

Air Quality Inside Broiler Barns: Comparing Straw and Peat Moss Bedding

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INTRODUCTION

This factsheet describes an on-farm research project in Ontario that measured and evaluated the air quality inside two commercial broiler barns comparing the use of peat moss and straw bedding materials. The project evaluated the measured dust levels inside the barns, their impact on bird health and possible concerns for people working in this environment.



Figure 1. Broiler chicks on peat moss bedding.

In the early 2020s, several broiler producers in Ontario began using peat moss bedding as an alternative to conventional straw or wood shavings (Figure 1). This shift was driven by the difficulty sourcing bedding materials and the idea that peat moss was a more absorbent bedding material. If the barns could be maintained in a drier state, there would be a reduced chance of ammonia production from the litter during the bird production cycle.

Shortly after the broiler sector started using peat moss bedding, several chicken-catching crews began to complain of their workers becoming ill after catching birds in these barns (i.e., shortness of breath, flu-like symptoms, eye irritation). The cause was suspected to be the peat moss bedding producing smaller dust particles than conventional bedding materials. These smaller particles were thought to bypass normal respiratory filtering mechanisms present in birds and mammals and penetrate deeper into the lungs where they were causing illness or adverse reaction. However, there was no data to confirm or disprove this theory.

Table 1. Common Bedding Materials in Ontario

Bedding Type	Availability	Cost	Absorbability	Renewable Resource
Chopped cereal straw	Yes	Reasonable	Less than peat but similar to shavings	Yes
Kiln-dried soft wood shavings	Harder to get in recent years	Variable	Less than peat but similar to chopped straw	Yes
Baled peat moss	Yes	Reasonable	Best	No
Pelleted straw	Yes	Higher cost option	Less than peat but similar to shavings	Yes

BROILER PRODUCTION AND COMMON BEDDING MATERIALS

In Ontario, broiler production follows an all in/all out production pattern. When starting a new flock, a couple of inches of clean bedding material is placed on the bare concrete floor, the barn is pre-warmed up to 30°C–32°C, and the new chicks are delivered into the barn by hatchery staff. Birds have free access to feed and water and can move about the building. The barns have a mechanical ventilation system to introduce fresh air into the building and exhaust moisture, carbon dioxide and other air contaminants from the building. Birds are grown in the barn until they reach the target shipping weight (30–45 days) requested by the processor. At this point, chicken-catching crews arrive to catch and load the birds onto transport trucks for delivery to the processor. Once the birds have been removed from the building, the producer cleans out all the litter materials and prepares the barn for the next flock.

The bedding material (Table 1) has several important functions as it provides a layer of insulation and comfort on the floors for the chicks when they are first introduced into the barn but more importantly, it provides an absorbent material to retain moisture. Broiler production is considered a litter-based system, as the birds deposit feces throughout the building on top of the bedding material.

If the litter is too dry, there is potential for the release of more dust into the airspace as the birds move around in the barn. If the litter becomes too wet during the grow-out period, there can be issues with the production of ammonia from the breakdown of nitrogen compounds in the airspace.

During colder times of the year, the producer operates the ventilation system to introduce fresh

air into the barn and exhaust water vapour from the barn to maintain the relative humidity inside the barn below 70%. If the barn is operated at a relative humidity above 70% for an extended period or there are events like a drinker line water leak, this can result in the litter becoming wetter than desired.

In a perfect scenario, the bedding material should be absorbent enough to retain excess moisture to provide a dry surface for the birds to walk over but damp enough to minimize dust production when the birds move around. Research^[2] concluded the optimum litter moisture content to minimize ammonia and particulate matter emissions is between 25%–35% (or 55%–75% dry matter).

DUST PROPERTIES AND MEASUREMENT

In a broiler barn, the dust is comprised of dried fecal matter, dead skin cells, bedding material, biological contaminants, etc. Dust is a form of particulate matter (PM). This term refers to microscopic matter suspended in air or water. Airborne particles are called aerosols. PM₁₀ includes particles less than 10 micrometres (µm) in diameter, while PM_{2.5} particles are less than 2.5 µm.

