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ORIGINAL ARTICLES

Optimization Of Dust Removal In Poultry Houses Using Electrostatic Wet Scrubber

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ABSTRACT

An air cleaning device basedon the principles of the electrostatically-assisted wet scrubber was built and tested to remove air particulates in a poultry house under the climatic conditions of Saudi Arabia. The particle removal efficiency of the device was experimentally investigated. Using home dust as test particle under controlled conditions, the wet scrubber with the negatively-charged water spray had significantly ($P<0.05$) greater mean removal efficiency η value (80.3%) than either the control (i.e., only fan with no water spray) (η=24.5%) or the uncharged water spray (η=62.4%). At poultry house, the device with the negatively-charged water spray had significantly ($P<0.05$) higher particle removal efficiency (η=72.4%) than either the uncharged water spray (η=48.2%) or the control (η=16.2%).It can also conclude that, this device was effective in removing airborne dust and can be used in various climatic conditions as an environmentally clean and energy efficient system.

Key words: Dust, charged water spray, electrostatic, poultry.

Introduction

Airborne dust is one of the primary means by which disease causing organisms are spread throughout our environment. Reductions in airborne dust levels have been associated with even greater reductions in airborne bacteria (Mitchell *et al*, 2004), and resulted in improvement in human respiratory responses. Several classes of health effects are linked to particle exposures that may be reduced via filtration. Allergy and asthma symptoms may be produced in susceptible people upon inhalation of allergenic particles, such as p*et al*lergens, dust-mite allergens, pollens from outdoor plants, and fungal spores or fragments from outdoors or indoor sources (Committee on Assessment of Asthma and Indoor Air, 2000). Due to growing environmental concern and stringent environmental regulations enforced by the legal bodies worldwide on particulate emission from various sources, researchers' attention was driven to look into alternative technologies, which are simple, cost effective and have high performances in removing these particulate matters from industrial effluents. Understanding dust effects will lead to obtain the best methods for dust control (Almuhanna, 2007,and *et al*., 2008).Particulates may be either emitted into the atmosphere (primary particulates) or formed within the atmosphere itself (secondary particulates) as a result of chemical reactions of primary pollutants (Melse *et al*, 2012). To some extent, particles are removed from the atmosphere by sedimentation and precipitation (the atmospheric residence time for particles >20 μm is several hours, while it is two to four days for 2 to 3 μm particles) (CAFE, 2004). Particles in the range 0.1 to 1 μm exhibit the longest lifetime in the atmosphere, ranging from days to a few weeks (Melse *et al*, 2012).

Air quality in livestock buildings should be improved to prevent potential occupational health problems. Engineering control strategies include the following: (1) reducing generation rates of the air contaminants or source control strategies, including use of feed additives (fat or oil), cleaning of dusty surfaces, and spraying water or oil over dusty surfaces; (2) dilution and/or effective room air distribution or ventilation control strategies, including increased ventilation rate, purge ventilation, and effective room air distribution system; and (3) air cleaning or removal control techniques, including ionizers, wet scrubbers, or other air cleaners.Strategies developed for protecting building environments from deliberately used aerosol agents require efficient air filtration and air cleaning systems [National Institute for Occupational Safety and Health (NIOSH), 2003]. Current trends observed in air pollution control technology are closely related to the development of new, more efficient hybrid systems, i.e., those, which simultaneously utilize two or more physical mechanisms for dust or gaseous contaminants removal. These systems can operate more economically than conventional devices.

The electrostatic scrubber (electro scrubber) is one of such types of devices, which combines advantages of electrostatic precipitators and inertial wet scrubbers, and removes many shortcomings inherent to both of these systems operating independently. The electro scrubber is a device in which Coulomb attraction or repulsion

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forces between electrically charged scrubbing droplets (collector) and dust particles are utilized for the removal of particles from a gas. Unlike wet electrostatic precipitators in which particles are precipitated only on the collection electrode, in electro scrubbers, the collection of dust particles takes place in the entire precipitator chamber. Compared to inertial scrubbers, the electro scrubbers can operate at lower droplet velocities, but the collection efficiency for a single droplet can be > 1 (Jaworek *et al*., 2006).Wet scrubber is one of air pollution control devices that can be used to remove particle and gaseous pollutants from industrial exhaust streams, simultaneously. In a wet scrubber, the dirty gas stream is brought into contact with the scrubbing liquid, by forcing it through a pool of liquid, or by some other contact methods (Lim *et al*., 2006). A wet scrubber uses a scrubbing liquid (e.g., water) to remove pollutants, including dust particles and gaseous pollutants, from gas streams. In addition to particle removal, wet scrubbing can be used to remove water-soluble gases, including ammonia and odorous compounds.

