Health & Safety Guidance

Health & Safety

3D printing - H&S precautions

3D printing, or Additive Manufacturing, refers to various processes used to create or replicate an object by using successive layers of material (usually plastics, but also metals) to create an object. Objects can be of any shape or geometry are produced from a 3D model or from a design fed into the 3D printer by a computer.

Uses of 3D printing

- industrial manufacturing of 3D objects
- manufacturing of prototypes
- medical applications
- design and engineering
- hobbyist practices
- in schools and educational institutions
- in libraries

A number of companies are now using large scale 3D printing. 3D printing is a fantastic example of a useful new technology, but it needs to be approached with caution as it could bring with it new health and safety problems.

Growing Concerns

In 2017 the European Agency for Safety and Health at Work published a discussion paper on the processes and materials involved in 3D printing, potential implications of this technology for occupational safety and health and avenues for controlling potential hazards. Most concerns involve gas and material exposures, in particular nanomaterials, material handling, static electricity, moving parts and pressures.

A US National Institute for Occupational Safety and Health (NIOSH) study noted particle emissions from a fused filament peaked a few minutes after printing started and returned to baseline levels 100 minutes after printing ended. Emissions from fused filament printers can include a large number of ultrafine particles and volatile organic compounds (VOCs).

The toxicity from emissions varies by source material due to differences in size, chemical properties, and quantity of emitted particles. Excessive exposure to VOCs can lead to irritation of the eyes, nose, and throat, headache, loss of coordination, and nausea and some of the chemical emissions of fused filament printers have also been linked to asthma. Based on animal studies, carbon nanotubes and carbon nanofibers sometimes used in fused filament printing can cause pulmonary effects including inflammation, granulomas, and pulmonary fibrosis when at the nanoparticle size.

Carbon nanoparticle emissions and processes using powder metals are highly combustible and raise the risk of dust explosions. At least one case of severe injury was noted from an explosion involved in metal powders used for fused filament printing. Other general health and safety concerns include the hot surface of UV lamps and print head blocks, high voltage, ultraviolet radiation from UV lamps, and potential for mechanical injury from moving parts.

Hazards to health and safety also exist from post-processing activities done to finish parts after they have been printed. These post-processing activities can include chemical baths, sanding, polishing, or vapour exposure to refine surface finish, as well as general subtractive manufacturing techniques such as drilling, milling, or turning to modify the printed geometry. Any technique that removes material from the printed part has the potential to generate particles that can be inhaled or cause eye injury if proper personal protective equipment is not used, such as respirators or safety glasses. Caustic baths are often used to dissolve support material used by some 3D printers that allows them to print more complex shapes. These baths require personal protective equipment to prevent injury to exposed skin.

Where 3D printing relies on curing by ultra violet light, there is a risk of skin problems through contact with uncured materials. For example in stereolithography, the printed uncured object is lifted out of the liquid epoxy resin, at which point the user's hands are in danger of becoming exposed to epoxy resin which is highly allergenic. Chemical resistance gloves must be worn. Droplets of liquid resin may land on the floor and other surfaces, causing possible exposure of less protected parts of the body. Uncured material remains a skin hazard. A completely cured object poses no health risk.

With 3D printing, an object can be made by using the following methods:

- Extruding - uses continuous filament of a thermoplastic material as the feedstock
- Sintering - an additive manufacturing procedure that uses a laser as a power source
- Curing - uses a liquid resin as the feed material and the object is built layer-by-layer and cured; this process takes place slowly.

ABS vs. PLA Feedstock

Each 3D printer is designed to use certain types of materials. The most common type of desktop 3D printer technology joins thin strands, or filaments, made of ABS (Acrylonitrile Butadiene Styrene) or compostable materials, such as PLA, a biodegradable thermoplastic aliphatic polyester derived from corn starch tapioca. Using a computer-generated image, a 3D printer heats and melts the feed material, placing layers of filament on top of one another to form a precise 3D replica of the image.

The materials being fed into the machine (feedstock) can have inherent hazards and may release vapours and gases that may be more hazardous, for example, after they are heated during the 3D printing process.

Research has found that common filaments used in 3D printers can emit volatile organic compounds (VOCs) during the printing process. According to the U.S. Environmental Protection Agency, excessive exposure to VOCs can lead to eye, nose, and throat irritation; headaches; loss of coordination; and nausea.

Emissions Linked to Asthma

A study has found that a desktop 3D printer emitted smaller particles than those from laser printers that use plastic toner and far greater amounts of certain chemicals linked to asthma. In what they believe is the first discovery of its kind, the investigators also found that 3D printers emit chemicals that combine to form new compounds, including a chemical linked to asthma. These findings suggest the need to take precautions to reduce emissions from desktop 3D printers in the home and office.

US Research has suggested that the level of harmful particles and fumes from 3D printing depends mostly on the filament material, not the make of printer.

ABS emitted styrene – a chemical that is both toxic and carcinogenic. Other materials based on nylon gave off caprolactam particles, which are linked with other non-life threatening health problems. The PLA filament emitted a benign chemical named lactide.

