March 10, 2023

Dust Generations, Impacts, and Control Strategies in Poultry Houses

Lilong Chai
Department of Poultry Science, University of Georgia, Athens, GA, 30602

Introduction

Animal feeding operations are important sources of air pollutant emissions into the environment. The primary air emissions include particulate matter (PM) and other gases like greenhouse gases and ammonia (NH_3), as these gases pose a high potential risk to air quality, public and animal health, and climate change. Among these air pollutants, PM is considered one of the harmful air pollutants within and outside of animal houses because of its composition and emission rates at the animal and local levels. According to WHO (World Health Organization), fine PM (especially size ≤ 2.5 microns or $PM_{2.5}$) causes 4.2 million premature deaths worldwide per year. Moreover, the fine PM generated in the environment is the main source of haze in some parts of the United States. In addition, depending on dust composition, settling down may cause lakes or streams to be acidic, reduce soil nutrients, and contribute to acid rain formation. According to Europe Environmental Agency, poultry and pig housings contributed approximately 50% & 30% of $PM_{2.5}$ (PM with aerodynamic diameter ≤2.5 μm) and 57% & 32% of PM_{10} (PM with aerodynamic diameter ≤10 μm) emissions, respectively. For poultry production, cage-free systems tend to have higher dust concentrations (Figure 1), which have negative impact on the health and welfare of animals and their caretakers (Table 1).

Figure 1. Dust in cage-free layer houses (photo credit: UEP).

Table 1. Effects of different PM sizes on health, behavior, and welfare of caretakers.

PM sizes/ types	Effects of PM on health, behavior, and welfare
$PM_{2.5}$	Greater risk to human health
$PM_{2.5}$	Damage human alveolar epithelial cells (A549 cells) and cause an inflammatory response
$PM_{2.5}$ (long-term exposure)	Increases the risk of cardiopulmonary mortality
$PM_{2.5}$ (10,000 mg/m^3)	24% increase in cardiovascular events and a 76% increase in mortality
PM_{10}	Premature death in humans with heart or lung disease Nonfatal heart attacks, irregular heartbeats, aggravated asthma, decreased lung function, irritation of the airways, coughing or difficulty breathing
PM_{10} (With endotoxin)	It affects the respiratory system, liver, kidneys, and nervous system and may even enter the bloodstream
PM_{10}	Respiratory problems Increase mortality and morbidity rates
PM_{10} (High concentration)	Chronic bronchitis, asthma-like symptoms, cardiovascular disease, lung cancer, COPD, and pneumonia lesions.
PM_{10} (every ↑ in 7000 mg/m^3)	33 % increase in COPD incidence
TSP	Higher asthmatic (42.5%) and nasal (51.1%) symptoms
TSP	Over-shift increase in respiratory symptoms and a decrease in pulmonary function tests were found. It causes harmful effects on the bronchi
PM >0.1 mg/m^3	Coughing, chronic phlegm, and bronchitis
Organic dust	Acute inflammation and chronic bronchitis

Note: PM2.5 - PM diameters that are generally ≤ 2.5 micrometers; PM10 - PM diameters that are generally ≤ 10 micrometers; TSP – total suspended particles.

Dust emissions from poultry farms are affected by various factors and changes according to variable climatic conditions, applied management practices, the number of birds, and housing types. Various researcher has explained many factors that cause PM emission, as shown in Table 1 and **Figure 2**.

Table 2. Particulate matter composition varies with different housing system.

Sources	PM type	PM constitute
Broilers	TSP	50% excreta, 30% litter, 15% Feed, and 5% feathers
Broilers	TSP	Feathers, skin, bacteria, fungus, fecal matter, spilled feed, mold spores, and bedding fragments
Broilers	$PM_{2.5}$ PM_{10}	72.1% Manure, 21.3% Feathers, 5.8% wood shaving, and 0.7% ambient PM 95.6% Manure and 4.4% Feathers
Layers	$PM_{2.5}$ PM_{10}	63.7% Manure and 36.3% Feathers 69.6% Manure, 30.0% feathers, and 0.4% ambient PM
Layers	$PM_{2.5}$ PM_{10}	54.2% Manure, 23.2% feed, 17.0% Feathers, and 5.5% ambient PM 85.5% Manure and 14.5% feathers
Turkey	$PM_{2.5}$ PM_{10}	39.1% Feathers, 34.8% Manure, 26.1% wood shavings, and 0.1% ambient PM 51.9% Manure, 25.1% Feathers, and 22.9% wood shavings
Poultry	TSP	Organic and inorganic particles: excreta, feathers, mites, dander, bacteria, fungi, fungal spores, and endotoxins
Poultry	TSP	90% organic composition like a feather, feeds, urine mineral crystal, manure, and bedding materials
Poultry	TSP	Bedding materials and floor
Poultry	TSP	Feed, excreta, hair, and dander