Dust particles are captured by liquid droplets via the following major collection mechanisms: inertial impaction, interception, and diffusion. Inertial impaction and interception are usually highly efficient for particles larger than 10 μm; whereas, diffusion is the dominant collection mechanism for particles less than approximately 0.3 μm (Hinds,1999).The main physical mechanisms that play a role in PM10 (particles with aero dynamic diameter equal or less than 10 μm) removal by scrubbers are direct interception, diffusion,inertial impaction and sedimentation (Melse *et al*, 2012).Inertial impaction occurs when a particle, because of its inertia, is unable to adjust quickly enough to the abruptly changing streamlines in the vicinity of a liquid droplet and crosses the streamlines to hit the droplet. Interception occurs when a particle is offset slightly from directly impacting a liquid droplet but, because of its finite size, strikes and is collected by the droplet. Collection by diffusion occurs when small particles, because of the random Brownian motion, happen to diffuse toward and are collected by the droplet. In some cases, electrostatics has been used to augment particle removal efficiency of water droplets (Hassler and Birgitta, 1978).In some cases, electrostatics has been used to augment particle removal efficiency of water droplets (Almuhanna, 2007, and *et al*., 2008). Almuhanna *et al*. (2008) indicated that the potential of electrostatically charged water spray in reducing dust concentration in enclosed spaces under controlledconditions. In the said research, they aerosolized test particles (i.e., corn starch and sodium bicarbonate) into a closed experimental chamber. Charged water droplets were then sprayed into the chamber. An Aerodynamic Particle Sizer™ (APS) spectrometer was used to measure the particle concentration and size distribution. In addition, a tapered element oscillating microbalance (TEOM) was used to measure the mass concentration. From the APS and TEOM data, the particle removal efficiency of the charged water spray was determined. In general, the electrostatically charged water spray proved to be effective in reducing airborne dust concentration in the chamber under controlledconditions.

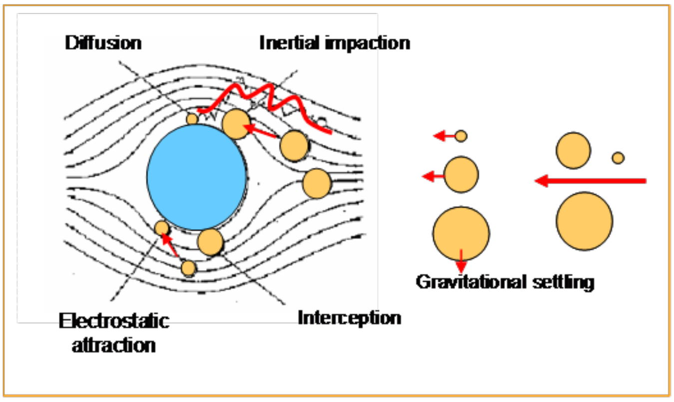

Fig. 1: Schematic diagram showing the particle collection mechanisms by awater droplet

The main parameters that determine the removal efficiency of particulates are usually the velocity, size, and mass of the particulates (Fuchs, 1989). Usually, the smaller the droplet size and the larger the number of droplet, the better the ability to capture smaller-sized particles. A high relative velocity between particles and liquid droplets also promotes particle capture. When a dust particle enters the humid scrubber environment, the size of the particle increases due to its hygroscopic properties (Kreidenweis *et al*., 2008; Hiranuma *et al*., 2008).As the particle grows and its diameter and mass increase, the chance of the particle being intercepted by sedimentation and impaction increases. Furthermore, design and operational parameters such as specific surface area ofthe packing, spatial structure of the packing, water flow rate, and airflow rate might affect the removal efficiency (Melse *et al*, 2012).

In process for producing liquid drops by injecting liquid at high pressure through nozzles, the important consideration for relative motion is the direction of injecting droplets. Reverse jet flow is used to achieve the large gas–liquid interfacial area, long residence time, and high differential velocities required for efficient collection for particles. Air-blast atomizing has been used in many industrial applications as fineness of droplets play very important role in modern industrial technologies. Especially in the scrubbing process of particles, the ratio of droplet size to particle size plays an important role (Raj Mohan *et al*., 2008).The clean air delivery rate (CADR) is defined as the measure of the delivery of contaminant free air by a portable household electric cord-connected room air cleaner, expressed in cubic feet per minute. The measuring method of CADR is as given in the AHAM (Association of Home Appliance Manufacturers) standard [AHAM AC-1-2000] (AHAM, 2000). The test procedure requires both a natural decay measurement and a particulate decay measurement. Both measurements are performed after filling the chamber with a test aerosol. The natural decay is defined as the decay of the test aerosols in the chamber with the air cleaner off. The particulate decay measurement is defined as the decay while the air cleaner is running.

