Assessing Particulate and Chemical Emissions from Additive Manufacturing Processes

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Introduction

• Additive manufacturing (AM), commonly known as 3-D printing, is a rapidly emerging manufacturing technology. Rather than removing materials (in subtractive manufacturing), AM processes develop three-dimensional parts from Computer-Aided Design (CAD) models. This process allows building parts with geometric and material complexities that could not be produced by alternative processes, such as subtractive manufacturing. 2

• AM technology could potentially cause emissions of harmful pollutants during the printing process. Thermal treatment and additive manufacturing of plastic materials are known to cause decomposition of the material, enabling the emissions of VOCS and fine particles. Exposure to these agents may cause sensitization, irritation, and inflammatory effects on the skin, lungs, mucous membranes, and vital organs. 3

• There are no current health standards specific to AM technology. However, it is feasible to compare the results obtained from the printing process to the background measurements taken prior to the start of printing.

• There were concerns regarding the emissions coming from the various types of printers utilized throughout the studied facility.

Table 1: Pollutant concentrations in the Teaching Lab before, during, and after the use of the desktop printer.

| Pollutant | Before Printing | During Printing | After Printing | Significance
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<td></td>
<td>p &lt; 0.001</td>
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<td>FDM printers operating simultaneously (two HEPA air cleaners were OFF)</td>
<td>2549 ± 641</td>
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Objective

The objective of this study was to measure the concentrations of airborne fine particles and VOCS emitted from various printing processes in a plastics printing laboratory and teaching laboratory at the University of Cincinnati.

Methods

• Air monitoring was conducted in two separate locations: Teaching Lab and Plastic Printing Lab. Five types of printers were tested as follows:

  - Teaching Lab
  - Three Stereolithography (SLA) printers operating simultaneously (no control available).
  - Three Fused Deposition Modeling (FDM) printers operating simultaneously (no control available).
  - Two Polyjet printers operating simultaneously with and without the control (local exhaust ventilation).
  - One Polyjet printer and with and without the control (activated carbon filter).
  - All eight printers operating simultaneously with their respective controls.

• Each test took approximately three hours to complete: 30-minute background monitoring, 2-hour monitoring while printing and post-processes, and 30-minute post-monitoring.

• Stationary monitoring was conducted using a P-Trak ultrafine particle counter (TSI Inc., St. Paul, Minnesota) and a PPBRae 3000 (Rae Systems, San Jose, California) side-by-side. A mobile P-Trak, relocated every 5 minutes, was used to obtain the spatial distribution of airborne particles.

• The ventilation rate in the rooms that housed the printers within the Plastic Printing Lab, the overall range of fine particle concentrations was similar to what was reported by Sienle et al. 2015.

• The data were analyzed using Microsoft Excel and the statistical computing software, R. A least was used for the following comparisons: background vs. during printing and printing without the control vs. with the control.

Results

• The preliminary results show that VOC concentrations in the Teaching Lab, including background, printing, and post-printing, ranged from 296 to 450 ppb. The HEPA air cleaners were on the LOW setting (50 CFM) and from 252 to 416 ppb when the HEPA air cleaners were on the HIGH setting (700 CFM). The VOC concentrations were 2.3 times higher during printing compared to the background when the HEPA air cleaners were OFF (p < 0.001). During printing, VOC concentrations decreased to almost 2.5 when the HEPA air cleaners on the LOW setting compared to the experiment without the HEPA air cleaners (Table 1) (p = 0.001). At the HIGH setting, these concentrations decreased close to the background levels. The maximum VOC concentration was 2649 ppb when the HEPA air cleaners were OFF.

• The fine particle concentrations in the Teaching Lab ranged between 300 and 5700 particles/cm3. Proively, decreased with the implementation of the HEPA air cleaners on the LOW setting compared to the experiment without the HEPA air cleaners (Table 1) (p < 0.001). At the HIGH setting, these concentrations decreased close to the background levels. In summary, the VOC concentrations were significantly lowered by implementing the control. Based on these results, the local exhaust ventilation is only effective in reducing fine particle concentrations, as opposed to VOCS. Therefore, if no local exhaust ventilation in the Plastic Printing Lab requires further evaluation before improvements can be recommended to improve its overall efficiency.

Conclusion

• Overall, fine particle concentration peak values for printers in the Teaching Lab and Plastic Printing Lab were much lower than those reported by Zhang et al., 2019, who measured concentrations up to 105 particles/cm3. However, our mean concentrations were similar to what was reported by Sienle, 2015. Furthermore, our VOC concentrations were considerably higher than those obtained by Albadri-Miheajer et al., 2015, who reported a maximum value of 750 ppb.

• After printing, the HEPA air cleaners in the Teaching Lab proved to be effective in reducing the overall concentrations of fine particles and VOCS. The experiments in the Plastic Printing Lab showed varying results on the efficiency of the control against VOCS. However, the fine particle concentrations were significantly lowered by implementing the control. Based on these results, the local exhaust ventilation is only effective in reducing fine particle concentrations, as opposed to VOCS. Therefore, if no local exhaust ventilation in the Plastic Printing Lab requires further evaluation before improvements can be recommended to improve its overall efficiency.

References


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