In comparison, a human hair is about 100 µm wide, so 40 PM_{2.5} particles would be needed to produce the same width. These particles are invisible to the human eye. Another problem with these smaller particles is their ability to stay suspended in the barn air for longer periods of time.

Occupational exposure to PM_{2.5} is particularly concerning as these particles are so small, they can deeply penetrate the lungs. The fraction of particles that are 0.5 µm and smaller can cross over into the blood stream and result in various cardiovascular and respiratory diseases.

During the research project, size fractionated particulate matter suspended in the barn air was measured every 5 minutes during the trial for each flock using a TSI DustTrak PM analyzer. The unit was located at the mid-point of each barn. Each PM analyzer was contained in a box suspended from the barn ceiling and had a length of sampling line hanging down to mid-barn height to collect samples of barn air.

The level of dust observed in the barns affected calibration and caused blockage of the filter unit with the PM analyzers. From previous experience collecting dust measurements inside commercial poultry barns, the site was visited twice a week to perform routine maintenance and calibration of the analyzers during flock monitoring periods to verify the units were working properly. Even with the twice weekly visits, there were several instances where the analyzers malfunctioned, and some data was not collected.

EXPERIMENTAL DESIGN FOR RESEARCH TRIAL

Farm/Barn Set-up

The site selected for the on-farm research trial had two single-story barns identical in terms of equipment layout (feeder lines, drinker lines, radiant tube heater location, fan location, etc.). Both barns were cross-ventilated with the same number and size of exhaust fans located on each long axis wall. The interior circulation fans for both barns used an identical pattern for air distribution. The same Genius model of ventilation controller was used to manage each barn.

To account for seasonal variation in the concentrations and emissions of particulate matter due to changing ventilation rates within the barns, a total of four flocks was monitored for this trial throughout the year (2022):

- Flock #1 from mid-February until end of March
- Flock #3 from July 1 until early August
- Flock #4 from August 31 until early October
- Flock #5 from November 4 until early December

Flock #2, which occurred during the April-June period, was not monitored due to the presence of High Pathogenic Avian Influenza in Ontario, and the researchers did not want to be visiting the poultry farm during this high-risk period.

The chicks in all flocks were placed on the same day in both barns at the same stocking density, fed the same feed ration and shipped for processing on or about Day 34 of the production cycle.

For each subsequent flock, the bedding type was alternated for each barn (i.e., if Barn #1 Flock #1 used peat moss bedding, then the next flock in Barn #1 would have straw bedding).

Besides PM₁₀ and PM_{2.5} dust measurements, the other environmental parameters sampled during this trial included the barn temperature and relative humidity at the same 5-minute frequency.

Litter Sample Collection

Litter samples were collected from each barn bi-weekly during the trial to check moisture content, pH and nutrient levels. Factors that influence the formation of gaseous ammonia from poultry manure and litter include high concentrations of ammonium (NH₄⁺), elevated temperatures and humidity in the air, and elevated moisture content and pH in the manure/litter.^[10]

Moisture

Water is a reactant required for ammonia (NH₃) formation during microbial breakdown of nitrogen compounds contained in the poultry manure. Higher moisture content in the litter results in greater NH₃ formation. If manure can achieve 60% dry matter content within the first 50 hours, ammonia emissions can be minimized.^[5] Favourable conditions for microbial activity are temperatures ranging from 20°C–30°C^[5] and pH levels ranging from 8–13^[9].

Flock Production

Flock production parameters were also recorded for each barn during the trial. These included the average shipping weight, daily mortalities, condemnations, etc.

Four sets of post-mortem examinations were performed for each monitored flock at the Animal Health Laboratory, University of Guelph. A total of 5 birds were collected from each barn at: chick placement, 7–10 days, 20–22 days and shipping age. Multiple time periods were selected to assess general bird health and disease or production issues with specific emphasis on the lung health of the birds from exposure to the barn environment.

