Technical Brief

A Strategic Research Initiative for 3D Printing: Safety Convergence for Manufactured Products

Introduction

Three dimensional or 3D printers are gaining momentum in the market for rapid prototyping and manufacturing especially in consumer, industrial, medical and military markets. There are low cost desktop versions that are accessible for homes, small offices and schools. This printing, also known as additive manufacturing, defines the process of joining materials to make objects from 3D model data.

This technology tool has the potential to streamline and expedite products into the marketplace and have a dramatic impact on design, manufacturing, availability and warehousing of products. Personal 3D printer growth (units typically costing less than $5K) is exponential with rapid adoption and use by educational facilities and businesses for early learning laboratories and prototyping. Home lobbyists are also adopting the technology for the design and printing of parts and devices. Larger and higher quality industrial and professional grade machines are used for large scale design, manufacturing, and warehousing opportunities.

Research opportunity

While there are traditional electrical and physical safety considerations of potential hazards from the application and use of 3D printers and additive manufacturing processes, this technology presents a human health concern related to the potential release of chemicals and particles into the air during operation. This in return can affect the indoor air quality and expose people to unexpected harmful pollutants. Few studies have been done to evaluate this human health risk.

Health studies are available indicating human toxicity resulting from emissions of heated thermoplastics, and the health impact of ultrafine particles (those less than 100 nm) is established. In fact, the Blue Angel Eco-Logo program in the EQ has a standard addressing chemical and particle emissions from laser and inkjet printers. The prolific use of a variety of materials and elevated heat during operation of 3D printing presents an opportunity for significant emissions and unintended human exposure to hazardous by-products.

The majority of 3D printers function by 1.) extruding a hot thermoplastic and depositing it in layers to shape a product according to a model or 2.) depositing various polymers using inkjet type of heads to form an object. Other techniques include sheet lamination, photopolymerization, and powder fusion bonding are also available. In all cases, a range of materials, plastics, polymers, binding and finishing agents, and metals are used, presenting potential health hazards resulting from volatile organic chemicals, aerosols, and particles released during printing.

These gaseous and particle emissions may become airborne or may deposit on small dust particles that may also be inhaled or ingested. Typical materials include polycarbonate, polystyrene, polyvinyl alcohol (PVA), crylonitrile butadiene styrene (ABS), polylactic acid (PLA), polyethylene terephthalate (PET), and nylon. Previous studies of the thermal decomposition products of these materials have raised concern over their toxicity. In addition, printing functions have been shown to be sources of particles, including ultrafine particles (UFPs) that are released into the air and present a significant health concern.

With the rapid adoption of 3D printers, especially in the consumer market where homeowners, children, educators, and small business employees can be affected, research data on their chemical and particle emissions is important in assessing the potential for human health risks and ultimately designing engineering controls and safer material selection for minimizing risks.

This basic research will provide data and increase knowledge related to the behavior of particle and chemical emissions released during the operation of 3 D printers and their impact on human health.

Outcomes

This research will investigate the chemical and particle release behavior of key 3D printing technologies, their impact on the indoor air, and potential human health risks. Particle emissions will be characterized for their size distributions, number of particles, and timing of release - all intrinsic to the type of printing technologies.

Chemical content of particle size distributions will also be made, identifying those chemicals adsorbed on the particles from the materials of print. In addition, cellular assays using lung macrophage cells will assess potential lung inflammation and health risks.

Data from this research will help lead to:

1) Defining appropriate measurement and risk evaluation techniques for types of products;
2) Assessment of the potential for human particle and chemical exposure through both inhalation (breathing particles and vapors) and dermal (hand to mouth or skin absorption); and
3) Assessment of potential risk levels and enables stakeholder

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discussion of mitigative routes through material substitutions or engineering controls.

Minimal research has been done on the indoor air quality and health impact of 3D printing. This work will allow UL to take a leadership role on a technical level and lead with science by bringing knowledge and data to the stakeholder discussion.

Key steps

Key measures to this research include engaging appropriate academic partners that have the particle and chemical characterization expertise and knowledgeable regarding health assessment for ultrafine particles and chemical exposure. Together, along with a select group of scientific stakeholders and technology experts, the test program is finalized to characterize particle and chemical emissions and their impact on IAQ and human health. Key research objectives include:

• Expand the safety paradigm to demonstrate traditional safety and health convergence (i.e. electrical, flammability mechanical and human health safe).
• Obtain a minimum of 3 different 3D printing technologies and three manufacturers of each for study. Run in a controlled environment and characterize particles by size, distribution, and timing and chemical content. Also measure volatile chemical releases. Evaluate potential acute and chronic health risks based on particle and chemical exposure opportunity from operation of the devices. Also identify asthmogens and chemicals of concern. Based on initial results, recommend steps to defining appropriate measurement methodologies for consistent evaluations and benchmarking of various 3D printing technologies and print materials.
• Based on initial chemical results, evaluate potential combustibility or flammability opportunities to bring to the safety convergence discussion.
• Publish study results in scientific, peer reviewed journal and present at technology conference.
• Recommendations for next steps to define safety of 3D printing.

Study facilities

Particle and chemical characterizations studies will be done at Georgia Institute of Technology, Department of Civil Engineering and Atmospheric Sciences where the expertise and measurement equipment is available.

Health risk studies will be done by Emory University, Department of Public Health with particle exposure expertise. Specific volatile organic compound analysis of emissions will be conducted at UL AQS.

The complete academic team will be located in Atlanta and additional advisory panel members will include an expert on 3D printing technologies and selection of material alternatives for safer products.

Research partners

Organization	Responsibility
UL-AQS	Measurement of volatile organic compounds
UL-NBK	Flammability considerations of combustible materials
Georgia Institute of Technology and University of Wisconsin	Measurement and characterization of particles and absorbed chemicals
Emory	Health and risk evaulations of ultrafine particles and chemicals of concern

Scientific research committtee

• Georgia Tech School of Atmospheric Sciences
• National Institute for Occupational Safety and Health/ Centers for Disease Control
• Emory University School of Public Health
• Georgia Tech Additive Manufacturing Laboratory
• Underwriters Laboratories, Inc. (ULI)
• German Federal Institute of Materials Research and Testing (BAM)