EMISSIONS AND HEALTH HAZARDS FROM CONSUMER LEVEL 3D PRINTERS

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RESEARCH PARTNERS

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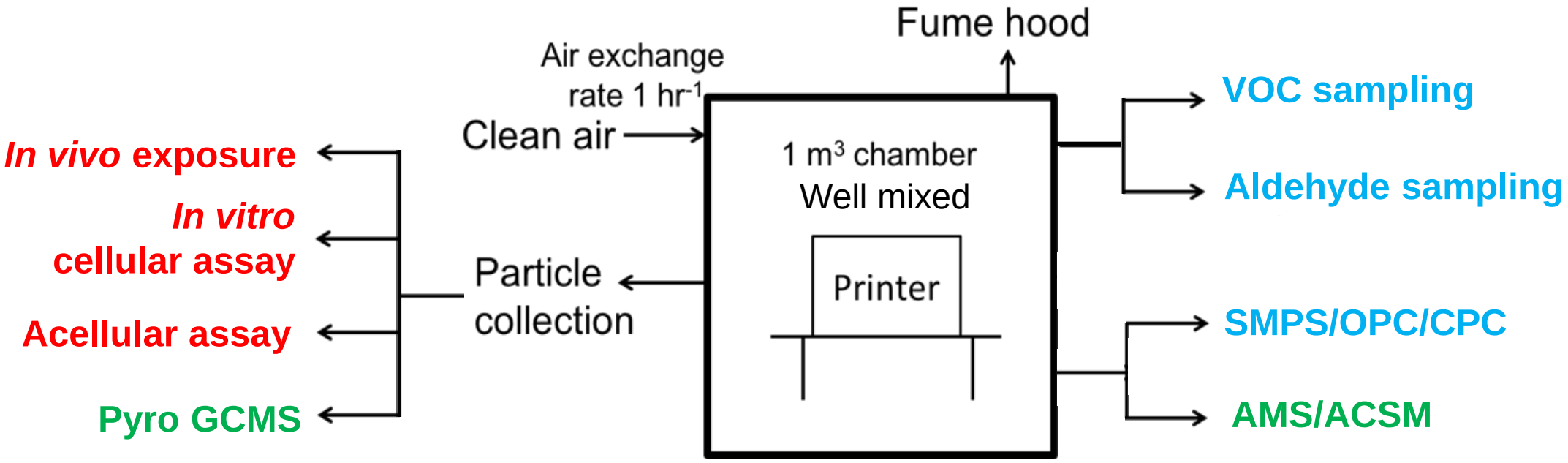
RESEARCH OBJECTIVES

- Characterize and quantity particulate and chemical emissions from 3D printers
- Establish testing method to measure the nanoscale particles and VOCs generated from 3D printers
- Evaluate emissions from 3D printers for human health impact
- Conduct toxicity studies of nanoparticles from 3D printers
- Consensus standard development for testing method and emissions criteria for 3D printers

METHODS: EMISSION MEASUREMENT

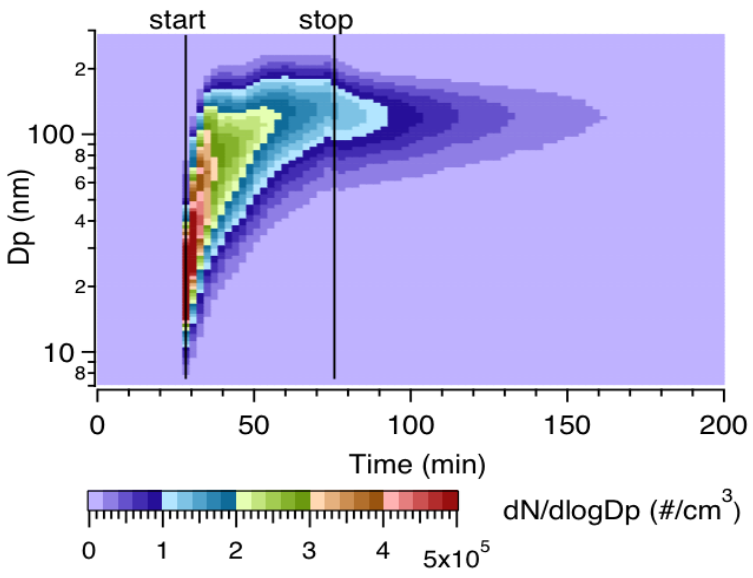


Test procedures and emission calculations follow basis of RAL-UZ 205 Blue Angel Method (BAM) developed for laser printers.

