Aerosol and gaseous emissions from a desktop 3D printer

L. Mendes[1, 4, 5 *], A. Kangas[2], K. Kukko[3], B. Mølgaard[1], A. Säämänen[2], T. Kanerva[2], I. F. Ituarte[3], M. Huhtiniemi[2], H. Stockmann-Juvala[2], J. Partanen[3], K. Hämeri[1], K. Eleftheriadis[4] and A.-K. Viitanen[2]

[1] Department of Physics, Division of Atmospheric Sciences, University of Helsinki, FI-00014 Helsinki, Finland

[2] Finnish Institute of Occupational Health, FI-00251 Helsinki, Finland

[3] Department of Mechanical Engineering, Aalto University, FI-00076 Aalto, Finland

[4] Institute of Nuclear & Radiological Sciences & Technology, Energy & Safety, Environmental Radioactivity Laboratory, N.C.S.R. "Demokritos", 15310 Athens, Greece

[5] Department of Environment, University of the Aegean, 81100 Mytilene, Greece

Keywords: Additive manufacturing, 3D printer, nanoparticles, aerosol, occupational exposure.
*Presenting author email: luis.mendes@ipta.demokritos.gr

Additive Manufacturing or 3D printing (3DP) has received great attention in recent years. Low-cost printers for professional, educational and recreational purposes are now widely available to the general public. The use of these devices in non-ventilated areas may pose health risks, regarding air quality issues.

Desktop 3D-printers have been shown to emit significant amount of nanoparticles, and gaseous compounds (Kim et al., 2015; Stephens et al., 2013), but studies are still scarce. Exposure to nanoparticle may lead to adverse health effects (Pope & Dockery, 2006), and compounds like styrene and formaldehyde can also be harmful at high concentrations (WHO, 2010). Further studies on emissions from 3DP are of utmost importance to assess users' exposure, and determine the need for product design improvements and user guidelines, in order to minimize possible health effects.

This study aimed to characterize both particle and gaseous emissions from a desktop 3DP based on the Fused Deposition Modeling (FDM) technology. We used the two most common printing polymers: Acrylonitrile Butadiene Styrene (ABS) and Poly-Lactic Acid (PLA). The experiments were performed both inside an air-tight chamber and a full scale room, ventilated by filtered air, allowing analysis with minimal background concentrations. Both online and offline analysis were performed.

For the first time in 3DP studies, the size resolved particle concentration was measured in the size range of 1 nm to 30 µm. In addition, a Volatility Tandem Differential Mobility Analyser was used to determine the particle volatility and the mixing state, and samples were collected for Transmission Electron Microscopy analysis. Gases and organic compounds were also measured, namely formaldehyde, 1,3-butadiene, styrene and hydrocarbons.

Particle emission rates were estimated both by direct measurement and particle modelling. The results show that emissions from 3D printers may lead to high indoor particle concentrations, mostly nanoparticles originating from the extrusion process, as shown in Figure 1 for a printing event using ABS. The measurement results yielded significant differences in emissions for different printing materials and operating temperatures. Emissions of gases and volatile compounds were shown to be low or negligible in this case. Further details on emission, concentrations and aerosol characterization will be discussed along with the results, which were significantly distinct from previous studies (Mendes et al., submitted).

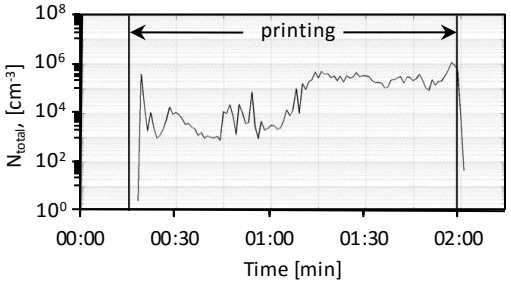

Figure 1. Total particle number concentration (10-420 nm) inside the chamber, measured by a NanoScan (TSI Inc.) during printing using ABS.

We conclude that 3DP based on FDM is likely to emit significant nanoparticle quantities, comparable to those emitted by laser printers or cooking activities. Precautionary measures should be taken both by users and manufacturers.

The study was supported by Finnish Work Fund (project numbers 114337, 114406, 114374), in collaboration with the FP7 Marie Curie ITN project HEXACOMM (grant no. 315760).

References:

Kim, Y., Yoon, C., Ham, S., Park, J., Kim, S., Kwon, O., & Tsai, P.-J. (2015). *Environmental Science & Technology*, *49*(20), 12044–12053.

Mendes, L., Kangas, A., Kukko, K., Mølgaard, B., Säämänen, A., Kanerva, T., … Viitanen, A. Characterization of desktop 3D printer' emissions. *Journal of Industrial Ecology*. *Submitted*.

Pope, C. A., & Dockery, D. W. (2006). *Journal of the Air & Waste Management Association*, *56*, 709–742.

Stephens, B., Azimi, P., El Orch, Z., & Ramos, T. (2013). *Atmospheric Environment*, *79*, 334–339.

WHO. (2010). *WHO guidelines for indoor air quality: selected pollutants*.