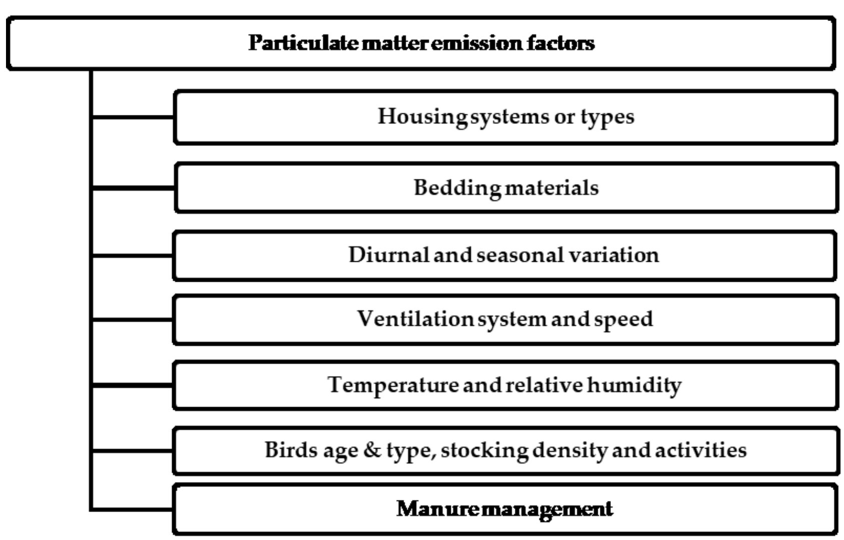

Figure 2. Factors affecting PM emissions in poultry housing.

The PM concentration in poultry housing is primarily affected by housing & feeding, animal species, stocking density, lighting duration, environment conditions (season), and existing mitigation practices. It is important to possess a deep knowledge of PM morphology to evaluate their effects and propose the best mitigating technologies in animal housing. Particulate matter mitigating strategies can be classified into three different groups: dilution & effective room air distribution, source-control techniques to reduce PM from the source, and PM removal or cleaning techniques by using acid scrubbers, electrostatic precipitators, or ionizers. Other techniques for improving air quality are oil spraying, manure handling, and electrolyzed water spray. Controlling the living space environment, including temperature, humidity, air quality, and litter quality, is critical for poultry well-being. Variations in indoor air quality have been linked to various factors, including barn architecture, manure management, animal densities, feed regimens, building ventilation, and farm management practices. Therefore, various biochemical, chemical, managerial, physical, and physiological practices must be implemented to decrease PM significantly lower than recommended guidelines.

Electrostatic ionization technique has been used to lower PM levels in AFOs. Recently, attempts have been made to employ the technology in animal housing conditions, and several studies have demonstrated the efficiency of this control technique in lowering airborne PM and bacteria. For example, Mitchell and Waltman (2003) tested an electrostatic charging system (ESCS; -30 K Vdc and 0.2 mA) in the hatching cabinet and reduced dust from 77-79%. Similarly, ESCS decreased Enterobacteriaceae and salmonella bacteria in the air from 93-96% and 33-83%, respectively. Furthermore, recent research used the prototype electrostatic precipitator (ESP) technique in different ventilation or weather condition (hot, warm, & cold weather) and found $PM_{2.5}$ and PM_{10} reductions up to 97.8% and 99.0%, respectively. Therefore, various research on electrostatic ionization has shown PM and airborne bacteria reduction up to 94 and 96%, respectively

Summary

PM emissions depend on various factors and changes according to climatic conditions, housing type, applied manure management strategies, ventilation system, temperature & relative humidity, bird numbers, and bedding materials used. The factors that release significantly high PM levels must be managed and decreased to preserve and improve the environment, human and animal health, and welfare. Several studies have shown significant PM reduction by applying biochemical, chemical, managerial, physical, and physiological practices, which can be managing housing system & cleaning, light intensity, oil and water spraying, filtration & biofiltration, acid scrubber, bedding materials, and electrostatic ionization. Single or integrated mitigation has shown significant PM reduction in the past. Future research must be implemented by including integrated mitigating strategies to obtain much better results to improve air quality in poultry houses and enhance caretakers' and birds' health. In addition, mitigation strategies could be cost prohibitive and have side effects. For instance, acid scrubber has up to 95% efficiency in mitigating both dust and NH_3, but the cost for installing the system is a primary barrier; the water spray has a lower cost in controlling PM generations in poultry houses, but the increased NH_3 should be considered in quantifying the mitigation efficiency and costs. Additional strategies such as litter additives and new bedding will be needed for NH_3 control if water spray resulted in higher NH_3 generations. Therefore, poultry farms should select mitigation strategies based on a number of considerations such as farm location, climate conditions, environmental policies, and available resources (assistance programs).

Further reading:

Bist, R. B., & Chai, L. (2022). Advanced Strategies for Mitigating Particulate Matter Generations in Poultry Houses. Applied Sciences, 12(22), 11323. https://doi.org/10.3390/app122211323