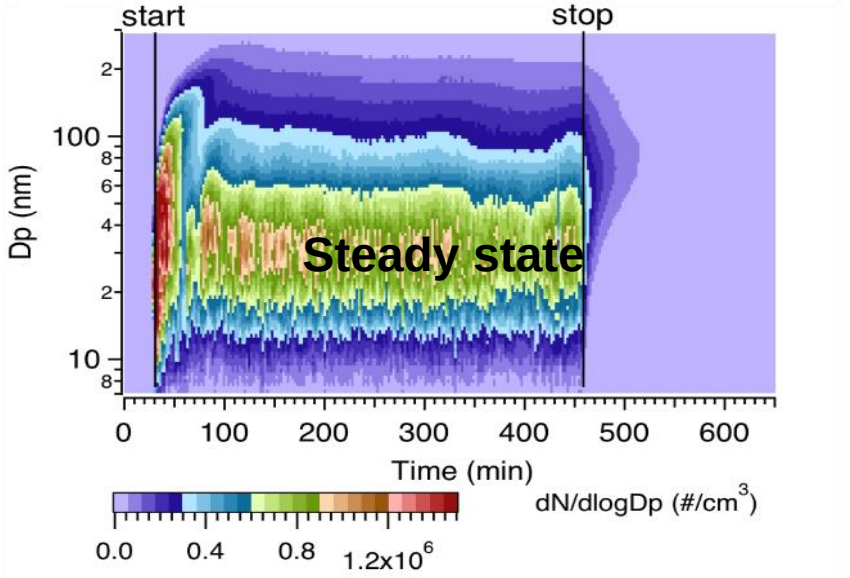
PARTICLE EMISSIONS: NUMBER VS. PRINT TIME

