Summary of Ammonia and Particulate Matter Emission Factors for Poultry Operations

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Primary Audience: Regulatory Agencies and Policy Makers, Researchers, Poultry Facility Operators, Air Quality Modelers

SUMMARY

Limited data on pollutant emissions from poultry operations are available to assess the effect of these operations on the environment and to put their contribution in perspective with other sources of pollutants. To alleviate this problem, numerous studies at various poultry facilities have been undertaken to improve the knowledge base in quantifying emissions of NH_3 and size-fractionated particulate matter (PM). For these emission data to be of practical use for government agencies and policy makers, the emission rates must be reported as an emission factor with a production unit that enables the emissions from one poultry operation to be correlated to another poultry operation. This paper presents a compilation of NH_3 and PM emission data from several studies in the form of emission factor on a per-500 kg of live weight or animal unit basis. In addition, best management practices that lower pollutant emissions from poultry operations have been reported along with their effectiveness at reducing NH_3 and PM. Unfortunately, the compiled data were insufficient to characterize the variability in emissions caused by differences in house design, suggesting that more studies are needed to complete a comprehensive emission inventory. Once complete, this inventory will enable poultry producers to estimate emissions from their facilities and, if necessary, select management practice(s) to lessen their emissions of NH_3, PM, or both.

Key words: broiler, layer, turkey, ammonia, particulate matter, emission factor, best management practice

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DESCRIPTION OF PROBLEM

Government agencies and research groups have initiated programs aimed at improving the understanding of pollutants released from smaller area sources such as livestock housing operations. Livestock housing is believed to contribute significantly to regional air pollution by emissions of NH_3 and particulate matter. In many regions, particularly those in North America, concentrated animal feeding operations are exempt from environmental regulations that industrial sources fall under. As a result, the emissions from animal housing operations are poorly characterized and often estimated by extrapolating emission factor (**EF**) data from limited data sets.

One type of animal housing that has relied heavily on extrapolated EF is the commercial poultry sector. In many North America jurisdic-

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tions, a single EF for a given pollutant has been used to describe the emissions from all types of poultry production. For this reason, several research groups have placed a higher priority on improving EF for poultry over other types of livestock housing.

The production of poultry results in the release of several pollutants to the atmosphere, although most research has focused on NH_3 and particulate matter (**PM**) emissions because of their detrimental effects to human health and the environment. Each type of poultry operation generates different amounts of these contaminants, and their emission rates are further confounded by the different house management and operation practices. Information on the emissions of NH_3 and PM from different types of poultry production is currently available, but the various findings need to be summarized by translating them into a comparable EF format using a consistent production unit.

This compilation of comparable EF will allow any knowledge gaps to be identified that may warrant additional measurement studies. A comprehensive set of emissions data will also enable individual poultry producers to select the most appropriate EF to estimate the target pollutant emissions from their specific facility. Government agencies can benefit from these data by developing more comprehensive inventories of NH_3 and PM releases. However, for policy makers to truly benefit from these data, they must be educated with additional information on mitigation techniques aimed at lessening the effect on air quality.

Various research groups have been investigating several innovative best management practices (**BMP**) for poultry facilities to reduce their effects on both the indoor and outdoor environments. For these BMP to be useful for poultry producers and government agencies, their potential to reduce the emission of a target pollutant must be reported for each type of poultry operation and house design. This information would enable policy makers to begin coordinating with poultry producers to work toward feasible pollutant reduction programs. Although this summary only investigates the potential pollutant reductions of the BMP, additional considerations, such as capital costs, availability, and maintenance costs of the BMP, need to be assessed before wide-scale implementation.

The objectives of the paper are to report the NH_3 and PM EF for various types of poultry operations and house configurations, which can be used to determine whether or not the variability in emissions has been fully characterized. The paper also describes several BMP along with their potential effectiveness at reducing NH_3, PM, or both, emissions that will provide an indication of the current knowledge gaps in this area.