RESEARCH RESULTS

Litter

For all flocks, the litter in the peat moss bedded barn tended to be drier than litter from the chopped straw barn. The one exception to this observation was during Flock #1 when the farmer used Straw Boss pellets instead of chopped straw. The litter moisture content increased during the production cycle in both barns as the birds grew (Figure 2).

For all flocks, the peat moss bedding started with a lower pH than the straw bedding because peat moss is harvested from an acidic environment. However, during the production cycle in both barns, as the birds deposited more feces on the bedding material, the pH of the litter began to rise above neutral into the alkaline range (> pH 7) (Figure 3).

The increase for the pH across the flock was more rapid for the peat moss when compared to the chopped straw. This indicates that chopped straw was a better buffer for maintaining pH than peat moss.

Particulate Matter

Each of the flock graphs showed a pattern of daily peak and valley particulate matter (PM) measurements. Peaks normally occurred during times when the birds were actively moving around, eating and drinking (lights on) versus valley times that often occurred in the middle of the night (lights off) when birds were resting on the litter.

PM readings were always higher in the peat barn, regardless of which fraction was being measured across all four monitored flocks.

Flock #4 had the most complete data set for PM, both PM_{10} and $PM_{2.5}$. Figures 4 and 5 are representative graphs for each type of bedding.

These graphs show an interesting pattern of the dust levels increasing significantly over the last 10 days for the production cycle in both barns. This corresponds with outside temperatures dropping 10°C–20°C below the barn setpoint temperature at certain times of the day (Figure 6). This would cause the ventilation controller to shut off several exhaust fans in each barn to maintain barn

setpoint temperature, thus reducing air exchange from each barn and causing the PM levels to rise. During the first 20–25 days of the production cycle, the ambient temperatures were quite warm, sometimes matching or exceeding the barn setpoint temperature. As a result, the ventilation controller would have turned on more fans to try to prevent barn temperature from rising further. This extra fan capacity would exhaust more particulate matter from bird space, resulting in lower particulate matter readings.



Figure 2. Moisture content of litter for Flock #5.

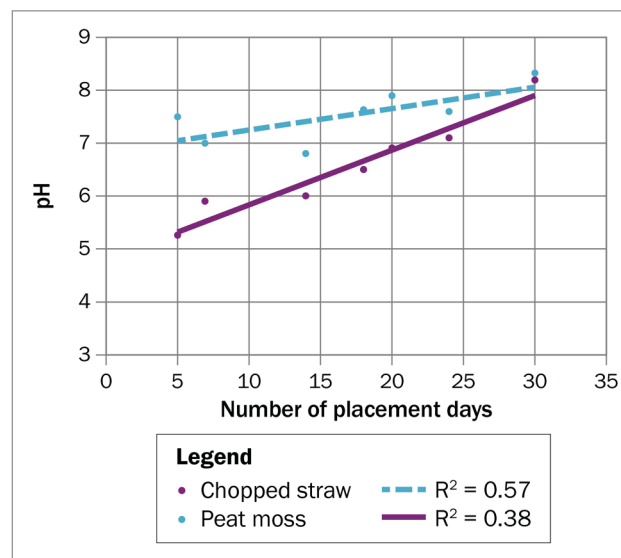


Figure 3. pH of bedding materials for Flock #5.

