EMISSIONS FROM 3D PRINTING PROCESSES: COMPARISON OF PRINTING SYSTEMS

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INTRODUCTION

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 sense, 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 (NO_2, SO_2, CO and TVOC) during the processes of manufacturing.

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

Fig. 2. Sampling site

Analysis

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

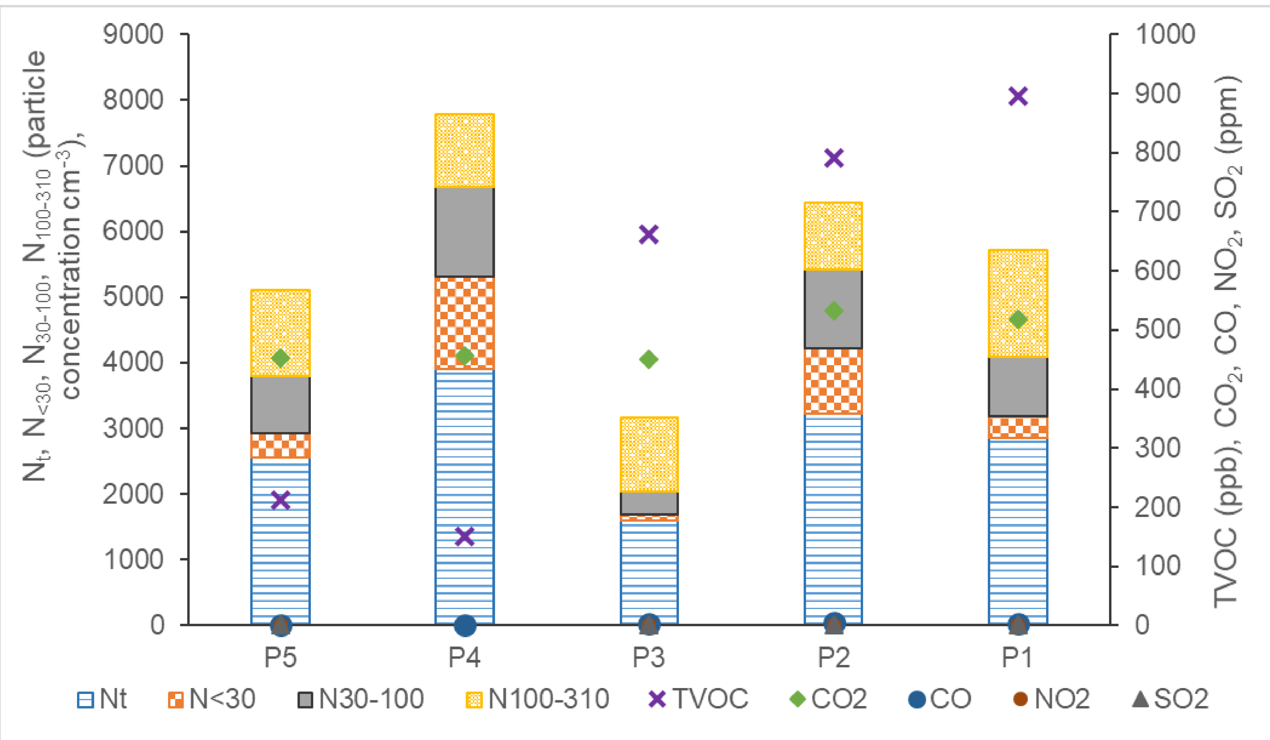
Scanning Mobility Particle Sizer spectrometer (TSI-SMPS Model 3938) to measure the particle number counter (PNC) between 8 and 310 nm in 110 channels

Three portable gas sensors of Aeroqual series 500 to measure NO_2 and SO_2.

An Automatic infrared monitor from Gray Wolf (WolfSense IQ-610) to register temperature, relative humidity, CO, CO_2 and TVOC

