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Occupational Safety in 3D Printing

Workplace Risk Assessment, Air Quality, Hazardous Substances and Protective Measures in FDM/FFF and SLA – the Austrian AUVA Framework with DACH and EU Context

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Note on scope and limit values

This document describes the general occupational-safety and technical framework (as of June 2026). It is NOT legal advice and does not replace a company-specific risk assessment.

Limit values are stated with their legal basis. The Austrian Limit Values Ordinance (GKV) is amended frequently – before binding use, verify all values against the current RIS version (GKV 2025, Annex I).

Schichtwerk is a contract manufacturer; the responsibility for operational implementation rests with the respective employer.

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Abstract

3D printing is not a harmless office device in occupational-safety terms. Material extrusion (FDM/FFF) emits ultrafine particles (< 100 nm) and volatile organic compounds (VOC) – including styrene from ABS/ASA, caprolactam from nylon and lactide from PLA. Photopolymer processes (SLA/DLP/MSLA) introduce skin-sensitizing (meth)acrylates and the flammable, explosion-prone cleaning agent isopropanol. In Austria, § 4 ASchG mandates a workplace risk assessment with measures defined according to the STOP principle. This paper presents the AUVA framework, the relevant emissions, the applicable occupational exposure limits (AT/DE/EU compared) and the tiered hierarchy of protective measures.

Keywords: *occupational safety; AUVA; ASchG; risk assessment; ultrafine particles; VOC; exposure limits; acrylate sensitization; isopropanol; STOP principle*

1. Legal Framework: The Austrian AUVA/ASchG System

The Employee Protection Act (ASchG, Federal Law Gazette 450/1994) is the Austrian counterpart to EU Framework Directive 89/391/EEC. It obliges employers to identify and assess existing risks to safety and health and to define measures accordingly. [1]

1.1 Core provisions

- § 3 – General employer duties; responsibility for the assessment process.
- § 4 – Definition of measures (workplace risk assessment): duty to identify and assess hazards. Workplace, work equipment, work substances, activities and the working environment must be considered; particularly vulnerable persons (young workers/apprentices, pregnant workers) are addressed separately.
- § 5 – Safety and health documents (documentation duty).
- § 7 – Principles of prevention: combating hazards at source, collective protection before individual protection.
- § 41 – Work substances; register of hazardous work substances. § 45/46 – Limit values and measurement obligation.

1.2 The STOP principle

From § 7 ASchG the mandatory hierarchy of measures derives: S = substitution/elimination, T = technical measures, O = organizational measures, P = personal measures (PPE). Technical and collective measures take precedence over personal protective equipment. [1]

The assessment is not a one-off act: it must be repeated after accidents, on suspicion of work-related illness, with new equipment, substances or processes, and on justified request of the Labour Inspectorate.

1.3 AUVA as carrier and information source

The AUVA (General Accident Insurance Institution) is the carrier of statutory accident insurance and provides free guidance leaflets. Relevant to 3D printing are, among others, M 391 (handling hazardous substances), M 705 (protective gloves), M 719 (respiratory filters), M 910 (ventilation) and M.plus 385 (safety data sheet). Assessment templates are available at eval.at. [2]

2. Workplace Risk Assessment for 3D Printing

The AUVA structures the assessment into five steps: (1) prepare, (2) identify hazards, (3) assess hazards, (4) define measures (STOP), (5) document and verify effectiveness. In addition, a register of hazardous work substances must be kept, with current safety data sheets on file.

2.1 Specific hazards

Hazard	FDM/FFF	SLA/DLP
Inhalation	ultrafine particles, VOC	resin vapours, IPA vapours
Dermal	low	uncured resin (sensitization), IPA
Thermal	nozzle ~200–270 °C, heated bed	low
Optical	–	UV radiation during curing
Fire/explosion	low	IPA baths and storage
Mechanical	moving axes, post-processing	post-processing, sanding

3D printers are machines and subject to product-safety/machinery law. German aids (BG ETEM S017, DGUV/IFA checklists on additive manufacturing, DGUV Information 202-103 for schools) are methodologically transferable.

