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Indoor Air Particulates in Broiler Environment During Winter

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Abstract: The impact of winter climate on indoor and outdoor air particulate concentrations (ID and ODPC), concentrations of TSP, sizes and nature in broiler houses were recorded weekly. In closed and Open houses (Chs and OHs) significant positive correlations were recorded between ID and OD climate. Significantly decreased ID Ta.^{0}C and A.V m/sec and increased RH% in open vs closed. OD Ta.^{0}C significantly decreased and RH% increased around OHs vs CHs. In CHs increased (OPC) vs (IPC) except at the 3rd and 4th week. The Indoor Organic Particulate (IOP) started small in sizes (1-2 μm ID and < 5 μm OD). The maximum Particulate Concentration (PC) and sizes were at 3rd week old age on floor litter. In OHs the IPC were permanently increased vs OPC except at the 1st week. Before chicks admission (IOP) were dominated. The Chemical Composition of Organic Particulate Ones (CCOP) showed higher SIO % vs Inorganic Particulate (IP). The indoor organic and inorganic particulates (IOP and IIP) were of big sizes and contained variable percents of non organic oxides of Si^{+4}, AL^{+3} and Ca^{+2}. IP was smaller than OP at early age but increased with age and contained variable percents of SI, Fe and Ca oxides. Conclusively the dominancy of IOP and OOP with large sizes before admission to 3rd week may induce health risk for birds and keepers. Improper controlled system in stocked poultry houses and the outdoor climate positively affected the indoor one especially in winter.

Key words: Open and closed houses (OHs and CHs), particulate concentration (PC), organic and inorganic dust, temperature (Ta.^{0}C), relative humidity (RH%), air velocity (AV m/sec)

INTRODUCTION

Enclosing and concentrating birds in confinement houses concentrating their wastes products and contaminants mainly dusts which contributed workers and bird health problems. Potential health hazards to the agricultural workers and livestock when exposed to these contaminants, where the large particulates were trapped by moist tissues in the nose and might cause irritation and sneezing. The particle 5-10 μm in size would reach wind pipe causing irritation of lining membranes and possible infection, while >5 μm called Respirable particles and might reach the bronchioles and alveoli presenting the most hazards one. Of airborne contaminants were particulates (viable and nonviable). Dust concentrations were higher for total and Respirable dust average 10 and 0.5 mg/m^3 respectively that was attributed to increased birds size and activity generating more dust. The non viable fraction (dust) is mainly of organic nature include particles of manure, litter, feed, dander, feathers, mold, pollen, grain mites, mineral ash, gram negative bacteria, microbial proteases, adsorbed particles, infectious agents, faecal matter, broken feathers barbules, fungal fragments and spores. Broiler dust had a lower level of fat but a higher percentage of protein due to the large amount of feathers shed during growth beside the traces of heavy metals which attributed to the chemical composition of food (Jones *et al*., 1984; Donham, 1986; Muller and Wieser 1987; Harmon *et al*., 1994). The mass concentration of inspirable dust particulates increased with bird age, activity and intensity at 15-20 days old and remained constant till reduced stocking density at 29 days old. Respirable dust concentration increased logarithmically in broiler houses with increased bird weight between 2-6 wks old, as well as, indoor climate included air change rate. The minimum rate of air supply were slow, 4 circa air changes//hour exposed birds continuously to aerial pollutants in form of inorganic and organic dusts at concentrations exceeded recommended occupational limits for humans. Adjustment of RH% of indoor airborne house to 75% would had an effect on inhalable dust but not on Respirable dust (Curtis, 1981; Yoder and Van Wicklen, 1988; Conceicao *et al*., 1989; Ellen *et al*., 2000). Seasons also may affect dust levels and sizes as reported by (Whyte *et al*., 1993) where dust concentration