Fig. 1. Analytical instrumentation

RESULTS AND CONCLUSIONS



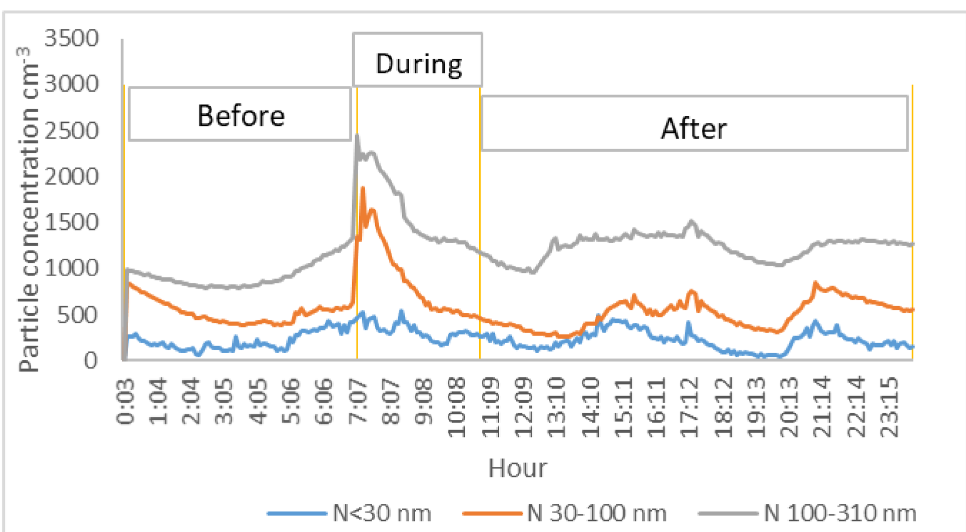
Results indicate that there are significant differences between the emissions of gaseous and particulate pollutants from the five 3D printing systems studied ($p < 0.001$) during the printing process.

The highest and lowest mean concentration of total particle number (Nt) was observed for P5 (2557 ± 704 cm^{-3}) and P3 (1587 ± 78 cm^{-3}), respectively (Fig. 3).

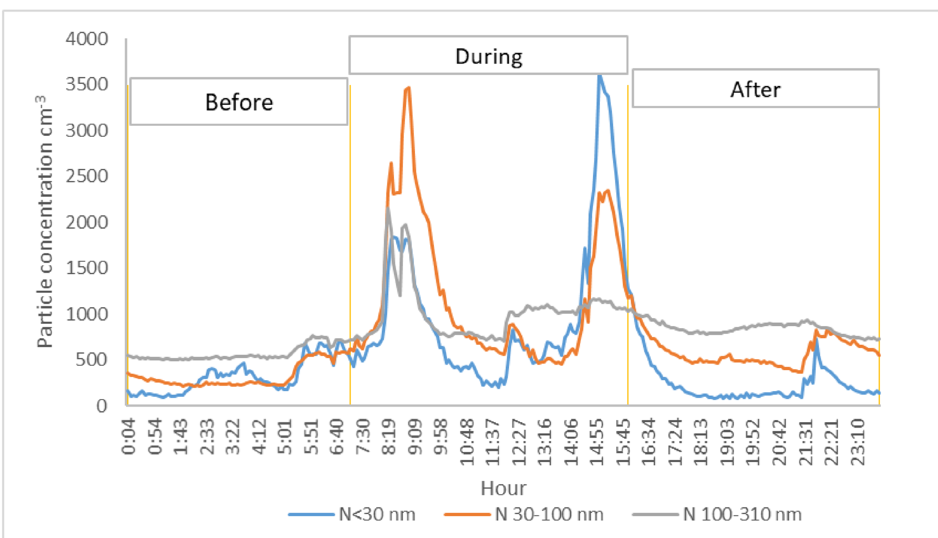
Regarding the concentrations of gaseous pollutants, the P3 printing system showed the lowest emissions of CO_2, CO, NO_2 and SO_2 with 450 ± 12 ppm, 1.96 ± 0.05 ppm, 0.038 ± 0.005 ppm and 0, respectively. Otherwise, P2 showed the highest concentrations of TVOC, CO_2, CO, NO_2 and SO_2 (792 ± 612 ppb, 532 ± 22 ppm, 4 ± 6 ppm, 0.04 ± 0.01 ppm and 0.06 ± 0.12ppm, respectively).

Fig. 3. Mean concentration of: TVOC, CO_2, CO, NO_2, SO_2, total particle number (Nt), modes: nucleation (N<30nm), Aitken (N30-100nm) and accumulation (N>1000nm).

