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Full Paper

Concentration and Size Distribution of Particulate Matter in a Broiler House Ambient Air

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Abstract: Atmospheric particulate matter (PM) is an important constituent of ambient air. The determination of its concentration and size distribution in different environments is essential because of its ability to penetrate deeply into animal and human respiratory tract. In this study, air sampling was performed in a broiler house to estimate the concentration and size distribution of PM emitted along with its activities. Low-vol impactor (< 10 µm), cyclones (< 2.5 e < 1.0 µm), and Sioutas cascade impactor (> 2.5; 1.0 – 2.5; 0.50 – 1.0; 0.25 – 0.50; < 0.25 µm) connected with membrane pumps were used. PM_{10} showed high concentration (209 - 533 µg m^{-3}). $PM_{2.5}$ and $PM_{1.0}$ initially showed relatively low concentration (20.8 and 16.0 µg m^{-3} respectively) with significantly increasing levels (412.9 and 344.8 µg m^{-3} respectively) during the samplings. It was also possible to observe the contribution of fine particles. This was evidenced by the high correlation between $PM_{2.5}$ and $PM_{1.0}$ and by the profile of particle distribution in the Sioutas sampler. PM concentration levels are considered excessively high, with great potential to affect animal and human health.

Key-words: indoor air quality; aerosol; particle size

1. INTRODUCTION

Atmospheric particulate matter (PM) is a complex mixture of small particles and liquid droplets [1]. Its action on human health can be quite harmful causing breathing problems, allergies, lung cancer and even premature deaths [2-4]. PM is usually classified as course (or inhalable), when the aerodynamic particle size is between 2.5 to 10 µm, and fine (or respirable), when the particle dimension is < 2.5 µm. Current classification includes the ultrafine PM when the aerodynamic particle size is < 0.1 µm [1].

PM course mode arises mostly from natural sources, while the fine one originates mainly from human action, such as burning of biomass and fossil fuels and industrial processes, among others [5-8]. Many studies have investigated PM composition in relation to ions, metals, elemental carbon, organic carbon, polycyclic aromatic hydrocarbons (PAH), endotoxin and other compounds, both in indoor and outdoor environments [9-14].

In addition to chemical composition, it is also important to understand particles' size because its potential action in the respiratory tract is related to its aerodynamic size. Inhalable particles (< PM_{10}) can enter the upper respiratory tract, where they can be retained. The respirable mode (< $PM_{2.5}$) has the ability to penetrate more deeply into the lower respiratory tract and may reach the bronchi and alveoli. In this way, the constituents of this PM size can access the bloodstream more easily [1, 15, 16].

PM course and fine fractions can be collected with cyclones and cascade impactor. Cyclone separates and collects air particles of certain sizes such as PM_{10}, $PM_{2.5}$ or $PM_{1.0}$, among others, while cascade impactor separates and collects particles in size ranges. The Sioutas personal impactor is a size-segregated PM with four impaction stages followed by an after-filter. Particles are separated in the aerodynamic particle diameter (D) of quasi-ultrafine mode (D < 0.25 µm), fine mode (0.25–0.5 µm, 0.5–1.0 µm, 1.0–2.5 µm) and coarse mode (> 2.5) [17, 18].

According to the World Health Organization (WHO), approximately 20% of the 3.7 million premature deaths in the world are associated to the

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action of fine PM [19]. There are many situations that involve health risks to workers. In Brazil, rural workers are often exposed to risks such as dust in animal housing. Contaminants are found in airborne particles and play an important role as allergenic elements to humans [20]. Poultry farming activities have great potential for PM emission [21-27]. Commercial poultry houses contain high concentration of airborne PM, due mainly to the body activity of the birds. These aerosols are composed of organic dust, microorganisms and endotoxins [28].

The Brazilian poultry industry employs a large numbers of workers that were often exposed to potential respiratory risks. Thus, the aim of this study is to estimate the concentration levels of course and fine PM and their size distribution in a commercial broiler house.

2. MATERIAL AND METHODS

2.1. Sampling

The samplings were performed in a broiler house located in a rural area in Londrina, Paraná from 9 to 21 July, 2015. The broiler house is a semi-open place with an area of 1000 m^2 for approximately 10,000 birds. A low-vol impactor PM10 (ZUF-Frankfurt, Germany) operated at flow of 9.0 L min^{-1}, two cyclones (PM2.5 URG-2000-30EH and PM1.0 URG-2000-30EH, URG Corporation, USA) operated at flow of 16.7 min L^{-1} and a Sioutas personal cascate impactor (SKC Incorporation, USA) with stages A, B, C and D (aerodynamic size (> 2.5; 1.0 – 2.5; 0.50 – 1.0; 0.25 – 0.50; < 0.25 μm) with flow rate of 9.0 L min^{-1} were employed for the sampling. Glass microfiber filters with 47 mm (Sartorius), 25 mm (Macherey-Nagel, USA) and 37 mm (Millipore, USA) were used. The filters were treated by 300° C (Biopar-S150ST) for 12 hours, placed individually in a Petri dish in a desiccator containing silica for 12 hours and put in a room with controlled temperature and humidity (22 ± 3° C and 30 ± 2%). After sampling, the filters were kept in the same room for 12 h and weighed. The sampling time for the collection of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ was 48 hours and for Sioutas impactor, 144 and 96 hours. The collectors were installed at 1.5 m (Figure 1).