EMISSION FACTORS

An EF production unit or activity level is usually selected at the discretion of the individual(s) reporting its value. In regards to poultry production, EF are commonly expressed with units of per house, per 1,000 birds, per animal unit (**AU**; equivalent to 500 kg of live weight), or per heat-producing unit [1]. Because this summary addresses all sectors of the poultry industry, the AU basis is most appropriate for comparison between different housing systems and bird weights.

For studies that do not provide the necessary information to convert their reported emissions to an EF on an AU basis, the following information provided by the NFPC [2] for typical poultry production was assumed as default for the industry:

- For broiler chickens, an average of 40,000 birds per house is raised in a single production cycle that lasts 45 d with 2 wk allotted after each flock to clean and disinfect the house. This equates to 6 production cycles annually. Considering the length of a production cycle, the average weight of a broiler (including both male and female statistics) is 1.56 kg per bird.
- Layer chicken facilities operate continuously throughout the year with an average of 20,000 birds in the poultry house. The average weight of a layer is 1.58 kg per bird.
- Turkeys are raised in a similar manner to broiler chickens with an average of 6,000 turkeys per house in a single production cycle lasting 20 wk. On average, turkey facilities are empty for 4 wk per year for biosecurity reasons. Given this time frame, only 2

complete flocks are raised annually with a third underway. During a growth cycle, the average weight of a turkey is 6.3 kg assuming an equal ratio of male and female birds.

It should be noted that these statistics are most appropriate for the Canadian poultry industry and may not reflect common practices in other jurisdictions such as the United States. Studies requiring the default statistics for conversion to an AU basis EF have been identified in Tables 1 and 2.

NH_3 Emissions

Ammonia emission factors, based on equivalent 500 kg of live weight AU, are summarized in Table 1. Ammonia emissions from poultry houses vary significantly based on the type of poultry operation, their climatological region, and the management practices used by the house operators. For this reason, the geographical location, type of ventilation, and manure management system were identified with the NH_3 EF summarized in Table 1.

The NH_3 EF for broiler production ranges, on an average basis, from 57 g/d per AU up to 391 g/d per AU, although most are consistently between 150 and 225 g/d per AU. This range of EF is only slightly higher than the 100 g/bird per year (equivalent to 118 g/d per AU using the NFPC [2] statistics) proposed by the US Environmental Protection Agency. The highest EF for this type of operation was developed by Wheeler et al. [3] and Lacey et al. [4] based on data from broiler houses in the United States (Kentucky and Pennsylvania and Texas, respectively). It is a common practice at commercial broiler facilities in most parts of the United States to reuse the floor litter for up to 3 or 4 bird-production cycles before replacing it with fresh bedding. In other regions, such as Canada and Europe, the litter is typically replaced after each production cycle. This manure management practice may explain the elevated NH_3 emissions in the United States. Because some inconsistencies in emissions still exists among the EF developed from the European studies using similar manure management practices, the ventilation system of the poultry house may be a better indicator of the EF variability. Only a few studies provide information on the type of ventilation system used at the studied facility, which is insufficient to confirm its influence on the emission of NH_3.

There is a large degree of spread in the developed EF for layer chickens, which range, on an average basis, from 64.8 g/d per AU up to 468 g/d per AU (or 724 g/d per AU if the variability in the Heber et al. [5] study is included). It is difficult to identify definitive reasons for some of the variability, because there is a variety of manure management systems used in egg production, and very little information is given on the type of ventilation system. Because NH_3 emissions typically result from the decomposition of poultry manure, layer operations that use a battery cage system with manure removal belts frequently generate less NH_3 emissions than those without a manure removal system (i.e., percheries and deep-pit systems). Once again, the United States studies consistently reported higher NH_3 EF for layer hens than those conducted in Europe.

Three studies have quantified the NH_3 emissions from turkey production, but 2 studies did not report the type of turkey operation. The NH_3 emissions from the unspecified turkey production (126 and 113 g/d per AU) are comparable to the grow-out turkey facility studied by Gay et al. [6] (120.5 g/d per AU). In addition, these EF are similar to those for broiler chickens on an AU basis. The brooder facility studied by Gay et al. [6] emitted much less NH_3 (7.2 g/d per AU). This EF may be misleading, because the emissions were measured for 2 d only with the turkeys being introduced to the facility shortly before the start of the measurement campaign. The turkeys may not have excreted enough fecal matter to generate representative EF.

