



## 3D Printer Health and Safety Guidelines

### Objective

The objective of this guide is to establish health and safety guidance for placement and use of 3D printers in university spaces to minimize the potential for injuries and exposure risks to faculty, staff, students and visitors of Illinois State University. This includes both department/program owned printers and personal units used in campus buildings, including but not limited to those affiliated with the sciences, fine arts, engineering, libraries, arts and craft studios, K-12 facilities, and general use applications.

### 3D Printing Technology

Three-dimensional “(3D) printing” is a technology which involves creating three-dimensional objects by laying down successive layers of materials, which may differ in composition. Initially, a virtual design is created and stored by computer-aided design (CAD) with 3D modeling software, and/or by using a 3D scanner/device. Once a design model (file) is created, a 3D printer/printing application will print the image by laying down definitive, discrete layers, to create the object, layer-by-layer. Images may be simple, with one type of material, or highly complex with different integrated materials. 3D scanners employ one of several technologies, with more common technologies including: “time-of-flight”, “structured/ modulated light”, and volumetric scanning.

### Primary Hazards Associated With 3D Printing

The hazards associated with 3D printing are related to the processes and technologies applied. These may range from electrical/shock, electromechanical force, burns from molten materials, ultraviolet light (UV)/ laser beams, and to health hazards associated with inhalation of ultrafine and/or toxic smoke, fumes and dust. *When installing 3D printers, various hazards should be considered for each type of technology/application, and the specific work environment where installed.*

- **Inhalation exposure to hazardous agents**

Many 3D printing processes use thermoplastics and other materials, which are heated, extruded, and/or fused using high energy sources. These processes emit ultrafine particle clouds and fumes in the nanoparticle range (i.e. 1/10,000 millimeter or sub-micron range). For example, 3D printing via material extrusion using polylactic acid (PLA) feedstocks, using relatively low-temperature desktop applications can generate in excess of 20 billion particles per minute. Higher temperature acrylonitrile butadiene styrene (ABS) feedstocks can release in excess of 200 billion particles per minute. Nanoparticles are of concern because they are very small, have large surface areas (low density) and can readily penetrate, interact with, and/or traverse the body’s systems (i.e. skin, lungs, nervous and brain tissues) at the cellular level. Exposure to high concentrations of nanoparticles has been associated with adverse health



effects, including: cardio-pulmonary and respiratory effects, cancer, asthma, and nervous system effects.<sup>2,3,4</sup> Though PLA feedstocks are intended to be non-toxic and compatible with biological tissues, there may be unknown effects at very high concentrations, particularly in poorly ventilated spaces. The thermal decomposition products of ABS feedstock have been shown to have toxic effects on lab rodents.

*Consult EHS, for assistance and support in determining acceptable exhaust ventilation or filtration for a specific application.*

- **Skin or respiratory sensitizers** – Certain thermoplastics and photopolymers (used in 3D printing) when activated by heat or UV light may contain toxic or hazardous monomers such as acrylates, or other sensitizing agents. U/V light may also pose a radiation hazard to the eyes or skin.
- **Biological material hazards** – Life and/or Material Science applications involving biological materials, such as use of cells for engineered tissue generation, may expose persons to aerosols containing biological materials or bio-hazardous agents. Appropriate biosafety and other engineering controls must be considered. *Consult EHS for assistance and support in determining needed biosafety and/or engineering controls.*
- **Hazards associated with support materials** – Support materials in the 3D print matrix may contain harmful agents (e.g. phenyl phosphates associated with thermoplastic acrylics). These can be hazardous during use, and downstream waste handling.
- **Powder resins and metals** – Reactive and highly combustible powder metals, as well as other resinous materials may be used in powder bed or direct energy deposition processes. These have applications in the construction of metal/alloy or other structural and functional tools and parts. Finely divided metal powders, such as titanium and aluminum, as well as other resin powders can be spontaneously combustible (pyrophoric) causing fires. The user must eliminate sources of potential ignition and not store the powder materials in a manner which may contribute to an explosion hazard. Class D metal fire extinguishers are required with the use of metal powders. Users must follow specific manufacturer instructions and verify that electrical equipment and wiring are suited for the application. These applications use very high heat and may expose users to thermal injury, as well as potential inhalation of the powders or associated fumes.

**Consult the 3D printer manufacturer website to locate Safety Data Sheets (SDS's) (previous material safety data sheets) to understand and evaluate the specific health and safety hazards associated with the 3D print materials used.**

## **Ventilation**

To the fullest extent possible, all 3D printers must be provided with enclosures. Exceptions to operating a 3D printer without an enclosure must be approved by EHS. Most 3D printer manufacturers have enclosures available as accessories. Ventilated enclosures may be required based on the type, volume, and location of printers.

3D printers installed in office spaces or any other location without a designated exhaust system must meet general ventilation requirements and have self-contained exhaust systems to completely capture and exhaust materials.