3. Air Quality and Emissions (FDM/FFF)

In material extrusion, filament is extruded through a heated nozzle, releasing ultrafine particles (< 100 nm) and VOC. FDM printers are classified as “high emitters” per the scheme of He et al. In the study by Stephens et al. (2013), particle emission rates for ABS were about an order of magnitude higher than for PLA: approximately 1.9×10^{11} versus 2.0×10^{10} particles per minute. [3]

The meta-analysis by Byrley et al. (2019) found mean particle number concentrations of about 300,980 particles/cm³ for ABS and about 65,482 particles/cm³ for PLA. The authors emphasize the considerable methodological heterogeneity and call for standardized test protocols; individual chamber studies also found higher values for PLA. [4]

3.1 VOC by material

Material	Lead VOC	Assessment
ABS / ASA / HIPS	styrene (+ ethylbenzene, xylenes)	styrene IARC 2A; ASA also acrylonitrile
Nylon / PA	caprolactam	respiratory/skin irritation
PLA	lactide	not health-critical
PETG	acetaldehyde, formaldehyde	low rates
POM	formaldehyde	carcinogenic (see limits)

3.2 Emission-measurement standards

ANSI/CAN/UL 2904 (2nd ed. 2023) defines a method for testing and assessing particle and chemical emissions from free-standing 3D printers in non-industrial indoor environments. In Europe, the Blue Angel (RAL-UZ 205) as well as ECMA 328 and ISO 28360 address emission-data determination. [5]

Assessment of ultrafine particles

There is no separate air limit value for ultrafine particles; assessment relies on the minimization principle.

Most effective single measure: enclosed build chamber with source extraction and verified filter performance.

4. Hazardous Substances and Limit Values (AT / DE / EU compared)

In Austria, only the MAK values (health-based) and TRK values (risk-based for carcinogens) from Annex I of the Limit Values Ordinance (GKV) are binding. TMW = daily average (usually 8 h), KZW = short-term value. Current version: GKV 2025, Federal Law Gazette II No. 339/2025, in force since 31 Dec 2025.

Substance	Austria (GKV)	Germany (AGW)	Classification
Styrene	TMW 20 ppm / 86 mg/m³	20 ml/m³ / 86 mg/m³	IARC 2A; Repr. 2
Formaldehyde	TMW 0.3 ppm / 0.37 mg/m³; KZW 0.6 ppm; III A2 (clearly carcinogenic)	0.3 ppm / 0.37 mg/m³; Carc. 1B	IARC 1
ε-Caprolactam	TMW 5 mg/m³ (inhalable); KZW 40 mg/m³	10 mg/m³	not carcinogenic
Isopropanol	TMW 200 ppm / 500 mg/m³; KZW 800 ppm*	200 ml/m³ / 500 mg/m³	H319, H336

** Isopropanol short-term value from a manufacturer SDS with GKV reference – verify against the RIS version before use. For caprolactam, the Austrian TMW (5 mg/m³) is lower than the German AGW (10 mg/m³).*

4.1 Photopolymer resins – CLP classification

Photopolymer resins are mixtures of (meth)acrylic esters and photoinitiators. Typical classification under CLP Regulation (EC) 1272/2008: H315 (skin irritation), H319 (eye irritation), H317 (skin sensitization – the most critical occupational-medicine endpoint), H411/H412 (hazardous to the aquatic environment), partly H361f (suspected of damaging fertility). A safety data sheet per REACH Annex II must be on hand for every resin and additive. [6]

4.2 (Meth)acrylate sensitization

Allergic contact dermatitis from uncured (meth)acrylates is a type IV hypersensitivity. The monomers act as haptens. Sensitization is cumulative, may occur after years of symptom-free exposure and is permanent. There is pronounced cross-reactivity between related monomers – a mere product change usually does not solve the problem; for sensitized individuals complete avoidance is recommended. [7]

Important: cured vs. uncured

Fully cured resins are rarely sensitizing. However, sanding/machining cured parts can release reactive monomers.

Monoacrylates are strong, monomethacrylates weaker sensitizers.

5. Protective Measures per the STOP Principle

S – Substitution

- PLA/PETG instead of ABS/ASA where technically possible (markedly lower UFP rates).
- For resin washing: consider water-based mixtures or solvents with a higher flash point; evaluate solvent-free methods.

T – Technical measures (priority)

- Enclosed build chamber as the most important single measure; source extraction before room ventilation.
- Filtration: HEPA (≥ H13) against particles + activated carbon against VOC; filter maintenance and at least annual performance check. Merely installing a filter without proof of effectiveness is not sufficient.
- Closed process handling for SLA/DLP (UV protection, sealed wash-&-cure station).

O – Organizational measures

- Separate, separately ventilated installation room (especially for print farms); access restriction.
- Operating instructions, training, hygiene (no eating/drinking in the area), substance register and SDS on site.

P – Personal protective equipment

- Respiratory protection: type A gas filter against VOC, P-filter (P2/P3) against particles, combination filter for resin work.
- Gloves: nitrile/butyl against resin and IPA – no latex. Observe breakthrough times, change regularly.
- Eye protection where splashing is possible; skin-protection plan; wash resin splashes off immediately with water and soap.