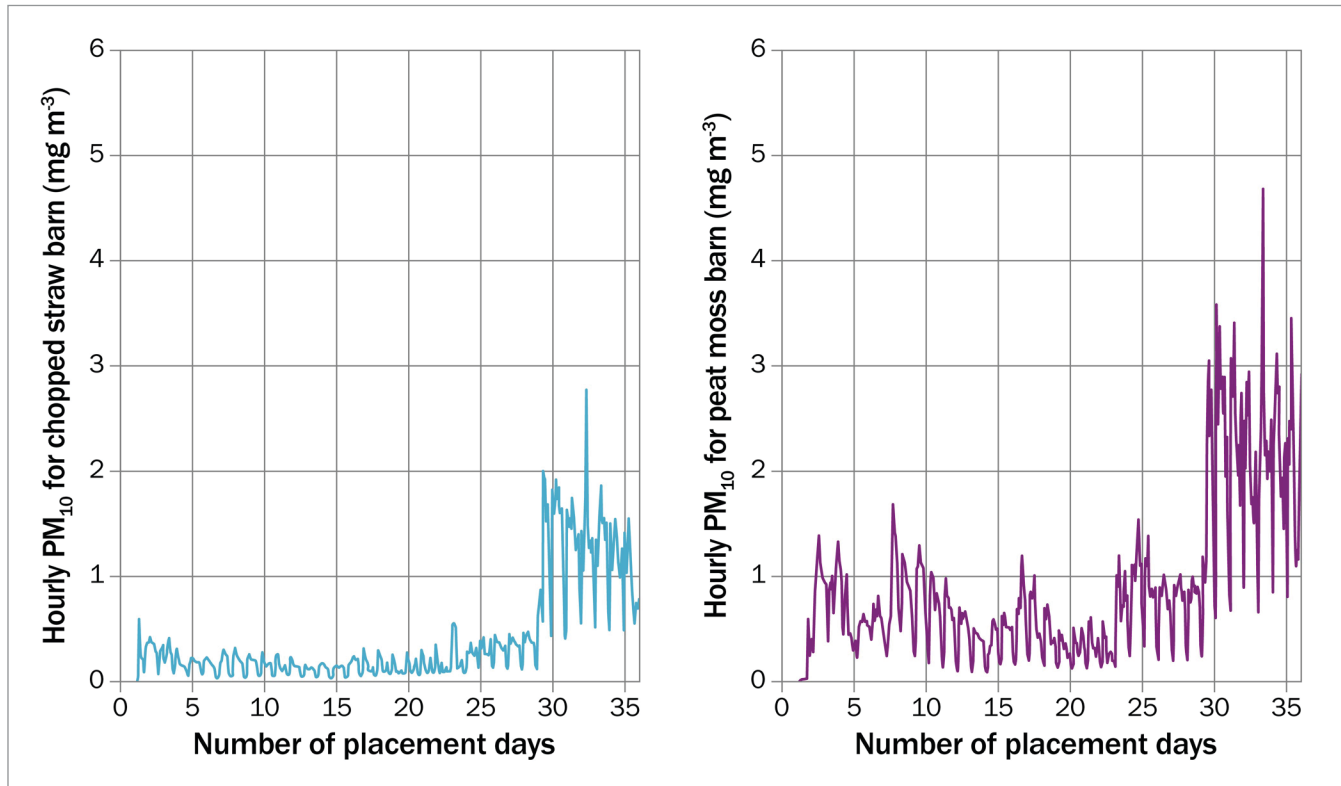


Figure 4. PM_{10} data for Flock #4.