Example particle concentration and size distribution

ABS ~1 h print



ABS ~7 h print

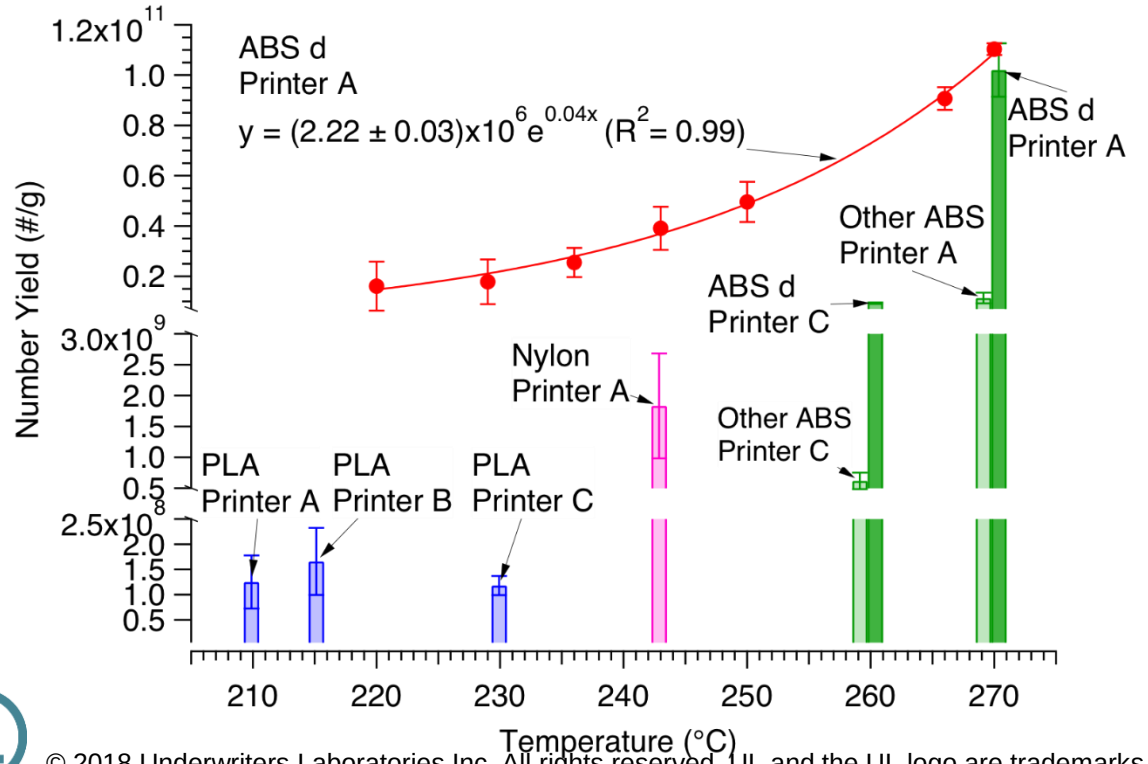


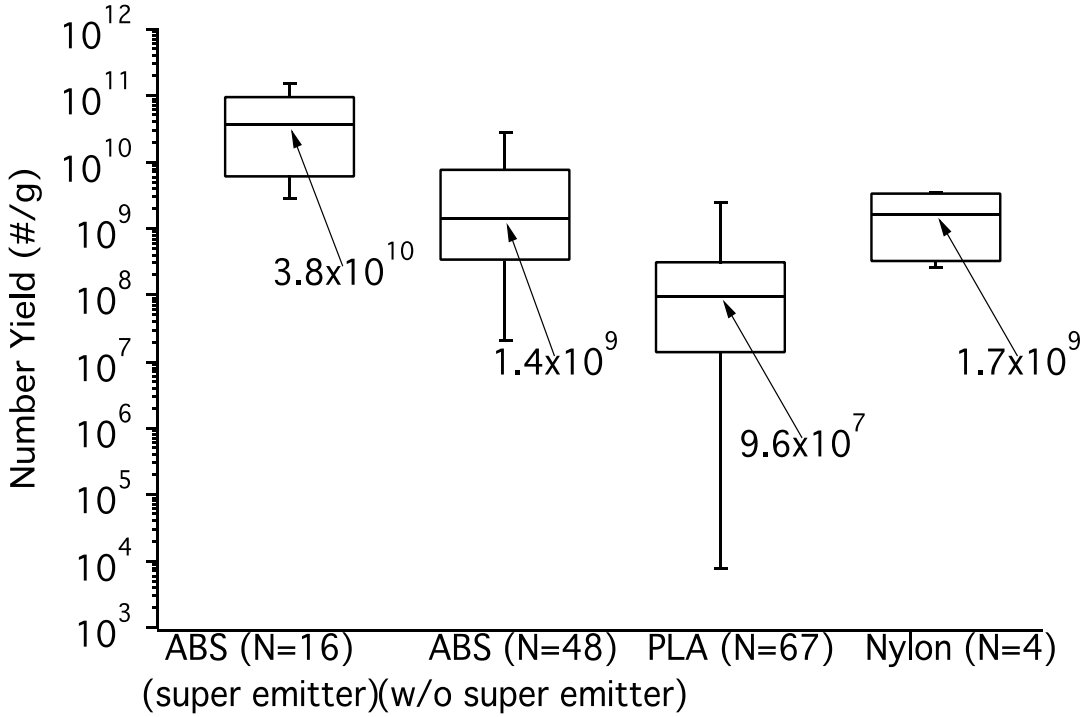
- Particle numbers peak at beginning, may reach steady state for long print times (other profiles also observed, but less frequent)
- ~ 90% of particles are ultrafine (Dp < 0.1 µm)

PARTICLE EMISSION: WHAT FACTORS ARE IMPORTANT?

- Print parameters that had the most influence on emissions
  - Filament material
  - Extrusion temperature (T)

Yield = total emission/printed object mass





3D Printer Particle Toxicity (oxidative stress)

Goal:

- Explore potential toxicity of 3D printer particles
- Compare filament material and brands

Particles tested:

- Tested three different aqueous samples containing 3D printer particles

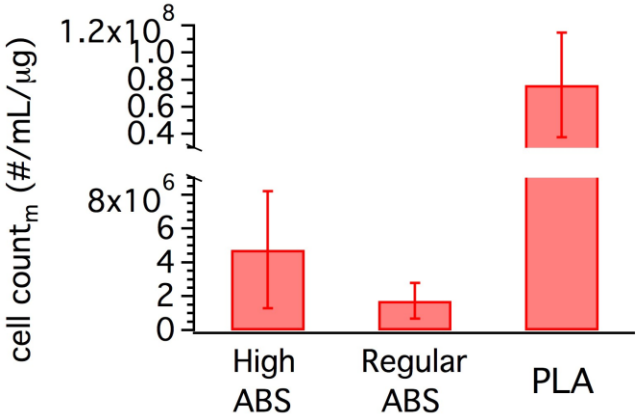
Experiments:

- *In vitro*: MTT assay, cell death, DCF assay (Rudich, Weizmann Inst.).
- *In vivo*: intratracheal instillation (Rudich, Weizmann Inst.)
- Acellular: DTT assay (GIT).

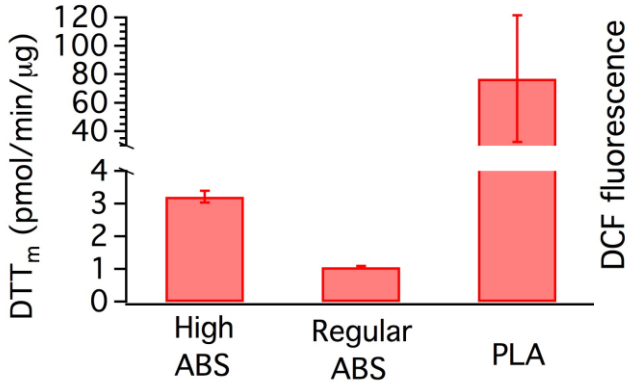
3D Printer Particle Toxicity: Assay Comparisons

Intrinsic property: normalized to sample mass, similar if normalize by surface area conc.

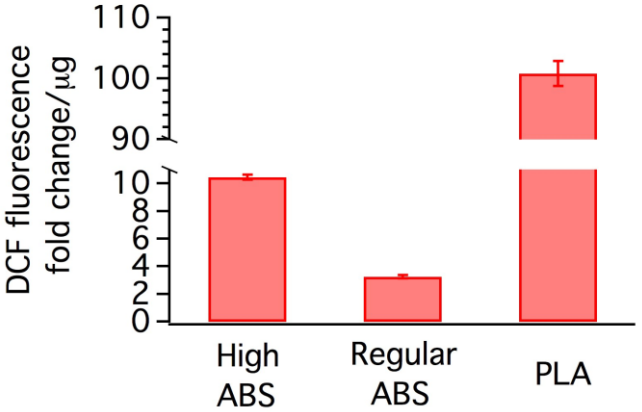
Mice *in vivo* exposure



DTT (chemical assay)