Two studies reported NH_3 EF but neglected to include the type of poultry operation the study was based on. Hence, Table 1 includes these studies under a generalized poultry category.

PM Emissions

Several characteristics of PM can be used to describe its toxicity, including its size (or aerodynamic diameter, **AD**), origin, formation mechanisms, chemical composition, and pathogenicity. Becasuse the AD of a particle will determine if it is capable of penetrating deep into

Table 1. Ammonia emission factors (EF) developed for various types of poultry production, ventilation systems, and manure management systems

Type of operation	Country	Study	Ventilation type	House and manure system	EF (g/d per animal unit)
Broiler	England, the Netherlands, Denmark, Germany	Groot Koerkamp et al. [1][1]	Various	Litter floor	53 to 199
Broiler	Europe	Asman [19][1]	Not reported	Litter floor	77
Broiler	Europe	Van Der Hoek [20][1,2]	Not reported	Litter floor	178
Broiler	Ireland	Hyde et al. [21]	Not reported	Litter floor	150
Broiler	Germany	Oldenburg et al. [22][3]	Not reported	Litter floor	182
Broiler	Slovenia	Amon et al. [15]	Mechanically ventilated	Litter floor	14 to 194
Broiler	United Kingdom	Demmers et al. [23]	Chimney-ventilated	Litter floor	57.2
Broiler	United Kingdom	Misselbrook et al. [24]	Not reported	Litter floor	149
Broiler	United Kingdom	Phillips et al. [25][4]	Not reported	Litter floor	204 to 223
Broiler	United Kingdom	Sneath et al. [26][5]	Not reported	Litter floor	178
Broiler	United Kingdom	Wathes et al. [27][4,5]	Various	Litter floor	204 to 220
Broiler	United States (KY and PA)	Gates et al. [28]	Mechanically ventilated	Litter floor	~0 to 768
Broiler	United States (KY and PA)	Wheeler et al. [3]	Mechanically ventilated	Litter floor	390.7
Broiler	United States (TX)	Lacey et al. [4]	Tunnel-ventilated	Litter floor	307
Layer	England, the Netherlands, Denmark, Germany	Groot Koerkamp et al. [1]	Various	Batter cage	15 to 224
Layer	England, the Netherlands, Denmark, Germany	Groot Koerkamp et al. [1]	Various	Perchery, deep pit	177 to 261
Layer	Germany	Hartung and Phillips [29][1]	Various	Battery cage	72
Layer	United Kingdom	Nicholson et al. [30]	Mechanically ventilated	3-tier cage	64.8
Layer	United Kingdom	Nicholson et al. [30]	Pit ventilation	Deep pit	33.6 to 196.8
Layer	United Kingdom	Phillips et al. [25][4]	Not reported	Battery cage	168 to 295
Layer	United Kingdom	Phillips et al. [25][4]	Not reported	Perchery	192 to 240
Layer	United Kingdom	Wathes et al. [27][4]	Various	Deep pit	220
Layer	United States (IN)	Heber et al. [5]	(Mechanical) Pit ventilation	High-rise	468 ± 256
Layer	United States (IN)	Heber et al. [5]	(Mechanical) Pit ventilation	High-rise	342 ± 136
Layer	United States (IN)	Jacobson et al. [31]	Mechanically ventilated	High-rise	200 to 500
Turkey	Europe	Asman [19][1]	Not reported	—	126
Turkey	Europe	Van Der Hoek [29][1,2]	Not reported	—	113
Turkey (grow out)	United States (PA)	Gay et al. [6]	Naturally and mechanically ventilated	Litter floor	120.5
Turkey (brooder)	United States (PA)	Gay et al. [6]	Naturally and mechanically ventilated	2 rows, litter floor	7.2
Poultry	United Kingdom, the Netherlands, Europe	Sutton et al. [32][6]	Various	—	162 to 338
Poultry	United States	Battye et al. [33]	Not reported	—	243

[1]Emission factors used in the development of the EF of the US Environmental Protection Agency.
[2]Emission factors were developed using statistics from NFPC [2].
[3]Emission factors were developed by Amon et al. [15].
[4]Emission factors were developed by Atai et al. [14].
[5]Emission factors were developed by Lacey et al. [4].
[6]Assumes an average weight of 1.013 kg.

