 3).

Figures 1,2 and 3. *Litter is often removed from the poultry house and transported out of the home watershed to prevent overapplying nutrients in intensive poultry production areas.*

Land application of poultry litter should be sustainably managed to recycle nutrients rather than for waste disposal. Environmental concerns about agricultural non-point source pollution make it imperative that farmers use poultry litter in the manner most beneficial for the environment— both in the poultry house and on the field. Hawkins and Walker (2018) have developed a litter land application worksheet to assist producers with land application management of poultry litter. Poultry litter should not be applied to soil beyond the limits of the growing crop's nutrient needs. This will ensure the **efficient use of manure nutrients and minimize nutrient leaching or runoff** into surface or groundwater systems. The soils in any field scheduled for poultry litter application should first be tested to determine fertility level, with periodic testing every 3 to 5 years recommended to monitor the nutrient supplying capability of the soil. Fertilizer recommendations based on soil tests and litter nutrient analyses are the only reliable methods to determine the crop nutrient requirement. Therefore, regular analysis of both litter and soil should be important parts of the overall farm operation (Sharpley et al., 2009). In addition, Hawkins and Walker (2018) offer best management practices for litter land application including setbacks, timing, etc.

Poultry litter has much potential for being recycled on agricultural land when managed correctly. Beneficial use through land application is based on litter's ability to favorably alter soil properties, such as plant nutrient availability, pH, organic matter content, cation exchange capacity, water holding capacity and soil tilth (Bolan et al, 2010). Poultry litter **contains 11 essential plant nutrients** (Prasad and Stanford, 2019) including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn), copper (Cu), zinc (Zn), boron (B) and iron (Fe), and it is well documented that poultry litter provides a valuable source of nutrients for crops (Kelley et al., 1996; Williams et al., 1999; Chan et al., 2008; Harmel et al., 2009). Poultry litter application to soils not only assists with the disposal issue but also enhances the physical, chemical and biological fertility of soils (Friend et al., 2006; McGrath et al., 2009).

Hawkins et al. (2025) reported that additional broiler litter has recently become more readily available to row crop producers in West Tennessee (where much of the state's soybean crop is produced) as an alternative row crop fertilizer. These researchers indicated that the value of litter for soybean production is **maximized for fields that require both P and K** to reach full yield potential. Previous research has indicated that fertilizing with litter will often result in taller soybean plants with more above ground biomass without significantly improving yield. However, improved yields will sometimes occur if litter provides mineral micronutrients that are deficient in the soil, and may some years be in part a result of litter providing N (Hawkins et al., 2025). Regular soil testing is essential, and litter should be prioritized to fields that are deficient in P and/or K.

Optimum **use of poultry litter requires knowledge of its nutrient composition** not only in relation to beneficial uses but also to environmental implications. Environmental concerns associated with the land application of poultry litter from intensive animal feeding operations include leaching losses of N in sub-surface drainage and to groundwater, contamination of surface water with soluble and particulate P, and reduced air quality by emission of greenhouse gases and volatile organic compounds (Williams et al., 1999; Ribaudo et al., 2003; Harmel et al., 2004; Casey et al., 2006). Protecting the environment is a major consideration when developing management practices to effectively use manure by-products as a nutrient resource and soil conditioner in agricultural and horticultural production systems (Sims and Wolf, 1994; Moore et al., 1995; Moore, Jr. et al., 2006).

Wet Litter Challenges

Avoiding overapplication of poultry litter to agricultural fields and the resulting accumulation of soil P is but one challenge facing poultry farmers today when litter is **outside** the poultry house. Another perhaps even greater **inside-the-house** challenge is the proper use of management practices to maintain dry litter (less than 20 percent moisture) while the material is still in the chicken house. The problem of wet litter, which occurs primarily in commercial broiler houses, has been recognized for over a century. Dann (1923) indicated that "wet litter in the poultry house is a rather troublesome problem to most poultrymen." Despite all our advances in other areas related to poultry production (nutrition, housing, ventilation, lighting, disease prevention, etc.), we have made **surprisingly little progress in the area of wet litter**, as it is still a major challenge for both growers and integrators today. In fact, it is an increasingly critical issue in contemporary broiler production as wet litter and associated conditions, especially footpad dermatitis, not only **affect flock production and performance** but have also developed into tangible **animal welfare issues** (Dunlop et al., 2016).