Objectives:

The main goal of this study is to develop a prototype air cleaning device that uses electrostatically-charged water spray to be used in poultry houses. Specificobjectives are to:

- Develop a prototype electrostatically-assisted particulate wet scrubberfor air cleaning.
- Characterize particles for TSP, PM_{10}, and $PM_{2.5}$ size ranges before and after using the scrubber.
- Evaluate the device under controlled and field conditions.

Materials and Methods

An apparatus based on the principles of electrostatic wet scrubbingwas design and built. The design of the device includes the development and modifications in the design and geometry, and using one electrostatically-charged spraying nozzle (air assisted inductioncharging nozzle).

Description of the Prototype device:

Figure 2 shows a schematic diagram of the prototype air cleaning and coolingdevice. It consists of the following components: (1) axial fan, (2) mixingchamber, (3) charged water spraying system, (4) air outlet, (5) air inlet, and (5) porous witting medium (cellulose cooling pad, straws, date palm soft tissue . ,etc). A 0.31m diameter axial fan (model Windy DVN-121, Sungdo Corporation, 402, MoksanBldg, 252-156 Yongdu-Dong, Dongdaemun-gu , Seoul, Korea) provided variable volumetric of up to 30 m^3/min (1059.4 cfm) pressure 13 millimeter mercury (mmHg) was mounted in inlet duct and its motor speed was controlled by a voltage controller. The air inlet was 0.16 m^2, and air outlet 0.0675m^2, and the area of prose media was 0.11 m^2. The volume of the mixing chamber was 0.216 m^3

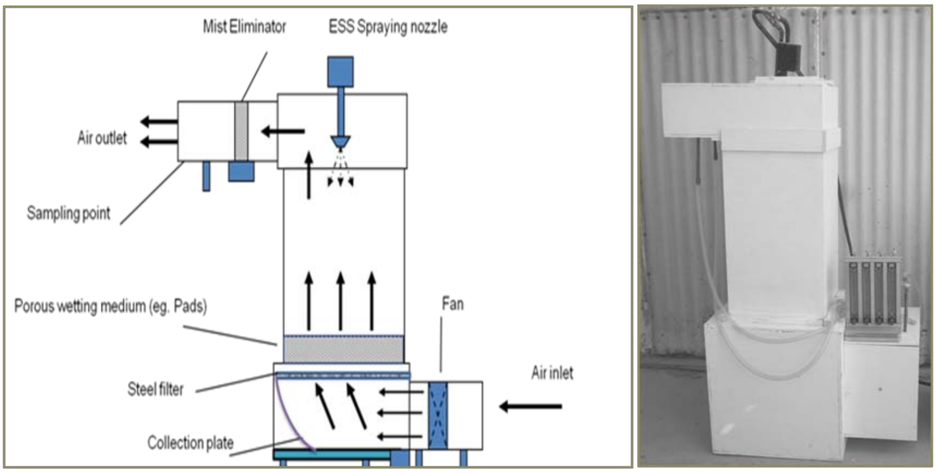

Fig. 2: (a) Schematic diagram showing the components air cleaning device (not drawn to scale),(b) photographs of the device.

Charged water spray was generated using a commercially available electrostatic water spraying device (ESS XT, Electrostatic Spraying Systems, Inc., Watkinsville, Ga.) developed for agricultural chemicals application (Law, 1978, 2001). The spraying nozzle was positioned on the top of the mixing chamber facing the direction of air stream (fig 2).In this study, the spraying system was operated at a liquid flow rate of 120 mL/min [at a water tank pressure of 103 kPa (15 psi)]. The droplets range in size from about 25 to about 60 µm as stated by the manufacturer. Measurement with a cascade impactor (model 110, MSP Corporation, Shoreview, Minn.) showed that the charged water spray had a mean geometric mean diameter (GMD) of 21 µm and a geometric standard deviation (GSD) of 1.8. The mean net charge-to-mass ratios of the charged droplets were -6.5 mC/kg (SD=0.9 mC/kg) for the negatively-charged water spray (Almuhanna *et al.*, 2008). Figure 3 is a schematic diagram ofthe charged water spraying system.