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ranged from 2.2-8.7 mg/m^3 in broiler house during winter (Redwine *et al*., 2002), the concentration of PM 10 µm fraction of TSP were 3.7-99.0 µ/g^3 in summer and 0.58-57g/h during winter. In broiler operations, respirable particle counts and total dust concentrations increased with flock age. Increases in dust concentrations in winter season were not statistically significance. For birds health risk, their keepers and even the outdoor neighbors who may attract the emitted air pollutants suspended and adsorbed on dust particulates with consequent respiratory disorders as asthma, bronchitis, allergy, bacterial. fungal and viral infections. As well as the evaluation of field environmental control efficiency for weather elements and management procedures either in open or closed houses through winter, spring and summer. Many respiratory, pulmonary, blood vascular diseases and nervous disorders that birds suffered strongly correlated with environmental management and its resultant of dust, particulates containing vegetative, organic active matters, microorganisms and gaseous products (Maria *et al*., 1989; Al-Dagal and Fung, 1990; Eglite *et al*., 1991; Senthilselvan *et al*., 2010). A better understanding of the poultry house environment is needed to improve the respiratory health of poultry workers. The climate in poultry houses influences the well being and health of humans as well as that of birds. The aerobiological pathway that results in dust production includes the source, aerosolization and dispersal, exposure, response and remediation. The amount of dust in a house depends on many different factors as temperature, relative humidity, type and age of the animals, type of litter used, feeding system, hygiene. Proper maintenance of poultry houses and regular cleaning creates more comfortable conditions for animals and better working conditions for humans (Just *et al*., 2009; Poultry CRC, 2010). Therefore the current field study was conducted looking for better understanding of the open and closed poultry houses environment in winter and assess potential health risk of emitted indoor air particulates to neighbor residents closet to poultry operations facilities.

MATERIALS AND METHODS

Field broiler houses: 2 houses had been investigated (open and closed). The available houses were located around Al-Dammam city (NW and NE) respectively, Eastern region, KSA. Litter floor was of wood shaving and Cobb 500 and Ross 308 broiler breeds were in accordance. Food and water were available *ad libitum* while light was available 23 h/day.

Procedures

Outdoor and indoor air measures: The indoor measures were recorded and samples were collected from 6 representative indoor fixed sites at the bird's breathing zone (15 cm from floor level). The Ta.°C, RH% and AV m/sec were determined by using digital thermo-hygrometer and anemometer (Radon *et al*., 2002) in both houses. Visits were weekly, started day before baby chicks admission till marketing age. Air samples for dust collection were done at 2 meter apart of and around the house from all direction (North, South, East and West) using dust collecting sampler left for l h (collective samples) around all sites then calculated/liter air/day (Davis and Morishita, 2005).

Determination of particulates concentration, sizes and nature: The collected dust samples were on the pre - weighed micro fiberglass or Whatmann filters and removed carefully from their cassette and reweighed to get the difference in weights of particulate matter (PM mg/L) of air withdrawn in known flow rate (Radon *et al*., 2002). These filters thereafter, were kept under dry condition and sent to Saudi Armco, Environmental Scanning Electronic Microscope unit (ESEM) to determine the sizes, chemical nature either organic or non organic of the collected particulates and the percentages of these elements for each PM fraction (Feddes *et al*., 1992).

Statistical analysis: Included descriptive, correlations (Pearson), t-test (one way ANOVA) using personal computer and Spss V.11 [Spss, 2004].

RESULTS AND DISCUSSION

Indoor and outdoor climate in closed and open ecosystems: Results of Table 1 revealed a significant positive correlation between ID and OD Ta.°C ($p = 0.045$), this was unexpected for the nature of closed controlled environment but it may be attributed to unexpected failure of ventilation system control panel under field condition. The significant positive correlation between ID and OD RH% ($p = 0.001$) was in regard to the nature of Eastern region with high humidity especially this winter where increased rain fall, beside increased humidity with age (Zucker *et al*., 2000) and possibility of default drinking system (Butcher and Milles, 2003) and the mentioned improper controlled system. The impact of improper control system in animal houses and the influence of OD climate on the ID one especially in winter previously reported by (Petkov and Baikov, 1984).

Results in Table 2, indicated significant correlation between ID and OD Ta.°C ($p = 0.022$). The ID RH% was positively correlated with OD ones ($p = 0.099$). These correlations were indicative to the nature of open non controlled system.