Figure 1. URG Cyclones, ZUF Impactor and Sioutas Personal Impactor collecting particulate matter in the commercial poultry house.

2.3. Gravimetric determination

The PM mass was obtained by the difference between the mass of the filter before and after each collection by using the ultra-analytical balance (METTLER TOLEDO, AX26) with accuracy of 1.0 μg. The measurements were performed under controlled temperature and humidity.

3. RESULTS AND DISCUSSION

3.1. Particular matter concentration

Six PM_{10} samples were obtained in the broiler house. The concentration varied from 209 to 533 µg m^{-3} and the profile can be seen in Figure 2.

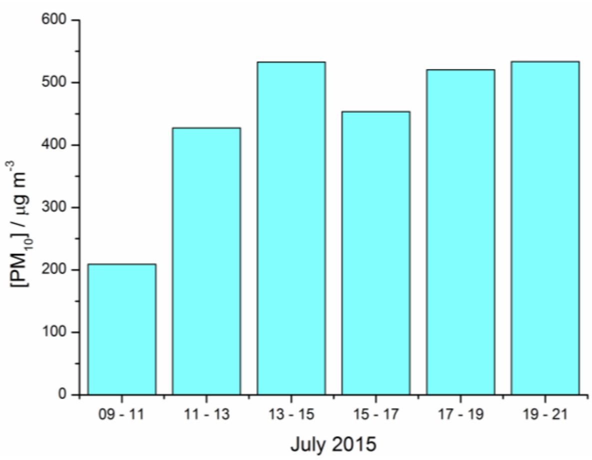

Figure 2. PM_{10} concentration profile in broiler house ambient air.

The $PM_{2.5}$ concentrations were relatively low (20 µg m^{-3}) in the beginning of the sampling but high (412 µg m^{-3}) at the end, increasing more than 20 times in the last collection. Unlike the PM_{10} concentrations, $PM_{2.5}$ rose gradually from the first to the third sampling, nearly doubling from the fourth to the sixth collection (Figure 3). The highest $PM_{2.5}$ level (412 µg m^{-3}) found in the broiler house exceeds the recommended WHO (World Health Organization) Air Quality Guidelines (AIG) of 25 µg m^{-3} for 24-h average concentration [29]. Physical activity in an environment where the air quality is at risk could undermine human health.

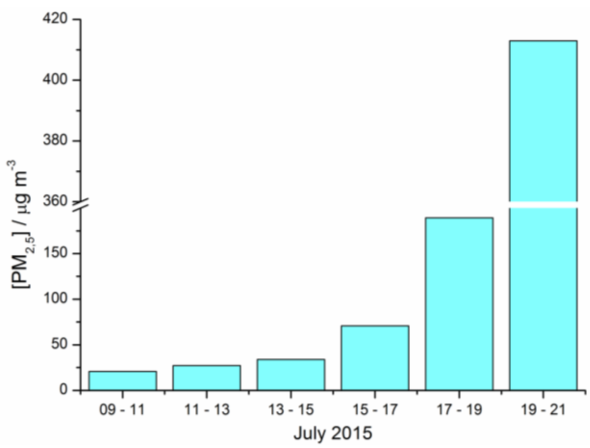

Figure 3. $PM_{2.5}$ concentration profile in broiler house ambient air.

Although the fraction $PM_{1.0}$ is yet not legislated, studies have showed that finer particles have high capacity to penetrate deeper in the respiratory tract [30, 31]. The $PM_{1.0}$ concentrations profile was similar to $PM_{2.5}$ (Figure 4). The values began relatively low (16 µg m^{-3}) and increased gradually to higher concentrations up to approximately 22 times (334 µg m^{-3}) compared to the first sample. $PM_{1.0}$ concentrations represented more than 50% of the fine fraction.

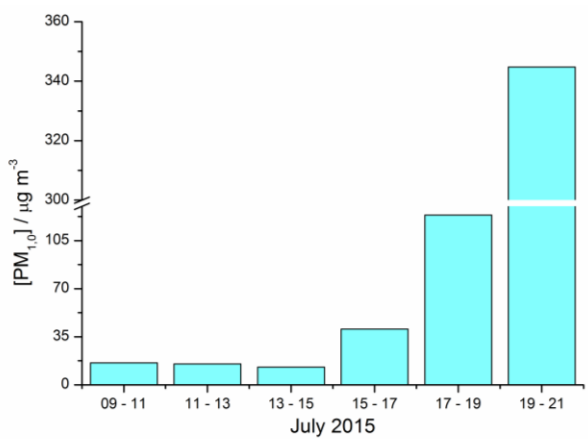

Figure 4. $PM_{1.0}$ concentration profile in broiler house ambient air.