Figures 4a, b, and c. *Failure to adequately remove moisture from the house through proper ventilation will result in varying amounts of wet litter: a) semi-dry, b) moist, and c) wet.*

Wet litter results from **large amounts of water added to the house environment** by the birds (through respiration and manure deposition), by burning fuel (propane or natural gas) to heat poultry houses, and the failure by producers to remove this water using ventilation in a timely manner. This water must be removed from the house by adequate ventilation to maintain dry litter. Failure to properly manage the ventilation program will result in wet, caked litter by the time the flock is harvested (Figure 4a, b, and c). However, these wet litter conditions at the end of a flock must be addressed before the next new flock arrives. Baby chicks cannot be started on wet, cold, caked, uneven litter material. The wet litter must either be removed from the house by decaking

(Figure 5) before the next flock or, if windrowing the litter is an option (Figure 6), incorporating the cake into the windrow for heat drying (Figure 7) and then evenly spread the heat-dried litter for a few days before the new flock is placed (Figure 8a, b, and c).

Figures 5, 6, and 7. *Wet litter should be removed from the house with a decaking machine (5) or incorporated into a windrow inside the house (6) and allowed to heat and dry as the windrow composts (7).*

Figures 8a, b, and c. *Dry, level, friable litter material must be in place to start each new flock of chicks.*

Within a broiler house, as a flock increases in age, increasing amounts of water is routinely added to the litter through manure deposition, spillage from drinkers, condensation, roof leaks and absorption of humidity from the air (Dunlop et al., 2015). Collett (2012) estimated that a flock of 20,000 birds can excrete up to **660 gallons of water per day** onto the litter. Control of litter moisture is complex and challenging due to environmental, economic, engineering and animal husbandry constraints (Tucker and Walker, 1992). Litter moisture influences ammonia emissions (Elliott and Collins, 1982; Liu et al., 2007; Miles et al., 2011), odors (Clarkson and Misselbrook, 1991; Murphy et al., 2014), dust (Roumeliotis et al., 2010) and health issues such as footpad dermatitis (Bilgili et al., 2009; Shepherd and Fairchild, 2010; de Jong et al., 2012). In addition, microbial populations flourish when litter moisture content is greater than 35-40 percent, which can lead to greater risks to bird health and food safety (Eriksson De Rezende et al., 2001; Agnew and Leonard, 2003; Wadud et al., 2012). Dunlop et al. (2015) indicated that when daily moisture application rates are at their greatest, it may be challenging to maintain litter in a dry state because **evaporation rates may be insufficient** to remove the required amount of water. In addition, conditions that result in high evaporation rates may also result in high emissions rates, odors and ammonia.

To better understand the critical relationship between ventilation and litter moisture, consider the following litter moisture control basics as presented by Czarick (2021). A bird will drink approximately twice as much water as it consumes in feed on a pound-for-pound basis throughout its life. Research has confirmed the relationship between feed and water is very consistent over the life of the flock. For example, a 21-day-old broiler will consume approximately ¼ pound of feed each day and will drink ½ pound (8 oz) of water. **Water consumption is the best and most inexpensive gauge to assess feed consumption.**

To effectively manage litter moisture, it is important to ventilate the house based on the amount of water the birds are adding to the house each day (which is roughly the same amount they are consuming each day). In other words, whatever amount of water the birds drink each day, **that is the amount we must remove each day**. If we fail to remove the water the birds add to the house each day, then over time the moisture builds up and we end up with wet litter which can lead to footpad dermatitis, increased ammonia, greater respiratory issues, poor flock performance, etc. Therefore, poultry producers must divide their time between managing the litter inside the house to provide the optimum environment for flock performance and utilizing the litter in a sustainable manner outside the house to protect the environment. Failure to do either or both will result in serious negative consequences. How do we know how much to ventilate each day to remove the water that the birds are adding to the house each day? For "typical" outside wintertime conditions (let's say 40 F and 50 percent humidity), a "general" rule of thumb is that it takes approximately 14,000 cubic feet of air to remove each gallon of water added to the house. So, let's say your water meter indicates that your house of birds consumes 1,000 gallons of water on a given day.

You will need to remove those 1,000 gallons of water. To do so you will need to exchange 1,000 gallons x 14,000 ft3/gallon or 14,000,000 ft3 of air per day (or in terms of cubic feet of air per minute... 14,000,000 ft3/day/24 hours/60 minutes = 9,722 cfm). The University of Georgia has developed an app (Poultry411 App-Minimum Ventilation Calculator) that can be a useful tool to help growers determine how much to ventilate based on how much water the birds are drinking.