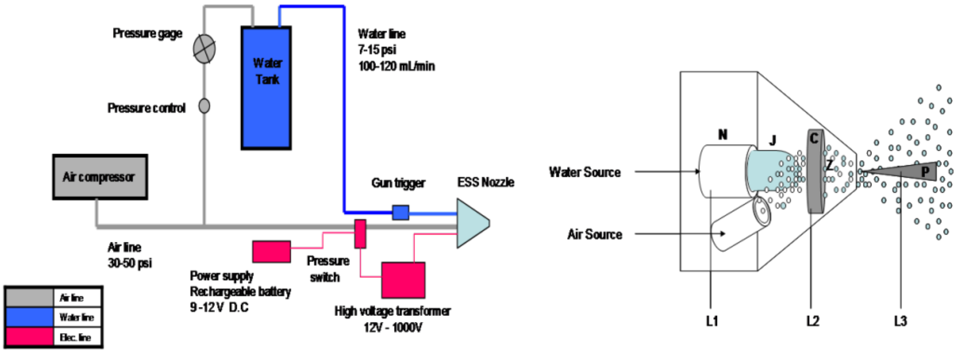

Fig. 3: Schematic diagrams of the (a) charging system, and (b) the electrostatic spraying charging nozzlesystem for water droplets (Law, 1978).

Water Use and Spray Cone Diameter:

Figure 4 shows the water usage as a function of time and pressure. Water use ranged from 1.6 mL/sec for a pressure of 10 psig to 2.3 mL/sec for a pressure of 20 psig. Figure 5 summarizes the diameter of the spray cone as a function of distance from the spraying nozzle. Spray cone diameter ranged from 10 to 35 cm depending on the distance from the tip of the nozzle.

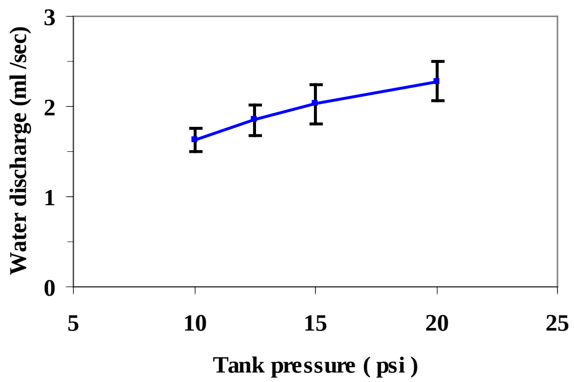

Fig. 4: Water consumption by the electrostatic spraying system as a function of tank pressure.

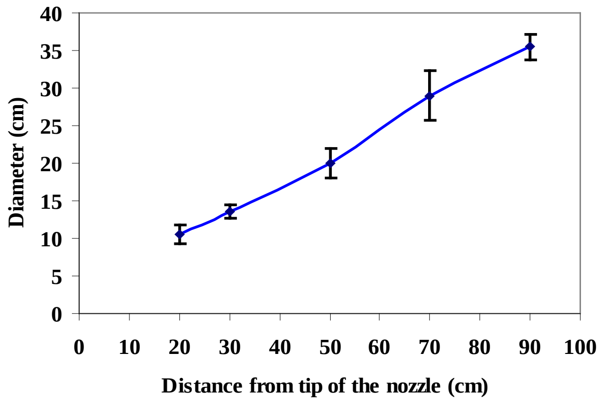

Fig. 5: Size of the spray cone produced by the electrostatic spraying nozzle.

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Droplet Size Distribution:

Almuhanna (2007) studied the size distribution and number concentration of the airborne droplets by using the APS spectrometer. This spectrometer measures the equivalent aerodynamic diameter of particles from 0.54 to 20 µm, and uses an air sampling rate of 1.0 L/min. The spectrometer was connected to a dilution unit, which was set at a 100:1 dilution ratio. The spraying system was operated at a liquid flow rate of 120 mL/min (water tank pressure of 15 psig). Figures 6 show the droplet size distributions, based on number and mass concentrations, respectively.

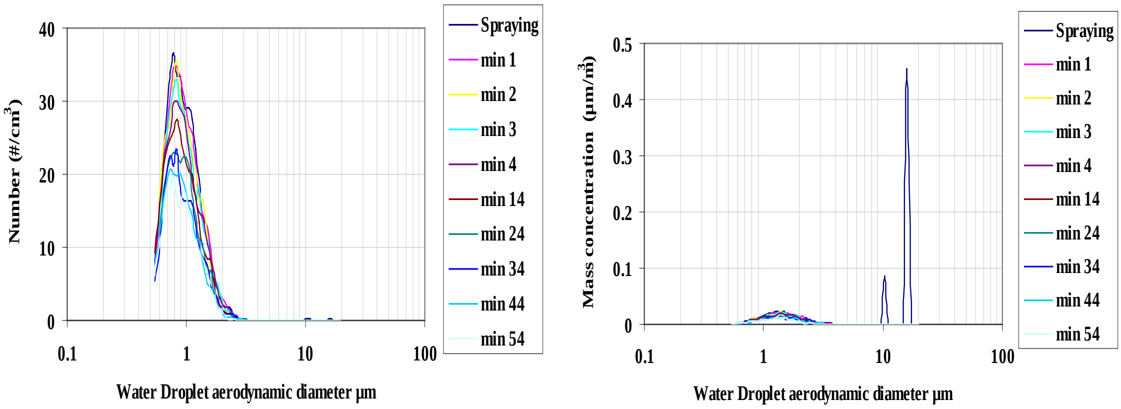

Fig. 6: Droplet size distribution (number and mass concentration) for the electrostatic spraying system during and after spraying (Almuhanna, 2007).

