Contribution ID: **75** Type: **Oral presentation**

Emission of airborne particles from 3D printing

Exposure to airborne particles in indoor environments is a significant concern for human health, as the presence of indoor particle sources leads to considerably higher concentrations of particles. The principal sources of particles in indoor environments include cooking activities, burning incense, candles, and mosquito coils, as well as resuspension from movement or cleaning activities and secondary particles formed from chemical reactions in the air. Even in clean indoor environments (non-smoking spaces), unexpected sources of particles, such as printers and photocopiers, can be present; these devices have been found to be significant emitters of ultrafine particles. In recent years, interest in 3D printers has grown exponentially, especially with their increasing use in homes, rising concern among users regarding emissions from these devices. In this work, we aimed to address the lack of data concerning the emissions of airborne particles using Thermoplastic Elastomer (TPE) and Thermoplastic Polyurethane filaments (TPU) during 3D printing. To this end, an experimental campaign was carried out to measure particle number concentrations and size distributions while the 3D printer was in operation. Tests were conducted using a Fused Deposition Modelling (FDM) 3D printer in a plexiglass chamber of 4,7 m3. The 3D printer used in this study was a ZYYX Pro II, which had a chamber that could be either closed or open. Both the base and the chamber were preheated before printing, and measurements were conducted in both open and closed configurations. The printed object was a cube with dimensions of 10 mm in width, 10 mm in depth and 5 mm in height. The nozzle temperatures used were 220 ℃, 230 ℃ and 240℃ to evaluate the effects of temperature on particle emissions. Measurements were performed using a Condensation Particle Counter (CPC, TSI) for the sub-micron particle concentrations, a NanoScan (TSI) for the sub-micrometric particle distributions and a DustTrack (TSI) for the particle mass concentrations (PM10). The emission rates were evaluated based on the particle concentration trends, adopting a well-known mass balance approach. As expected, the emission rates of both TPE and TPU during printing with the chamber closed were lower than the emission rates during printing with the chamber open. Specifically, the emission rates were 1.02 × 109 and 1.04 × 1010 part./min for the chamber closed at 230 ℃, compared to 1.26 × 1011 and 1.55 × 1011 part./min for the chamber open at 230 ℃. Moreover, the emissions were higher at increased temperatures: for TPE the emission rate at 220 ℃ was 1.01× 1010 part./min, at 240 ℃ was 3.68 × 1011 part./min, for TPU the emission rate at 220 ℃ was 1.47× 1011 part./min, at 240 ℃ was 2.06 × 1011 part./min, both with the chamber open. The emission rates observed for TPE and TPU are consistent with the findings of previous studies on various filament materials, suggesting a comparable impact of these materials during the printing process. The particle size distribution reveals that TPE exhibits a mode at 87 nm, while TPU shows a mode at 65 nm, indicating a difference in the particle size generated by these two materials. Furthermore, there is a notable increase in the concentration of smaller particles, particularly in the diameter range of 20-27 nm, for both TPE and TPU. This trend highlights the importance of monitoring sub-micrometric particle emissions, as smaller particles can have different health and environmental implications compared to larger ones. There was no effect of the printing on particle mass concentration for either material; the measurements were quite similar to the background measurements in the room. All the tests performed showed that printing TPE and TPU filaments emit sub-micron particles. The emission rates for the 3D printer's filament measured in the preset work are similar to those of filaments made from other materials. Moreover, these measured emission rates are comparable to the typical emission rates from significant indoor particle sources characterized by combustion phenomena, such as cooking activities and candle/incense burning. In fact, they are even higher than the typical emission rates from conventional office printers.

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