Table 1: Impact of indoor climatic conditions on outdoor ones in closed ecosystem

	Outdoor		
	Climatic conditions		
Indoor	Ta.°C	RH%	A.V (m/sec)
Ta.°C	0.414**	0.370	-0.374
	0.045	0.075	0.072
RH%	0.201	0.712***	-0.099
	0.347	0.001	0.647
A.V (m/sec)	-0.034	-0.050	0.127
	0.875	0.817	0.555

*p≤0.1; **p≤0.05; ***p≤ 0.01

Table 2: Impact of indoor climatic conditions on outdoor ones in open ecosystem

	Outdoor		
	Climatic conditions		
Indoor	Ta.°C	RH%	A.V (m/sec)
Ta.°C	0.521**	0.223	0.242
	0.022	0.358	0.319
RH%	0.738***	0.390*	0.399*
	0.001	0.099	0.091
A.V (m/sec)	-0.299	-0.121	-0.358
	0.214	0.623	0.132

*p≤0.1; **p≤0.05; ***p≤ 0.01

OHs remarked by significant decrease of ID Ta.°C and RH% (p = 0.001) and A.V (p = 0.036) as in Table 3. OHs had lowered Ta.°C and A.V significantly Vs CHs (p = 0.001 % 0.036 respectively) while RH% was increased (p = 0.001). OD Ta.°C significantly decreased around OHs (p = 0.001) while RH% increased (p = 0.001) Vs CHs as indicated in Table 3.

Indoor and outdoor particulates in both ecosystems: Results in Table 4 indicated increased (ODPC) vs (IDPC) except at the 3rd and 4th week old. IPC ranged 1.7-16.2 mg/m^3 with mean 8.08±5.29. OPC ranged 5.9-15.0 mg/m^3 with mean 9.45±3.69. However, previous researches reported higher concentration than current results even far at 3 m from poultry building exhaust fans, where dust concentrations can be relatively high (32-75 mg/m^3) but fall below 2 mg/m^3 by 12 m from ventilation fans (Davis and Morishita, 2005). At 1st wk old the (OP) dominated with different sizes P<5 µm as in (Fig. 1) 1.57-1.73 µm and the (IOP) size was 1.05-2 µm, as well as the OPC was 9.1 mg/m^3 Vs the IPC was 6.9 mg/m^3. At 2nd wk old the Outdoor Inorganic Particulates (OIP) were dominated with 82.72 µm in size (Fig. 2) and other smaller size 3.34 µm (Fig. 3), the Total Particulate Concentrations (TPC) were 12.84 and 5.7 mg/m^3 OD and ID respectively. At 3rd wk old, IOP dominated with various sizes ranged 2-15.6 µm (Fig. 4), with sizes 5.0-15.6 µm and TPC 16.2 and 15 mg/m^3 for ID and OD respectively. The IOP were dominated and increased with age while Indoor Inorganic Particulates (IIP) were mixed. From the aforementioned data, the origin of the OP seemed to be indoor and this was expected due to birds activities, increased excreta with age and size, litter and food particles, expelled droplet, as well, the particulates sizes related to the mentioned factors, where their maximum concentration and sizes at 3rd week Vs zero age (24 h before chicks admission, these results were coincided with (Poultry CRC, 2010; Senthilselvan *et al*., 2010). The maximum TPC and inhaled PC to which keeper supposed to be exposed were 21.3±3.2 and 4.6±0.9 mg/m^3 respectively as reported by (Golbabe and Islami, 2000). The small sizes started at early ages and became larger later, that might be correlated with increased detached feather and tissue and noticed dried litter in this house, these observation was in agreement with those recorded by (Louhellainen *et al*., 1987; Yoder and Van Wicklen, 1988). The effect of seasons on particulate sizes and concentrations were reported by (Whyte *et al*., 1993; Redwine *et al*., 2002) where they found dust concentration in broiler house during winter ranged from 2.2-8.7 mg/m^3 and the PC of 10 µm fraction of TSP were 3.7-99.0 µg^{-3} in summer and 0.58-57g/h during winter. These particulates represent health risk of birds and their keepers and even the outdoor neighbors who expect to attract the emitted air pollutants suspended and adsorbed on dust particulates with consequent respiratory disorders. Despite recent data recorded increases in dust concentrations in the winter season were not statistically significance (Senthilselvan *et al*., 2010).