5.1 Fire and explosion protection for isopropanol

Pure isopropanol has a flash point of about 12 °C and forms explosive vapour/air mixtures already at room temperature (lower explosion limit ~2.0 vol-%, upper ~12.7 vol-%); the vapours are heavier than air. Recommended are local extraction, tightly sealed extracted washers, earthed conductive containers, drip trays, explosion protection, an explosion-protection document and recurring inspection. [8]

5.2 Waste disposal

Liquid and cured resin as well as contaminated IPA and contaminated filters/wipes are hazardous waste and must be disposed of via authorized contractors – not into the sewer or household waste. Fully post-cure cured resin under UV before disposal.

6. Trade-Law Classification (Austria, with German comparison)

In Austria, the commercial production of functional 3D-printed parts (contract manufacturing) is assigned to the regulated craft “plastics processing” (proof of qualification required). Restricted trade authorizations specifically for 3D printing exist (“contract manufacturing” or “copyshop”). The competent professional organization is the Federal Guild of Plastics Processors (WKO, Crafts and Trades division). [9]

This is to be distinguished from the classic printing trade (paper/film), which does not cover additive plastics 3D printing. The final classification is made by the trade authority, where applicable by declaratory decision. In Germany, mandatory membership applies with the competent employers’ liability insurance association – depending on the main activity BG ETEM (de facto leading on 3D printing) or BG RCI (chemistry/plastics-heavy operations).

7. EU Framework

- REACH Regulation (EC) 1907/2006 – safety data sheets (Annex II), DNEL, restrictions.
- CLP Regulation (EC) 1272/2008 – classification and labelling (H-statements on resin SDS).
- Framework Directive 89/391/EEC – basic employer duties (AT: ASchG, DE: ArbSchG).
- Directive 98/24/EC (chemical agents) and 2004/37/EC (carcinogens/mutagens) – basis of occupational exposure limits (IOELV/BOELV).

8. Recommendations (tiered)

Tier 0 – before commissioning: document the workplace risk assessment per § 4 ASchG; set up the substance register and SDS; provide operating instructions and basic PPE.

Tier 1 – technical baseline: enclosed printers with source extraction and HEPA (≥ H13) + activated-carbon filtration; for resin a sealed wash-&-cure station and IPA management with explosion protection.

Tier 2 – verification: workplace measurement for continuous operation of ABS/ASA/nylon in enclosed rooms, multiple printers or complaints; escalation (separate room, higher ventilation) when approaching a limit value.

Tier 3 – commercial/organizational: clarify trade-law classification (WKO); register with AUVA/social insurance; document annual effectiveness checks of ventilation.

Declarations

Conflict of interest: The author operates Schichtwerk, a service company in additive manufacturing. This work reflects the published state, without external funding.

Data availability: based on published literature, standards and legal sources; no new primary data. Limit values must be checked against the current RIS version of the GKV before binding use.

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[1] Employee Protection Act (ASchG), Federal Law Gazette 450/1994 as amended. §§ 3–7, 41, 45/46. RIS – Federal Legal Information System.

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[3] Stephens B, Azimi P, El Orch Z, Ramos T. Ultrafine particle emissions from desktop 3D printers. Atmos Environ. 2013;79:334–339.

[4] Byrley P, George BJ, Boyes WK, Rogers K. Particle emissions from fused deposition modeling 3D printers: Evaluation and meta-analysis. Sci Total Environ. 2019;655:395–407.

[5] ANSI/CAN/UL 2904. Standard Method for Testing and Assessing Particle and Chemical Emissions from 3D Printers. 2nd ed. Underwriters Laboratories; 2023. Cf. RAL-UZ 205 (Blue Angel).

[6] Regulation (EC) No 1272/2008 (CLP) and Regulation (EC) No 1907/2006 (REACH), Annex II. Official Journal of the EU.

[7] Aalto-Korte K, Suuronen K, Kuuliala O, et al. Occupational contact allergy to monomeric acrylates. Contact Dermatitis. 2010;63(6):340–346.

[8] German Social Accident Insurance Institution for the energy, textile, electrical and media products sectors (BG ETEM). Isopropanol – hazardous post-processing of 3D prints. etem 2/2025; and BG ETEM S017.

[9] Austrian Federal Economic Chamber (WKO). Federal Guild of Plastics Processors; Plastics Processing Ordinance Federal Law Gazette II No. 66/2003 as amended by II No. 399/2008. Trade Act 1994.

[10] Limit Values Ordinance (GKV) 2025, Federal Law Gazette II No. 339/2025, Annex I. RIS. German comparison: TRGS 900 (BAuA).

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