Table 2. Size-fractionated particulate matter emission factors (EF) for different types of poultry operations, ventilation systems, and manure management systems

Type of operation	Country	Study	Ventilation type	House and manure system	EF[1] (g/d per AU)				
					TSP	PM_{10}	RD	$PM_{2.5}$	PM_1
Broiler	Canada (Ontario)	Roumeliotis and Van Heyst [8]	Mechanically ventilated	Litter floor	—	5.79 ± 0.19	—	1.22 ± 0.05	0.99 ± 0.04
Broiler	Denmark, England, Germany, the Netherlands	Takai et al. [34]	Various	Litter floor	85.7	—	12.4	—	—
Broiler	The Netherlands	Van Der Hoek [35][2]	Various	Litter floor	—	1.9	—	—	—
Broiler	United Kingdom	Wathes et al. [27]	Various	Litter floor	120 to 204	—	14.4 to 20.4	—	—
Broiler	United States (TX)	Lacey et al. [4]	Tunnel-ventilated	Litter floor	245	12.9	—	—	—
Layer	Denmark, England, Germany, the Netherlands	Takai et al. [34]	Various	Battery cage	15.3	—	1.9	—	—
Layer	Denmark, England, the Netherlands	Takai et al. [34]	Various	Perchery	73.9	—	14.3	—	—
Layer	The Netherlands	Van Der Hoek [35][2]	Various	Cages, belt system	—	0.23	—	—	—
Layer	The Netherlands	Van Der Hoek [35][2]	Various	Litter floor	—	2.6	—	—	—
Layer	United Kingdom	Wathes et al. [36]	Various	Battery cage	21.6 to 52.8	—	1.8 to 6.2	—	—
Layer	United Kingdom	Wathes et al. [36]	Various	Perchery	20.4 to 33.6	—	4.1 to 5.3	—	—
Layer	United States (IN)	Jacobson et al. [31]	Mechanically ventilated	High-rise	—	2.0 to 10.0			
Layer	United States (IN)	Lim et al. [7]	Mechanically ventilated	Battery cage	63 ± 15	15 ± 3.4	—	1.1 ± 0.3	—
Turkey	The Netherlands	Van Der Hoek [35][2]	Various	Litter floor	—	9.3	—	—	—

[1]TSP = total suspended particulates; PM_{10} = particles with an aerodynamic diameter (AD) equal to or smaller than 10 μm; RD = respirable dust; $PM_{2.5}$ = particles with AD equal to or smaller than 2.5 μm; PM_1 = particles with AD equal to or smaller than 1 μm.
[2]Emission factors were developed from a compilation of emission data from other studies and were converted to a per-animal unit (AU) basis using statistics from NFPC [2].

the human respiratory-cardiopulmonary system, it is the most commonly used particle classification scheme. In the past, particles have been divided into 3 size classifications: total suspended particulates, those capable of entering the respiratory tract (or particles with an AD equal to or smaller than 10 μm, **PM_{10}**), and respirable dust (**RD**; equivalent to 5 μm or less). More recently, 2 additional particle sizes have been introduced to better describe the toxic effects of PM, specifically particles with AD equal to or smaller than 2.5 and 1 μm (**$PM_{2.5}$** and **PM_1**, respectively). Limited research has been conducted at poultry facilities to quantify the emissions of the latter 2 particle size classifications, and as such, the developed EF may not accurately represent the average PM emissions from typical poultry houses. The size-fractionated PM EF from several studies, given in Table 2, have been divided into the type of poultry operation and their location.