3D printers using PLA media exclusively may be set up in a workspace having at least four air changes per hour. The number of PLA printers in one location should be limited by the size of the space. One printer per standard office and no more than two printers for a standard classroom or workroom is allowable. Requests for the placement of multiple PLA printers in any space must be reviewed by EHS before proceeding.

3D printers using ABS media or nylon must be fully enclosed and may only be used in work areas having local exhaust ventilation and at least six air changes per hour.

EHS highly recommends discussing filtration and exhaust mediation accessories with the vendor prior to purchase of 3D printer units.

3D printers using other types of media, including but not limited to thermoplastics, photopolymers, high impact polystyrene, high density polyethylene, thermoplastic polyurethane (TPU), metal filament, biological media or other uncommon medias shall be reviewed by EHS on a case-by-case basis with specific precautions required based on the hazards unique to the printing process.

## **Equipment-Specific Hazards**

As previously noted, in addition to health hazards, examples of equipment-related hazards may include:

1. Thermal/ hot surfaces: Print head block and U/V lamp
2. Electrical/high voltage: Electrical components, connections including U/V lamp connectors, circuits, conductors, etc. operating at 50 volts or higher must be guarded. Electric outlets must be safely certified with grounding wire intact.
3. Ultraviolet radiation/UV lamp: Don't look at the lamp; make sure the UV screen is intact.
4. Guarding: Pulleys, chains, belts, rods, carriages, fan blades, rotating/moving parts (i.e. printing assembly), power transmission apparatus, and any other type of pinch point must be guarded.

## **3D printer installations and maintenance**

Consumer-Grade 3D Printers – Must be installed and maintained according to manufacturer's instructions, and in well-ventilated areas.

Industrial-Grade 3D Printing Systems – Must be installed at the direction of the manufacturer, operated by manufacturer-trained users, and serviced by the manufacturer or personnel trained by the manufacturer.

### **Operator/ User training**

Persons working with hazardous chemicals in 3D printing are minimally required to complete OSHA Hazard Communication Training provided by EHS.

3D printing applications shall additionally require orientation/training, as recommended by the manufacturer and any site/equipment specific safety training as determined by the unit on site operator/manager.

### **General Safety Considerations**

1. Always follow manufacturer guidelines.
2. Consult EH&S for a hazard assessment when considering modifications/ novel uses.
3. Notify coworkers before beginning non-routine and hazardous work.
4. To prevent respiratory irritation, ventilate areas where model and support materials are used. *Consult EHS for assistance and support with new installations and determining ventilation rates.*
5. Once a printing job is started, do not open the cover, or defeat/override interlock switch.
6. If the interlock safety switch fails, do not use the printer.
7. As determined necessary by hazard assessment, and in addition to all pertinent laboratory personal protective equipment (PPE), chemical protective gloves and suitable dust mask may be required when accessing the printer stage after printing.
8. Uncured material may be hazardous; wear suitable/ recommended glove protection.
9. If material can splash, wear safety goggles.
10. In the event of a leak/ spill of printing material cartridges, use solvent-absorbent pads for model/ support material spills. Dispose clean-up materials as chemical waste. Contact EHS when responding to any major spills.
11. Keep model and supporting materials away from areas where cosmetics are applied, or food and drink are stored, prepared or consumed.

This guidance was developed in recognition of the continued expansion of 3D printer use. Studies have indicated that 3D printers can generate potentially harmful concentrations of ultrafine particles (UFP) and chemical vapors during the print process and through processes used following printing to treat the finished product. Other inherent hazards associated with 3D printing include electric shock, electromechanical force, burns, ultraviolet(UV)/laser beams, and fire-related risks.

## **RESPONSIBILITIES**

### **Environmental Health and Safety (EHS)**

- EHS will be responsible for the review and approval of all 3D printer purchases.
- The review will consider the type of printer, the type of print media to be used, the proposed location of use, necessary air filtering features, safeguards being proposed, and room ventilation dynamics before approval is granted.
- EHS may request modification of a proposed printer location, or the addition of improved exhaust ventilation before purchasing approval is granted.
- EHS has final authority over all safety issues and may immediately halt any operations or procedures it considers unsafe at any time at its discretion.
- EHS is available to perform air monitoring and hazard assessments upon request.

### **3D Printer Managers (Those with Assigned Oversight)**

- 3D Printer Managers are responsible for enforcing the provisions of this policy, including but not limited to ventilation, general safety, training, and personal protective equipment.
- 3D Printer Managers are responsible for following all manufacturer guidelines and recommendations pertaining to safety precautions, printer installation and set-up, printer operation, and routine preventative maintenance.
- 3D Printer Managers are responsible for providing the required personal protective equipment (PPE) and enforcing its correct use.

