GUIDELINE

Rowan University
ENVIRONMENTAL HEALTH & SAFETY

3D Printing General Safety Guidelines

3D Printing (also known as Additive Manufacturing), is a group of technologies that allow for the construction of physical objects from computer models. Some of the most encountered materials include plastic filaments and liquid resins, however some equipment utilizes powdered plastics or metals, or thin sheets of materials to build objects. 3D Printing has also expanded into the biomedical field utilizing biocompatible and biological materials in the process. The technology has grown increasingly accessible in recent years, and many new advancements and potential applications have been realized making this equipment commonplace in many settings.

3D Printing Technologies:

- Material Extrusion (Fused Deposition Modeling): The single most common and recognizable 3D Printing technology available. A thermoplastic filament such as ABS (acrylonitrile butadiene styrene) or PLA (polylactic acid) is melted and deposited in layers by a moving nozzle.
- Vat Polymerization: The most common method in use is known as stereolithography (SLA). A UV laser acts on a liquid photopolymer resin, which hardens the resin in successive layers.
- Material Jetting: Tiny droplets of feed material are selectively deposited onto a build platform. When the droplets cool and solidify, the next layer is deposited on top.
- Sheet Lamination: Objects are formed by using a laser or a blade to cut and bond thin layered materials (e.g., fabric, aluminum foil) together layer-by-layer.
- Binder Jetting: A liquid binder is sprayed onto a bed of ceramic or metal powder, causing it to solidify. The process is repeated in successive layers to build the object.
- Powder Bed Fusion: Selective Laser Sintering (SLS) is the most common form of this technology. Plastics, metals, ceramics, or glass powders are fused together using lasers to form a solid object.
- Directed Energy Deposition: A metal powder or wire is melted while simultaneously being deposited by a moving print head.

Hazards of 3D Printing:

The hazards associated with 3D Printing vary widely depending on the material as well as the printing technology in use. The rapid expansion of 3D Printing technologies has drawn a greater emphasis on the importance of researching potential health hazards. The hazards listed below are not comprehensive, and novel materials or methods could create additional health and safety risks.

- Chemical Vapors: Filaments such as ABS and PLA produce Volatile Organic Compounds (VOCs) when heated by a 3D printer. Exposure to VOCs can cause headache, nausea, as well as eye, nose, and throat irritation.
- Nanoparticle Hazards: ABS, PLA, and other filaments produce nanoparticles during printing operations. If inhaled, these nanoparticles can travel deep into lung tissue. The health effects of nanoparticles are not well understood, but preliminary research suggests that inhalation is associated with cardiovascular and pulmonary diseases.
- Respirable Dusts: Many of the plastic and metal powders utilized in certain printing methods come in the form of a very fine dry powder that can easily generate respirable dusts. Depending on the material and particle size, there is the potential for adverse health effects from exposure.

- Ultraviolet Light/Laser Radiation: Eye exposure to the UV lights used in SLA printers can cause temporary or permanent vision loss. Directed Energy Deposition and Powder Bed Fusion printers often use powerful Class 4 lasers which can cause permanent eye injury from direct or reflected light.
- High Temperatures: UV lamps, motors, heat beds, print heads, and other components become hot during operation and can cause burns if touched.
- Biological Hazards: Printers using biological materials can produce aerosols which may be inhaled or deposited onto nearby surfaces. Biological materials may be biohazardous and require specialized equipment and facilities to work with safely.
- Flammability: Fine metal powders such as aluminum, steel, and titanium can spontaneously combust under normal atmospheric conditions or upon exposure to moisture. Powdered plastics can also be a fire/explosion hazard if airborne particles reach an ignition source under certain conditions.

See the Appendix section on the last page for information on the known hazards associated with common 3D printing technologies along with VOC emissions from common printing filaments.

General 3D Printer Safety Guidance:

- 3D Printers should always be operated in a space with adequate ventilation. Whenever possible, benchtop printers should be operated with an exhaust snorkel positioned to capture emissions.
- If available, purchase 3D printers with a UL 2904 or equivalent certification indicating that they are engineered to reduce the release of harmful emissions.
- Always ensure that all operators read the operator manual, all SDSs, and SOPs for the equipment and materials that are to be used.
- UV light sources and lasers must be enclosed with materials that can block these types of light to prevent eye and skin exposures. Laser safety glasses must be used with exposed lasers. Review the Laser Safety web page for additional laser safety guidance.

Filaments and Resins:

- Most plastic filaments produce toxic ultrafine particles and volatile organic compounds. The emissions of PLA are less hazardous than other plastics and it is the preferred filament when feasible.
- To minimize VOC and particle emissions, operate the printer extrusion nozzle and base plate at the lowest possible temperature to achieve the desired results.
- Thoroughly clean the printer nozzle and print bed after each use. Refer to the operator manual for instructions on proper cleaning procedures.
- If the printer nozzle clogs, turn off the printer and allow it to ventilate for 10 minutes before opening the enclosure. Concentrations of vapors and particles are at the highest at the beginning of the print run and when a printing failure occurs.