Variation in Litter Nutrient Content

Proper ventilation is perhaps the greatest challenge faced by commercial poultry producers, but it is far from the only challenge. Another challenging aspect of litter management is the **range of variation regarding litter nutrient content.** Determining utilization potential of litter relates to the variation of its physiochemical composition because of the use of different biomass as bedding materials and the variation in management, storage and handling of poultry litter (Bolan et al., 2010; Crippen et al., 2016).

While the fertilizer value of litter is well recognized, the **nutrient concentration of litter can vary**, depending on a variety of factors (VanDevender et al., 2000), including type and amount of bedding material (wood shavings, rice hulls, sawdust, straw, etc.), litter type (broiler, breeder hen, or turkey litter or layer manure), number of flocks between cleanouts and the nutrients included in the poultry diet. Tabler and Berry (2003) followed nine flocks of broilers on the same litter at a commercial broiler farm in Arkansas and found N increased from 33.8 (1.7 percent) to 60.3 (3.0 percent) lbs/ton, phosphorus (as P2O5) increased from 42.5 (2.1 percent) to 69.3 (3.5 percent) lbs/ton, and potassium (as K2O) increased from 36.6 (1.8 percent) to 58.3 (2.9 percent) lbs per ton on an as-is basis (Table 1) over the course of nine consecutive flocks. Litter moisture ranged from a low of 22.3 percent to a high of 26.0 percent. Berry (1997) reported a 4-year average N, P as P2O5, and K as K2O content of litter from an Arkansas commercial broiler farm cleaned out completely on an annual basis was 57.3 (2.9 percent), 64.9 (3.3 percent), and 55.9 (2.8 percent) lbs/ton, respectively, on an as-is basis (Table 2). Moisture content of the litter over the 4-year period ranged from 23.1 to 28.1 percent.

In the end, if litter remains in the house for multiple flocks, the flock-to-flock variation is less critical than the variation at cleanout when the litter is land-applied, which may be more consistent. Always test the litter at cleanout to know what you have but expect it to be in the 2.5 to 3 percent range by mass on an "as is" basis for N, P2O5, and K2O. This expectation agrees with Espinoza et al. (2005) who found that the average N:P2O5:K2O ratio in litter on an "as is" basis in Arkansas was about 3.0:3.0:2.5. Because plants need more N than P, this ratio does not supply nutrients according to the plant's nutrient requirements. Therefore, it is recommended that poultry litter be applied based on the ***phosphorus*** needs of the crop to be grown and/or the corresponding P recommendation obtained from a soil test. Applying litter based on the crop's ***nitrogen*** requirement would result in P rates well above the P-fertilizer rate required for optimum crop growth and yield (Espinoza et al., 2005).

Keep in mind, plants primarily absorb nutrients that are in the inorganic form, regardless of their original source. Nutrients in inorganic fertilizers are readily available for plant uptake upon application, while the organic forms of nutrients are slowly available. We will assume that the majority (~90 to 100 percent) of the P and K in poultry litter is available for plant uptake during the season of application and that the total P and K content of litter, expressed in units of P2O5 and K2O, is equivalent to equal rates of inorganic P and K fertilizers. However, only a small portion (<20 percent) of the total N in poultry litter is present in the inorganic form, most of the N is in the organic form. Organic N must be mineralized (broken down) into inorganic N before it is considered plant-available N. Mineralization of organic N is performed by soil microbes and is affected by temperature, soil moisture and soil pH, among other factors. Because mineralization is affected by environmental and manure source factors, the general rule is that between 50 percent and 60 percent of the organic N is mineralized the first year, ~20 percent the second year and ~10 percent the third year (Espinoza et al., 2005).

Table 1. Litter nutrient analysis at a University of Arkansas broiler farm over a 9-flock grow-out during 1995-96[1,2,3].

