An aerobiological perspective of dust in cage-housed and floor-housed poultry operations


Natasha Just (natasha.thiessen@usask.ca)
Caroline Duchaine (caroline.duchaine@bcm.ulaval.ca)
Baljit Singh (baljit.singh@usask.ca)

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Anae robiologicalp erspectiveof d ustic age-housedan d floor-housed poultry operations

Natasha Just1, Caroline Duchaine2 and Baljit Singh*1

1Department of Veterinary Biomedical Sciences, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, Canada
2Centre de Recherche de l’Institut Universitaire de Cardiologie et de Pneumologie, Québec, 2725C heminS aint-Foy, Québec, Québec, Canada

Email
Natasha Just: natasha.thiessen@usask.ca
Caroline Duchaine: caroline.duchaine@bcm.ulaval.ca
Baljit Singh: Baljit.singh@usask.ca

*Corresponding Author:
Baljit Singh, Ph.D.
Department of Veterinary Biomedical Sciences, Western College of Veterinary Medicine, University of Saskatchewan, 52Campus Drive, Saskatoon, Saskatchewan, Canada, S7N 5B 4
baljit.singh@usask.ca
Abstract

The Canadian poultry production industry contributes nearly $10 billion to the Canadian economy and employs nearly 50,000 workers. However, modern poultry facilities are high glycontaminated with iron dusts. Although there are any bioaerosols in the poultry environment, endotoxins typically attributed with iron dusts negatively affect the respiratory symptoms observed with workers. These diverse respiratory symptoms have higher prevalence of some respiratory symptoms. Workers in age-housed operations compared to loor-housed facilities export higher prevalence of some respiratory symptoms. Further review of current knowledge and biological pathways of poultry dusts including the source and aerosolization of dusts to worker exposure and response. Further research is necessary to develop management practices to reduce worker exposure and response.
Review

In 2007, chicken held the largest share (33.2%) of consumed meat by Canadians. The industry is nation-wide, with facilities in every province. Consumer expenditure on chickens contributes up to $9.5 billion to the Canadian economy, creating 49,700 jobs with average earnings of $1.78 billion. Aged persons and non-urban residents are more likely to consume chicken. Endotoxin concentration (EU/mg) is shown to be a significant predictor of workplace injury incidents in poultry facilities. Moderate levels of poultry dust may be associated with asthma and allergic rhinitis. The exposure of workers to dust from poultry houses is also associated with respiratory symptoms and sensitization. The use of dust suppressants and dust control measures is recommended to reduce the risk of respiratory illness among workers.

Cage-housed and floor-housed poultry workers were exposed to higher levels of dust compared to non-poultry workers. In cage-housed poultry systems, workers are exposed to high levels of dust due to the movement of birds and feed. Dust levels are also higher in floor-housed systems due to the presence of manure and litter. Workers in these environments are at risk of developing respiratory diseases such as asthma and allergic rhinitis. The use of dust suppressants and control measures is recommended to reduce the risk of respiratory illness among workers. The health of workers is a significant concern in the poultry industry.
of chronic phlegm [6]. Therefore, type of housing may influence levels of environmental contaminants in the dust.

Abe tterunde rstandingo ft hepoul tryhous ee nvironmenti sne ededt oi mprovet he respiratory ealthf pouly trwy orkers. T hea eroibiologicalp athwayt hatr esultsi ndus t productioni ncludedes hes ource, a erosolizationa nddi spersal, e xposure, r esponea nd remediation (Figure1). Elucidationof t hispa thway willhe lpi dentifym eansof preventiona nd ort reamentof t her espiratory symptoms of servedi npouly trwy orkers. Examination of t het y peso fpouly tryope rationss eparatedlym ay reveald ifferentm eans ofi mprovingr espiratory healthi nt het y peso w orkers.