DCFDA (cellular assay)*

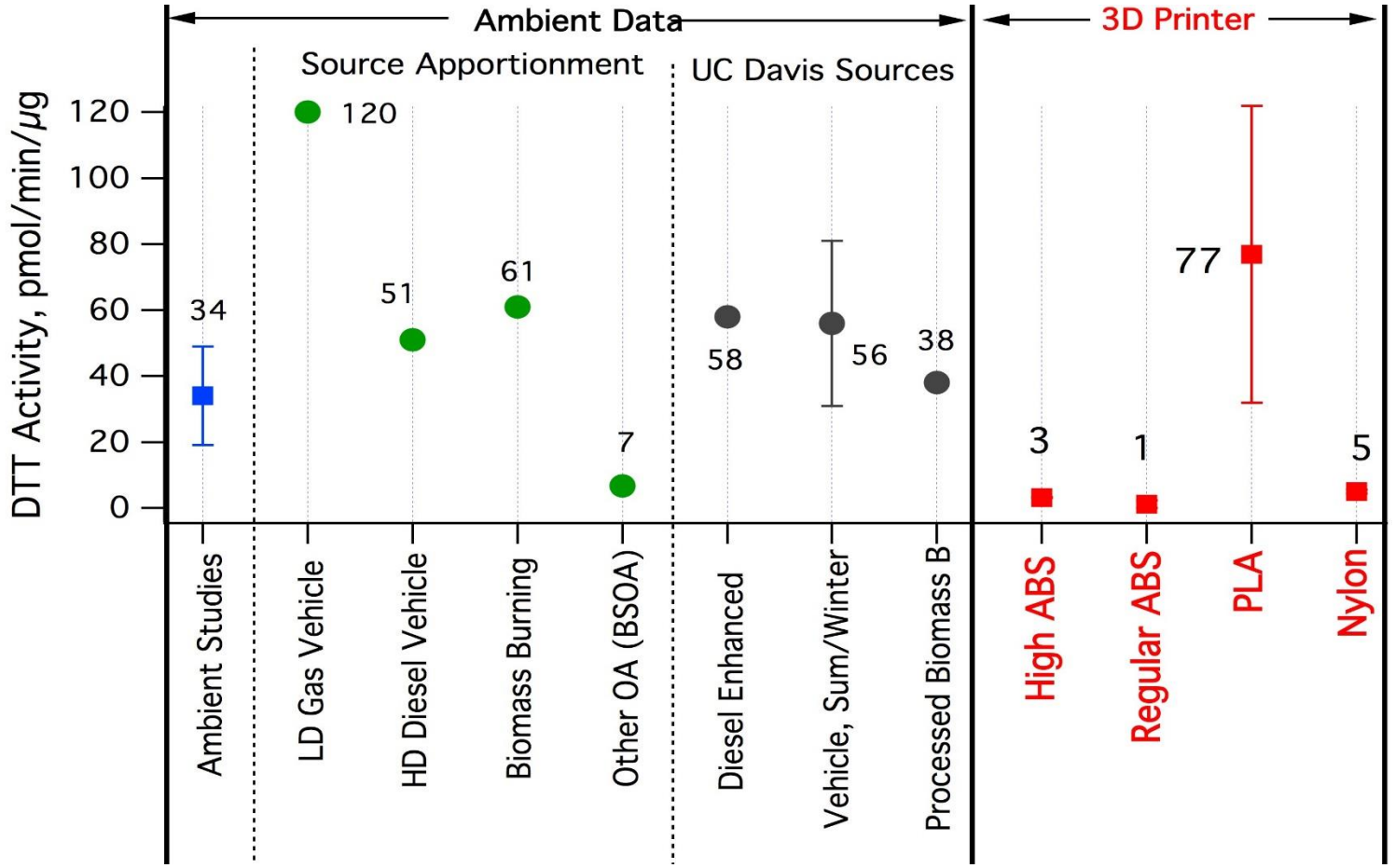


* 2 cell types give similar trend, only rat macrophage shown

Intrinsic properties from different methods follow the same trend: PLA ~ one order of magnitude higher than ABS

Compare these levels to Ambient Data

Comparison of ”Toxicity” by DTTm assay to Ambient Aerosols

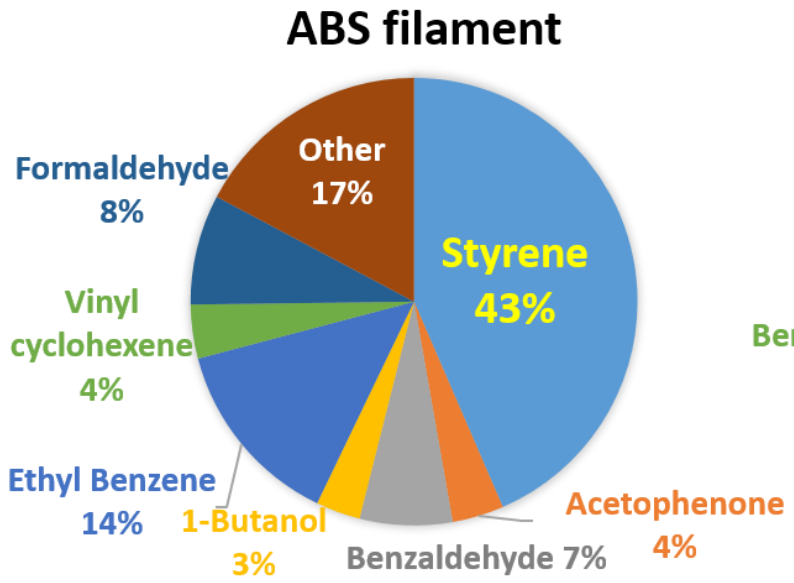


ABS and Nylon particles similar to lowest levels of ambient sources (biogenic emissions)

