



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; SP-9(1): 434-439
Received: 17-10-2025
Accepted: 20-11-2025

Mahapatra M
Professor and OIC, AICRP on
ESAAS, Department of FMPE,
College of Agriculture Engineering
and Technology, OUAT,
Bhubaneswar, Odisha, India

Mhatre CS
Ph.D., Scholar, Department of
FMPE, College of Agriculture
Engineering and Technology, OUAT,
Bhubaneswar and Scientist, ICAR
CIWA, Bhubaneswar, Odisha, India

Swain P
Animal Scientist AICRP on MAH,
OUAT, Bhubaneswar, Odisha, India

Sahoo R
SRF, Directorate of Research,
OUAT, Bhubaneswar, Odisha, India

Behera A
Assistant Professor and OIC AICRP
on MAH, Department of FMPE,
College of Agriculture Engineering
and Technology, OUAT,
Bhubaneswar, Odisha, India

Behera S
B. Tech Student, College of
Agriculture Engineering and
Technology, OUAT, Bhubaneswar,
Odisha, India

Basa SK
B. Tech Student, College of
Agriculture Engineering and
Technology, OUAT, Bhubaneswar,
Odisha, India

Parida OP
B. Tech Student, College of
Agriculture Engineering and
Technology, OUAT, Bhubaneswar,
Odisha, India

Corresponding Author:
Mhatre CS
Ph.D., Scholar, Department of
FMPE, College of Agriculture
Engineering and Technology, OUAT,
Bhubaneswar and Scientist, ICAR
CIWA, Bhubaneswar, Odisha, India

Dust analysis in poultry litter management: Worker impact and mitigation strategies

Mahapatra M, Mhatre CS, Swain P, Sahoo R, Behera A, Behera S, Basa SK and Parida OP

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i1Sf.4780>

Abstract

Poultry litter, a mixture of manure, bedding materials, feathers, and spilled feed, requires careful management to prevent environmental hazards such as water and air pollution, ammonia emissions, and pathogen spread. India generates approximately 3.30 million tonnes of poultry manure annually, sufficient to fertilize about 3.56 million hectares of farmland. In Odisha alone, the poultry population during 2020–21 included about 8.7 million commercial layer chickens and 6 million broilers, underscoring the scale of litter management required. Litter agitation, the process of stirring or loosening bedding mixed with manure, is essential to control moisture, reduce ammonia buildup, and prevent caking. But this litter agitation raises dust of various particle sizes in the workplace atmosphere. This dust leads to different level of health hazards. This study evaluated three common litter agitation methods—by foot, by hand rake, and by mechanical means—focusing on dust issues and its ergonomic implications for poultry workers. Dust exposure was quantified through three replications, with particle size distribution and settlement times recorded. The total particle density ($\mu\text{g}/\text{m}^3$) for initial condition was Results showed that all methods increased dust density compared to baseline, with mechanical agitation producing the highest levels and foot agitation the least. Fine particles (PM_{2.5}) required up to nine minutes to settle, compared to two minutes for PM₁₀, indicating prolonged inhalation risks.

Keywords: Poultry litter management, litter agitation methods, dust exposure, ergonomic hazards

Introduction

Poultry farming relies on a variety of litter materials to maintain bird health, welfare, and overall production efficiency, providing both comfort and hygiene for poultry populations. But the same litter, if not managed properly, leads to occupational health hazards due to exposure to dust. The dust in these environments is composed of a complex mixture of particles originating from multiple sources: bird feed, excrement, feathers, bedding or litter material, mould spores, and microbial contaminants. (Santos *et al.*, 2021) ^[16] This particulate matter, especially at high concentrations, significantly compromises air quality within poultry houses, posing substantial respiratory and dermal health risks to workers (Santos *et al.*, 2021) ^[17]. Consequently, understanding the composition, generation, and dispersion of poultry dust is crucial for developing effective mitigation strategies aimed at safeguarding worker well-being and ensuring sustainable poultry operations (Ahaduzzaman *et al.*, 2021) ^[1] (Bist & Chai, 2022) ^[2, 4].