The air velocity within the scrubber was measured at various traverse points at the scrubber inlet and outlet cross-sections using Testo 435-2, (Testo Inc. 40 White Lake Road Sparta, N.J. 07871 – USA**)** multi-function instrument equipped with hot wire anemometer probe.

The electrostatic charge was measured with a dynamic Faraday cage sampler (Almuhanna, 2010), which was designed in accordance with the ASTM guidelines (*ASTM Standards*, 1997) and can be used to measure the net charge-to-mass ratio of particles. Table 1 summarizes the charge measurement for the air that was coming out from the scrubber outlet. It can be seen that considerable amount of charge was generated with the device.Dust mixed with water was collected inside the mixing chamber and drained outside the scrubber via a drain hole in the bottom of the scrubber and was then collected in a waste tank.

Table 1: Charge measurement for the air for the air exiting the scrubber.

Scrubber Fan	Spray Nozzle	Charge (nC)[a]
OFF	OFF	+0.11 (Background charge)
	OFF	+0.15
	Air only without charging	+0.33
ON	Air only with charging (negative)	-0.63
	Water spray without charging	+0.19
	Water spray with charging (negative)	-123

[a]Measurements were made using a dynamic Faraday cage sampler with a sampling duration of one minute (Almuhanna, 2010) at a distance of 0.5 m from the scrubber outlet.

Experiments involved designing, constructing and testing the air cleaning device. Experiments were conducted to study the different variables that will affect the design and performance of the device.The device was compared to the case in which the scrubber was operated with uncharged water (i.e., uncharged scrubber) and that in which only the fan (i.e., no water spray) was operated. The case in which only the fan was operated served as the control.

For all cases, air sampling was done under isokinetic conditions at two locations within the inlet and outlet ducts of the device. The filter samplers had 11-mm probe inlet diameter and 37-mm filter assembly (fig. 7). The sampling heads were positioned within the sampling area facing the air stream. The filter holder was attached to a rigid tube, which was connected by flexible tubing to a vacuum pump. The air sampling flow rate was adjusted to isokinetic conditions by varying the sampling flow rate to match the air velocity at the inlet area of the sampler with the air stream velocity outside the sampler.

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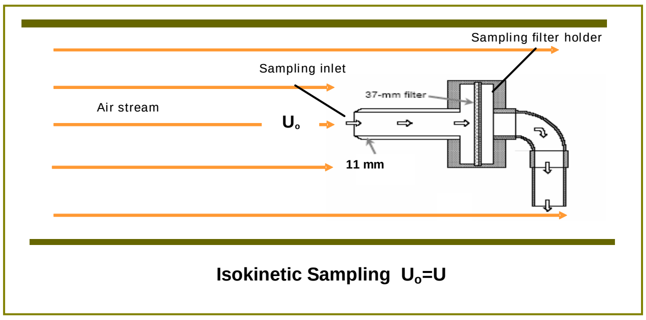

Fig. 7: Schematic diagram of a dust sampler with 11-mm probe inlet diameter and a 37-mm filter assembly. U_o is the mean free stream velocity and U is the average air velocity through the sampling probe.

The required sampling flow rates for isokinetic sampling (table 3) were determined by conducting a velocity traverse over the sampling area prior to sampling (Predicala and Maghirang, 2004). The dust collection filters (Type AE, SKC, Eighty Four, Pa.) were conditioned by placing them in the oven for 24 h at 103°C before and after sampling. Filter conditioning was done to minimize the effect of humidity and collected water droplets on filter weights. All filters were weighed in an electronic analytical balance (Model AWD-120D, Shimadzu Corporation, Kyoto Japan) with a sensitivity of 0.01 mg.

The removal efficiency of the device was determined by comparing the dust concentrations at the inlet and exhaust of the scrubber. The device dust removal efficiency (η_d) was calculated using the following equation:

$$\eta_d = \frac{C_i - C_o}{C_i} \times 100$$

whereC_i is the mean dust mass concentration at the scrubber inlet and C_o is the mean dust mass concentration at the scrubber exhaust.

The mean η values were analyzed statistically by using PROC GLM of SAS (Version 9.1, SAS Institute, Inc., Cary, N.C.). Means were compared at a level of significance of 5%.

Controlled ConditionsEvaluation:

The device was first tested under controlled conditions to establish the effects of the particle type (i.e., Homedust) on its performance. It was also compared to the case in which the scrubber was operated with uncharged water (i.e., uncharged scrubber) and that in which only the fan (i.e., no water spray) was operated. The case in which only the fan was operated served as the control. Tests were done with no witting porous media.