Sources

Dusti sa c omplexmixtureof pa rticlesof or ganica ndi organicor igina nd different gasesa bsorbed ina erosolrd oplets. T he sourcesof dus tf rom po ultryf acility includedr iedf ecalm atter na ndr ine, s kinf lakes, a mmonia, c arbondi oxide, pol lens, f eed andl itterpa rticles, f eathers (which pr oduce a llergena ndruff), grainm ites, fungi, s pores, bacteria, vi rusesa ndt heirc onstituents, pe ptidoglycan, β-glucan, m ycotoxina nd endotoxin [3, 6, 11 -13]. Endotoxin ist hem ostf requentlyr eported environmental contaminanti npouly trdy ust. E ndotoxin st hef amilyo fl ipopolysaccharide (LPS) fragmentst hatc oatt heo uterm embranoe G ram-negativa b cteria [14]. LPSi s composedof t hrees tructurale lements: a c oreol igosaccharide, a n O-specificc hainm ade upof r epeatings equencesof pol yaccharidesa nd al pidA c omponent, w hichi s responsiblef ort het oxice ffectsof LPS exposition [15]. C ommonoc cupationalso urcesof exposurei ncludel ivestock, g raindus t, a ndt extiles, but s ignificantc oncentrations iso occuri nt hehos eholdf rompe ts, c arpetinga ndi ndoorve ntilations ystems. E ndotoxin hasa lsobe en foundi nt obaccos moke andpa rticulatem atter na irpol lution [14]. I npoultrype ratione, e ndotoxinor iginatesf romba cteriat hatc anbe f ounnd i ndecalm atter, urine, l itter, gr aina ndt herve getablem atteri npo ultryf eed [3, 16, 17]. E ndotoxin an bem easuredb yt he Limulosa moebocytel ysat-based (LAL) bi oassay, w hichm easures
biological activity of endotoxin, or by mass spectrometry, which can quantify endotoxin biochemically through detection of LPS-characteristic 3'-hydroxyfatty acids [18].

Airborne dust settled on the walls of the hemiacid positions. Of the studies showed that approximately 900 g/kg dry mass at the age of 150 g/kg nitrogen, 6.5 g/kg phosphorous, 30 g/kg potassium, 4 g/kg chloride, and 3 g/kg sodium. Our feathers are crystallized in the form of the inner core [12]. The solid components of dusts can cause respiratory or noxious ases and biological contaminants, all of which are emitted from the natural or man-made dust [19].

Organic dust components are further divided into non-visible and visible particulate matter, or biological aerosols [11]. Microorganisms represent less than 1% of airborne articles but are often associated with heme-gatieve althe effects associated with the pollen try. Industry [19]. The heavy organic ceteria common in poultry try facilities include: Bacillus p., Micrococcus p., Proteus p., Pseudomonas p., Staphylococcus p.a and E. coli, and mona aerobic bacteria ceteria re Clostridias p. [20]. Experimental poultry houes show that 80% of airborne ceteria are Gram-positive rods and 7-17% are Gram-negative odsw hen it is worn asp esen. However, approximately 40% of the Gram-negative bacteria can be trapped by the aspirable fraction of dusts using an Andersen sampler. Coliform bacteria are able to grow in the absence of a are creative or mona let her [3].

Types and levels of fungicidal compounds are pend on management practices. The hich may already be epr esenti that is being ld ing[3]. In floor-covered, dogs of hens are not hown that level of a iborne dust. Chemicals in dusts increase throughout the week cycle often hec hickens [11]. The his increase parallel to the increase of bi mass (number of bi robots in bird's eight) due to growth of ceteria and other corresponding factors. Ecelsofungicidal s kinde brisa nd feathers.

Typically, the incidence of microorganisms is reported to be 3 x 10^5 CFU/m^3, or 10^5 CFU/m^3, for 10^6 and 2.8 x 10^4 CFU/m^3, or 10^4 CFU/m^3, for ulturable fungi and the porcine ceteria [21]. However, the recent results show that the growth rate of microorganisms is much lower than the previous findings.
that culture-dependent techniques underestimate total bacteria or total fungi measured by culture-independent approaches such as epifluorescence. The measurement of total fungi in pools trye rations s 2.0x10⁷/m³ andm measures of total bacteria ranged from 5.3x10⁵/m³ to 4.7x10⁹/m³ [5,11].

Antimicrobial selection is used to forgo or postpone the treatment of illness in the hospital. Some of these antimicrobials may be identical in chemicals, but the total number of microorganisms is higher than that measured. The approval of use of antimicrobials is necessary. The number of microorganisms was chosen among various resistant bacteria. For example, fluoroquinolone-resistant Campylobacter in pools trye operations st transferred the same amount of fluoroquinolone-resistant Campylobacter infections [23].

Characterization of dust in the air is important for determining the type of dust. For example, endotoxin is the cause of the respiratory tract. A thought experiment of feces, urine, and dust is needed to explain the tryptophan reduction, the presence of feces, and the effect of various bacteria, providing pot ential of anti-inflammatory sources of endotoxin.