Literature Review

Understanding the specific sources and characteristics of dust within poultry environments is fundamental to devising targeted control measures. Research indicates that the primary contributors to dust generation are the birds themselves and their excrements, with various housing systems influencing the specific dust sources and their chemical compounds (Ellen *et al.*, 2000) ^[5]. For instance, cage-free housing, while offering welfare benefits, often exacerbates particulate matter and ammonia levels due to increased bird activity and direct contact with litter (Chai *et al.*, 2019) ^[4] (Bordignon *et al.*, 2025) ^[3]. The constant movement of poultry, such as pecking, scratching, and wing flapping, directly contributes to the resuspension of settled dust particles and the fragmentation of litter components, thereby increasing airborne concentrations

(Yang *et al.*, 2024) ^[21].

Litter agitation is the process of stirring or breaking up poultry litter composed of bedding material and manure within a poultry house to improve its condition. This practice helps control moisture, reduce ammonia buildup, and prevent the formation of compacted or caked areas. By aerating the litter, it promotes drying, reduces the growth of harmful bacteria and parasites, and enhances overall air quality and bird health. Litter agitation can be done manually using tools like rakes or mechanically with equipment such as rotary tillers, and it is typically performed during or between flock cycles to maintain a clean, dry, and healthy environment for poultry. However, while litter agitation offers significant benefits for poultry health and environmental control, it simultaneously poses a substantial challenge by increasing the generation and dispersion of airborne dust, thereby intensifying occupational exposure risks for poultry workers. This heightened dust concentration necessitates a thorough analysis to quantify the specific components and assess their implications for worker respiratory health.

Dust in poultry farms can be categorized based on particle size. Respirable dust includes particles that are 5 micrometres (μm) or smaller, which can reach deep into the lungs. Inhalable dust consists of particles up to 100 μm in size, capable of entering the nose and upper respiratory tract. Total dust refers to all airborne particles regardless of their size. Conversely, particulate matter larger than 100 μm is generally too heavy to remain airborne for extended periods, settling rapidly and thus posing a lower inhalation risk but contributing to surface contamination.

The size of dust particles is measured in micrometres (μm), while the concentration is expressed as milligrams or micrograms per cubic meter of air (mg/m^3 or $\mu\text{g}/\text{m}^3$). Common sources of dust in poultry farms include feather and skin dander, feed particles, manure and litter particles, bedding materials, and dry faecal matter. Several tools are used to measure dust in poultry environments.

Dust particles are also classified into standard size categories. PM10 refers to particulate matter with a diameter of 10 μm or less, while PM2.5 includes finer particles with a diameter of 2.5 μm or less. These classifications help assess the potential health risks and guide air quality management practices in poultry farms. Furthermore, recent advancements in Internet of Things monitoring systems offer continuous, high-resolution data collection, enabling a dynamic and comprehensive assessment of dust concentrations and environmental gradients within poultry barns (Bordignon *et al.*, 2025) ^[3]. Such systems facilitate real-time identification of dust hot spots and periods of elevated concentration, providing crucial insights for targeted intervention strategies.

Gravimetric samplers collect dust on filters which are weighed before and after sampling. Real-time dust monitors, utilized by

occupational hygienists, provide instantaneous data for tasks such as walkthrough surveys, background sampling, and assessing the efficacy of dust control systems (Walsh *et al.*, 2009) ^[19].