Table 3: Impact of kind ecosystem on indoor climatic conditions

Climate	Closed house (Mean±SD)	Open house (Mean±SD)	T. value	Sign.
Ta.C ind.	27.9621±2.0545	18.4696±2.1887	15.96	0.001***
RH% ind	57.2414±8.3778	69.3130±5.8559	6.10	0.001***
A.V m/sec. ind	0.33517±0.44534	0.15000±0.08660	2.19	0.036**
Ta.C out	23.0583±2.6018	17.4950±1.5693	8.74	0.001***
RH% out	56.3250±10.2481	66.0850±2.2644	4.54	0.001***
A.Vm/sec/Out	3.40208±3.01747	3.68000±1.84579	0.38	0.710

*p≤0.1; **p≤0.05; ***p≤ 0.01

Table 4: Indoor and Outdoor Particulates Concentration (IPC and OPC) mg/m^3 in closed house

Age/week	IPC mg/m^3	OPC mg/m^3
24 h prior admission	1.7	5.9
1st wk	6.9	9.1
2nd wk	5.7	12.84
3rd wk	16.2	15.0
4th wk	11.3	6.86
5th wk	6.0	6.89
Mean±SD	8.08±5.29	9.45±3.69

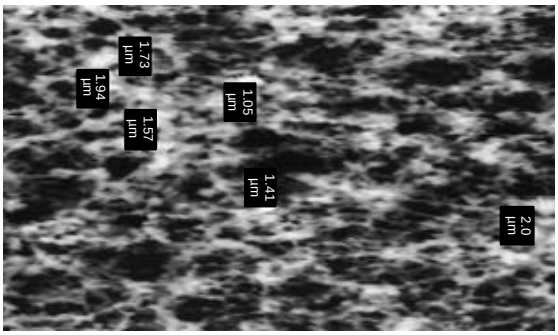

Fig. 1: Outdoor OP of sizes ranged 1.57-1.73 µm at 1 wk old in closed house (X 2000 Millipore filter, ESEM) (for closed house)

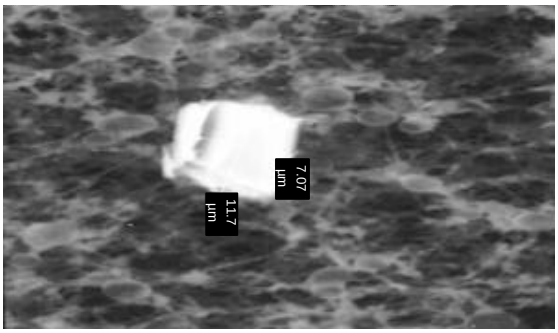

Fig. 2: Outdoor IP of sizes 82.72 at 2 wk old around closed ecosystem (X 2439 Millipore filter, ESEM) (for closed house)

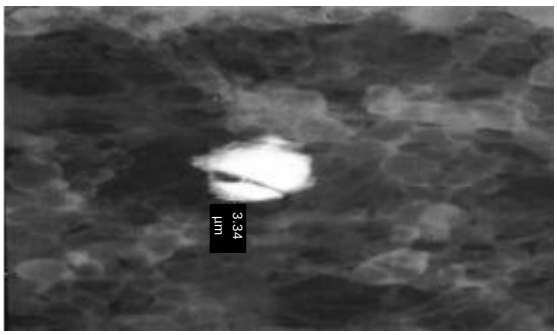

Fig. 3: Outdoor IP with sizes 3.34 µm around closed ecosystem at 2 wk old (X 5000 Millipore filter, ESEM) (for closed house)

Table 5: Indoor and Outdoor Particulates Concentration (IPC and OPC) mg/m^3 in open house

Age/week	IPC mg/m^3	OPC mg/m^3
24 h prior admission	2.0	1.3
1st wk	2.7	4.0
2nd wk	8.0	4.5
3rd wk	16.7	13.3
5th wk	10.7	6.7
Mean±SD	8.02±6.06	5.96±4.53