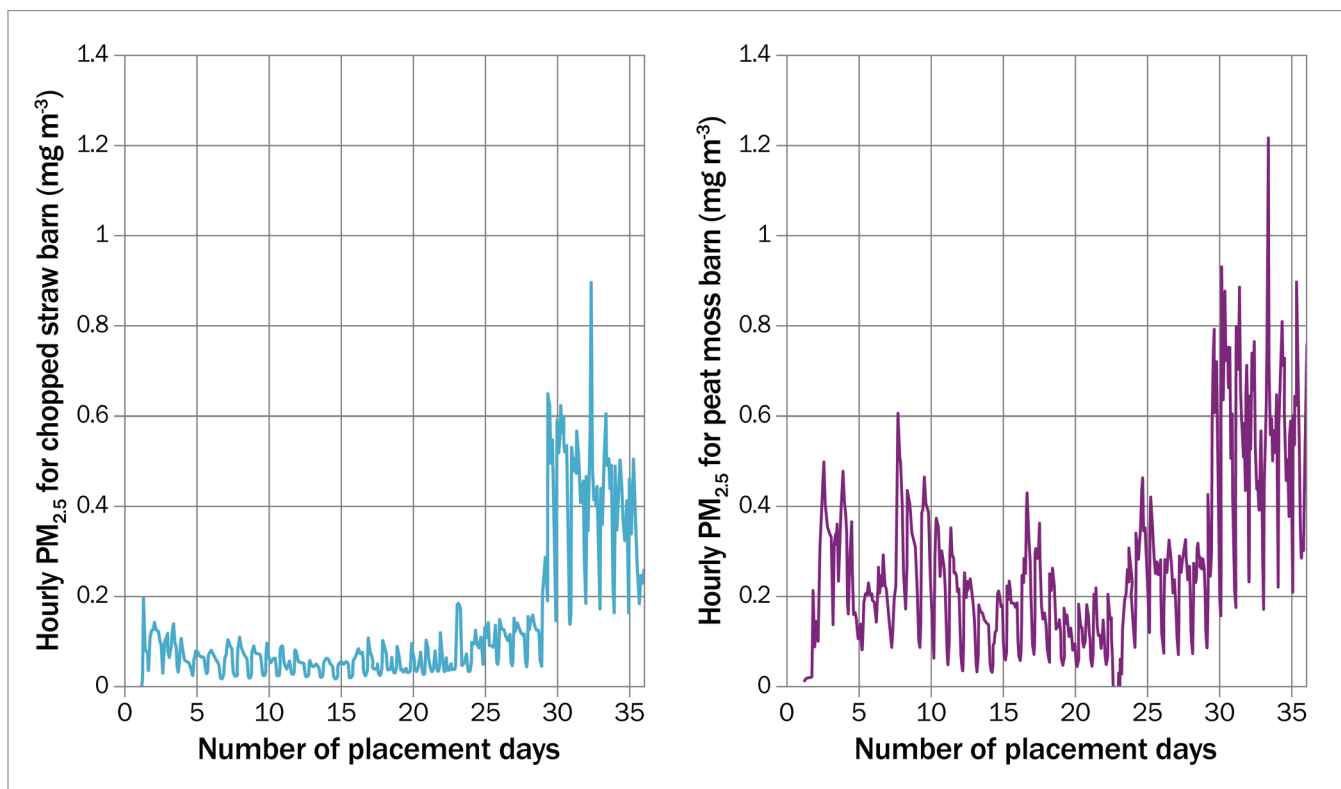


Figure 5. $PM_{2.5}$ data for Flock #4.