The amount of total suspended particulates emitted on an AU basis by broiler chickens (170.2 g/d per AU on average) is significantly greater than that released by layer chickens (42.8 g/d per AU on average). However, the PM_{10} emissions from both types of operations, as well as turkey production, are all within the range of 0.23 to 15.8 g/d per AU, which implies that a large portion of the total suspended particles are in the larger size fraction. Possible sources for the coarser particles are mechanical generation by the poultry, the manure management systems, and the feed delivery systems. Contrary to the fairly consistent PM_{10} EF reported for all types of poultry facilities, the RD EF are larger for broiler operations than all types of layer operations. In fact, the RD emissions, a smaller size fraction than PM_{10}, from broiler houses are greater than the measured PM_{10} emissions from similar houses. Given that the studies reporting RD emissions were conducted 5 yr earlier than those reporting PM_{10} emissions, it is possible that the instrumentation used to quantify the PM emission rates have improved the EF estimates. Advancements in PM measurement technologies have enhanced the on-site and semicontinuous quantification capabilities of the instruments, which has eliminated the inherent errors associated with sample transport and laboratory analysis.

Since recognizing the importance of the 2 fine PM size classifications, only 2 studies have generated poultry house EF for $PM_{2.5}$. The 2 studies, one at a layer facility [7] and the other at a broiler house [8], reported similar $PM_{2.5}$ EF on a live weight basis. The mean $PM_{2.5}$ release for both types of operations is slightly greater than 1 g/d per AU. The broiler house study is the only one to report a PM_1 EF, which was estimated to be slightly less than 1 g/d per AU. The nearly equivalent $PM_{2.5}$ and PM_1 EF reported indicates that the fine fraction of PM emitted from poultry operations is mostly comprised of submicron particles. However, this conclusion is not definitive, because it is difficult to gauge variability within the poultry sector with only 1 PM_1 EF.

BEST MANAGEMENT PRACTICES

There have been numerous strategies proposed to reduce NH_3 and PM emissions from confined animal housing operations. The 4 main groupings of BMP and control methods are oil spraying, litter amendments, feed additives, and electrostatic precipitators. Each category of BMP has been investigated at both commercial broiler and layer houses by 1 or more research groups, and their results, in terms of percentage of reduction in NH_3 and PM emissions, are given in Table 3. Note that studies have not considered the different size fractionations of PM, and consequently, Table 3 reports all PM size classifications as a collective grouping. Also, in some instances, the focus of the research group was placed on reducing the indoor levels of a pollutant, so only the percentage of reduction in its concentration was reported rather than its emission. It was therefore necessary to assume that a decrease in concentration would translate to the same decrease in emissions to the atmosphere.

Oil Spraying

Oil spraying is primarily used to lower the PM concentrations in the house by causing the fine particles in the litter to conglomerate into larger particles. Some researchers, however, have begun demonstrating promising results for decreasing the volatilization of NH_3 as well [9]. Unfortunately, no studies have reported a percentage of reduction for NH_3 emissions for poultry operations.

Table 3. Percentage of reduction in NH_3 and particulate matter (PM) emissions using various best management practices (BMP) at different types of poultry operations

Type of operation	BMP	Study	NH_3 reduction (%)	PM reduction (%)	Notes
Broiler breeder	Electrostatic precipitation	Mitchell et al. [17][1]	56	60	Space charge system
Broiler	Feed additive	Amon et al. [15]	8	—	2% clinoptilolite additive
Broiler	Litter amendment	Amon et al. [15]	15 to 35	—	5 kg/m^2 of clinoptilolite
Broiler	Oil spraying	Ellen et al. [10]	—	12	Water-3% rapeseed oil solution
Layer	Electrostatic precipitation	Gast et al. [18][1]	—	36.6 to 65.6	Negative air ionization
Layer	Litter amendment	Wilson [37][1]	71	—	Liquid aluminum sulfate
Layer	Litter amendment	Li et al. [13]	63 to 94	—	Liquid aluminum sulfate
Layer	Litter amendment	Li et al.[13]	74 to 92	—	Poultry litter treatment
Layer	Oil spraying	Ikeguchi [11][1]	—	42 to 49	2% emulsified canola oil solution
Layer	Oil spraying	von Wachenfelt [12][1]	—	50	10% oil with water
Poultry (not specific)	Feed additive	McCubbin et al. [16]	10.0 to 25.0	—	Protein reduction technique
Poultry (not specific)	Litter amendment	McCubbin et al. [16]	25.0 to 70.0	—	Aluminum sulfate
Poultry litter	Litter amendment	Atai et al. [14]	99	—	Aluminum sulfate (laboratory-scale test)

[1]Reported by Patterson and Adrizal [9].