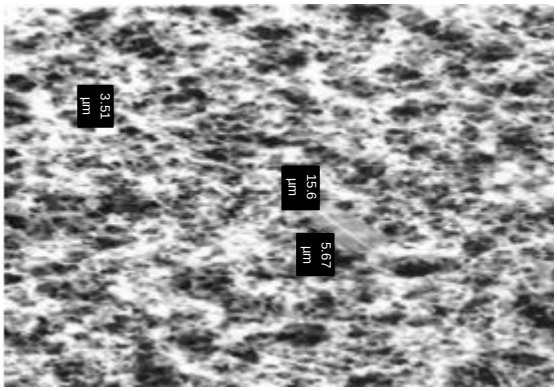

Fig. 4: Indoor OP of sizes 5.67-15.6 µm at 3 wk old in closed ecosystem (X 1000 Millipore filter, ESEM) (for closed house)

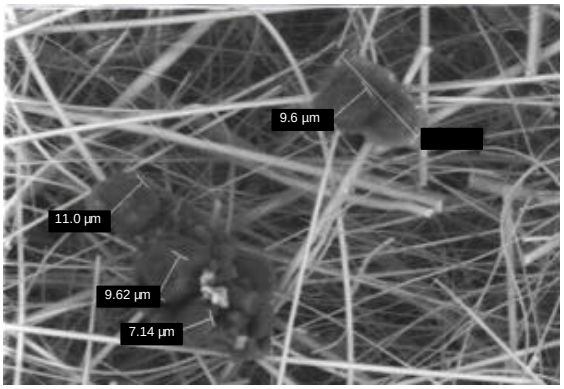

Fig. 5: IOP before birds admission with sizes ranged 23.8-73 µm

Results in Table 5 revealed that; in OHs, the IPCs were permanently increased Vs OPC except at the 1st week. They were ranged 2-16.7 mg/m^3 with mean 8.02±6.064 mg/m^3 while OPC were 1.3-13.3 mg/m^3 with mean 5.69±4.531 mg/m^3. IOP were dominated before birds admission zero age with sizes ranged 23.8-73 µm (Fig. 5) and bigger sizes ranged 202.74-390.6 µm which contained 43.35% carbon and non organic elements 56.65% with 9.65% of SIO and 1% for K, Mg (Fig. 6), meanwhile the IIP size was 1185.84 µm and the IOP with size 508.08 µm (Fig. 7) and chemically contained 39.8% carbon, 9.13% of AL and 1% of Mg, P and S oxides. The IOP chemically revealed 39.08% of its

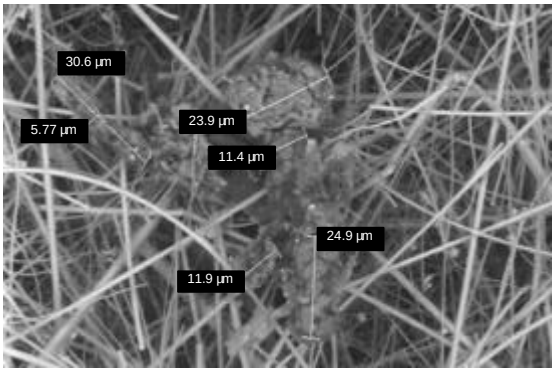

Fig. 6: IOP before admission with sizes 202.74-390.6 µm (X 400)

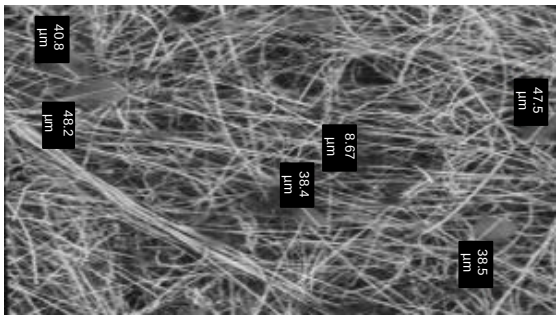

Fig. 7: OP with sizes 508.08 µm before admission (X 1600) (for open house)