Table 2: Statistics of the initial particle size distributions (mass basis) of dispersed home dust.

	Home dust	
Parameter	Mean	SD
Median diameter (µm)	15.6	0.56
Mean diameter (µm)	14.7	0.45
Geometric mean diameter, GMD (µm)	13.9	0.70
Geometric standard deviation, GSD	1.44	0.06

While results with these particles may not be the same as with typical dust in poultry buildings, they will provide an indication of the relative effectiveness of the device. All experiments were conducted in an experimental chamber (fig. 3) in which air temperature and relative humidity were maintained at approximately 25°C and 40%, respectively. For each experiment the chamber was prepared by cleaning the surfaces and running its air filtration system. There was no ventilation of the chamber during the experiment.Particles were dispersed into the chamber by using a pressurized canister at 652 kPa (80 psig). A nominal mass of 20 g was used; the actual mass deployed ranged from 7.4 to 12.5 g.Dispersion took approximately 2 s. To further disperse the particles inside the chamber, two mixing fans inside the chamber were operated for about 2 min after deployment of the particles. The scrubber fan and the water spray were operated starting at t=2 min (i.e., 2 min after particle deployment).

Poultry house Evaluation:

Field measurements were conducted in the poultry unit at the experimental and training station of King Faisal University, Al-Hassa, Saudi Arabia. The field work included the following:

- Testing the device to evaluate the collection efficiency for different sizedparticles and characterizing the particles for TSP, PM_{10}, and $PM_{2.5}$ upstream anddownstream of the scrubber.
- Evaluate and compare the following cases:
  - (1) negatively-chargedwater spray (i.e., negatively-charged);
  - (2) uncharged-waterspray (i.e., uncharged scrubber);
  - (3) fan with no water spray (i.e ,.control).
- Optimizing the wet scrubbing by electrostatically-charging the water spray.

Poultry housing facilities:

The naturally ventilated poultry house possessed a total width, length, and height of 12 m, 20 m, and 3.6 m, and the surface area of the floor and volume of the building were 240 m^2 and 864 m^3, respectively, as shown in Fig. 8. The naturally ventilated poultry house was oriented in an east-west direction. The side walls were made of 20-cm thick concrete bricks, and the ceiling was made of insulated reinforced concrete. The longitudinal side walls (north and south) had 24 opening windows with a total area of 20 m^2. In total, 52 metal pens were arranged in four rows with two central alleys. Each pen was 1.5 m by 2.5 m and contained one feeder and one drinker. The broiler house was occupied by a total of 1560 local breed flocks, and 30 birds were housed in each pen. The broiler house facility used in the present study was occupied by birds at a bird to total floor surface area ratio of 8 bird/m^2.

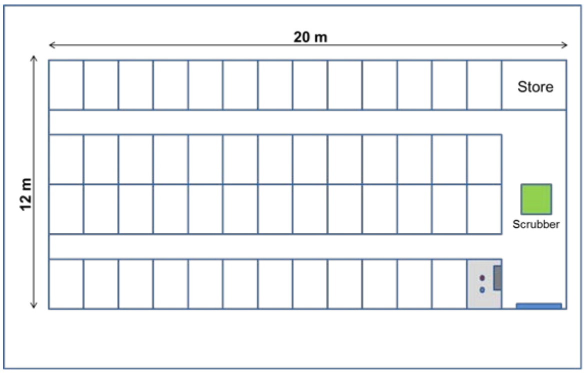

Fig. 8: Schematic depiction of the naturally ventilated broiler house, including the distribution of all 52 pens inside the house (plan view - not drawn to scale).

Table 3,and 4 summarize the test conditions and article statistics in the poultry building during the field evaluation.

Table 3: Measured parameters inside the Poultry building during the testing period.

Parameter	Mean	SD	Range
Temperature (°C)	23.2	7.9	19.3-27.3
Relative humidity (%)	31.4	10.8	23.7-38.3
Net charge-to-mass ratio of airborne particles (mC/kg)	- 1.33	0.71	-
TSP (mg/m^3)	11.21	3.2	5.3-16.1
PM_{10}(mg/m^3)	5.52	2.1	2.1-9.2
$PM_{2.5}$(mg/m^3)	0.78	0.09	0.32-0.89

Table 4: Particle statistics of the poultry house on mass basis during tests period.