Date	Flock Length (Days)	Flocks on the same litter	pH	Moisture (%)	Ash (%)	------------lbs/ton on as-is basis------------			
						N	P_2O_5	K_2O	Ca
Jun-95	41	1	7.4	33.1	19.6	33.8	42.5	36.6	36.2
Aug-95	41	2	7.6	31.5	22.5	43.6	47.9	44.1	43.0
Oct-95	41	3	7.6	28.7	26.2	51.8	57.7	45.6	46.1
Dec-95	40	4	7.2	33.8	24.6	51.0	51.0	44.2	42.6
Feb-96	45	5	6.9	36.0	24.4	55.3	52.9	48.4	43.2
Mar-96	41	6	7.5	34.7	24.9	53.0	52.8	45.6	41.2
May-96	42	7	7.8	27.3	24.0	62.9	58.2	52.9	47.4
Jun-96	42	8	7.3	28.7	26.0	49.5	59.3	54.2	47.3
Aug-96	43	9	7.8	22.3	22.6	60.3	69.3	58.3	53.5

[1]Adapted from Tabler and Berry (2003)
[2]Initial bedding material was 50:50 mix of rice hulls/pine shavings/sawdust. [3]Figures represent averages of four 40' x 400' houses

Table 2. Litter production variables from four years of broiler production at a University of Arkansas farm[1].

Date	Flk age (wks)	# of flks	pH	Moisture (%)	Ash (%)	lbs/ton on as-is basis				Depth (in)	Density (lb/ft^3)	lb litter[2]/ lb chicken
						N	P_2O_5	K_2O	Ca			
Apr-93	8	6	7.25	23.78		57.7	57.0	64.1	41.7	6.44	30.50	0.369
Apr-94	8	5	6.87	28.13	27.20	58.1	68.0	49.1	51.0	5.13	37.09	0.466
Apr-95	6	7	7.61	25.04	26.61	55.9	66.1	52.5	53.2	3.96	35.14	0.407
Aug-96	6	9	7.80	23.09	23.87	57.5	68.4	58.0	54.2	4.64	41.58	0.416
AVG:			7.38	25.01	25.89	57.3	64.9	55.9	50.0	5.04	36.08	0.415

[1]Adapted from Berry (1997)
[2]Weight is on as-is basis

Malone (1992) reported an average (as-is basis) of 2.9, 3.2, and 2.0 percent for N, P as P2O5, and K as K2O, respectively, from several U.S. sources. Chamblee and Todd (2002) reported Mississippi broiler litter contained 2.9, 1.5, and 3.0 percent N, P as P2O5, and K as K2O, respectively. Patterson et al. (1998) reported broiler litter in Pennsylvania to have an average N, P as P2O5, and K as K2O content of 3.7, 3.1 and 2.2 percent, respectively. Sharpley et al. (2009) reported N, P as P2O5, K as K2O, and WEP levels of 62 (3.1 percent), 68.7 (3.4 percent), 62.4 (3.1 percent) and 1.9 lbs/ton, respectively (Table 3).

Table 3. Broiler litter analysis on an "as is" basis over a three-year period (2005-2007) analyzed by University of Arkansas Agricultural Diagnostic Laboratory[1].

	Sample size	Minimum	Maximum	Average
Moisture. %	297	13	67.2	30.8
pH	297	5.6	9.4	8.4
N, lb/ton	297	20.0	88.0	62.0
P2O5 , lb/ ton	297	27.5	119.1	68.7
K2O, lb/ton	297	2.6	81.6	62.4
WEP2, lb/ ton	297	0.5	9.9	1.9

[1]Adapted from Sharpley et al. (2009)
[2]Water extractable phosphorus.

Espinoza et al. (2005) reported poultry litter samples analyzed by the University of Arkansas Agricultural Diagnostic Laboratory between 1993 and 2001 had an average N, P as P2O5, and K as K2O content of 60 (3.0 percent), 57 (2.9 percent) and 52 (2.6 percent) lbs/ton, respectively (Table 4). The majority of these samples were broiler litter with small amounts of breeder hen and turkey litter. Tabler et al. (2015) reported that Mississippi broiler litter contained 47.4 (2.4 percent), 69.4 (3.5 percent), 61.4 (3.1 percent) and 9.22 lbs/ton of N, P as P2O5, K as K2O, and WEP, respectively (Table 5). Based on the number of flocks grown on the same litter, Tabler et al. (2015) indicated that nutrient concentrations of N, P as P2O5, K as K2O and WEP in broiler litter tended to **increase until approximately 15 flocks had been grown** and then stabilized, regardless of how many additional flocks were grown.

Table 4. Nutrient and moisture levels of poultry (primarily broiler with small amounts of breeder hen and turkey) litter from samples submitted to the University of Arkansas Agricultural Diagnostic Laboratory between 1993 and 2001[1].

