

Emissions from 3D printing processes: comparison of printing systems

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The use of three-dimensional (3D) printing systems is becoming more and more popular, mainly due to the fact that it is a rapid prototyping and small-scale manufacturing technology. Numerous studies show that 3D printing emits both particulates and volatile organic compounds (TVOC); and that emissions can depend on many factors, including printer brand, filament material, brand and filament colour (Zhang et al., 2019). Indoor air quality can be deteriorated by these emissions, representing a risk associated with the health of people who use this type of technology. In this same line, the main aim of this study is the comparison of five 3D printing systems (Table 1), through the analysis of particle number concentration and gaseous pollutants (NO₂, SO₂, CO and TVOC) during the processes of manufacturing.

In order to analyse the indoor air quality in the laboratory during the manufacturing processes the following equipments were used:

- a Scanning Mobility Particle Sizer spectrometer (TSI-SMPS Model 3938) to measure the PNC between 8 and 310 nm in 110 channels;
- an automatic infrared monitor from Gray Wolf (WolfSense IQ-610) to register temperature, relative humidity, CO, CO₂ and TVOC;
- three portable gas sensors of Aeroqual series 500 to measure NO₂ and SO₂.

Table 1. 3D printing systems

3D printing system	Material
Project660 (P1)	Calcium sulphate
Ultimaker (P2)	Polylactic acid
ProjectMJP5600 (P3)	Polycarbonate
Markforged (P4)	Elonys
Homemade (P5)	Boun

Preliminary results indicate that there are significant differences between the emissions of gaseous and particulate pollutants from the five 3D printing systems studied ($p < 0.001$) during the printing process. The highest and lowest mean concentration of total particle number (Nt) was observed for P5 ($2557 \pm 704 \text{ cm}^{-3}$) and P3 ($1587 \pm 78 \text{ cm}^{-3}$), respectively (Fig. 1). Regarding the concentrations of gaseous pollutants, the P3 printing system showed the lowest emissions of CO₂,

CO, NO₂ and SO₂ with $450 \pm 12 \text{ ppm}$, $1.96 \pm 0.05 \text{ ppm}$, $0.038 \pm 0.005 \text{ ppm}$ and 0, respectively. Otherwise, P2 showed the highest concentrations of TVOC, CO₂, CO, NO₂ and SO₂ ($792 \pm 612 \text{ ppb}$, $532 \pm 22 \text{ ppm}$, $4 \pm 6 \text{ ppm}$, $0.04 \pm 0.01 \text{ ppm}$ and $0.06 \pm 0.12 \text{ ppm}$, respectively).

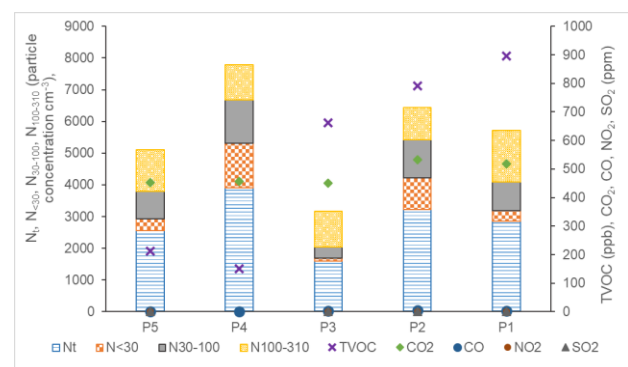


Figure 1. Mean concentration of: TVOC, CO₂, CO, NO₂, SO₂, total particle number (Nt), modes: nucleation (N_{<30nm}), Aitken (N_{30-100nm}) and accumulation (N_{>100nm}).

The results show that the type of printing system, as well as the type of material used for printing, are determinant to estimate the exposure of workers to the emissions exposed during the 3D printing processes.

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