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# Toxicological Exposure and Risk Assessment of Emissions from 3D Printers

A Panel Presentation and Discussion presented by the Society of Toxicology – facilitated By Dr. Treye Thomas of CPSC and Dr. Yong Qian from NIOSH

Speakers:

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*The summary information presented was prepared by and reflects the review of Dr. Qian Zhang.*

## BACKGROUND

3D printing has been widely applied in industrial, transportation, consumer products, medical, architectural and academic fields. As it is gaining popularity with the general public and becoming common in offices, schools and homes, issues regarding health and safety implications and mitigation practices have been rising. This workshop covered characterization of emissions from different types of 3D printers and their potential health impacts assessed by various methods. It included research studies on aerosol and volatile organic compound (VOC) emissions, in vivo and in vitro toxicity assessments, model estimation of exposure, impact of printer type and condition on emissions, and strategies on mitigating exposure.

## HIGHLIGHTS INCLUDED

In vivo inhalation exposure of rats to real time 3D printer emissions from acrylonitrile butadiene styrene (ABS) filament was conducted in a chamber for various exposure doses and time. Measures of pulmonary injury, inflammation, oxidative stress, systemic and other organ toxicity, and microvascular function were obtained. In general, response levels for different measures were inconsistent and dependent on exposure dose and duration. Minimal and transient effects on lungs and some indices in serum were found, while no significant inflammatory, histopathological or hematology effects were found. Systemic microvascular dysfunction was found as attenuated arteriolar responsiveness of both endothelium-dependent and -independent arteriolar dilation, while adrenergic sensitivity was not changed.

In vitro assessment was applied to human small airway epithelial cells with emissions from ABS (both particles and VOCs) directly collected into the cell culture medium during printing; assessments included physicochemical properties, cytotoxicity, oxidative stress and cytokine production. Results showed decreased cell viability and production of reactive oxygen species (ROS) and proinflammatory cytokines, in a dose-dependent manner.

Particle toxicity was also assessed by collecting particles on filters and extracting in liquid for exposure assays. Extracted particles from printing with polylactic acid (PLA) and ABS filaments were used for assessing toxicity in vivo and in vitro. Intratracheal instillation to mice showed inflammatory responses induced by both PLA and ABS emitted particles; three in vitro cellular assays on two different cell types assessing cell viability, ROS production and cell death mechanism all showed cytotoxic responses for both PLA and ABS emitted particles. A chemical assay estimating total particle oxidative potential (on extracted particles with the filter) was applied to particles emitted from PLA, ABS and nylon filaments. Results showed that particle mass based responses were comparable among filaments and lower than those of ambient fine particulate matters using the same assay. However, overall exposure responses combining exposure levels for ABS-emitted particles may be higher than ambient for some indoor conditions and PLA-emitted particles had the lowest responses.

## DISCUSSION

Uncertainty and inconsistency exist in toxicity analysis. Toxicity assessment methods vary in different aspects including target model (animals vs. cells, in vivo vs. in vitro); exposure manner (real time chamber exposure vs. collected sample and extraction, single time vs. multiple time, inhalation vs. other pathways); exposure measuring metrics (particles number vs. mass or surface); and measurements of outcome (selection of biomarkers, systemic or specific organ impact, acute vs. chronic effect). Biological toxicity responses are usually exposure dose and time course dependent and not linear due to the complex mechanism. A dose-response curve may be needed to understand exposure impact pattern.

There have been limited field measurements of 3D printer emissions (e.g. particle concentration and size information). However, real time measurements on site of particle and VOC composition that are associated with health concerns are still challenging. Furthermore, field emissions associated health impacts are yet to define, due to the difficulty of converting laboratory toxicity results to actual environment situations. In some ways, chemical assays may be advantageous over biological models, as they can provide substantial and reproducible data with less uncertainties, allowing comparison between studies. Exposure hazards in real environments can be estimated from combining assay measured toxicity responses and exposure levels.

## IN SUMMARY

Although uncertainties and inconsistencies have been noted among different toxicity assessment methods, all studies showed some level of toxicity or health impact associated with emissions from 3D printers, advancement of studies is recommended.

## REFERENCES


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