In general, the oil solutions are not purely oil but a mixture consisting of a low percentage of oil in water. Researchers have tested different types of vegetable oil at various levels of dilution, which has resulted in inconsistent findings. Another possible reason for the inconsistencies in the reduction potential is the method of applying the oil solution. Oil can be applied by automated sprinkler systems, manual sprayers, ultrasonic sprayer, or foggers [9, 10]. Each method will produce a different mean diameter of the oil droplets, which will affect its efficacy to conglomerate fine particulates as well as the distribution of the oil on the litter. Patterson and Adrizal [9] recommend a mean droplet size of approximately 150 μm to obtain the most effective oil application.

Only 1 study has applied this type of BMP at a broiler house [10]. The oil solution consisted of 3% rapeseed oil in water, which caused a 12% decrease in PM concentrations. However, it should be noted that the control for this experiment was another broiler house using water spraying on the litter. The application of water to broiler litter may be able to reduce PM releases slightly, because it may cause some particles to conglomerate, just to a lesser extent than oil spraying. Two studies have tested different mixtures of vegetable oil (2% emulsified canola oil in water and 10% vegetable oil in water) at layer operations [11, 12]. Ikeguchi [11] utilized an ultrasonic sprayer to apply the 2% emulsified canola oil solution and was able to achieve an emission reduction for various size fractionations of PM between 42 and 49%. Von Wachenfelt [12] applied the 10% vegetable oil mixture and achieved a 50% reduction in PM. Although the 2 researched layer facilities demonstrated promising results, they are inconsistent with the studied broiler facility.

Ultimately, this BMP needs to be further investigated to generalize its overall effectiveness for size-fractionated PM and NH_3 at different types of poultry facilities. A standardized oil, application rate, application method, and oil:water ratio is also necessary to better estimate its pollutant reduction efficiency.

Litter Amendment

A variety of litter amendments exist that target reductions in NH_3 emissions from poultry litter rather than PM emissions. For all types of amendments, their intent is to lower the litter pH, which effectively inhibits the generation of NH_3. In the United States, poultry litter treatment (**PLT**) is becoming the most commonly used litter amendment. It is a dry granular mixture of primarily sodium bisulfate and other compounds, which lower the litter pH [13]. Application rates of PLT ranging from 0.5 to 1.5 kg/m^2 in layer facilities have demonstrated an NH_3 reduction potential of 74 to 92% [13].

The addition of aluminum sulfate is the most commonly used means to acidify litter, and its effectiveness has been investigated at a few poultry operations as well as on litter in a controlled laboratory-scale study [14]. The reduction in NH_3 can vary between 25 and 94% at commercial facilities, although the laboratory-scale study suggests that the volatilization of NH_3 from litter can be nearly entirely eliminated with the addition of aluminum sulfate. Amon et al. [15] report the only findings for a litter amendment at a broiler house. This makes it difficult to assess whether its relative ineffectiveness (15 to 35% NH_3 reduction) is a result of the chemical used or an undetermined distinctive factor in the broiler house environment.

Overall, these preliminary studies suggest that litter amendments can substantially lessen the NH_3 emissions from various types of poultry operations and, in particular, layer facilities. Given the success of litter amendments, it would be of interest to examine whether litter amendments were capable of effectively lowering PM releases as well. Particulate matter reduction is a possibility with this BMP, because liquid applications will agglomerate some of the particulates within the litter matrix and thus prevent them from becoming entrained in the poultry house air.