	Sample size	Minimum	Average
Moisture. %	2	47	23
N, lb/ton	22	98	60
P2O5 , lb/ ton	18	96	57
K2O, lb/ton	23	80	52

[1]Adapted from Espinoza et al. (2005)

Table 5. Effect of division on number of flocks of broiler litter, litter pH, litter moisture percent, N, P_2O_5, K_2O, and water-extractable phosphorus (WEP)[1].

					-----------lbs/ton on as-is basis------------			
Division	# of farms	# of flocks	pH	Moisture %	N	P_2O_5	K_2O	Ca
1	18	7.28^{c}	$7.48a^{b}$	24.46^{efg}	44.08^{bc}	43.13^{c}	61.84^{ab}	9.58^{bcd}
2	20	7.95^{c}	6.67^{f}	25.35^{defg}	44.42^{bc}	50.78^{c}	61.94^{ab}	6.59^{ef}
3	18	5.94^{c}	7.61^{a}	23.85^{gf}	38.76^{c}	52.53^{c}	59.94^{ab}	4.95^{f}
4	20	8.05^{c}	7.19^{cd}	27.23^{bcd}	46.68^{b}	55.23^{c}	60.23^{ab}	13.38^{a}
5	4	11.25^{c}	7.27^{bc}	27.11^{def}	47.42^{b}	73.49^{b}	$60.16a^{b}$	9.40^{cd}
6	10	22.40^{b}	7.12^{cd}	26.39^{cde}	47.08^{b}	77.24^{ab}	57.37^{b}	8.00^{de}
7	10	10.50^{c}	6.84^{ef}	28.95^{ab}	49.46^{b}	74.78^{b}	59.19^{ab}	$9.52b^{cd}$
8	16	12.87^{c}	7.14^{cd}	25.73^{def}	45.52^{b}	75.82^{b}	66.86^{a}	10.83^{bc}
9	7	34.43^{a}	$6.81e^{f}$	26.71^{cd}	46.61^{b}	78.65^{ab}	57.02^{b}	10.45^{bc}
10	12	12.58^{c}	6.71^{f}	27.92^{ab}	49.84^{b}	85.99^{ab}	59.67^{ab}	10.47^{bc}
11	18	25.22^{b}	6.99^{de}	28.37^{g}	60.85^{a}	89.30^{a}	64.73^{ab}	11.29^{b}
12	5	6.20^{c}	7.10^{cd}	30.26^{a}	48.56^{b}	75.78^{b}	67.44^{a}	6.16^{f}
Average	**13.72**	**13.72**	**7.08**	**26.86**	**47.44**	**69.39**	**61.37**	**9.22**

[abcdefg]Means within a column not sharing a common subscript differ significantly ($P<0.05$).
[1]Adapted from Tabler et al. (2015).

Inorganic forms of N (ammonium N or NH_4-N and nitrate N or NO_3-N) in poultry litter account for ~14 percent of the total N and are readily available for plant uptake or volatilization losses, depending on temperature and moisture content (Sharpley et al., 2009). The remaining portion of the total N (86 percent) is in an organic form and must be mineralized prior to becoming available for plant uptake (Sharpley et al., 2009). Phosphorus in poultry litter also exists as organic and inorganic P (Edwards and Daniel, 1992; Sharpley and Smith, 1995; Sharpley et al., 2004). Most of the P in litter is inorganic (~90 percent; Sharpley and Moyer, 2000), with the remainder in organic forms that can become plant-available upon mineralization. While most P in litter is considered available to crops, **WEP in litter is a P pool prone to immediate loss**, which has been correlated with dissolved reactive P in runoff nd leaching (Pote et al., 1996; Maguire and Sims, 2002; Kleinman and Sharpley, 2003) and is considered the gold standard indicator for P loss potential (Roswall et al., 2022).

However, only about 6 percent of the total P is water extractable (Sharpley et al., 2009). Although, WEP is an important environmental parameter primarily because it represents that portion of the P pool that is available to runoff, and research has shown a close correlation between the WEP content of litter and total P loss in the runoff Sharpley et al., 2009). Surface runoff f P from agricultural soils receiving poultry litter continues to be a major source of P reaching waterways. Despite best management practices to guide litter applications and increased local and state regulations to address the issue, soil P levels remain elevated in many intensive poultry production regions such as northwestern Arkansas and the Delmarva region, leading to the creation of “legacy P” soils, where P losses remain above environmental thresholds (Toor et al., 2020; Lucas et al., 2021, 2022; Roswall et al., 2021; Yang et al., 2022), even when additional P sources are eliminated. The take home message here is to avoid legacy P soils and discontinue litter applications once very high soil P levels are reached, at which point no further agronomic benefit exists for additional P application