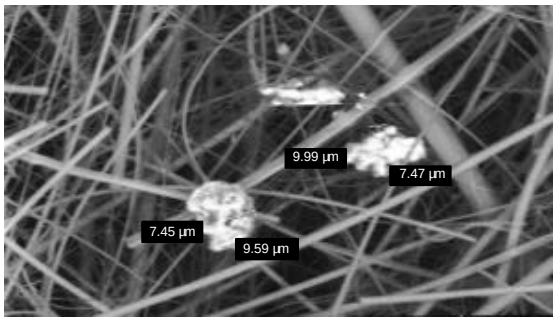

Fig. 8: OIP size 33.2 µm, 1st wk (X 1600) (for open house)

weight was carbon and the rest was inorganic oxides where Aluminum oxide was the highest 9.13% and the lowest were 1% for each of Mg, P and S (Fig. 8). The OOP size was 2628.6 µm and IOP was 33.2 µm (Fig. 9) and PC was 1.3 mg/m^3, chemical composition of OP included 34.31% Carbon while non organic oxides were 37.13% with the highest of Sl 16.15% and the least was of Mg 0.43% while IP chemical composition included 6.3% carbon, 53.71% non organic oxides mainly of Ca^{++} (20.86%) and least of S (0.48%).

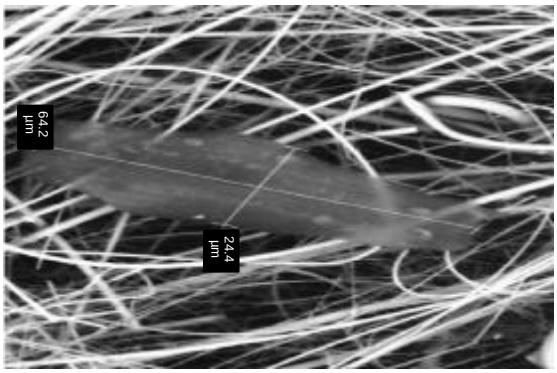

Fig. 9: IOP at 2 wk dominated with big sizes ranged 2369.64-5522.4 µm and lower sizes ranged 8.67-48.2 µm (X 200) (for open house)

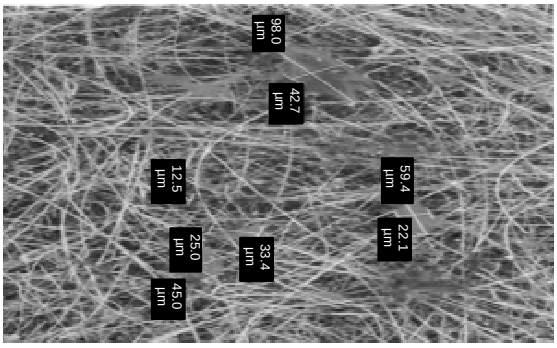

Fig. 10: OOP 2nd wk old were dominated with sizes 7.14-22.4 µm (X 1000) (for open house)

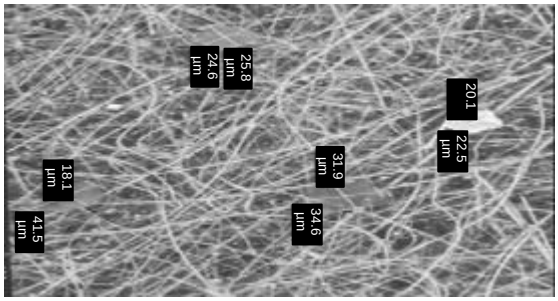

Fig. 11: IOP 2nd wk with sizes 11.4-176.6 µm (X 800) (for open house)

At 2 wk old, IOP were dominated with sizes 7.14-22.4 µm as in (Fig. 10) and their contents of carbon was 30.48% of weight while non organic oxides were 35.98% where the highest was Silicon oxide 17.88% and the lowest 1% for Mg, S and Ca^{++}. At the same age the OIP dominated with sizes 6.2-544.17 µm and a little of OOP sizes were 11.4-176.6 µm (Fig. 11) and contained 27.45% of C and 47.18% of oxides where highest SIO % was 12.37 and the lowest 1% was for each of S, CL and K. The dominated IP had 37.68% of non organic oxides mainly of Fe (44.18%) and least of K (0.7%).

At 3 wk old, IOP dominated with big sizes ranged 2369.64-5522.4 µm and contained 50.39% of C and 28.54% of non organic oxides mainly of Sl 11.12% and the lowest was less than 1% for S, Mg, Ca and CL. The OOP dominated with sizes ranged 844.8-1461.71 µm, their chemical composition included 37.17% non organic oxides with highest Ca^{++} 17.23% and least 15 of Mg, S and CL, other OOP sizes 1566.48 µm.