3.2. Size distribution

The results obtained with the use of Sioutas cascate impactor showed a bimodal distribution as expected (Figure 5). The greatest mass contribution was in stage A (> 2.5 µm), which represents the particle course mode. The mass concentration falls steadily up to stage D (0.2 to 0.50 µm) and goes up in the last stage where the after-filter (< 0.25 µm) was. The mass distribution found was 84, 6.6, 2.3, 1.3 and 5.7 %, corresponding to stages A (> 2.5 µm), B (1.0 to 2.5 µm), C (0.50 to 1.0 µm), D (0.25 to 0.50 µm) and after-filter (< 0.25 µm) respectively.

When the PM fine fraction is analyzed separately (stages B, C, D and after-filter), the contribution of 36 % of ultrafine particles (< 0.25 µm) and 42% of fine particles in the interval from 1.0 to 2.5 µm (Figure 6) is observed. This makes PM potentially more harmful as its deeper penetration in the lower respiratory tract [30].

3.3. Pearson correlation

Pearson correlation was used to understand the origin of fine and course particles in the broiler house ambient air. The concentration values of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ were correlated. Correlation between $PM_{2.5}$ and $PM_{1.0}$ was 0.99, which is considered strong and suggests the same source. For $PM_{1.0}$ and PM_{10} the correlation was 0.45 and for $PM_{2.5}$ and PM_{10} it was 0.50. These correlations are considered moderate and this might indicate that in the beginning of the sampling the fine fraction does not have a representative role in the coarse fraction. Over time the fine PM contribution increased, whereas the PM_{10} concentrations did not vary significantly (Figure 2). These results indicate that coarse and fine PM fraction can have different sources. Coarse particles normally have natural origin. The floor was covered with natural material and this is the main source of course particle. Dust coming from outside can also contribute to this fraction.

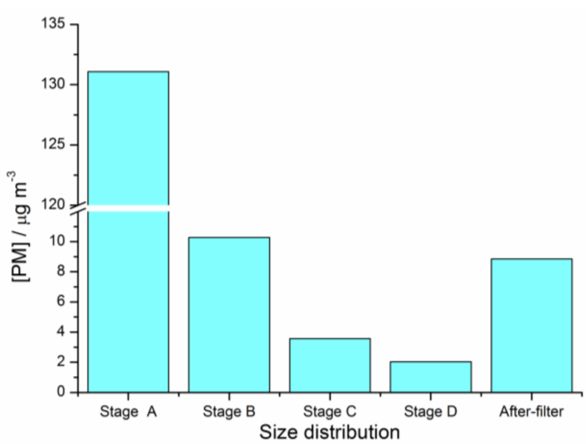

Figure 5. Size distribution of fine particulate matter in broiler house ambient air. Stage A (> 2.5 µm), stage B (1.0 to 2.5 µm), stage C (0.50 to 1.0 µm), stage D (0.25 to 0.50 µm), and after-filter (< 0.25 µm).

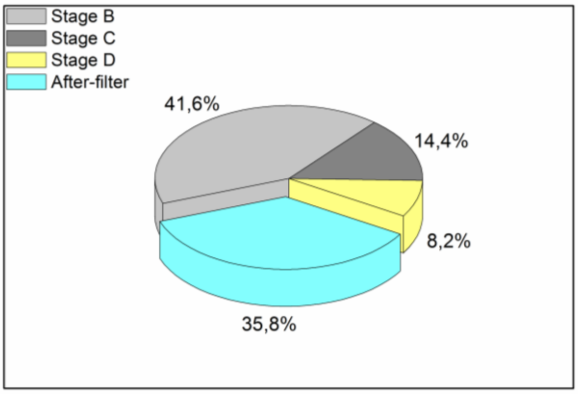

Figure 6. Size distribution of fine particles in a broiler house ambient air. Stage B (1.0 to 2.5 µm), stage C (0.50 to 1.0 µm), stage D (0.25 to 0.50 µm), and after-filter (< 0.25 µm).

The sampling period of 13 days represented approximately 1/3 of the birds' growth cycle. As the birds grew, fine PM concentration also rose, as it can be seen in Figures 3 and 4. The increase of fine PM fraction matches the birds' growth period. Therefore, the emission of fine and ultrafine PM was tightly related to this breeding activity. Indoor dust concentration in poultry houses should be controlled to provide adequate air quality for workers and animals. From the arrival of the animals to their removal for slaughtering, animal nutrition and internal maintenance is done manually. Throughout this period, about 45 days, workers are exposed to the PM produced in this environment.

4. CONCLUSION

Industrial poultry production has a harmful effect on the environment during the birds' growth. Dust emission is considered an air pollutant and is associated with health risks for workers and animals inside the houses. High concentration of PM in the course and fine fraction was found in a commercial broiler house. The fine fraction ($PM_{2.5}$ and $PM_{1.0}$) increased along sampling and showed high correlation, indicating the same origin, while PM_{10} presented high concentration but few variations along the days. Considering recommended indoor dusts limits, PM concentrations were relatively high and both workers and animals, as well as the surroundings, were impacted by this activity.

5. ACKNOWLEGMENTS

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