Aerosolization and dispersal

The contaminants in the air are easily aerosolized and dispersed throughout the hospital by the air. Aerosol concentration is affected by the temperature and relative humidity, ventilation rate, and building ventilation. Animal maintenance, animal feed, and feed management influence the distribution of rats. Relative location and relative humidity are important for the distribution of dust and presence of endotoxin.
Microorganismsexistsuspendedi

The survival time for bacteria is affected by many factors: metabolism of cell, temperature, humidity, susceptibility, and the open-air factor, which can influence microorganisms. Therefore, management practices can directly affect the evelsof bacteria. For example, increasing the number of birds in facilities where birds are housed on the floor and movement is restricted can increase the concentration of airborne germs.

Circulating fans can help maintain humidity and temperature, but measures are needed to control the concentration of airborne particles. Escherichia coli and Salmonella are examples of bacteria that can be present in poultry facilities. T3m from poultrybui ldin exhaustf ans, dus tc oncentration sc an be r elativelyy gh(32-75mg/m³) butf allbe low2m g/m³ b y12m f rom ve ntilationf ans[13]. V entls ocateda longt hew alld andi nt her oofa llowf or outdoor air intake. O utdoors irc ontainse ndotoxindue t o aerosolizationof Gram-negative bacteria on the rom of eaves. O utdoors ndotoxinc anc ontribute to indoor evels due t o heghi ghout door air intake of small acilities[13].

An increase in ventilation rate will not necessarily reduce the levels of dust present in the facility. Less ventilation leads to increased humidity. Adjustment of relative humidity (75%) will help maintain dust levels at a low level. However, it is important to consider the use of ventilation systems that will allow for better air flow and dust control.

Mechanical disturbance by no small ventilation st hepr imem ethef of aerosolizationi n poul try facilities. If the gipient ograms a re ed, dus tc oncentrations are much lower in the air. The use of ventilation systems that allow for better air flow and dust control is essential.
The type of flooring and litter used in the facility alters aerosolization of dust particles [13]. Generally, dust concentrations are low, especially in the areas where the flooring is clean and free of dust. Dust concentrations tend to increase in areas where the flooring is dirty and dusty. Dust concentrations are also higher in areas where there is a concentration of dust, such as near air vents or in areas with a high density of dust.

Exposures

Aerosolization occurs when dust particles are inhaled, either through the mouth or nose. Aerosolization can occur in a variety of environments, including industrial environments, hospitals, and homes. In industrial environments, aerosolization can occur when dust particles are generated during the process of work, such as in the production of metal or in the machining of wood. In hospitals, aerosolization can occur when dust particles are generated during thecourse of medical procedures, such as when dust particles are generated during the cleaning of patient rooms or in the storage of medical equipment.

In homes, aerosolization can occur when dust particles are generated during the cleaning of rooms or in the storage of household items. In all environments, aerosolization can occur when dust particles are generated during the course of work, such as in the production of metal or in the machining of wood. In hospitals, aerosolization can occur when dust particles are generated during the course of medical procedures, such as when dust particles are generated during the cleaning of patient rooms or in the storage of medical equipment.

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Particles of all sizes may be deposited in the nose and pharyngeal region. However, only particles with an aerodynamic diameter of less than 15 μm can penetrate the lower respiratory system [3]. Approximately 50% of particles with a diameter of 5 μm aerodynamic diameter penetrate the respiratory system in each breath [3]. The penetration of angew is through the respiratory system of position at hel ung 1-2 μm n aerodynamic ameter. Respirable dusts ta ccountsf or ~ 18% of total dusts are ass [3]. Particles in allert han 0.5 μm nm eana aerodynamic ametera are still erespirable, but ti sm ore likelyt hatt haya ree xhaled ndndt of positedi nt hel ung. T herefore, i interestl iesi n controlling “modified”r espirable dusts t,0.5- 5 μm, a nd “modified”i nhalable dusts. >5 μm n mea erodynamic ameter [25].

Dust concentrations n poul trfy acilities an af ron 0.02t o81.33m g/m³f or inhalatedus ta nd0.01t o6.5m g/m³f ororr espirablest s t.C age-housed facilities howt he lowestus tc onentrations, <2mg/m³, w hiledus tc onentrationsi nf loor-housed operationsa re typically f outh of ivet imeshi gher [12]. E ndotoxins elvesa rea lsot ypically higher forc age-housed v erus floor-housedope rations [6]. E ndotoxinc oncentrationof respirablest s t,20t o40 g/mg,i sc onsiderablyhi ghert hane ndotoxinc oncentrationof totalus t,6t o16ng /mg, suggestingt hate ndotoxin se ntihed i ns mallerp articles [26]. I ti shypothesizedt hatf inepa rticle onentrationsdi fferbe tweent het wot ypesof poul trly facilities.T hel owert otaldus ti nc ageb arnsce ouldbe a r esultof m oref ine particlesw ith lowerw assbut l argers urface area, c arryngm ore endotoxins heti sa blet er email aerosolizedl ongera nderal enetrated eeperi nt hel ung [6]. Interactionsbe tweeene ndotoxin andt hel ung resulti nne gaver esperatorya ndi mmuner sponses.