### **Users of 3D Printers (faculty, staff, and students)**

- All users shall ensure they have received training in the correct and safe operation of the 3D printer, including Hazard Communication (HAZCOM) training for employees relevant to the media and other chemical products used in the printing process.
- Required personal protective equipment shall be used.
- No eating or drinking is allowed in areas where 3D printers are present.

## **PROCEDURES**

3D printing is a type of additive manufacturing technology. All 3D printing variations have the potential to produce health and safety hazards depending on the type of feedstock used and on other processes involved in printing. Whenever possible, printers certified to the ANSI/CAN/UL 2904 Standard, which tests and certifies printers for low emission rates, should be purchased.

Fused filament fabrication (FFF) represents one of the more popular types of 3D printing. This process typically uses a thermoplastic filament, though other types of media can be used depending on the printer. Thermoplastic media generates ultrafine particulate (UFP), nanoparticles, and volatile organic compounds (VOC) at varying concentrations regardless of which filament media is used. Recent studies have also found that formaldehyde can be produced by all types of filament media. The volume of contaminants produced depends on the type of media used, the extruder nozzle temperature, and any additives present in the media.

Another popular type of 3D printing is stereolithography (SLA), which uses resins to produce the desired product. Chemicals in these resins can be irritants and sensitizers.

The following sections will serve to address the health and safety issues associated with 3D printers.

### **Print Media Types**

Filament media can be found in numerous forms. The more commonly used filaments include polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), and nylon. While all filament media types can be hazardous, PLA is generally considered the least hazardous of the group and should be used whenever possible. Special ventilation considerations may be necessary when using other types of filament media or 3D printing processes.

Locations with 3D printers using combustible media such as powdered metals or carbon nanotubes must be reviewed and in compliance with fire safety and other health and safety requirements before the printer begins operation.

### **Ventilation**

To the fullest extent possible, all 3D printers must be provided with enclosures. Exceptions to operating a 3D printer without an enclosure must be approved by EHS. Most 3D printer manufacturers have enclosures available as accessories. Ventilated enclosures may be required based on the type, volume, and location of printers.

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### **General Safety**

All printers must be installed according to the manufacturer's requirements and according to NFPA 72 National Electric Code (current code requirements can be found at [Building Codes Enforcement](#).)

Modifications to units that would void an existing certification (i.e. UL) are not allowed.

A location with a sprinkler system is highly recommended for installation of 3D printers due to fire safety concerns.

Safety Data Sheets (SDS) must be provided for all print feedstock and for any other chemical product used in the printing process. SDS must be readily accessible for review in the event of an emergency.

Printer extruder nozzles should be operated at the lowest temperature capable of producing the desired result.

Keep 3D printers away from heavily trafficked areas and out of egress pathways.

Even if local exhaust ventilation is provided, there should be a waiting period in place to allow cool down and contaminant dissipation before opening the printer to access the finished product.

Safety interlock switches must be enabled and working properly during printer operation.

Operators must be protected from hot surfaces associated with the printers.

If UV light is used in the curing process, personal protective equipment and/or shielding must be utilized to protect personnel.

### **Training Requirements**

3D printer managers must ensure that anyone using a printer receives the appropriate level of training prior to use. This may be achieved with basic operating instructions provided through posted signage in the case of public access printers that are fully enclosed. Training

for users with access to the internal components and who perform service work on the unit must receive more extensive training specific to the manufacture's guidelines and functionality for each unit.

All employees working directly with 3D printer media, or chemical cleaning agents/solvents are required to have Hazard Communication (HAZCOM) training covering any hazardous materials used in the process and manufacturer Safety Data Sheets(SDS) must be maintained and made available to all users.

Users must be familiar with the locations of fire extinguishers.

Completion of the training must be documented in writing with the records maintained by the manager of the printing operation.

### **Personal Protective Equipment (PPE) Requirements**

Follow all PPE recommendations found in the Safety Data Sheet (SDS) for the specific printer media used.

Eye protection is required during any activity where airborne projectiles may be present (i.e. cutting off rough edges of a printed item).

For print processes using an alkaline bath to dissolve support material, an emergency eyewash will be required in the immediate vicinity of the work.

A handwash facility must also be available, particularly in areas where the media or processes used represent dermal hazards (i.e. resin printers).

A spill kit capable of neutralizing the caustic components of the alkaline bath shall also be provided.

### **Prohibitions**

The use of a 3D printer to fabricate any item in whole or in part that is designed to be used as a weapon is prohibited.

A partial list of prohibited items includes:

- Firearms
- Knives
- Striking instruments
- Martial arts weapons
- Bow and arrow combinations
- Explosive devices

#### ADDITIONAL INFORMATION AND RESOURCES

The National Institute of Occupational Safety and Health (NIOSH) has additional health and safety information for 3D printers at the following links:

[3D Printing with Filaments: Health and Safety Questions to Ask \(cdc.gov\)](#)

[3D Printing with Metal Powders: Health and Safety Questions to Ask \(cdc.gov\)](#)