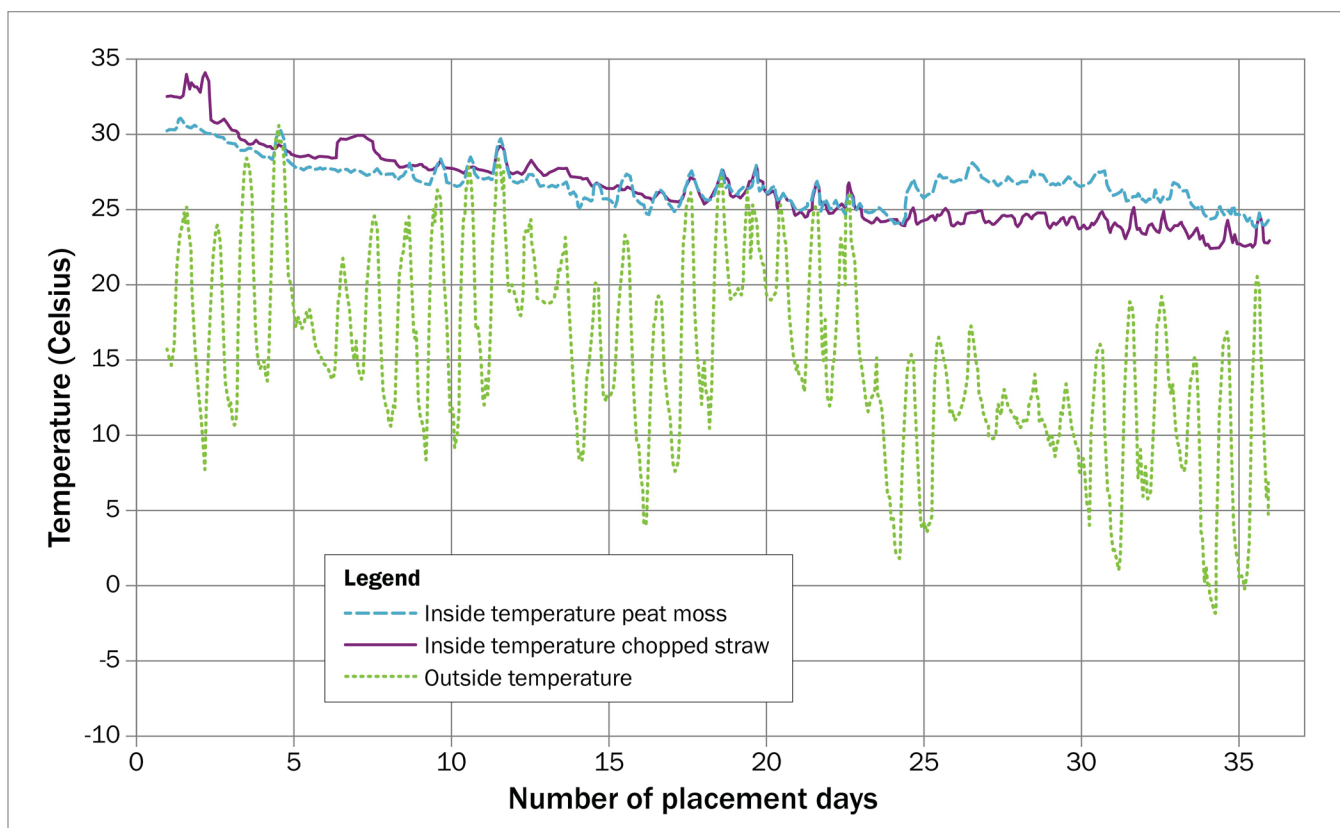


Figure 6. Barn temperature compared to ambient temperature for Flock #4.

The peak values of PM recorded for each flock and each barn, showing the comparison of PM₁₀ and PM_{2.5}, are shown in Table 2. Some datasets were not complete due to equipment problems so there may have been higher peak values that were not recorded.

The highest recorded values of PM during the entire on-farm research project for both PM₁₀ and PM_{2.5} occurred in the peat moss bedded barn with Flock #1 during the first couple of days after chick placement. This was likely due to a combination of very low ventilation rates (minimal fresh air mixing) for these

young birds during the coldest time of the year and the peat bedding being very dry since frozen bales had been brought into the heated barn several days prior to chick placement to thaw prior to spreading.

Lowest recorded PM₁₀ and PM_{2.5} peak levels were observed in both barns during the summer flock (Flock #3). This was related to the much higher air exchange rates through the barns with all the exhaust fans operating to control barn temperature for the birds during this period of higher ambient temperatures.

Table 2. Peak PM Values Recorded for Each Barn During Each Flock

Flock	Peak PM ₁₀ Straw	Peak PM ₁₀ Peat Moss	Peak PM _{2.5} Straw	Peak PM _{2.5} Peat Moss
Flock #1 Feb 18–Mar 25	1.8 mg/m ³	8.3 mg/m ³	0.7 mg/m ³	3.0 mg/m ³
Flock #3 Jul 1–Aug 6	0.5 mg/m ³	3.7 mg/m ³	0.3 mg/m ³	1.0 mg/m ³
Flock #4 Aug 31–Oct 4	2.8 mg/m ³	4.7 mg/m ³	0.9 mg/m ³	1.1 mg/m ³
Flock #5 Nov 4–Dec 8	2.1 mg/m ³	5.5 mg/m ³	0.7 mg/m ³	1.3 mg/m ³