Legacy Phosphorus

Legacy P is phosphorus accumulated over time in any compartment of a watershed, in effect a historical cumulative result of prolonged over application often of P fertilizers. Legacy P applies across all scales (i.e., from fields to watersheds) and encompasses all anthropogenic inputs (i.e., point and nonpoint sources). Legacy P, a concept advanced by Sharpley and colleagues and originally applied to the persistence of anthropogenic impacts in watersheds, has since been adopted in a variety of settings to help guide the science and management of P (Shober et al., 2024). Throughout his career, Andrew Sharpley’s research **balanced the P management requirements of production agriculture with the mitigation of agriculture’s water quality impacts.** Sharpley et al. (2013) elevated the legacy P concept in a landmark paper that brought it to the forefront of science in many different fields including agronomy, watershed science, soil chemistry, water quality and aquatic ecology.

The rise in popularity of the legacy P concept began after Sharpley et al. (2013) framed the ways in which anthropogenic P inputs accumulate, are stored, and are transported in the landscape (Figure 9). Sharpley et al. (2013) identified terrestrial legacy P pools (i.e., fertilizer- and manure-amended soils and sedimentary stores beyond the edge-of-field, including downslope areas and flo dplains), as well as aquatic legacy P pools (e.g., P stored in sediments and biomass in wetlands, rivers, standing waters, and in groundwater). Both terrestrial and aquatic legacy P pools can provide a sustained source of P that is mobilized through biogeochemical processes and transported to receiving water bodies, where it can continue to impair water quality over timescales ranging from years to centuries (Jarvie et al., 2013; Sharpley et al., 2013; Haygarth et al., 2014).

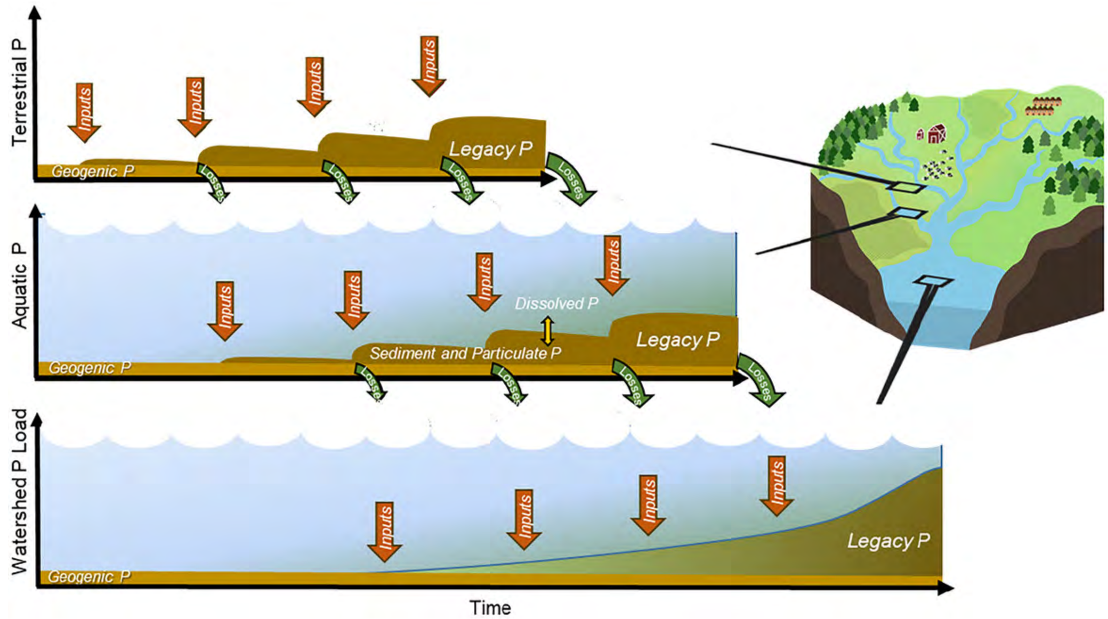

Figure 9. *A graphic depiction of legacy P where past land management processes are tied to the buildup of soil P and the subsequent cycle of P release and storage within the soils and watershed at various spatial and temporal scales. Here, the "legacy of P" is the resulting lag in water quality improvements even when new P sources are eliminated. Source: Shober et al., 2024.*