Asm entioned a bove, dus tis a c omplexmixture of bot hvi ablea ndnon- viable sources, i ncludinge ndotoxin, ba cteria ndf ungi. T herefore, m onitoring of s evertl ypes ofe xposuresi sne cessary. C haracterizingt ypical exposurest ea ohf oft hese contaminantst is erquired tohe lps ete xposure imitsa ndf indm eansof l owering exposures, f orpot entialr emediation(Figure 1).
The following lung function measurements are used during the assessment of respiratory health: forced expiratory volume in one second (FEV₁), forced vital capacity (FVC), and forced expiratory volume in one second rate between 5 and 75% of FVC (FEF₂₅-₇₅). Decreased FEV₁, FVC, and FEF₂₅-₇₅ may be indicative of obstructive or restrictive lung function. Allergic and non-allergic rhinitis, organic dust toxic syndrome (ODTS), chronic bronchitis, and hypersensitivity pneumonitis (Farmer’s disease) may be diagnosed.

Exposure to ndotoxin is associated with increased symptoms of rhinitis, asthma, and increased use of respiratory medications. Occupational exposure to ndotoxin may lead to chronic respiratory symptoms, including cough, wheezing, and shortness of breath. Workers with a history of asthma are at increased risk of developing occupational asthma, which may be worsened by exposure to ndotoxin.

Inhalation of ndotoxin may lead to increased symptoms of rhinitis, asthma, and increased use of respiratory medications. Occupational exposure to ndotoxin may lead to chronic respiratory symptoms, including cough, wheezing, and shortness of breath. Workers with a history of asthma are at increased risk of developing occupational asthma, which may be worsened by exposure to ndotoxin.

Worker’s response

The following lung function measurements are used during the assessment of respiratory health: forced expiratory volume in one second (FEV₁), forced vital capacity (FVC), and forced expiratory volume in one second rate between 5 and 75% of FVC (FEF₂₅-₇₅). Decreased FEV₁, FVC, and FEF₂₅-₇₅ may be indicative of obstructive or restrictive lung function. Allergic and non-allergic rhinitis, organic dust toxic syndrome (ODTS), chronic bronchitis, and hypersensitivity pneumonitis (Farmer’s disease) may be diagnosed.

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Worker’s response
Lung), toxin fever and occupational asthma or asthma-like syndrome\[3,5,9,10\]. Significant differences in symptoms are observed between cage-housed and floor-housed workers. Current Nationwide Homicide EGMO Curedm, Oregon NWS Homicide and California Age Barns. Endotoxin concentration (EU/mg) is howt ne a s significant and ediorof chronic phlegm\[6\]. However, the symptoms generated by those who do not have these symptoms are caused by a variety of agents, which makes the difficult of understanding relationships between exposure and health. The literature contains several reports of non-environmental exposure thanpoul tryba ne nvironmental exposure. Natives subject to exposed to he swine in the environment who has howt oxygen. Using shortness of breath, fever, and cough can cause a variety of symptoms. Another polymorphism alters the extracellular domain of the TLR4 receptor. An additional polymorphism is non-specific and caused by a variety of agents, which makes it difficult to understand the relationship between exposure and health. Further detailed knowledge of the undetermined “healthy workers” is required.

Adaptation of the repeat of xposure resulted in a reduced injury response compared to a subject not exposed alone. There is evidence that supports the adaptive response to endotoxin exposure in animals. It is observed that the inflammatory cells are covered by the host response to inflammation and exposure to endotoxin. A polymorphism of TLR4 (Asp299Gly) is observed in approximately 10% of individuals in the general population, which is associated with the development of co-morbid conditions and is not trophic in a mice model. The pulmonary response of LPS is mediated by TLR4 and LPS binding alters the extracellular domain of TLR4 receptor. A single nucleotide polymorphism
(Thr399Ile) co-segregates with Asp299Gly substitution [30]. C o-segregating missense mutations rea lso associated with n haled LPSi n humans. T heser esults nicate hei mportance of otherge netic and/or environmental factors in de termining esonset oi nhaled ndotoxin nda ne edf or urthers ttiest o understandt hem echanisms.