Table 3. Flock Performance

Flock	Average Shipping Weight		% Mortality (includes birds left behind at shipping)		% Condemnations at Processing	
	Barn #1	Barn #2	Barn #1	Barn #2	Barn #1	Barn #2
Flock #1 Feb 18–Mar 25	2.41 kg (peat)	2.37 kg (straw)	7.8% (peat)	4.1% (straw)	1.50% (peat)	1.50% (straw)
Flock #3 Jul 1–Aug 6	2.45 kg (straw)	2.50 kg (peat)	3.6% (straw)	6.6% (peat)	2.23% (straw)	3.52% (peat)
Flock #4 Aug 31–Oct 4	2.32 kg (peat)	2.30 kg (straw)	5.6% (peat)	6.3% (straw)	1.84% (peat)	3.98% (straw)
Flock #5 Nov 4–Dec 8	2.18 kg (straw)	2.22 kg (peat)	4.1% (straw)	5.4% (peat)	1.01% (straw)	0.90% (peat)

Flock Performance Results

For recording purposes during the trial, the percentage mortality of the flock included all birds that died in the barn during trial plus any birds left behind after loading that were euthanized by the farmer. Reviewing the performance data for each flock (Table 3) revealed the following:

- in every flock, the average bird weight at shipping was higher in the peat moss bedded barn
- bird mortality was higher in the peat moss barn in 3 out of 4 monitored flocks

Health Implications

For people, short- and long-term exposure to particulate matter can cause adverse health effects including asthma, chronic bronchitis, irritation to the airway, decreased respiratory function, higher incidence of lung cancer and premature death in individuals with a history of lung or heart disease.^[14]

In Ontario, the [Occupational Health and Safety Act, 1990](#), provides an exposure level for workers exposed to poultry dust in [O.Reg. 833, Control of Exposure to Biological and Chemical Agents](#). The regulation defines the “time-weighted average limit” (TWA) as the time-weighted average airborne concentration of a biological or chemical agent to which a worker may be exposed in a work day or work week. The TWA level for poultry dust (total dust) is 5 mg/m³.

O.Reg. 833, Control of Exposure to Biological or Chemical Agents, has an occupational exposure limit set for particulates:

- TWA standard for the inhalable fraction of particulates at 10 mg/m³
- TWA standard for the respirable fraction of particulates at 3 mg/m³ ([O.Reg. 833](#)).

The inhalable fraction refers to PM₁₀ and the respirable fraction refers to PM_{2.5}.

Birds are considered to have the most efficient respiratory gas exchange system of all vertebrates (Figure 7). Adaptation for flight has resulted in a more efficient air exchange system. Parabronchi (the smallest gas exchange airways in birds) are 3–10 µm in diameter compared to the smallest alveoli in mammals (35 µm, shrew). The blood-gas barrier is approximately a third of the thickness of mammals.^[7]

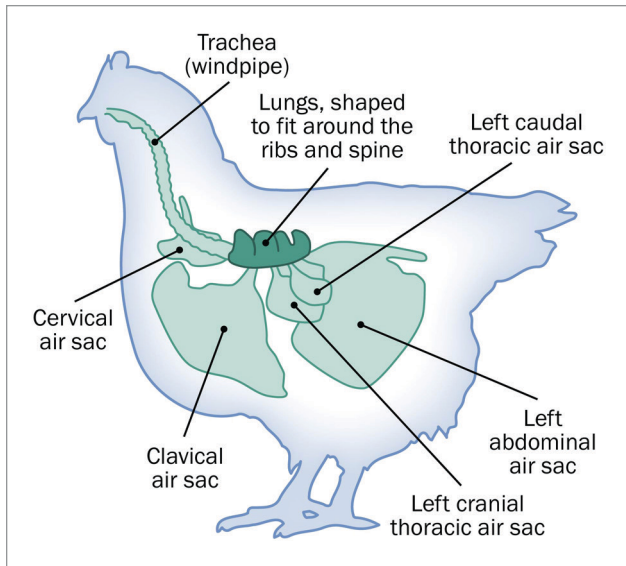


Figure 7. Bird respiratory system (adapted from [The Poultry Site](#)).

