Seasonal variability of the PMx chemical composition and ammonia concentration in loose-housing cowshed

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Livestock housing is an important source of primary particulate matter (PM) emissions and contributing to secondary PM levels through emission of precursor gases such as ammonia (NH_3). Elevated levels of PM and NH_3 are harmful to environment, as well as to the human and livestock health. NH_3 can also participate in atmospheric reactions (e.g., gas-to-particle conversion) once airborne, forming ammonium aerosols such as ammonium sulphate, -nitrate, -chloride, which tend to have longer atmospheric residence lifetimes (1–15 days) due to a decrease in dry deposition velocity (Aneja et al. 1998) and therefore may be transported and deposited further downwind from the source (Blunden et al., 2008). PM emissions from livestock housings vary with type of housing and livestock. To assess impact to PM levels and contribution to secondary PM suitable emission factors (EF) is necessary to identify NH_3 levels in cowshed. The aim of the current study was to create emission factors and emission database for loose housing cowsheds as this is dominant type of housing used in Estonia. As indoor air of loose housing cowsheds are strongly influenced by ambient air patterns of PM10 and PM2.5, also ambient levels of PM were measured. Results enabled to identify actual emissions of the loose housing system during the whole year.

Microclimate parameters (temperature, °C; relative humidity, %); CO_2 and NH_3 concentration, (ppm) as well as fractional distribution of particulate matter (PM) mass (μg/m^3) and number (1/cm3) concentrations (size classes with aerodynamic diameter less than 10, 8.17, 5.18, 3.12, 1.97, 1.24, 0.77, 0.49, 0.32, 0.20, 0.12, 0.07 and 0.04 μm) were measured continuously at 2.5 meter height from the floor in semi-insulated loose housing cowshed in Märja, Estonia.

An electrical low pressure impactor (ELPI^{TM}, Dekati) with the sampling rate of 29.25 l/min was used for the measurements of mass and number concentration of the PM fractions. The minimum detection level at 1 stage for the mass concentration is 0.01 μg/m^3 and for the number concentration 142 1/cm^3. The upper concentration limit at 13 stage for the mass concentration is 8269 mg/m^3 and for the number concentration 2.7E+04 1/cm^3. At the particle inlet the Dekati® Dryer DD-600 was used. Ionic composition of the particles fractions were analyzed by ion chromatography (Dionex DX2000 and DX2100).

For the NH_3 the Picarro G2103 (Picarro) analyzer was used, which uses for the NH_3 detection the Wavelength-Scanned Cavity Ringdown Spectroscopy (WS-CRDS), with the range from 1 ppb to 50 ppm.

Wind direction and speed inside the cowshed was measured with 2D ultra-sonic anemometers (WMT-52, Vaisala), for the humidity measurement Vaisala HUMICAP® 180R sensors (HMT 130, Vaisala) were used, for the temperature measurements Pt1000 RTD Class F0.1 IEC 60751 sensors were used and for CO_2 measurements NDIR sensors were used (GMT 220, Vaisala).

For the PM10 and PM2.5 ambient measurement BAM 1020 (Met One Instruments Inc.) was used, which measures ambient particulate concentration using beta ray attenuation with 1 h resolution from 1 μg/m^3 to 1000 μg/m^3.

Results

Within measurement campaign was a significant correlation between measured NH_3, PMx and CO_2 concentrations and within NH_3, PM10 and RH significant correlation was found. This indicates that indoor concentrations are directly influenced by the ventilation rate. NH_3 in the air inside the cattle shed was more strongly correlated with the concentration of the fine fractions up to 1 μm of PM. Background concentrations of PM and NH_3 should be taken into account, which is not always the case if EF are calculated.

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