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TECHNICAL BRIEF

A Strategic Research Initiative on the Indoor Air Quality Impact of 3D Printing with Dental Resins

Introduction

3D printers have been widely used in schools, offices, and homes. However, depending on the type of 3D printing technology, the use of 3D printers can generate particulate matter (PM) and volatile organic compounds (VOCs), which may pose health risks to the users. Chemical Insights Research Institute (CIRI) of UL Research Institutes has found that material extrusion 3D printing generates elevated levels of ultrafine particles and various hazardous VOCs[1], but data for vat photopolymerization 3D printing is limited. Vat photopolymerization technology uses photopolymer resin that can be cured selectively by light-activated polymerization. This type of 3D printing can create finely detailed parts with a smooth surface finish, making it widely used for dental and medical applications.

CIRI's characterization study using a laboratory exposure chamber shows stereolithography (SLA) 3D printing, a type of vat photopolymerization, emits primarily VOCs, including sensitizers, carcinogens, and irritants.[2] CIRI recently partnered with the Campus, Safety, Health, and Environmental Management Association (CSHEMA) to produce the guidance document UL200B Safe Use of 3D Printing for Institutions of Higher Education. The publication of this document has raised awareness of 3D printing safety on college campuses and helped identify gaps in knowledge and best practices. Since vat photopolymerization is routinely used in dental schools, more data is needed on emissions and exposure-related health concerns within these settings.

This research initiative will characterize potential airborne hazards associated with new technologies and methods being used in modern dentistry and dental education. Of particular interest is the impact of the vat photopolymerization 3D printing processes on indoor air quality and human exposure. 3D printing with resins is widely used in university dental schools; however, the printing and post-printing processes are potential sources of airborne PM and VOCs, which may potentially pose health risks from exposure for users, especially vulnerable populations.

Study Objectives

- Evaluate indoor VOCs, aldehydes, and airborne particulates in dental school settings where technologies and methods such as vat photopolymerization 3D printing and milling activities commonly occur.
- Characterize VOCs and particle emissions from a variety of dental resins under ambient and printing-process temperatures.
- Assess the impact on indoor air quality and exposure risks to users and general building occupants from resin 3D printing and post-printing processes.

Study Plan Overview

The study objectives will be achieved using the following sample and assessment plan:

1. Emission profiles will be characterized under ambient and printing-process temperatures for common dental resins used in vat photopolymerization using CIRI's microchambers.
2. Indoor VOC, aldehyde, and PM levels will be measured using field monitoring techniques at dental school study sites where resin 3D printing, post-processing, and milling activities occur. The impact of these activities on indoor air quality will also be evaluated.
3. Airborne particle concentration and size distribution will be measured in real-time with a NanoScan Scanning Mobility Particle Sizer (TSI 3910) for 10 to 420 nm particles and an Optical Particle Sizer (TSI 3330) for 0.3 to 10 µm particles. In addition, 37 mm PTFE (polytetrafluoroethylene) filter samples will be collected, further extracted, and analyzed by inductively coupled plasma-mass spectrometry (Agilent 7900) according to U.S. EPA methods 3051A and 6020 for metal elements.
4. VOC and aldehyde samples will be collected using portable pumps calibrated to 0.2 and 0.5 liters per minute onto Tenax tubes and 2,4-dinitrophenylhydrazine (DNPH) cartridges, respectively. Tenax tubes will be analyzed according to U.S. EPA TO-17 method for VOCs using gas chromatography-mass spectrometry (Agilent 8890 and 5977B) and DNPH cartridges will be analyzed according to U.S. EPA TO-11A method for low molecular weight aldehydes using high-performance liquid chromatography (Agilent 1260 Infinity).

Scientific Outcomes

1

Characterization of chemical and particle emissions associated with 3D printing using various resins, as utilized in modern dentistry and dental education.

2

Quantification of indoor air quality impact from vat photopolymerization and common milling techniques in dental schools.

3

Identification of health risks to users and general building occupants when preparing and operating resin 3D printers.

References

1. Qian Zhang and Marilyn Black. Exposure hazards of particles and volatile organic compounds emitted from material extrusion 3D printing: Consolidation of chamber study data. Environment International, 2023, 182. https://doi.org/10.1016/j.envint.2023.108316
2. Qian Zhang, Aika Y. Davis, and Marilyn S. Black. Emissions and Chemical Exposure Potentials from Stereolithography Vat Polymerization 3D Printing and Post-processing Units. *ACS Chemical Health & Safety*, 2022, 29 (2), 184-191. https://pubs.acs.org/doi/10.1021/acs.est.9b04168