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Toxicity of Particles Generated from a Consumer Fused Deposition Modeling 3D Printer Using Animal, Cellular and Acellular Models

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Introduction

- Fused deposition modeling (FDM) 3D printers are popular with the general public and usually used in indoor environments not designed for manufacturing.
- High levels of ultrafine particle and gas emissions from 3D printers have been reported, levels dependent on printer and filament properties¹, which may cause adverse health effects.
- Particle chemical composition and potential health impacts have not been systematically investigated.

Objectives

- Examine chemical composition of 3D printer-emitted particles and compare with bulk filament material.
- Investigate potential toxicity of emitted particles based on oxidative stress mechanism and compare between filament materials.

Methods

Chamber experiment

- Print conditions: Fused deposition modeling (FDM) 3D printers are popular with the general public and usually used in indoor environments not designed for manufacturing.
- Particle emission: High levels of ultrafine and fine particle emissions (ABD).
- Particle chemical composition: PLA and Nylon.

Particle sample and offline analyses

- Extract in DI water.
- Liquid sample.
- In vitro cellular assays.
- Cell viability (WST-1 assay).
- Cell death mechanism (Annexin V-FITC).
- Intracellular reactive oxygen species (ROS) (H₂DCF-DA).
- Particle oxidative potential.

Results

Particle emission

- High levels of ultrafine and fine particle emissions.
- Solid particles (i.e., water insoluble) shown by SEM images.
- Chemical composition of particles not always the same as bulk material.
- All biological analyses (in vitro & in vivo) showed toxic responses when exposed to 3D printer emitted particles.

Particle chemical composition

- ABS-emitted particles’ mass spectra not like ABS monomers → not formed from monomers directly.
- PLA-emitted particles’ mass spectra similar to PLA monomers.
- Pyrolysis GC-MS showed ABS-emitted particles not like bulk ABS filament.

Particle toxicity via biological models

- Cell viability.
- Cell death.
- Intracellular ROS.

Conclusions

- Chemical composition of particles not always the same as bulk material.
- Particle formation associates with bulk material (PLA) or additives (ABS) → particle toxicity may not be the same as bulk material and may vary largely by filament brands.
- Various testing methods showed 3D printer emitted particles can induce toxic responses, depending on material type, etc. → PLA-emitted particles more toxic on a particle mass basis.
- Real exposure levels mostly driven by emission levels → ABS-emitted particles of more concern when using the same amount of filament.

References