3D Printing Emissions: Nanoparticles & Vapors

To reduce the potential for nano particles to create aerosols or be inhaled by users, it is best to purchase 3D printers with an enclosure or have an enclosure made.

Nanoparticles (ultrafine particles less than 1/10,000 of a millimeter) are one of the by-products emitted during the 3D printing process. Recent studies have shown that 3D printing using the low-temperature polylactic acid (PLA) feedstock can release 20 billion particles per minute, while a higher temperature acrylonitrile butadiene styrene (ABS) feedstock can release 200 billion.

Nanoparticles are of concern for the following reasons:

- They are very small,
- They have large surface areas, and
- Can interact with the body’s systems, including the skin, lungs, nerves and the brain.

Exposures to nanoparticles at high concentrations have been associated with adverse health effects, including total and cardio-respiratory mortality, strokes and asthma symptoms. While PLA feedstock is designed to be biocompatible, the thermal decomposition products of ABS feedstock have been shown to have toxic effects on lab rodents.

Many companies are already looking into non-toxic printing materials for consumers, but until then, the study suggests that caution should be used when operating many printer and filament combinations in enclosed or poorly ventilated spaces or without the aid of gas and particle filtration systems.

Good ventilation

A Finnish study shows that desktop 3D printers release produce airborne nanoparticles that should be controlled to avoid hazardous exposures. According to the Finnish Institute of Occupational Health (FIOH), 3D printers have become more common in homes, schools and libraries as their prices have come down. But a study by FIOH and the University of Helsinki also confirmed nanoparticles are emitted into the air when printers are used. FIOH notes:

Exposure can be reduced by acquiring an encased printer that has been designed with emission management in mind, by avoiding staying in the same room with a printer for longer periods of time or, most reliably, by directing the emissions out of the indoor air. The study identified pollution arising from use of both ABS and PLA, the two most common plastic mixtures. It added treating the printed objects with chemicals is an integral part of 3D printing and is typically used in printing on an industrial scale.

Chemicals used for cleaning the objects, such as isopropanol, can irritate the eyes, the skin and the respiratory tract. Some of the cleaning chemicals are corrosive (sodium hydroxide), some may affect the central nervous system. Always use appropriate personal protective equipment.

Cleaning of objects produced in a powder bed causes exposure to material dust, which may irritate the respiratory tract. Use local exhaust ventilation during the cleaning process.

Sanding may produce dust that irritates the respiratory tract. Due to the exposure risk, the plastic must be cured before sanding.

Surface treatment of objects may involve a variety of chemicals, such as sensitizing epoxies, cyanoacrylate or acrylate compounds, and paints containing isocyanates.

HSE Report

The Health and Safety Executive (HSE) started investigating 3D printers after concerns were raised about the increasing use of desktop 3D printers in schools and colleges. They found that using a hood with filtered ventilation led to a massive reduction in particle emission rates. They also established that particles released inside the enclosure took about 20 minutes to clear, so they have warned users to wait for at least this period before opening the hood. The report has concluded that emissions can be controlled by:

- using polymer filaments from reputable suppliers
- choosing filament materials with a lower emission rate
- setting a lower operating temperature for the nozzle of the printer
- placing the printer inside an enclosing hood with a suitable air filtration system
- waiting sufficient time for emissions to clear before opening the hood

Precautions

- Before a 3D printer is used there must be a full risk assessment
- Always follow the manufacturer guidelines.
- Always use the manufacturer's supplied controls (full enclosure appears more effective at controlling emissions than a cover).
- Use the printer in a well-ventilated place, and directly ventilate the printer. Once a printing job has been started, do not open the cover, defeat, or override the interlock switch.
- Avoid staying in the same room with a printer for longer periods of time or, most reliably, by directing the emissions out of the indoor air.
- At the very least, maintain a distance from the printer to minimize breathing in emitted particles, and choose a low-emitting printer and filament when possible.
- Turn off the printer if the printer nozzle jams, and allow it to ventilate before removing the cover.
- Wear non-permeable gloves and a dust mask when accessing the stage area of the printer after printing.
- Always favour Local Exhaust Ventilation over respiratory protection (masks).
- Wear protective gloves when handling uncured printing material.
- If material can splash, wear safety goggles.
- In the event of a leak or spill of printing material cartridges, use solvent-absorbent pads for model material and support material spills.

Useful Links

European Agency for Safety and Health at Work (2017)
https://osha.europa.eu/en/tools-and-publications/publications/3d-printing-new-industrial-revolution/view

Finnish Institute of Occupational Health (2017)
https://www.ttl.fi/wp-content/uploads/2017/03/3D_web_EN.pdf

US National Institute for Occupational Safety and Health (2019)
https://blogs.cdc.gov/niosh-science-blog/2018/08/16/3d-printing/

Health and Safety Executive
Research Report 1146 Measuring and Controlling Emissions from Desktop 3D printers
www.hse.gov.uk/research/rrpdf/rr1146.pdf