Iti shypothesizedt hat “ healthy workers” ha vea di minishedd esonset odus t contaminants, i ncluding endotoxin, t hroughg netic actors. Furtherunde rstanding of t he geneticst hatr esulti nh yporesponsiveness sm ayl eadt opent entialm eansof r emediation, b y treatingo rpr eventingt he orker reponsei nnon- healthy workers (Figure 1).

**Remediation**

Theove rwhelming evidence of t hen egativer espiratorys ymptomsa nd immunologicale ffectsof poul trydus te xposures uggestsa n eed forr emediation. However, m anys ources ofdus t, i ncludings omes ourcesof endotoxin, a rei ntrinsict ot he poultrypr odutioni ndustry andt herefore, r emediationi sdi fficult (Figure 1). K eeping poultryf acilitiesc leanh asl ongbe ene ncouraged asa m ethodt opr otechu man respiratoryh ealth. A dopting anagementpr actess ucha sus eo fpe lletedf ood,r outline entryi ntobui ldings and useof l ightinge yclesc anc ontrold usta nda mmonial evels. However, s omepr acticessm ayl owerone contaminantw hilei ncreasing another. F or example, dr yl itterr educesa mmoniapr odutionb uti sa erosolizedm oree asilyb y animal activity. A Iso, a pplicationof w aterm istsc an reducedus tpr odutionb yi ncreasingt he settlingve locity of a irbornep a rticlesbut i ncreaseras elativehum idity, w hichf acilitates ammoniapr odution[3]. B oth heus eof well-fittedN - 95r espiratorsb yw orkersa nd spraying wateror oi ln ixturesr or educedus ta res hownt obe e ffective atr educingdus t exposurei na nimalc onfinemebntbui ldings[12,19,25,31,32] . A lthoughs praying water isus efta tr educingdus tpr odution,i ti ncreases relativehum idity, w hichf acilitates microbialgr owth[3].

Alteringm anagementp acticesm aybe am eansof r educinga erosolizationof ba rn contaminants, t husr educingw orkere xposure.U nderstandingt hel evelsof worker
exposurest obi aeroosolm ayh elpi ntroducene w managementpr acticest o reduce
exposure,s ucha sbe tter personalpr otectivee quipment.B etteringund erstandingof t he
workersr eponent ayl eadt one wm eanso ft reament(Figure1).E xaminingt he
environmentaldi fferencesbe tweeenc age-houseda ndf loor-housedpoul try operationsm ay
providei nsighti ntoot herm eansof r emediaion.

Conclusions

Dusts ources,i ncludinge ndotoxin,a repr esenta th ighc oncentrationsi npou ltry
facilities.T hea erobiologicalpa thwayof poul try dusti sout linedi nf igure one.
Endotoxic anbe r ecoveredf roma irs amplesdue toi tsa ssociationw ithdu stpa rticles.
Thepr oductionof poul try dustc anva rydu et of actorsi ncluding:a nimala ctivity,a ir
temperature,r elativehu midity,v entilationr ate,a nimals tockingde nsity,t ypeo fl itter,
typeof bi rd,bi rda ge,t ypeo f eed,f eedingm ethod,t imeof da y, airdi stribution,r elative
locationsof dus ts ources andpr esenceor absence ofa irc leaningt echnologies[ 3,12].
Also,pa rticles izei sa ke y factori npoul trydus tp roductions incere ateof a erosolization,
settlingve locitya nd esuspendionr ateof airborne particlesdi fferde pendantonpa rticle
size[ 19].

Dustpr oductioni st ypicallyhi gheri nf loor-housedve rsus cage-housedpo ultry
facilities[ 6].M anagementpr acticsdi fferb etweent het wot ypeso fpoul try facilities.
Animala ctivityi shi gher inf loor-housedope rationsw herebi rdsm ove freely asoppos ed
tobe inghous edi nc ages.T hishi gherl evelof a ctivityc ontributest o greaterpa rticle
aerosolization. Litteri sa ourceof dus tp r oductiona ndi sus edi nf loor-housed
operationsbut not i nc age-housedf acilities.T he predominanceo ff emale birdsnc age-
housedope rationsa sw ella sdi fferentbi rdt ypesc ontributet odi fferencesi nt hea ir
environment.B ird agei sa lsoa f actort hatdi ffers betweent het wob arnt ypesa ndha sa n
effectonbi oaresols.T hesedi fferencesc oincide withobs ervationsof greaterdus t
concentrationsi nf loor-housedpoul try facilities.