Effective management of legacy P requires an understanding of how traditional conservation practices interact with legacy P sources. Farmers and land managers must consider the limitations and potential tradeoffs of such practices (Kleinman et al., 2022). In addition, many past conservation practices were developed under historic climate baseline conditions. As a result, the modern-day extreme weather events associated with c**limate change can reduce the efficacy of traditional conservation practices**, resulting in accelerated movement of legacy P in the environment (Shober et al., 2024). As a result, Shober et al. (2024) proposed defining legacy P as P within the environment (e.g., sediments, water bodies, soils) resulting from historic human activity, excluding geogenic (originating from the earth) P stores, noting the need to determine if geogenic P that is transported and deposited within a watershed due to past human disturbance is also legacy P. Recognizing that legacy P presents both a water quality "challenge" as well as a stored resource, or "opportunity," for crop production, sustainable P stewardship strategies are critical to managing legacy P and maximizing co-benefits for crop production and water quality (Shober et al., 2024). Without sustainable P stewardship practices, the end result of overapplication of P is eutrophication, recurrent algae blooms, changing aquatic species resulting from poor water clarity and low oxygen concentrations.

These sustainable P stewardship strategies are often made more challenging by poultry litter's N:P ratio being 1:1 (or slightly higher) as compared to crop nutrient needs that may be 8:1 or higher (Beauchamp and Hamilton, 1970; Greenwood et al, 2008; Veneklaas et al., 2012). Therefore, **applying litter to meet crop N needs results in an overapplication of P** (Sims et al., 2000). As a result, techniques to transform or reduce P in poultry litter are imperative to sustainably use litter in an environmentally friendly manner (Roswall et al., 2022).

Benefits of Poultry Litter as Fertilizer

Despite all its challenges, poultry litter offers numerous benefits as a valuable and useful organic fertilizer source. Farmers, for generations, **have used various animal manures as fertilizer for their crops** (Stevenson et al., 1926). While regarded as a waste product by many, farmers recognize poultry litter's value as a natural source of essential plant nutrients for both row crop fields and grasslands/hay fields. Even in the case of soybean application, where applying litter can be perceived as a poor agronomic practice due to the ability of soybean to fix N, and because most research indicates that N applications to soybean will not improve economic returns, the risk is minimal when litter is applied at planting because soybean will utilize litter N early season instead of relying solely on N fixation (Hawkins et al., 2025). However, guessing at how much to apply is not an economically or environmentally sound method to determine an appropriate litter application rate for agricultural fields.

As discussed earlier, you must have a **nutrient analysis of the litter** to determine nutrient application rates to apply and **a soil test on the fields or pastures** receiving the litter to determine what nutrient levels currently exist and what level of nutrients should be added, otherwise, you are only guessing. It is now critical to apply litter at rates that are determined by the agronomic needs of the crop, which can easily be accomplished by referring to the Tennessee Poultry Litter Application Worksheet (Hawkins and Walker, 2018). In some cases, it may be necessary to assess the risk of P loss from the field by using the Tennessee P Risk Assessment tool if the site is designated and regulated as a concentrated animal feeding operation (CAFO) in Tennessee or if the producers are working with the Natural Resources Conservation Service (NRCS) and are required to follow the Nutrient Management Conservation Practice Standard (also known as the 590 Conservation Practice Standard) (Walker and Hawkins, 2016). Visit your local county Extension office for information and assistance with soil and litter sampling procedures. The University of Tennessee Soil, Plants and Pest Center Laboratory charges $15.00 for each soil sample submitted. The Mississippi State University Chemical Laboratory (662-325-3428), the University of Arkansas Agricultural Diagnostic Laboratory (479-575-3908) and Waypoint Analytical (901-213-2400) offer nutrient analysis of poultry litter samples. Each requires forms to accompany the litter samples. Call for current pricing schedules and information on completing the proper forms and mailing addresses.

Fertilizer costs represent a substantial portion of input cost for crop production, accounting for approximately **30 to 40 percent of input costs for crops with a high N requirement like corn** (Pokhrel and Shober, 2024). Poultry litter offers a local, cost-effective alternative to commercial fertilizers, especially in times of elevated fertilizer prices or shortages or when commodity prices are low. Poultry litter provides benefits in addition to the primary N-P-K macronutrient profile, providing additional secondary macronutrients, micronutrients and organic matter (Hawkins et al., 2025). As a result, the use of poultry litter as a fertilizer source can be beneficial to crop production and soil health in ways that extend beyond what commercial fertilizers can offer.