Working with Powdered Materials:

Any researcher looking to purchase or operate a 3D printer that utilizes powdered materials must contact Laboratory Safety at LabSafety@Rowan.edu or 856.256.5105. Printers that operate through Powder Bed Fusion, Binder Jetting, Directed Energy Deposition, or similar technologies will have very specific health and safety needs requiring a thorough review. All powdered materials of any composition and particle size should be treated as hazardous, including metal alloys and non-metallic substances. Metal powders must be used with great caution as they are often pyrophoric or water reactive. Personal exposure can cause chronic health effects, and improper handling can result in fire or explosion.

Working with Biological Materials:

3D Bioprinting is a highly specialized process utilizing biomaterials such as living cells to fabricate 3D tissue structures including skin, cartilage, tendons, muscle, and bone. A biomaterial can be any material designed to interact with a living system. The bioprinting process typically involves two steps. This first involves the construction of a non-living scaffold using a biocompatible substance. The second step utilizes a bioink, which will form the living part of the structure. Bioinks are generally formulated as a living cell slurry. Once a 3-dimensional scaffold is created, the bioink is deposited onto the scaffold and solidified, creating the final tissue structure.

Potential hazards from 3D Bioprinting can include, but are not limited to:

- Mucous membrane exposure to bloodborne pathogens while prepping human-derived bioink or cleaning the printer.
- Inhalation of bloodborne pathogens through aerosolized human-derived or other potentially infectious materials during the printing process or deposition of bioink.
- Inhalation of respirable particulate or volatile organic compounds (VOCs) while printing scaffold.

Contact Laboratory Safety at LabSafety@Rowan.edu or 856-256-5105 before beginning any work involving the 3D printing of biological materials.

Managing 3D Printer Wastes:

3D Printing technologies and associated techniques can generate wastes that must be managed and disposed of properly. These wastes can be in the form of finishing solutions, solvents, and unused or expired chemical products such as liquid resins.

Certain 3D printing techniques require the use of a finishing bath, typically involving the use of an acidic or caustic solution. Along with the corrosivity, these solutions can become contaminated with resins and other substances. Therefor, once a finishing bath is spent, it needs to be disposed of as hazardous waste.

SLA and other printing methods often require the use of solvents such as Isopropyl Alcohol to clean excess resin from the finished product. These solvent solutions eventually become “spent” or too contaminated to use and require disposal. The resulting solvent and resin solution waste must be disposed of as hazardous waste.

If you have chemical waste that must be disposed of, collect the waste in a suitable sealed container with an appropriate Hazardous or Non-Hazardous Waste label. When ready, complete a Waste Pickup Request Form on the Laboratory Safety Website to arrange a pickup. If you require assistance or have any questions, please contact Laboratory Safety at LabSafety@Rowan.edu or call 856-256-5105.

Appendix

Printing Technologies & Known Associated Hazards	
Technology	**Hazards**
Binder Jetting	Exposure to VOCs and airborne powders, dermal exposure to powders and binders.
Directed Energy Deposition	Exposure to airborne metal powders, thermal burns, laser/radiation exposure.
Material Extrusion	Exposure to VOCs, airborne ultrafine particulates, and thermal burns.
Material Jetting	Exposure to VOCs, dermal exposure to resins and solvents, UV exposure.
Powder Bed Fusion	Exposure to airborne powders, explosion, laser radiation exposure.
Sheet Lamination	Exposure to VOCs, laser radiation exposure.
Vat Photopolymerization	Exposure to VOCs, dermal exposure to resins and solvents, UV exposure.
Source: Underwriters Laboratories Inc.	

VOC Emissions from Common 3D Printer Filaments			
Chemical	**ABS**	**PLA**	**Nylon**
Formaldehyde (Known carcinogen, eye, nose, throat, skin irritation.)	×	×	×
Benzene (Known carcinogen, eye, skin, respiratory irritation, reproductive effect.)	×	×	
Styrene (Probable carcinogen, eye, respiratory, reproductive development, nervous system.)	×		×
Ethylbenzene (Possible carcinogen, liver, kidney, endocrine system.)	×	×	×
Acetaldehyde (Possible carcinogen, eye, respiratory system.)	×	×	×
Vinyl Cyclohexene (Possible carcinogen, reproductive, respiratory system.)	×	×	
Caprolactam (Eye, skin, respiratory irritation, cardiovascular, central nervous system, liver, kidney.)			×
Benzaldehyde (Eye, skin, respiratory irritation.)	×	×	×
Methyl Methacrylate (Eye, skin, respiratory system.)	×	×	×
1-Butanol (Eye, skin, respiratory, central nervous system.)	×	×	×
Source: Underwriters Laboratories Inc.			

Please contact Laboratory Safety at 856-256-5105 or LabSafety@Rowan.edu with any questions related to 3D Printer safety.