Interestingly,obs ervationsof hi ghert otaldus tc oncentrationsi nf loor-housed
operationsa renot i na greementw itht heobs ervationsof gr eaterr espiratoryd ysfunction
inc age-housed workers. Further investigation of dust concentrations at different fraction sizes suggests that cage-housed operations have second; FVC - forced vital capacity; IL-1β - interleukin-1beta; IL-6 - interleukin-6; IL-8 - interleukin-8; LAL - Limulus amoebocyte lysate.

Abe terunde rstandingo fit heba m aire vvironment, i ncludingbi aerosols, i s required or educe aerosolization nddi spersal, de creaseworker exposure ndpr eventor treatr spiratory symptoms. Further examination of the hea erobiological path way illhe lp tof indm ensof r emediation. S incep ricles izei sa ni importantf actor for aerosolization, furtherr esarchi ntobi aeroesol ontaminationnda diferentp articles izef ractionsi s necessary. V iblem icroorganismc ontributingt obi aeroesolpr odution havebe en identified. H owever, m ehtods toi dentifyt hec ontributionsof non - viablem icrobesa re required. Ins winef acilities, s omef orms of r emediationha vebe ent ested. These methods includet heus e orf spiratorsb y workersa nds prayingof canolao ilr or educe duste exposure. S uchm ehtodns e edt obe e valuatedi nt hepoul tryri ndustry. T hee econim importancef m aintainingt he poutrypr oductioni ndustry sobvi ous. H owever, t he spiratoryd ysfuctionof poul tryw orkersi sa m ajorhe althi ssuex ndr equriesde tailed investigation.

**Abbreviations**

BAL - bronchoalveolar lavage; CFU - colony forming unit; E - endotoxin unit; FEF25-75 - forced expiratory flow rate between 25% and 75% of FVC; FEV1 - forced expiratory volume in one second; FVC - forced vital capacity; IL-1β - interleukin-1 beta; IL-6 - interleukin-6; IL-8 - interleukin-8; LAL - Limulus amoebocyte lysate;
LPS – l ipopolysaccharide; O DTS- or ganicdu s tt oxics yndrome; P C R- pol ymerasec hain reaction; sp.– spec ies; TNF-α - t umor e croisf actor-alpha; TLR2 -t oll-lik er eceptor2 ; TLR4 - t oll-lik er eceptor 4

**Competing Interests**
The authors declare that they have no competing interests.

**Authors’ Contributions**
N Jp anticipated ndr a ftingt hem anuscript. C Da ndB Spa rticipatedi nr evisi ngt he manuscript. A Ila authors h aver e ada nd a provedt hef inalm anuscript.

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References


Figure legend

Figure 1 - A erobiological pathway of dust in poultry facilities
Common factors influencing the age of the poultry are indicated in the grey boxes, specific age-housed factors are highlighted in white boxes. Remediation opportunities for each stage of the pathway are indicated in the white boxes.
**REMEDIATION**

**RESPONSE**
Can preventative measures result in workers being less responsive? Can knowledge of “healthy workers” identify new therapies?

**EXPOSURE**
What exposures should be monitored? What is an appropriate exposure limit? How can exposure levels be lowered?

**AEROSOLIZATION**
How can aerosolization be reduced? Are new management practices necessary?

**SOURCE**
Can any of the sources be removed?

**Floor-based:**
- lower current and chronic cough, less reported wheeze

**Common:**
- toxin fever, asthma-like syndrome, airway obstruction & hyperreactivity, influx of inflammatory cells & cytokines

**Cage-based:**
- greater current and chronic phlegm, higher reported shortness of breath

**Floor-based:**
- greater total dust, lower endotoxin

**Common:**
- particle size, aerodynamic diameter

**Cage-based:**
- endotoxin-enriched respirable fraction

**Floor-based:**
- type of litter, animal activity, stocking density, stationary feeders, young birds

**Common:**
- temperature, humidity, ventilation, bird type, bird age, type of feed, time of day, air distribution

**Cage-based:**
- manure pits, animal mass, belt feeders, mature birds

**Floor-based:**
- use of litter, moulting phase of young birds

**Common:**
- poultry feed, fecal matter and urine, skin flakes, feathers, bacteria, fungi, microbial components

**Cage-based:**
- presence of eggs, predominance of female birds

Figure 1