Methodology

Litter agitation involves stirring, turning, or breaking up the litter to maintain its quality. Here's a simple way to classify these types:

- Hand agitation involves using tools such as a rake, hoe, shovel, or stick to scrape or fluff up caked litter. This method is commonly employed in small farms or rural settings where automated systems may not be available. Its primary advantages are its low cost and the absence of a power source, making it accessible for farms with limited resources. (Naik *et al.*, 2023) ^[13] However, it is labor-intensive, requires significant manual effort, and is less effective for managing deep litter, as reaching the lower layers for proper aeration can be challenging.
- Foot Agitation: This technique involves disturbing or aerating the poultry litter by foot, typically during worker movement within the poultry house. It is frequently employed in small-scale or domestic poultry operations where specialized equipment may be unavailable. The primary objective of foot agitation is to loosen the litter, thereby preventing the formation of compacted layers. Its principal benefit lies in its inherent simplicity, requiring no specialized tools and minimal exertion. However, a significant limitation is its superficial impact, as it only disrupts the uppermost layers of the litter. Consequently, this method is unsuitable for extensive areas or deep litter systems due to its insufficient depth and limited efficacy in achieving thorough aeration or comprehensive litter management.
- Mechanical agitation, commonly employed in medium to large-scale commercial poultry operations, utilizes machinery such as litter rotavators, tillers, or skid-steer loaders to disrupt and aerate poultry litter. This method is crucial for comprehensive litter management, as it enables the deep and uniform agitation necessary for effective moisture regulation and ammonia reduction across the entire housing facility. A significant advantage of mechanical agitation is its efficiency, as it is time-saving and highly effective for deep litter systems, thereby substantially improving litter quality and avian health. However, its primary limitation is the substantial cost associated with the equipment and the requisite fuel or electrical power, which can render it less accessible for smaller or resource-constrained farms.



Fig: Methods of litter agitation Hand Racking(a), Foot Agitation (b) and Mechanical Litter Agitator (c)

In the current experiment, hand agitation is performed using a rake, foot agitation with a rubber boot, and mechanical agitation with a battery-operated mechanical agitator developed by Odisha University of Agriculture and Technology, Bhubaneswar. The dust generated by the three different methods was analysed in real time for its composition and concentration to evaluate the potential occupational exposure risks for workers, with a focus on respirable and inhalable particulate matter.

A poultry facility, previously housing a flock of 250 poultry for a full 45-day production cycle, was chosen for the study. The floor of the poultry house was demarcated into three equivalent sections, each measuring 11 m. Within each section, the litter underwent agitation using a distinct methodology. The mean depth of the litter material was determined to be 22.7 mm. On the day of the experimental procedure, the ambient temperature registered 36.34°C, with a corresponding relative humidity of 48%. A PALAS Dust Sampler, powered by an 11.1V lithium-ion battery, was employed to measure dust settlement times and concentration levels. Measurements were consistently recorded at the operator's breathing zone (nose level). Data collection was commenced under initial conditions and continued at one-minute intervals until the entirety of each designated section had been agitated using its respective method. This systematic approach ensured a consistent and comparable analysis of dust generation across the different agitation techniques.

This rigorous methodology facilitated a direct comparison of dust profiles, thereby enabling an objective assessment of the occupational hazards associated with each agitation technique and informing subsequent mitigation strategies.

Results

The Dust size data and settlement time were recorded in three replications and were analysed using appropriate statistical tools. The results of the same are given below.

Dust Size: Dust in poultry farms can be categorized based on particle size. Respirable dust includes particles that are 5 micrometres (μm) or smaller, which can reach deep into the lungs. Inhalable dust consists of particles up to 100 μm in size, capable of entering the nose and upper respiratory tract. Total dust refers to all airborne particles regardless of their size.

The size of dust particles is measured in micrometres (μm), while the concentration is expressed as milligrams or micrograms per cubic meter of air (mg/m^3 or $\mu\text{g}/\text{m}^3$). Common sources of dust in poultry farms include feather and skin dander, feed particles, manure and litter particles, bedding materials, and dry faecal matter.

The final dust density increased in all three methods compared to the initial dust levels. Among the three methods, agitation by foot produced the least dust, while agitation by machine resulted in the highest dust level.