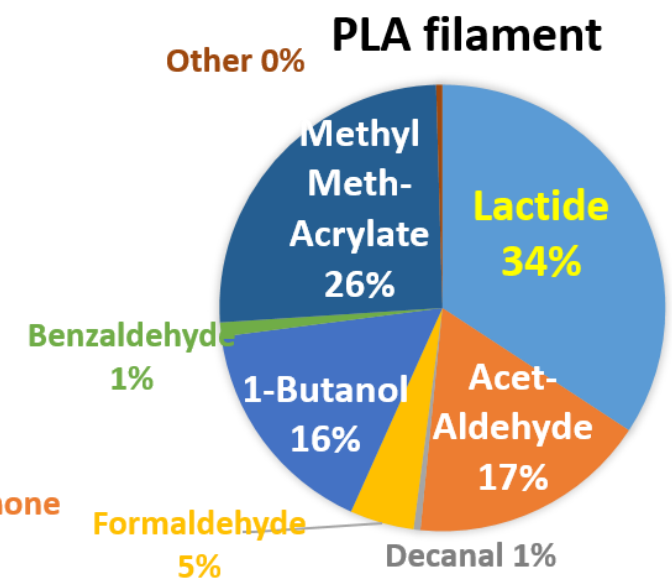
PLA similar to vehicle (gas and diesel) and biomass burning (wood smoke) by DTT assay

COMPOSITION OF GASEOUS EMISSIONS

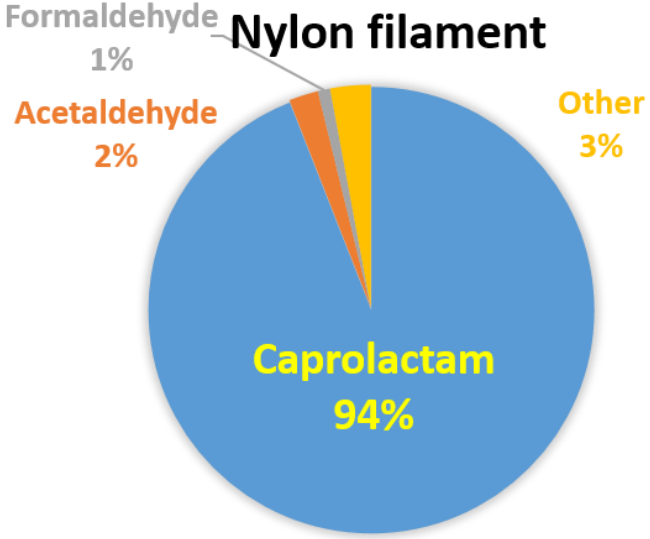
179 chemicals, 51 on reg. list



58 chemicals, 36 on reg. list



49 chemicals, 30 on reg. list



Total VOC emission rate (toluene equivalent)	835 µg/h	193 µg/h	1662 µg/h

GENERAL RESULTS

- 3D printers can emit significant levels of ultrafine particles (<= laser printers)
- VOCs of concern from 3D printers include
  - Formaldehyde
  - Caprolactam
  - Styrene
- Emission levels vary with specific machine and print media
  - Filament material/brand and nozzle temperature
- In vitro and In vivo results show that nanoparticles from 3D printers show toxicity
- Users of 3D printers should reduce emissions exposures to minimize health concern

STANDARD DEVELOPMENT IN PROCESS

UL/ANSI 2904: The Standard Method for Testing and Assessing Particle and Chemical Emissions from 3D Printers

- Objectives: Accurately measure particle and chemical emissions from 3D printers and minimize hazardous exposure to users
- UL/ANSI consensus Standard Technical Panel began November 2017
- UL/ ANSI completion expected Winter 2018
- First global 3DP standard for minimizing hazardous emissions

UL/ANSI 2904: The Standard Method for Testing and Assessing Particle and Chemical Emissions from 3D Printers

- Test method using environmental chamber
  - 3D printer/filament set up and requirements
  - Particle measurements
  - VOC measurements
- Data Analysis
  - Particle emission (size distribution and concentration) analysis
  - VOC emission analysis
- Criteria
  - Total particle count, TVOC, and Individual VOCs

Thank you!

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