Emissions from 3D printing processes: a printing systems comparison

F. Oduber[1], C. Blanco-Alegre[1], A.I. Calvo[1], A. Castro[1], A.I. Fernández-Abia[2], M.A. Castro-Sastre[2], P. Rodríguez-González[2], J. Barreiro[2], R. Fraile[1]

[1]Department of Physics, IMARENAB, University of León, León, Spain
[2]Department of Mechanical, Informatics and Aerospace Engineering, University of León, León, Spain
Keywords: air quality, exposure, indoor, printing, SMPS.
Presenting author email: rfral@unileon.es

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 (NO_2, SO_2, 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:

i) a Scanning Mobility Particle Sizer spectrometer (TSI-SMPS Model 3938) to measure the PNC between 8 and 310 nm in 110 channels;
ii) an automatic infrared monitor from Gray Wolf (WolfSense IQ-610) to register temperature, relative humidity, CO, CO_2 and TVOC;
iii) three portable gas sensors of Aeroqual series 500 to measure NO_2 and SO_2.

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 ± 704 cm^{-3}) and P3 (1587 ± 78 cm^{-3}), respectively (Fig. 1). 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).

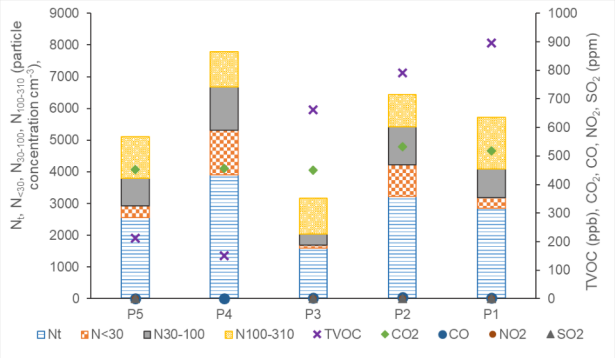

Figure 1. Mean concentration of: TVOC, CO_2, CO, NO_2, SO_2, total particle number (Nt), modes: nucleation ($N_{<30nm}$), Aitken ($N_{30\text{-}100nm}$) and accumulation ($N_{>1000nm}$).

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.

The sampling campaign was partially supported by the Spanish Ministry of Science, Innovation and Universities (Grant RTI2018-098189-B-I00), the University of León (Programa Propio 2015/00054/001 and 2018/00203/001), the AEROHEALTH project (Ministry of Science and Innovation, Grant PID2019-106164RB-I00, co-financed with European FEDER funds) and by the Junta de Castilla y León co-financed with European FEDER funds (Grant LE025P20). Authors thank to Ministry of Science, Innovation and Universities of Spain for the support through the research project with reference DPI2017-89840-R. C. del Blanco Alegre also acknowledges the grant FPU16/05764 from the Spanish Ministry of Education.

Zhang, Q., Pardo, M., Rudich, Y., Kaplan-Ashiri, I., Wong, J.P.S., Davis, A.Y., Black, M.S., Weber, R.J., 2019. Environ. Sci. Technol. 53, 12054–12061.