Table 1: Average Dust density of different particle sizes during litter agitation

Particle Size	Particle Density, $\mu\text{g}/\text{m}^3$			
	Initial	Foot agitation	Hand rake agitation	Mechanical agitation
PM 1.0	12.38	22.34	87.57	105.36
PM 2.5	29.34	107.01	1023.33	1217.30
PM 4.0	56.09	250.71	2687.86	3191.58
PM 10.0	106.67	679.21	7445.09	8760.37
PM tot	254.85	2243.79	23627.10	27361.43

Before starting the work, the initial dust density of the workplace was measured. The dust concentrations for different particle sizes were recorded as follows: PM1 (1 μm) was 12.38 $\mu\text{g}/\text{m}^3$, PM2.5 (2.5 μm) was 29.34 $\mu\text{g}/\text{m}^3$, PM4 (4 μm) was 56.09 $\mu\text{g}/\text{m}^3$, PM10 (10 μm) was 106.67 $\mu\text{g}/\text{m}^3$, and the total dust particles measured were 254.85 $\mu\text{g}/\text{m}^3$. These values represent the background dust level in the area before any type of agitation was carried out. To evaluate the impact of different agitation methods i.e. by foot, by hand rake, and by machine on the dust density, statistical analysis was conducted using the ANOVA (Analysis of Variance) method. The ANOVA test helped determine whether there was a significant difference in dust levels caused by the three agitation methods. The analysis data found as follows

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Sample	8.08E+08	2	4.04E+08	7.128997	0.001668	3.150411
Columns	3.2E+09	4	8E+08	14.11744	3.55E-08	2.525215
Interaction	1.25E+09	8	1.56E+08	2.747293	0.011846	2.096968
Within	3.4E+09	60	56658761			
Total	8.65E+09	74				

It can be seen that for samples (treatments) F is greater than the F_{crit} , hence we failed to reject the null hypothesis. Thus, analysis shows that the dust generated by the different methods of litter agitation is significantly different from each other. Specifically, the highest inhalable particulate matter concentrations were observed during mechanical agitation, with mean concentrations significantly exceeding those from foot or hand agitation techniques. This observation is corroborated by previous studies which indicate that distinct operational tasks within poultry environments lead to varying particulate matter fractions and concentrations (Ransbeeck *et al.*, 2014).

The F value for columns is also greater than the F_{crit} , hence we failed to reject the null hypothesis, so we can conclude that the concentration of different size particles are also significantly different from each other for each method of litter agitation. This observation suggests that the different particulate matters are of varying aerodynamic properties and thus exhibit distinct behaviors regarding suspension duration and deposition patterns within the poultry house environment. Hence, the mitigation must be encompassing all their properties.

There is also significant interaction between the particle size and the type of agitation method. These findings underscore the critical need for tailored mitigation strategies, particularly for mechanical agitation, which generates substantially higher levels of both inhalable and respirable dust, thereby posing a greater occupational health risk to poultry farm workers. These elevated particulate matter concentrations, particularly in floor-housed operations, are consistent with previous research indicating higher dust levels where litter is present, necessitating further investigation into the specific health impacts on workers (Just *et al.*, 2009) [12] (Górny *et al.*, 2023) [6]. Moreover, the observed increase in fine particulate matter during mechanical agitation aligns with findings that such activities elevate the concentration of smaller particles capable of deep lung penetration, exacerbating potential respiratory issues (Górny *et al.*, 2023) [6]. According to the National Ambient Air Quality Standards (NAAQS) set by the Central Pollution Control Board (CPCB), the safe 24-hour limit for PM2.5 is 60 $\mu\text{g}/\text{m}^3$ and the annual limit is 40 $\mu\text{g}/\text{m}^3$, while for PM10, the 24-hour limit is 100 $\mu\text{g}/\text{m}^3$ and the annual limit is 60 $\mu\text{g}/\text{m}^3$. In this study, the initial dust density of PM2.5 was found to be within the safe limit. However, after

the agitation activity, the PM_{2.5} level increased significantly and exceeded the 24-hour permissible limit. Similarly, the initial dust density of PM₁₀ was already slightly above the standard limit and showed a sharp rise after the work was done. This observation aligns with findings from other studies, which indicate a substantial increase in particulate matter concentrations during active periods compared to quiescent phases in broiler houses (Yasmeen *et al.*, 2019) ^[22]. This substantial increase in airborne particulate matter highlights the critical need for effective dust control measures, particularly given that occupational exposure limits for PM₁₀ and PM_{2.5} are suggested not to exceed 100 µgm⁻³ and 60 µgm⁻³, respectively, based on 24-hour concentration thresholds.