Feed Additives

Feed additives are primarily intended to alter the diet of a bird to improve their uptake of N so the amount being excreted is reduced, which in turn, lowers the quantity capable of being converted to NH_3 in the litter. Some other feed additives have been investigated that focus on a different aspect of NH_3 release, and a few have been aimed at reducing PM emissions at the feed delivery stage. Ultimately, though, feed additives are relatively ineffective at reducing NH_3, and no studies have reported on their ability to inhibit the release of PM.

Amon et al. [15] applied a 2% by weight clinoptilolite to the feed ration at a broiler facility. The NH_3 emissions from the broiler house were reduced by 8% using this feed additive. McCubbin et al. [16] focused on altering the protein levels in poultry feed to reduce the amount of N excreted by the birds. These authors stressed the importance of lessening the overall protein content without disrupting typical bird growth and egg production. To achieve the desired protein levels, only the essential amino acids were added to the feed. With this feed formulation, McCubbin et al. [16] suggested that an overall decrease of 10 to 25% in NH_3 concentration was achievable for poultry operations in general.

Feed additives are less effective at lowering NH_3 emissions than other BMP but are becoming increasingly popular, because they are easy to incorporate into a poultry house with no additional labor. Although other BMP may only delay the NH_3 emission to the time of field application of the manure, feed additives essentially remove a portion of N permanently from the waste stream and thus contribute to reducing the NH_3 emissions from the whole farm system. There is, however, some uncertainty in the reduction potential of PM emissions of feed additives.

Electrostatic Precipitators

Unlike the previous management practices that inhibit the release of target pollutants, electrostatic precipitators are a control technology used to reduce already airborne particulates and gaseous NH_3. These devices provide a negative charge to aerosols, which results in their precipitation onto grounded surfaces [9]. It is somewhat unclear as to how the electrostatic precipitators are able to efficiently reduce NH_3 emissions, although it is possible that positively charged ammonium ions condense to surrounding particles and settle with the aerosol.

Different variations of electrostatic precipitators have generated high PM and NH_3 reduction efficiencies. Electrostatic space charge systems consist of an enclosed space with several grounded trays. Particles exiting a poultry facility pass through the enclosed space and are given a strong negative charge, causing them to collect on the grounded trays [17]. In a broiler breeder facility, electrostatic precipitators were capable of reducing NH_3 and PM emissions by 56 and 60%, respectively [17].

Gast et al. [18] installed negative air ionizers inside environmental isolation chambers to charge particles being exhausted from a layer house. Similar to the space charger, the charged particles precipitate onto grounded surfaces. Using this technology, PM emissions from a layer operation were decreased by 36.6 to 65.6%. Unfortunately, gaseous NH_3 was not considered in this study. Overall, the performance of the electrostatic precipitators in these 2 studies suggests that this control technology is capable of effectively reducing both NH_3 and PM emissions.

CONCLUSIONS AND APPLICATIONS

1. The NH_3 and PM EF developed from the various studies were inconsistent, even within a particular sector of poultry production. It is likely that the local climate of a poultry house as well as its type of ventilation and manure management systems could account for this variability, but more studies are needed to determine the extent of the variations caused by each of these housing parameters.
2. Before government agencies begin introducing policies and regulations for any type of livestock operation, they must ensure that the current inventories are based on scientifically defensible measurements of both size-fractionated PM and NH_3 that are typical of the practices in their jurisdictions. This information will only become available to policy makers once more extensive emission quantification studies are completed.
3. The BMP presented in this paper were given to provide an initial assessment of their ability to reduce NH_3, PM, or both, emissions. Based on the preliminary findings, electrostatic precipitators are the most effective management practices at reducing both the PM and NH_3 emissions. However, oil spraying and the addition of PLT or aluminum sulfate to litter are also relatively effective BMP for selective pollutants (PM and NH_3, respectively). Further studies are required, however, to assess the reduction potentials along with an economic analysis. Although more research is required, concentrated animal feeding operation producers, government agencies, or both, may wish to consider one or more of these BMP to mitigate the release of either NH_3 or PM.

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