Parameter	Mean	SD	Range
Mean diameter (µm)	7.03	0.11	6.91-7.09
Standard deviation (µm)	1.72	0.08	1.63-1.81
Geometric mean diameter (µm)	8.31	0.09	8.14-8.64
Geometric standard deviation	1.59	0.02	1.55-1.63

Measurements and data acquisition:

The air temperatures and relative humidity just entering and leaving the device were measured using a HOBO® U12 Logger (Onset Computer, Bourne, MA) with a manufacturer stated accuracy of ±0.35°C. The data updated by a scan of all sensors every 1s and the mean of 60 scans recorded every minute. The mass concentration was measured by Real-time TOPAS**,**(Turnkey Optical Particle Analysis System) monitor designed to continuously record environmental TSP, PM_{10}, and $PM_{2.5}$particles. The size distribution and number concentration of airborne particles were monitored using a particle counter (Model GW3016A, GrayWolf Sensing Solutions, Advanced Environmental Measurements, 12 Cambridge Drive, Trumbull, CT 06611 USA). The spectrometer measured particles with aerodynamic diameters ranging from 0.3 to 10 μm at an air sampling rate of 0.1 CFM (2.83 LPM). Moreover, six channels were used, and a counting efficiency of 100% was employed for particles with diameters of >0.45 μm. The spectrometer displayed the particle count and mass concentration readings in $\mu g/m^3$. The electrostatic charge was measured with a dynamic faraday cagesampler (Almuhanna and Maghirang, 2010).

Results and Discussion

Controlled Conditions Evaluation:

Table 5 summarizes the mean η values for homedust for the negatively-charged water spray, uncharged water spray, and control. The negatively-charged water spray had significantly ($P<0.05$) greater mean η value (80.3%) than either the control (η=24.5%) or the uncharged water spray (η=62.4%). Also, the uncharged water spray had significantly ($P<0.05$) greater mean η value than the control. The mechanisms for particle removal of water droplets (charged or uncharged) are relatively well understood (Mathai, 1983). When an uncharged water droplet approaches a cloud of particles with a relative velocity, particles may directly collide with the droplet (i.e., collection by inertial impaction), barely touch the droplet (i.e., collection by interception), or entirely miss the droplet (i.e., particle is not collected). As such, it is expected that the uncharged scrubber would be more effective than the control (i.e., no water droplets) in removing particles because of the capture of particles by the water droplets. When the water droplets are highly charged, as in the electrostatically particulate wet scrubber (EPWS), electrostatic forces enhance the capture of the dust particles by the water droplets (Law and Giles, 2009), resulting in improvement in overall collection efficiency of the droplets, as was the case in this study.

Table 5: Controlled conditions dust removal efficiencies (η) of the EPWS for operation with charged water spray, uncharged water spray, and fan only.

Treatment	Mean[a]	SD	No. of Reps
Negatively-charged scrubber	80.3 a	11.2	3
Uncharged scrubber	62.4 b	7.3	3
Control (i.e., only the fan was operated)	24.5 c	6.7	3

[a]Column means followed by the same letter are not significantly different at 95% level of confidence.

Poultry house Evaluation:

Table 6 summarizes the mean η values for the air cleaning device inside the poultry house. The negatively-charged water spray was significantly ($P<0.05$) more effective in removing poultry dust particles (η=72.4%) than either the uncharged scrubber (η=48.2%) or the control (i.e., only fan was operated) (η=16.2%).

With only the fan, removal of particles was likely due primarily to impaction of particles to surfaces and to each other. With uncharged droplets, removal of particles was enhanced by capture of particles by the water droplets. With highly charged water droplets as collection surfaces, electrostatic forces could have enhanced the capture of the dust particles.

Comparison of the controlled conditions and field evaluations, however, indicated that the mean η value for the EPWS was slightly smaller in the poultry building (η=72.4%) than in the experimental chamber for Homedust (η=80.3%).

The lower mean η value could be due to differences in concentration and size distribution between the particles in the poultry building and the test particles used in the controlled conditions evaluation. For example, the concentration was smaller in the poultry building than in the chamber (<1 mg/m^3 for the poultryhouse, and >5 mg/m^3 for the experimental chamber). With smaller concentration in the poultry building, collisions between the water droplets and the particles are expected to be lower, resulting in smaller removal efficiency. In addition, the mean GMD of the particles in the poultry building when the EPWS was being tested was 8.31μm, which was smaller than that of homedust. Again, smaller particles are more difficult to remove than larger particles, even with electrostatic forces.

Poultry house dust removal efficiencies for different sizes (TSP, PM_{10}, and $PM_{2.5}$) by using charged water spray, uncharged water spray, and control (no water spray –fan only) were plotted (fig.9). It’s clear that charged water spray achieved the highest removal efficiency followed by uncharged water spray comparing with no water spray (control) for all size ranges.

Table 6: Poultry house dust-removal efficiencies (TSP) of the device for operation with charged water spray, uncharged water spray, and fan only.

