I. PURPOSE

The purpose of this guideline is to help protect Eastern Michigan University faculty, staff, students and visitors when using 3D printers. This guideline covers general procedures for the safe use and operation of 3D printers and the safety issues to consider before purchasing a 3D printer for use on campus.

II. SCOPE AND APPLICATION

This guideline applies to all Eastern Michigan University faculty, staff and students using and operating 3D printers. 3D printers must be placed in areas designed as labs. Labs must have increased ventilation rates of 6-12 air changes per hour (ACH).

III. RESPONSIBILITES

A. Deans, Directors and Department Heads

1. Shall understand and comply with the requirements of this guideline.
2. Shall contact Environmental Health and Safety when a 3D printer is requested for purchase. The manufacturer's instructions and Safety Data Sheets (SDS) must be provided to assist with the assessment review.
3. Shall ensure all employees working directly with a 3D printer attend General Safety Awareness and Hazard Communication Training (HAZCOM).
4. Shall ensure the safe use and operation of 3D printers according to this guideline.

B. Faculty, Managers and Supervisors

1. Shall comply with the procedures outlined in this guideline.
2. Shall provide the required personal protective equipment (PPE) and enforce its correct use.
3. Shall review Safety Data Sheets (SDS) for material specific safety information before using it in a 3D printer.
4. Shall ensure no eating, drinking, applying cosmetics, chewing gum or handling contact lens occurs where 3D printers are being used.
5. Shall ensure eye protection is worn when cutting off the rough edges of printed parts.
6. Shall maintain a clean and dust free work area in rooms where 3D printers are used.

C. Employees and Students

1. Shall inform their supervisor or instructor of any problems, defective equipment or any issues relating to 3D printers and equipment.
2. Shall review Safety Data Sheets (SDS) for material specific safety information before using it in a 3D printer.
3. Shall wear eye protection when cutting off the rough edges of printed parts.
4. Shall follow the requirements of this guideline.

D. Environmental Health and Safety (EHS)

1. Develops and updates the written 3D printing guideline.
2. Reviews and approves or denies all 3D printer purchase requests.
3. Completes risk assessments and reviews manufacturer's instruction and any Safety Data Sheets when new 3D printers are purchased.
4. Conducts routine inspections to ensure the proper use and operation of 3D printers.
5. Has the final authority over 3D printing safety issues, including immediately stopping any unsafe operations or procedures.

IV. TYPES OF 3D PRINTING

A. Fused Deposition Modeling (FDM) or Fused Filament Fabrication (FFF)

1. These printers melt a thermoplastic filament depositing the melted plastic in layers until it fills up a model.
2. Acrylonitrile Butadiene Styrene (ABS) and Polylactic Acid (PLA) plastics are commonly used in this process, but other filament materials are available.
3. When heated during the print process, both media types produce large concentrations of ultrafine particles (UFP).
4. Exposures to UFP or nanoparticles, particularly at high concentrations, have been associated with adverse health effects. Elevated concentrations of volatile organic compounds (VOC) can also be produced during the printing process.

B. Stereolithography (SLA)

1. These machines use a laser or ultraviolet (UV) light to cure photopolymer resins (usually thermoplastics) layer by layer into a prototype form built on a support that must be manually or chemically removed.
2. Rapid prototyping SLA printers do not require a support allowing faster builds to occur.

C. Masked Stereolithography (MSLA)

1. This utilizes an LED array as its light source, shining UV light through an LCD screen displaying a single layer slice as a mask.

D. Selective Laser Sintering (SLS)

1. A type of stereolithography where powdered metals are sintered (fused) together using Class 4 lasers to form a solid structure.
2. Some powdered metal printers use an adhesive rather than laser sintering to bond the metal powder.

E. Selective Laser Melting (SLM) or **Direct Metal Laser Melting (DMLM)** or **Laser Powder Bed Fusion (LPBF)**

1. This technique is designed to use a high power-density laser to melt and fuse metallic powders together.

F. Multi-Jet Modeling (MJM)

1. Also called Multi-Jet Printing (MJP) is a printing process that deposits UV photo-curable plastic resin or casting wax materials layer by layer.

G. Material Jetting (MJ)

1. This works in a similar way to a standard inkjet printer.
2. The key difference is that, instead of printing a single layer of ink, multiple layers are built upon each other to create a solid part.

H. Electronic Beam Melting (EBM)

1. Electron beam melting is still a slow and expensive process that only works with a limited set of metals.
2. Parts usually require significant amounts of post-processing.

I. Digital Light Processing (DLP)

1. This type of 3D printing technology is almost the same as SLA.
2. The key difference is that DLP uses a digital light projector to flash a single image of each layer all at once (or multiple flashes for larger parts).

J. Drop on Demand (DOD)

1. This type of 3D printing technology uses a pair of inkjets.
2. One deposits the build materials, which is typically a wax-like material.
3. The second is used for dissolvable support materials.
4. As with typical types of 3D printing technology, DOD printers follow a predetermined path to jet material in a point-wise deposition, creating the cross-sectional area of an object layer-by-layer.

V. TYPES OF 3D PRINT MEDIA (FILAMENTS)

A. Polylactic Acid (PLA)

1. This filament is one of the most commonly used filaments and is usually made of corn starch or sugar cane.
2. It is useful in a broad range of printing applications as it is non-toxic and biodegradable.

