Finnish Institute of Occupational Health

Chemical safety of 3D printing at workplaces

Additive Manufacturing, or 3D printing, refers to a manufacturing process in which successive layers of material are formed based on a virtual model (e.g. CAD) to create an object.

Examples of 3D printing materials

- plastics (PLA, ABS, PEEK, etc.)
- metals (titanium, cobalt-chrome, etc.)
- sand
- wax
- ceramics
- paper
- gypsum

Where is 3D printing technology used?

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

IMAGE. An enclosed printer reduces the spread of pollutants

3D printing

3D printing can be divided into **small-scale printing** and **industrial printing**. In addition to the actual printing, a 3D print job may include pre- and post-processing work, as well as maintenance tasks. The FIOH Control Approach focuses on the most common 3D printing methods, but it can be applied to other methods as well.

Safety of 3D printing

Printing materials and technologies are continually evolving , and new materials and technologies emerge frequently. At the same time, 3D printing is finding applications in new fields. In 3D printing, adverse health effects may be caused by printing materials, their thermal decomposition products during the printing process, as well as by post-processing chemicals and processing methods.

New research on the safe use of 3D printing is being conducted in different parts of the world and new information is becoming available. The safety of employees can be improved through good working practices.

REMEMBER SAFETY IN ALL STAGES OF 3D PRINTING

Possible harmful effects of 3D printing

Pre-processing

Printing materials may cause irritation to the skin, eyes and respiratory tract. Some metals, such as nickel, for example, may cause allergic dermatitis, rhinitis or asthma, and may also be carcinogenic. Furthermore, fine metal powders may be spontaneously combustible.

Printing

The health effects associated with the printing process depend on the printing methods and materials, among other things.

MATERIAL EXTRUSION: In this method, molten plastic is extruded layer by layer through a small nozzle. Typically, this method uses ABS or PLA polymers. Small-scale printers are often based on this technology. The process may release significant amounts of nanoparticles depending on the printing material and temperature.

Exposure to nanoparticles may lead to inflammatory reactions in the lungs, but all potential health effects are not yet known. The printing process releases gaseous compounds (formaldehyde, styrene, etc., depending on the material), but in small-scale printing the concentrations are typically low and harmful effects are not likely to occur.

POWDER BED FUSION: In this method, fine powdered material (e.g. plastic or metal powder) is fused into the desired shape with a laser layer by layer. The printers are enclosed and in some cases completely isolated from the workplace air.

VAT PHOTOPOLYMERIZATION: A vat of photopolymer (usually an epoxy resin) is cured with a laser beam to create an object. The printers are enclosed.

Post-processing

CLEANING AND REMOVAL OF SUPPORT STRUCTURES: Chemicals used for cleaning the objects may cause irritation or even corrosion to the skin, eyes or respiratory tract. Solvents may affect the central nervous system. Cleaning of objects produced in a powder bed causes exposure to material dust.

The epoxy resin used in photopolymerization may cause allergic contact dermatitis. In this method, the products are usually washed with a solvent, which means that the not fully cured objects are handled. This involves a particularly high risk of skin exposure to epoxy and solvents.

SANDING OF THE OBJECTS: Sanding dust may cause irritation. The plastic must be cured before sanding.

SURFACE TREATMENT: The surface treatment of objects involves a variety of chemicals. Solvents may affect the central nervous system. Particular care must be taken when handling allergenic epoxies, cyanoacrylates and acrylic compounds. Paints containing isocyanates may cause irritation of the skin and the respiratory tract and cause asthma or allergies.

KNOW THE CHEMICALS YOU USE! READ THE SAFETY DATA SHEET, LEARN ABOUT ADVERSE EFFECTS OF THE CHEMICALS USED AND ASSESS THE RISKS.

FOLLOW SAFE WORKING PRACTICES IN ORDER TO AVOID SKIN CONTACT AND INHALATION EXPOSURE.

IMAGE.
Cleaning a printed object

Remember safety and carry out risk assessments with focus on:

- **the printer** (printing method, enclosure, ventilation)
- **harmful substances in raw materials** (skin/inhalation exposure)
- **the work environment** (ventilation, location and other dangers, such as laser, hot surfaces, fire safety and thermal radiation)
- **work stages** (pre-processing, printing, post-processing, maintenance)
- Consult experts when necessary!

Occupational exposure limit values

In connection with a risk assessment, the employer must observe the OEL values for the workplace air for concentrations of the substances used.

