A pilot study of the impact of a prototype sealed enclosure with recirculating gas and particle filtration on emissions from desktop 3D printers

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February 2016

The goal of this pilot project was to evaluate the effectiveness of a prototype sealed enclosure with a recirculating gas and particle filtration system (manufactured by 3DPrintClean) for reducing ultrafine particle (UFP) and total volatile organic compound (TVOC) emissions from high-emitting combinations of desktop 3D printers and filaments using controlled experiments in a 3.6 m^3 environmental chamber (Figure 1).

One printer was tested (LulzBot) with two of the highest UFP- and VOC-emitting filaments characterized in Azimi et al. (2016) *Environ Sci Technol* (Nylon and ABS filaments). The Nylon filament was previously shown to emit caprolactam as its primary speciated VOC, while ABS was shown to primarily emit styrene. We measured UFP concentrations using a TSI Model 3007 condensation particle counter (CPC) and TVOC concentrations with a RAE Systems ppbRAE 3000 TVOC monitor as indicators of these and other compounds.

Figure 1. 3DPrintClean enclosure and filtration system with a LulzBot printer in the controlled environmental chamber

Figure 2 shows time-varying UFP concentrations measured inside the chamber under four conditions: the ABS and Nylon filaments each with and without the sealed enclosure installed with the filtration system operating continuously on "high." These concentrations are measured inside the chamber but outside the enclosure, thus representing only the UFPs that escape the system. The average reduction in time-varying UFP emissions achieved by the enclosure and filtration system was 91% for the ABS and 66% for the Nylon filament. Differences in these reductions may be attributable to differences in the sizes of UFPs emitted from the two filaments, although we do not have size-resolved concentration data for these filaments.

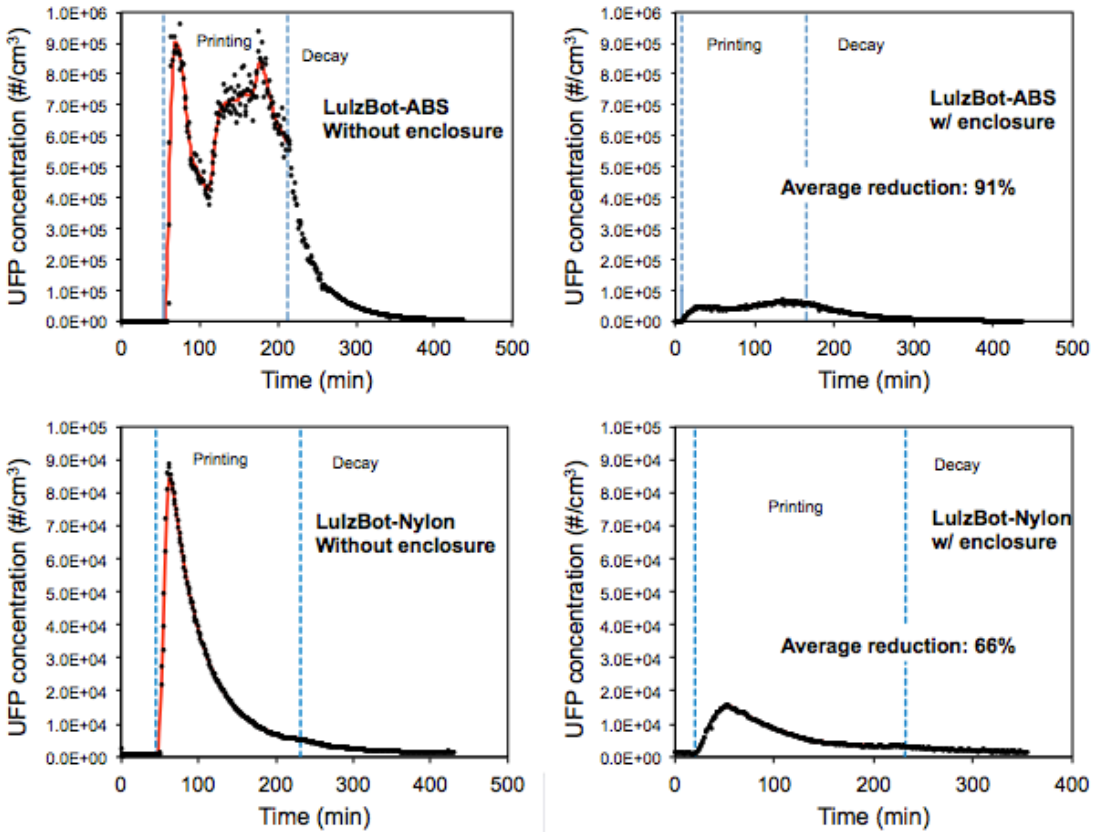

Figure 2. Time-varying UFP concentrations with and without the enclosure installed and gas and particle filtration operating continuously

Similarly, Figure 3 shows time-varying TVOC concentrations measured inside the chamber under the same four conditions: the ABS and Nylon filaments with and without the enclosure installed and filtration system operating continuously on "high." The average reduction in time-varying TVOC emission rate was 85% for the ABS filament and 94% from the Nylon filament.