To make the most of poultry litter's many benefits, understanding and managing litter nutrient variability is essential to optimize agronomic results. There are book values available to estimate poultry litter nutrient content and application rates. However, you should not rely on these book values as they may not provide an accurate representation due to variation in litter nutrient values discussed above. Litter nutrient content is influenced by multiple management factors which underscores the **importance of regular poultry litter analysis and soil sampling.**

Poultry litter provides the traditional macronutrients (N, P and K) needed by plants, along with other benefits including the addition of micronutrients, as well as increases in soil pH, water-holding capacity and organic matter content (Risse et al., 2006). As a result, several studies have documented that manure application can increase crop yields while decreasing surface runoff (up to 60 percent) and erosion (up to 65 percent) (Mueller et al., 1984; Gilley and Risse, 2000). Regular soil and litter sampling are necessary because there is a soil- and management-specific application rate of manure/litter, above which the **addition of nutrients in excess of crop needs negates these benefits by increasing nutrient runoff** (Edwards and Daniel, 1993; Sharpley et al., 2007).

Summary

Even though poultry litter provides multiple benefits as a fertilizer source, it also comes with several management challenges. Producers are faced with two separate but equally critical challenges: 1) keeping the litter dry inside the poultry house to maintain animal welfare conditions and avoid issues like high ammonia levels and footpad dermatitis concerns and 2) proper utilization of the litter once it is removed from the poultry house to avoid overapplication of nutrients, especially P and to prevent surface runoff of nutrients during heavy rainfall events which could lead to eutrophication, algae blooms and decreased surface water quality. Keeping litter dry while in the chicken house may be the greatest of these challenges for poultry producers. Wet litter results from water addition to the house and inadequate ventilation and can be a serious animal welfare issue. Once removed from the poultry house, proper utilization and environmental protection become the greatest challenges associated with land-applied poultry litter. Land application of litter as a fertilizer requires access to specialized equipment or someone who has the specialized equipment. Adjustments in application rates will be necessary each year based on the nutrient content of the litter and soil test results. This will require regular litter nutrient analysis and soil testing. Farmers should be considerate of neighbors and the environment and manage litter applications to reduce odors and prevent overapplication of nutrients.

Over-application of litter can result in nutrient buildup in the soil, especially where P is concerned, and can enrich surface waters with nutrients that degrade both local and distant receiving waters (Hawkins and Walker, 2018). Do not apply litter to frozen, snow-covered or saturated soils or to steep (> 20 percent) slopes. Avoid litter applications during or immediately prior to precipitation events capable of producing field runoff approximately ¼-inch plus rainfall). Delay litter application if precipitation is likely within 24 hours of the planned application time period (greater than or equal to 50 percent precipitation chance based on local weather forecast) (Hawkins and Walker, 2018).

Despite the challenges, when managed properly, **poultry litter is a valuable asset** to Tennessee farmers, offering a cost-effective and nutrient-rich alternative to high-priced commercial fertilizer. In addition, the benefits of land-applying poultry litter extend beyond the nutrient needs of the crop by positively impacting soil health, advancing sustainable agricultural practices and leading to a more circular bioeconomy. Poultry litter application supports sustainable crop and forage production across Tennessee by providing a steady supply of macro and micronutrients plus beneficial organic matter to Tennessee soils.

Online Resources

University of Tennessee Extension litter land application worksheet: https://tiny.utk.edu/W796

University of Georgia Poultry411 App-Minimum Ventilation Calculator app: play.google.com/store/apps/details?id=com.ugacaes.poultry411&hl=en_US

Mississippi State University Chemical Laboratory sample submittal form: mscl.msstate.edu/sites/www.mscl.msstate.edu/files/inline-files/F-004%20Sample%20Submission%20Form%20%26%20Limitations%20Form%201.4.xlsx.pdf

University of Arkansas Agricultural Diagnostic Laboratory manure for fertilizer value information sheet: bpb-us-e1.wpmucdn.com/wordpressua.uark.edu/dist/3/599/files/2024/07/AGRI-429.pdf

Waypoint Analytical manure sample submittal form: waypointanalytical.com/Docs/samplesubmittalforms/WaypointManureInformationSheet-Tennessee.pdf

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