3D-Printing—Safe Work Practices

Introduction:

Additive Manufacturing or Three-dimensional (3D) printing involves the layering of successive layers of material to create or replicate 3-dimensional objects. Depending on the printer, 3D-objects are created through extrusion, sintering or curing. 3D printers are now commonly used in many industries including, but not limited to, aerospace, architecture, automotive, consumer products, defense, dentistry, education, and medical fields. 3D-printing has also become common in University labs and classrooms. Though 3D printing holds considerable potential, the workplace health and safety risks are still being determined.

Types:

Multiple types of 3D-printers are available to create three-dimensional objects. The most commonly used types of 3D printers are listed below:

Types	Description
Material Extrusion [Fused Deposition Modeling (FDM)]	FDM printers use a thermoplastic filament, which is heated to its melting point, to create a 3-dimensional object. This is the most common type of 3D printer.
Vat Polymerization [Stereolithography (SLA)]	Vat polymerization uses a liquid photopolymer resin to create a model and then cure each layer of resin using an ultraviolet (UV) laser or digital processing lamp.
Material Jetting	Material jetting selectively deposits droplets of feed material onto a build platform, allows the droplets to cool and solidify and then builds on the solidified droplets to create a 3-dimensional object.
Binder Jetting	Binder jetting distributes a layer of powder onto a building platform and then applies a liquid bonding agent (i.e., a glue) to bond the particle layers together to create a 3-dimensional object.
Powder Bed Fusion [Selective Laser Sintering (SLS)]	SLS deposits a thin layer of plastic powder that is a melted by a laser on a building platform. 3D objects are created through layer-by-layer construction in the powder bed.
Directed Energy Deposition (DED)	DED uses a laser or electron beam to a melt material (usually metal powders or wires) from the nozzle of a multi axis arm as it is being deposited.
Sheet Lamination	Sheet lamination creates 3D objects by using a laser or a sharp blade to cut and bond thin-layered materials (e.g., paper, aluminum foil, etc.) together layer-by-layer.

Hazards:

3D-printing involves the melting of plastics [*Acrylonitrile Butadiene Styrene (ABS), Polylactic Acid (PLA), Polyvinyl alcohol (PVA), Polycarbonate (PC), etc.]*, metals (*steel, aluminum, titanium, copper, silver, gold, nickel, etc.*), composites, and photopolymers. Exposure to emissions from the melting of print media could lead to negative health effects. The hazards associated with 3D-Printing are indicated below:

Health Hazards	
Biological	3D printers used to create cells and/or engineered tissues may release biohazardous aerosols.
Flammability	The finely divided metal powders (e.g., aluminum, titanium, etc.) or resins used in some 3D printers can be spontaneously combustible (pyrophoric), leading to fires. Contact EHS prior to using printers with finely divided metal powders/resins.
Sensitizers	3D printer by-products from the melting of particular thermoplastics and photopolymers can cause allergic reactions upon contact or inhalation.
Toxicity	3D printers using certain print media have been shown to emit volatile organic compounds (VOC's). Some VOC's have been linked to eye, nose and throat irritation, headaches, damage to the liver, kidney and central nervous system and cancer.
Ultrafine Particles (UFPs)	The health effects associated with exposure to UFPs (i.e., particles less than 100 nm) are currently being researched. Past studies have indicated that exposure to UFPs at high concentrations have the ability to produce inflammatory responses in cardiovascular and respiratory systems.
Ultraviolet Radiation	3D printers using lasers to melt print media can emit ultraviolet radiation. Exposure to ultraviolet radiation may result in acute or chronic effects on the skin, eyes and immune system.
Physical Hazards	
Hot Surfaces	Contact with the print head block and/or UV lamp can cause burns.
Electrical	Unguarded electrical components in some 3D printers could pose a risk of electrical shock.
Moving Parts	3D printers with ingoing nip points and/or rotating parts can cause pinch or crush injuries.

Control of Hazards:

In order to reduce exposure to the hazards associated with 3D printers, the following controls are recommended:

Training	
1.	Employees working in labs with 3D printers are required to complete *General Lab Safety Training Management Training* through EHS. Employees working in non-lab areas with 3D printers are required to complete *HAZCOM RTK* training through EHS. Students working with 3D printers in University- sanctioned spaces must be provided a copy of these guidelines to ensure awareness of the hazards.
2.	3D printers using class 3B, 3R, or 4 laser systems must be registered with The Laser Safety Officer. Laser use must comply with all requirements of the Laser Safety Officer, as applicable.
Engineering Controls	
1.	Fully enclose (preferred) or cover 3D printers to limit exposure to VOC's and UFPs.
2.	Use 3D printers in well-ventilated areas. EHS recommends keeping 3D printers in rooms with 4-10 fresh air changes per hour.
3.	Provide local exhaust ventilation for ABS printers or place in a fume hood. ABS printers have been shown to emit styrene, a possible human carcinogen by the *International Agency for Research on Cancer*.
Work Practices	
1.	Install, use and maintain 3D printers as indicated by manufacturer specifications.
2.	Safety Data Sheets (SDS) must be present and accessible in the immediate work area for all print media and other chemical products involved in the printing process.
3.	Maintain a safe distance from the printer(s) to limit inhalation of emitted particles.
4.	Limit the number of printers per room. One printer per standard office space (~150ft^2) for a non-lab area can be used as a guideline. Multiple 3D printers in the same room may be possible based on the ventilation rate, enclosures and room size.
5.	Store print media and other chemicals associated with the printing process as indicated by the manufacturer.
6.	Choose a low-emitting printer and filament, if feasible.
7.	Since 3D printers run for extended periods, rooms/labs should avoid altering ventilation rates based on occupancy sensors, unless local exhaust is being used to remove emissions.
8.	An eyewash and safety shower is required in the immediate work area if corrosive materials are present or used in the printing process.
9.	Eating or drinking is not allowed in areas where 3D printers are being used.
10.	Avoid contact with heated surfaces to prevent burns.
11.	Live parts on 3D printers operating at 50 volts or more must be guarded against accidental contact.

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12.	3D printers with ingoing nip points and/or rotating parts must be properly guarded. (i.e., no exposed belts, gears, pulleys or other moving parts or points of operation).
Personal Protective Equipment	
1.	Eye protection recommended by the manufacturer in safety data sheets/printer specifications is required (if applicable).
2.	Gloves recommended by the manufacturer must be worn while handling print media and other chemicals associated with the printing process (if applicable).
3.	Respirators may be necessary for use with some 3D printers (e.g., metal and ceramic powders). If employees are required or voluntarily choose to wear respirators, they must comply with the requirements of the *Virginia Tech Respirator Program*.

References:

- **Ultrafine Particles in Ambient Air**
- **Control Measures Critical For 3D Printers**
- **Emissions of Ultrafine Particles and Volatile Organic Compounds from Commercially Available Desktop Three-Dimensional Printers with Multiple Filaments**
- **Emission of Particulate Matter from a Desktop Three-Dimensional (3D) Printer**

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