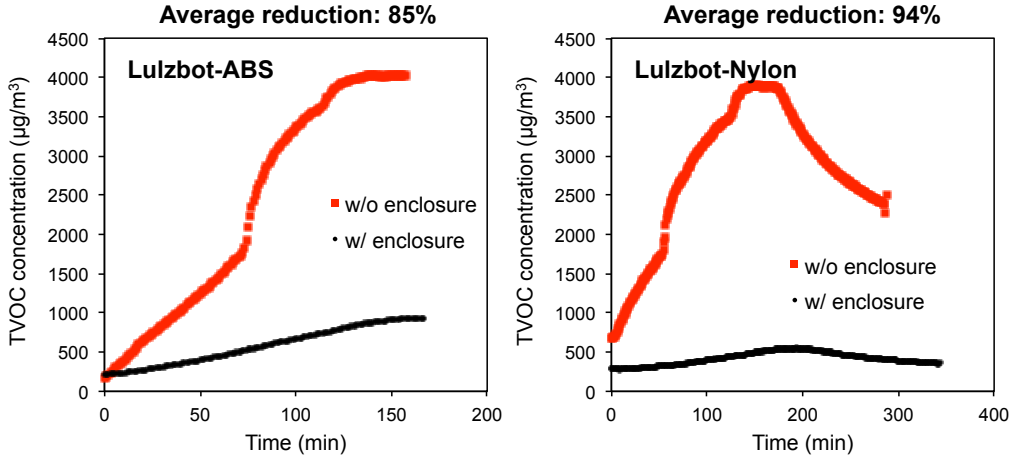

Figure 3. Time-varying TVOC concentrations with and without the enclosure installed and gas and particle filtration operating continuously

Figure 3 shows similar measurements made *inside* the sealed enclosure and filtration system for the duration of one printing period with ABS filament. These data demonstrate the time that is required for UFPs and TVOCs to decay inside the enclosure before it is safe to open. The printing period ended at approximately 200 minutes (marked on the figure). Subsequently, concentrations of UFPs decayed more rapidly than TVOCs: approximately 50 minutes for UFPs compared to more than 100 minutes for TVOCs. These data suggest that decreasing the time required for the flush out period could improve the practicality of the enclosure system.

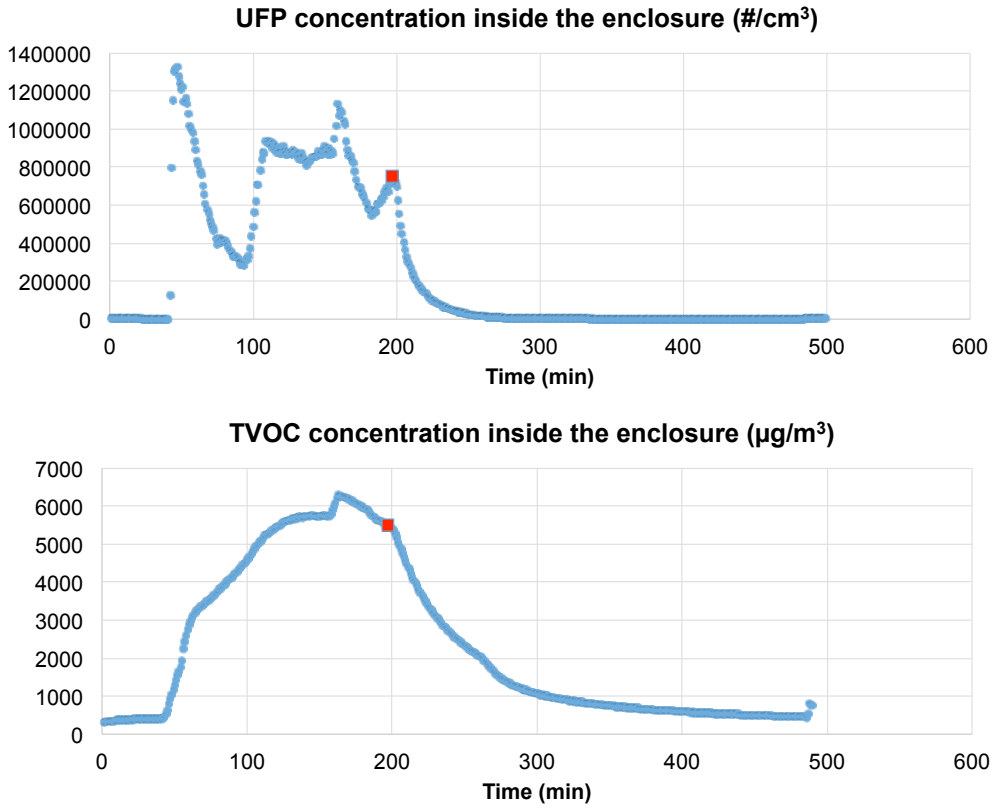

Figure 4. UFP and TVOC concentration data *inside* the sealed enclosure with a LulzBot+ABS filament combination (the red square marks when printing stopped)