B. Polyvinyl Alcohol (PVA)

1. This filament is non-toxic and water soluble.

C. Acrylonitrile Butadiene Styrene (ABS)

1. This filament is petroleum based non-biodegradable plastic and produces fumes when melted.
2. It makes durable parts which can withstand higher temperatures. The fumes released are possibly carcinogenic.

D. High Impact Polystyrene (HIPS)

1. It is like ABS but, less likely to warp.
2. It can bend without cracking when cooled.

E. Polyethylene Terephthalate (PET) or Polyethylene Terephthalate Glycol (PETG)

1. This filament combines the ease of use of PLA filament with the strength and durability of ABS filament.
2. It rarely warps and produces no odors or fumes when printed.

F. Nylon Polyamide

1. This filament is strong, lightweight, flexible and durable.
2. It is less brittle than PLA or ABS.
3. When this filament is heated it will break down and emit toxic fumes.

G. Polycarbonate (PC)

1. This filament is strong and resistant to impact.
2. It may emit toxic fumes when heated.

VI. POTENTIAL RISKS OF 3D PRINTING

A. Generation of Ultrafine/Nano-sized Particles (UFPs)

1. During the 3D printing process, thermoplastics are heated, nozzle extruded and then deposited onto a surface to build an object.
2. As a by-product of the process, nanoparticles (ultrafine particles less than 1/10,000 of a millimeter) are emitted.
3. The health effects associated to UFPs are currently being researched.
4. Studies have indicated exposure to UFPs at high concentrations could produce inflammatory responses in cardiovascular and respiratory systems.
5. When inhaled they can end up deep inside the body and even make their way to the brain.
6. Occupational exposure limits for 3D printer emissions have yet to be established.
7. 3D printers should only be located in labs having ventilation rates of at least 6-12 air changes per hour.
8. Whenever possible, purchase fully enclosed 3D printers to reduce exposures to the users.
9. Do not congregate around 3D printers while running. This minimizes the inhalation of the particulates being created.

B. Exposure to Volatile Organic Compounds (VOCs)

1. 3D printers using certain print media (filaments) have been shown to emit volatile organic compounds.
2. Some have been linked to eye, nose and throat irritation, headaches, damage to the liver, kidneys and central nervous system and cancer.
3. Examples of VOCs are: acrylonitrile, styrene, formaldehyde, acetaldehyde, toluene and ethylbenzene.
4. 3D printers should only be located in labs having ventilation rates of at least 6-12 air changes per hour.
5. Whenever possible, purchase fully enclosed 3D printers to reduce exposures to the users.

C. Risk of Burns from Hot Surfaces

1. Temperatures of 374 to 500 degrees Fahrenheit at the hot end of the extruder are needed to melt plastic to the right consistency for 3D printing.
2. This can lead to skin burns if the user encounters the heated extruder.
3. 3D printers should have a guarding system which prevents the user from touching the nozzle or product until it has cooled.
4. Smoke alarms must be present where 3D printers are used.

D. Mechanical Hazards from Moving Parts

1. Check for loose parts (i.e., belts, pulleys, motors, threaded rods, small fans and carriages) which pose a risk of entrapment or entanglement during operation.
2. Rotating parts can cause pinch or crush injuries.
3. Long hair, loose clothing, head coverings or scarves can cause injuries if not properly secured before using any 3D printing device.
4. Safety interlock switches must be enabled and working properly during printer operation.
5. The user should never leave a 3D printer unattended while in use.
6. The user should check regularly and never leave the area with the 3D printer running.

E. Electrical Hazard

1. High voltage power supplies and shock are the primary electrical hazards.
2. Turn off, unplug and cool down the unit prior to cleaning or repairing.
3. Ensure all maintenance or modifications are performed by a competent person.

VII. 3D PRINTERS CONTAINING LASERS

A. Any 3D printer containing a high-powered Class 3B or Class 4 laser must be registered with EHS; contact the Laser Safety Officer at 734-487-0794.

1. If the laser on the printer is not completely enclosed, the room must be secured during operation and all individuals within the space must wear approved laser safety eye protection.
2. A laser in use sign must be posted on the door of the space using the 3D printer with laser.

VIII. PURCHASING

A. EHS is responsible for the review and approval of all 3D printer purchases. EHS reviews the type of printer, print media and proposed location of the printer set up before approval.

B. 3D printers should be Nationally Recognized Testing Laboratories (NRTL) listed. Examples are: **CSA**, **ETL**, **FM**, **NSF**, **TUV** and **UL**.

C. Confornite Europeenne (**CE)** French for European Conformity is not a certification, it is a manufacturer's declaration their product complies with the essential requirements or the relevant European health, safety and environmental protection legislation. **CE** is not adequate for equipment purchased at EMU. Equipment needs to be NRTL listed.

D. If possible, purchase fully enclosed 3D printers. This reduces exposures to the user.

IV. REFERENCES

A. formlabs - Guide to 3D Printing Materials
B. Protolabs - Types of 3D Printing Technology

V. HISTORY

Revision	Date	Changes
0	7/11/2023	Original Program