This increase in both fine (PM_{2.5}) and coarse (PM₁₀) particles indicates that the agitation process is posing potential health risks. This is especially concerning given that particles smaller than 10 µm and 2.5 µm (PM_{2.5}) are known to penetrate the respiratory system, with ultra-fine particles (<100 nm) posing even greater toxicity due to their deposition patterns and potential to transport microorganisms (Santos *et al.*, 2021) ^[16]. Furthermore, the mechanical agitation method consistently generated the highest concentrations across all particle sizes, exceeding levels observed with both foot and hand rake agitation, thereby presenting the most significant health hazard to workers. This heightened particulate matter concentration is exacerbated by activities within controlled environmental facilities, further amplifying occupational exposure risks for workers. Hence, it is recommended the use of protective masks, safety glasses, and ensuring good ventilation, to minimize direct exposure to harmful dust particles. The elevated particulate matter concentrations highlight the critical need for comprehensive dust mitigation strategies within poultry environments, particularly during litter agitation processes. These strategies should encompass both engineering controls, such as improved ventilation systems and modified agitation techniques, and administrative controls, including task rotation and enhanced worker training on best practices for dust reduction and personal protective equipment usage (Ischer *et al.*, 2016) ^[11]. Additionally, the implementation of respiratory protection programs, which include regular monitoring and adherence to safety protocols, is crucial for safeguarding the health of poultry farm workers (Santos *et al.*, 2021) ^[16].

Dust settlement time (min): Several factors influence how quickly dust particles settle in a poultry farm environment. Particle size plays a major role; larger particles tend to settle faster due to their weight, while smaller particles can remain suspended in the air for longer periods. Airflow or wind speed also affects settlement; strong airflow can keep dust particles airborne, increasing exposure time. Humidity impacts dust behaviour as well; moist air can cause particles to clump together, making them heavier and causing them to fall more quickly. Additionally, ventilation systems may either help remove dust from the air or, if not properly designed, redistribute it throughout the space. The physical properties of dust, such as particle density and shape, also contribute to their settling velocity, with irregular or less dense particles exhibiting slower deposition rates. This complex interplay of factors necessitates a comprehensive understanding of dust dynamics to effectively design and implement mitigation strategies in poultry operations (Just *et al.*, 2009) ^[12]. The table below illustrates the varying durations for dust particles of different sizes to settle, an essential consideration for assessing exposure risks post-agitation and determining appropriate re-entry times for

workers.

Table 2: Dust settlement time for different particle sizes during litter agitation

Dust Size(µm)	Dust settlement time (min)
PM ₁	15
PM _{2.5}	9
PM ₄	5
PM ₁₀	2
PMTot	10

After each agitation operation of the litter material by different methodology, the dust particles were allowed to settle, and the time taken by different-sized particles to return to their initial levels was recorded. From the observations, it was found that smaller particles took more time to settle compared to larger and heavier particles. Specifically, PM_{2.5} particles took around 9 minutes to settle, whereas PM₁₀ particles settled within 2 minutes. This shows that finer dust remains suspended in the air for a longer period, which increases the risk of inhalation and potential health problems. This prolonged suspension of fine particulate matter, including PM_{2.5}, significantly elevates the cumulative exposure burden for workers, even during periods when active tasks are not being performed, thus exacerbating the potential for adverse respiratory health outcomes (Hassouna & Guingand, 2013) ^[8] (Huneau-Salaün *et al.*, 2018) ^[10]. The extended airborne duration of these fine particles also facilitates their dispersal throughout the poultry facility, impacting areas beyond the immediate work zone and contributing to broader environmental contamination (Tixier-Boichard & Duclos, 2022) ^[18].