All areas of the respiratory system (nasal sinuses, trachea, primary and secondary bronchi of the lungs) have ciliated epithelium and mucus-producing glands. This allows capture of foreign material in the mucus layer and removal by the movement of the cilia. However, these physical barriers have their limitations. When these barriers are either bypassed or damaged, particulate matter can penetrate the respiratory system.

Inhalable particles on inspiration will reach the nasal sinuses, trachea and large bronchi. In humans, inhalable particles are $<10\ \mu\text{m}$ ^[6] while in poultry particles larger than $5\text{--}6\ \mu\text{m}$ in diameter deposit in the nasal sinuses^{[11],[15]}.

Respirable particles can reach deep into the gas exchange areas of the lungs of both humans (alveoli, $<4\text{--}5\ \mu\text{m}$) and poultry (parabronchi and air capillaries, $<2.5\ \mu\text{m}$) indicating that respirable dust has a smaller diameter in birds vs mammals.^{[4],[6],[16]} If dust particles contact lung tissue, they can cause irritation and inflammation and may carry pathogens such as bacteria, viruses, fungi and endotoxins.^{[6],[15]} Ammonia gas can affect cilia function, slowing clearance of foreign particles, increasing the risk of inflammation and increasing the opportunity for infection. However, larger particles can penetrate deeper into the respiratory system if there is mouth breathing^[12] or panting to dissipate heat^[3].

Poultry barns are known to have higher concentrations of particulate matter in the air compared to pig or cattle barns. Between poultry housing systems, measured PM concentrations are higher in litter (broilers) versus cages (hens).^[1]

In the Ontario study, we compared the dust exposures of birds raised on shavings versus peat moss bedding. Plant particles infiltrated the lungs and air sacs of all birds regardless of the bedding material selected for the barn. During microscopic examination of tissue samples for all three time periods examined per flock (i.e., days 7–10, 20–22 and at shipping), it was more common to identify:

- increased levels of plant particles in the upper and lower respiratory system of birds from peat moss bedded barns
- embedded plant particles in the lower respiratory system of birds from peat moss bedded barns

These embedded particles are often associated with inflammation of the secondary bronchi or noted within macrophages within parabronchi. It is documented that there are health effects related to exposure to fine particulate matter ($\leq 2.5\ \mu\text{m}$) that, in broilers, can induce lung inflammation and disrupt the lung microbiota.^[13] Animals exposed to high particulate matter concentrations are more likely to suffer from non-welfare, low productivity (decreased average daily gain) through the development of respiratory disease and increased mortality, affecting the ability to reach a high-level production.^{[1],[15]}

When looking at the concentration of PM in the air space of the barn, it was identified that the PM decreases in direct proportion to the height above the floor.^[8] Therefore, while birds live in the highest concentration of PM, agricultural workers are also exposed. Research into PM exposure in humans reported $2.5\ \mu\text{m}$ particles induce lung microbial disorders.^[16] The Ontario study demonstrated the presence of $2.5\ \mu\text{m}$ PM in the smallest airways of broiler chickens raised on peat moss bedding.

CONCLUSIONS

Peat moss bedding resulted in slightly drier litter conditions in the broiler barn compared to straw bedding. Significantly higher dust levels were measured in the barn using peat moss bedding for all four monitored flocks.

Commercial broiler chickens used for this trial were a relatively short-lived bird as they were shipped for processing after 34 days in the grow-out barn. The health effects on a longer-lived bird, (turkeys, layers or breeders) raised on peat moss bedding is unknown. The time exposure to this environment and the bird behaviours (dust bathing) could contribute to more of a dust challenge. This would also become a human health concern for the producers and support industries (catchers, vaccination crews, artificial insemination crews, etc.) working in these barns for extended periods of time.

Levels of aerosols in the PM₁₀ size range and the more dangerous PM_{2.5} size bordered on the TWA limits specified in O.Reg. 833. Therefore, anyone working inside this barn environment should be using a properly fitted N95 mask or respirator to protect themselves from inhaling this particulate matter.

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