At 4th week old, IOP dominated with sizes 12.5-4184.6 µm and others with sizes 11.3-40.1 µm. Chemical composition of the IOP contained 52.12% C and 31.35% non organic oxides mainly of Sl 6.97% and minority of K and Mg 1%. The dominated OOP sizes were 4.31-470.28 µm, other sizes were 18.1-41.5 µm, the OIP size was 452.25 µm. The OOP contained 26.35% C, non organic oxides 39.81% mainly of Sl 17.89% and least 1% was of Mg, S and CL, while the OIP in same figure contained 43.35% of non organic oxides mainly of Sl 22.24% and least 0.49% of CL.

From the current results, the IOP were dominated with sizes 7.14-552.4 µm while the IIP sizes were 2.73-1185.84 µm. The OOP were dominated with sizes 4.31-2628.6 µm and the OIP sizes were 33.2-24949.3 µm. Airborne and settled poultry dusts had similar chemical compositions. Approximately 900 g/kg dry matter showed, 95 g/kg ash, 150 g/kg nitrogen, 6.5 g/kg phosphorous, 30 g/kg potassium, 4 g/kg chlorine and 3 g/kg sodium. Down feathers and crystalline dust are the major physical components of dust (Just *et al*., 2009). Dominancy of OP indoor and outdoor (zero age and 3rd wk) especially with large sizes throw light on expected risk for birds and their keepers health because its organic origin and contents which may originate from droppings which represent the most persistent indoor air particulates in turkey houses, food, feathers, detached skin, fungal spores and fragments, litter materials (Lenhart and Olenchock, 1984; Thelin *et al*., 1984; Louhellainen *et al*., 1987). On regarding increased IPC Vs OPC (16.7 mg/m^3 Vs 13.3 mg/m^3) in winter with big sizes particulates in winter season may be related to their accumulation during brooding and trials to keep indoor temperature and warm environment nevertheless resulted pollutants including particulates and their contents. The big sizes also affected by indoor humidity level where increased RH to 75% affected the inhalable not respirable Particulate, these results were in agreement with (Feddes *et al*., 1992; Wathes *et al*., 1997; Ellen *et al*., 2000). The decreased PC post 3rd week (10.7 mg/m^3) was attributed to increased available floor area and the non controlled ventilation in this house system. The PC was more than recorded (1.9-7.6 mg/m^3) by (Lenhart and Olenchock, 1984) and within the limits (0.02-81.33 mg/m^3) as reported by (Ellen *et al*., 2000). The mass concentration of inspirable dust particulates increased with bird age, activity and intensity as mentioned by (Conceicao *et al*., 1989; Ellen *et al*., 2000). The IOP contained non organic oxides mainly of Sl 11.4% while the OOP contained Sl 15.62%, IIP had no silicon oxide but OOP had Sl 25.22%. The significant correlation between indoor and outdoor PC in open ecosystems in winter reflected the effect of improper control of indoor air quality (different pollutants) and the health risk for birds and keepers and seasons may affect dust levels and sizes as reported by (Whyte *et al*., 1993) where they found dust concentration in broiler house during winter ranged from 2.2-8.7 mg/m^3 and (Redwine *et al*., 2002) where they recorded the concentration of particulate matter 10 µm fraction of total suspended particulate were 3.7-99.0 µ/g^3 in summer and 0.58-57g/h during winter. The current results revealed dominated big sizes IOP and OOP at 1st and 4th visits which represented great risk for bird and their keepers especially of being organic nature as coincided by (Louhellainen *et al*., 1987).

Conclusively the dominancy of IOP and OOP before admission to 3rd week especially with large sizes may induce health risk for birds and their keepers for its organic nature and contents. Improper controlled system in stocked poultry houses and the outdoor climate induced impact on the indoor one especially in winter. Kind of house and management practice affected nature, sizes, concentrations and chemical structure of IP and OP with variable sizes and possible occupational health risk for birds, their keeper and residents if existed. Risk assessment for disease-linked particulates that may be attracted by poultry keepers must be considered.

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