Therefore, implementing strategies that reduce the generation of fine dust or accelerate its removal from the air column are critical for mitigating occupational health risks in poultry operations. Based on this finding, it is suggested that during continuous work, frequent short breaks should be taken. These breaks not only help workers to recover their energy but also allow dust particles to settle, thereby reducing the chances of exposure to harmful airborne particulate matter. This approach can help improve both worker safety and air quality in the work environment. The low relative humidity at the time of operation exacerbated the dust suspension, as drier air prevents particles from agglomerating and settling quickly (Just *et al.*, 2009) ^[12]. This observation underscores the importance of maintaining optimal humidity levels within poultry houses as a passive dust mitigation strategy, alongside active measures such as air filtration and ventilation. The implementation of oil spraying on poultry litter, for instance, has demonstrated a significant reduction in PM₁₀ exposure for stock handlers, ranging from 60% to 80%, without adversely affecting bird performance or ammonia emissions (Winkel, 2016) ^[20]. Similarly, increasing absolute humidity can reduce airborne particles, though relative humidity should not exceed 80% to prevent other issues (Hennig-Pauka & Altrock, 2022) ^[9]. Given that factors like temperature and relative humidity can influence particulate matter emissions, adjusting environmental controls to maintain optimal conditions within poultry houses could further reduce PM concentrations (Guo *et al.*, 2020) ^[7].

Conclusion

The study concludes that foot agitation produces significantly lower dust levels compared to the other litter management methods evaluated. Among all particle categories, PM₁₀ exhibited the highest concentration, yet it also demonstrated the

shortest settling time, indicating rapid dispersion but quicker deposition. Despite these differences, dust concentrations across all agitation techniques exceeded recommended occupational exposure limits, highlighting potential health risks for poultry workers.

For small-scale poultry houses in India, both foot agitation and hand-rake agitation may remain feasible due to their simplicity and lower operational demands, albeit with ergonomic concerns. However, these manual methods are inefficient for large-scale commercial operations, where work volume and frequency are substantially higher. In such settings, mechanical litter agitation offers the required operational efficiency, but it also generates the highest dust concentrations, necessitating appropriate dust-mitigation strategies and worker-protection measures.

Hence integrated environmental management strategies, combining both active and passive dust control measures, are therefore essential for creating a safer and healthier working environment for poultry farm personnel (Winkel, 2016) ^[20] (Just *et al.*, 2009) ^[12]. Ongoing monitoring of airborne dust levels, particularly PM_{2.5} and PM₁₀, alongside biological and chemical constituents, is critical to assess the efficacy of these interventions and adapt strategies as needed (Santos *et al.*, 2021) ^[17]. The continuous evaluation of dust composition, including organic and inorganic components, is also vital for tailoring specific mitigation approaches that target the most hazardous elements of airborne particulate matter in poultry environments (Ischer *et al.*, 2016) ^[11]. Moreover, understanding the diverse sources and characteristics of poultry dust, including variations between farm tasks and facilities, is paramount for developing targeted and effective control measures (Tixier-Boichard & Duclos, 2022) ^[18]. This necessitates a multi-faceted approach, incorporating advanced ventilation systems, litter amendments, and personal protective equipment, to holistically address the complex challenges posed by airborne particulates in poultry operations. It may be noted that the study of the dust only in the form of its concentration and settlement time provides an incomplete picture of the overall health risk; therefore, it is imperative to analyze the chemical and biological composition of the dust, given that approximately 90% of particulate matter in broiler housing is organic (Pereira *et al.*, 2023) ^[14]. Hence, further study should focus on identifying specific organic constituents, such as endotoxins, fungi, and bacteria, and their correlation with observed health effects in poultry workers.

Acknowledgement

Research was supported by the Indian Council of Agricultural Research, Department of Agricultural Research and Education, Govt. of India

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