There are no limit values set for nanoparticles. For industrially generated nanoparticles, the Finnish Institute of Occupational Health (FIOH) has defined target levels for an exposure time of 8 hours:

20000 PARTICLES/CM3 (DENSITY > 6000 KG/M3)
40000 PARTICLES/CM3 (DENSITY < 6000 KG/M3)

FIOH's target levels for workplace dust concentrations (8 h):

0,1 MG/M3 (PLASTIC AEROSOLS)
0,5 MG/M3 (GENERAL DUST, RESPIRABLE FRACTION)
2 MG/M3 (GENERAL DUST, INHALABLE FRACTION).

These values can be applied if there is no specific OEL value for the dust in question.

IMAGE. Vacuuming of extra powder.

Risk management in 3D printing

1. REPLACE HARMFUL CHEMICALS

When purchasing chemicals, pay attention to their hazard properties and demand to see the relevant safety data sheets. Give priority to harmless or less harmful chemicals.

2. STOP POLLUTANTS FROM SPREADING

Printers should be enclosed and equipped with local exhaust ventilation to prevent pollutants from spreading. Local exhaust ventilation is also required at the pre- and post-processing stages. Consult an expert when necessary.

3. ORGANIZE THE WORK AND TASKS

Reduce the number and/or exposure time of persons working at processes involving the risk of exposure. Keep the workplace clean and tidy: store the chemicals safely, prevent the powder materials from spreading. Train the employees to follow good working practices.

4. PERSONAL PROTECTIVE EQUIPMENT

Evaluate the need for respiratory, skin and eye protectors. Choose appropriate protective equipment on the basis of the risk assessment and protection instructions for the substances used at each particular stage of work. Consult an expert when necessary.

PAY SPECIAL ATTENTION TO THE FOLLOWING:

Uncured plastic chemicals, such as the ingredients for and mixtures of epoxies, acrylates and urethanes are not be touched. Contamination of surfaces and clothes must be prevented.

Persons processing epoxy resins should always wear chemical resistant gloves and appropriate protective clothing. The gloves should be selected carefully, taking into account the solvent that may be used in the work.

AN ENCLOSED PRINTER REDUCES THE SPREAD OF POLLUTANTS

 | FIOH, P.O Box 40, FI-00032 TYÖTERVEYSLAITOS | +358 30 4741 | firstname.surname@ttl.fi | www.ttl.fi

CHECKLIST

EMPLOYEE

- ☐ Is the workplace clean and tidy?
- ☐ Are the chemicals stored and handled in an appropriate manner?
- ☐ Have you read the safety data sheets of materials and chemicals?
- ☐ Have you read the operating and safety instructions of 3D printers and do you follow the instructions?
- ☐ Do you follow the safety instructions at all work stages?
- ☐ Have you read the operating and maintenance instructions of protective equipment and do you follow the instructions?
- ☐ Do you use the personal protective equipment as instructed?

EMPLOYER

- ☐ A risk assessment has been conducted at the workplace.
- ☐ There are operating and safety instructions for the equipment.
- ☐ There are safety data sheets available.
  - ☐ Printing material
  - ☐ Post-processing chemicals
- ☐ Work stages involving a risk of exposure have been identified.
  - ☐ Inhalation exposure
  - ☐ Dermal exposure
- ☐ Can the device be enclosed?
- ☐ Is it possible to install local exhaust ventilation?
- ☐ Adequate ventilation of room air.
- ☐ Can the equipment be positioned in a separate room?
- ☐ There are appropriate premises for the handling and storing of chemicals.
- ☐ There is appropriate personal protective equipment available.
- ☐ Laser safety has been taken care of and the employees have received appropriate instructions.
- ☐ Fire safety has been taken care of.
- ☐ Potential spontaneous combustion risk of printing materials, as well as EX protection of the equipment has been taken care of.
- ☐ All employees have received instructions and training on how to safely carry out all the various stages of 3D printing (preprocessing, printing, post-processing, maintenance).
- ☐ Regarding work with carcinogenic substances, it must be separately evaluated whether the employees should be entered in the ASA register and whether or not they should work during pregnancy.

HAVE THE SAFETY ASPECTS BEEN TAKEN INTO CONSIDERATION IN THE PROCUREMENT PLAN?

FURTHER INFORMATION (IN FINNISH)

- www.ttl.fi/malliratkaisut
- www.ttl.fi/epoksikansio
- www.ttl.fi/tavoitetasot
- www.tyosuojelu.fi/tyoolot/kemiallisettekijat/raja-arvot

 | FIOH, P.O Box 40, FI-00032 TYÖTERVEYSLAITOS | +358 30 4741 | firstname.surname@ttl.fi | www.ttl.fi