Treatment	Removal Efficiency		No.
	Mean[a]	SD	of Reps
Negatively-charged scrubber	72.4 a	9.3	4
Uncharged scrubber	48.2 b	6.6	3
Control (i.e., only the fan was operated)	16.2 c	8.4	3

[a]Column means followed by the same letter are not significantly different at 5% level of significance.

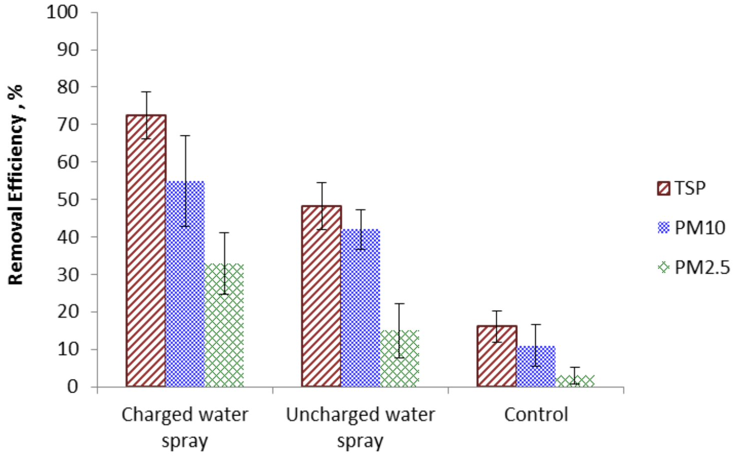

Fig. 9: Poultry house dust removal efficiencies for different sizes (TSP, PM_{10}, and $PM_{2.5}$) by using charged water spray, uncharged water spray, and control (no water spray –fan only)

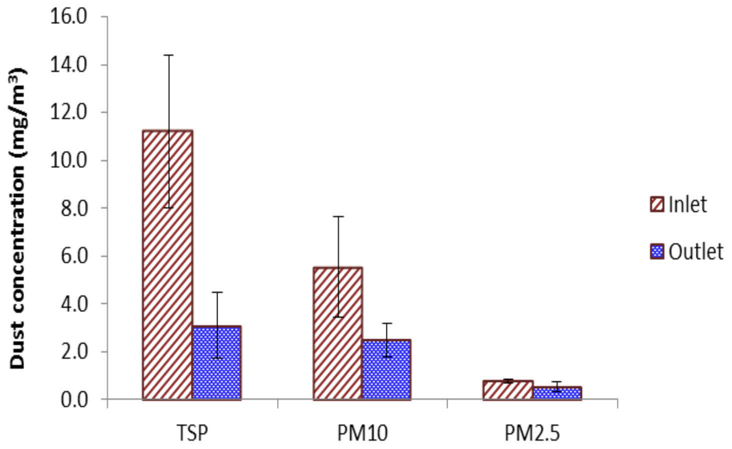

Fig. 10: Dust (TSP, PM_{10}, and $PM_{2.5}$) concentrations at the inlet and outlet of the scrubber using charged water spray

Figure 10 shows the particulate concentrations of the three particles sizes (TSP, PM_{10}, and $PM_{2.5}$) at the inlet and outlet of the scrubber representing the reduction in dust concentrations due to negatively charged water spray scrubbing effect.

It should be noted that the prototype device tested in this study was designed to have only one spray nozzle. Other potential designs, with different number of nozzles, sizes, etc., are possible depending on the application and size of the building. Future work is needed to optimize the design and further enhance the performance. For example, more spray nozzles can be used to increase the removal efficiency.

Conclusions:

A prototype electrostatically assisted particulate wet scrubber (EPWS) was developed and tested under both controlled conditions and field conditions. The following conclusions were drawn from this research:

- Usinghomedust under controlled conditions the negatively-charged water spray was significantly ($P<0.05$) more effective in removing dust particles (η=80.3%) than either the uncharged scrubber (η=62.4%) or the control (i.e., only fan was operated) (η=24.5%).

- Under field conditions (poultry house) the negatively-charged water spray was significantly ($P<0.05$) more effective in removing dust particles (η=72.4%) than either the uncharged scrubber (η=48.2%) or the control (i.e., only fan was operated) (η=16.2%).
- The efficiency was affected by the type of particle; the device was generally more effective in removing home dust (generally larger) than poultry house particles (smaller).

It should be noted that the air cleaning device tested in this study was designed to have only one spray nozzle. Other potential designs, with different number of nozzles, sizes, etc., are possible depending on the application and size of the poultry house. An extension to thisresearch work will cover the effect of adding different porous witting media to the device, and studying their effect on the cooling and dust removal efficiencyand the interaction between each other. Furthermore, the effect of the environmentalfactors onthe cooling and dust removal efficiency will be studied and evaluated.

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