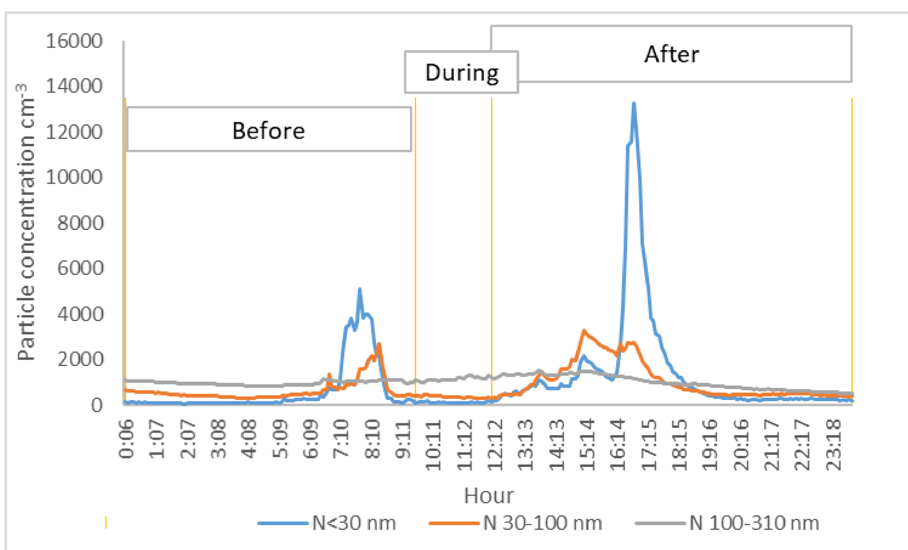
P1



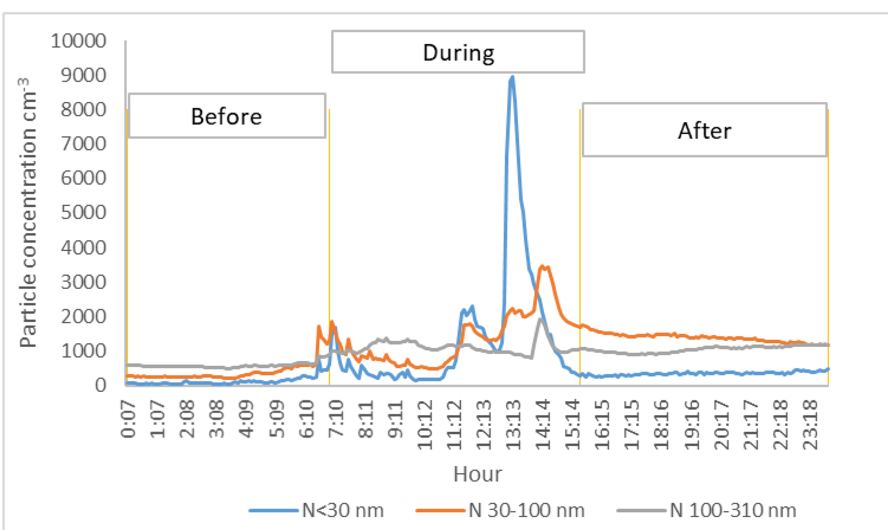
P2



P3



P4



P5

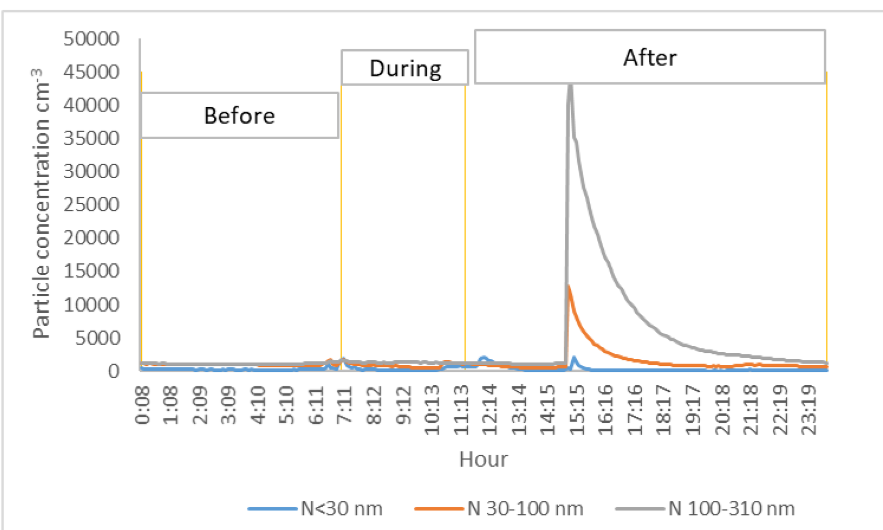


Fig. 4. For each 3D printer system (P1, P2, P3, P4 and P5), particle number concentration of modes: nucleation (N<30nm), Aitken (N30-100nm) and accumulation (N>1000nm). before, during and after the printing process

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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