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CH-1214 Vernier, Geneva ~~West Conshohocken, PA 19428-2959, USA~~
Phone: +41 22 749 01 11 ~~Phone: +610 832 9634~~

Fax: +41 22 749 09 47 Fax: +610 832 9635
Email: copyright@iso.org Email: lchooper@astm.org
Website: www.iso.org Website: www.astm.org

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Introduction

This document refers to the assessment of hazardous substances emitted during operation of material extrusion type AM machines, commonly known as “3D printers” installed in schools or public places for educational and hands-on purposes, and basic countermeasures for reducing the substances.

This document provides the necessary information and test procedures to reflect the characteristics of the AM process based on the previous international standards related to indoor air quality and to assess hazardous substances in the non-industrial places.

Operator, supervisor, and manager who are working at the non-industrial places will be able to use this document to measure and diagnose air quality. This document also includes appendices to help them try to reduce the hazardous substances emitted into the non-industrial spaces.

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Additive manufacturing — Environment, health and safety — Test method for the hazardous substances emitted from material extrusion type 3D printers in the non-industrial places

1 Scope

This document specifies a test method for measuring hazardous substances emitted during the operation of material extrusion type AM machines commonly used in the non-industrial places and includes non-normative suggestions for ways to reduce them.

This document specifies some of the main hazardous substances emitted from this type of machine during operation for currently commonly used materials, it describes the additional information and the associated test method for measuring hazardous substances, and includes considerations for reducing the hazardous substances and basic countermeasures.

This document specifies how to measure concentrations of hazardous substances generated in the non-industrial places (school, public place and so on) in which this type of machines are installed, and to maintain an acceptable work environment by managing field facilities, machines, filaments, and additive manufactured products for the reduction of hazardous substances.

However, this document does not cover all gas-phase chemical emissions. Only a range of Volatile Organic Compounds (VOCs) from n-hexane to n-hexadecane, including aldehydes are included. Considerations for reducing chemical emissions and for improving the work environment are given in [Annexes A and B](#).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

~~<std>ISO 16000-2:2004, Indoor air — Part 2: Sampling strategy for formaldehyde</std>~~

~~<std>ISO 16000-3:2022, ISO 16000-2, Indoor air — Part 2: Sampling strategy for formaldehyde~~

~~ISO 16000-3, Indoor air — Part 3: Determination of formaldehyde and other carbonyl compounds in indoor and test chamber air — Active sampling method</std>~~

~~<std>ISO 16000-4:2011, Indoor air — Part 4: Determination of formaldehyde — Diffusive sampling method</std>~~

~~<std>ISO 16000-5:2007, Indoor air — Part 5: Sampling strategy for volatile organic compounds (VOCs)</std>~~

~~<std>ISO 16000-6:2021, ISO 16000-6, Indoor air — Part 6: Determination of organic compounds (VOC, VOC, SVOC) in indoor and test chamber air by active sampling on sorbent tubes, thermal desorption and gas chromatography using MS or MS FID</std>~~

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~~<std>ISO 16000-9:2006, Indoor air — Part 9: Determination of the emission of volatile organic compounds from building products and furnishing — Emission test chamber method</std>~~

~~<std>ISO 16017-1:2009ISO 16017-1, Indoor, ambient and workplace air — Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography — Part 1: Pumped sampling</std>~~

~~<std>ISO 16017-2:2003ISO 16017-2, Indoor, ambient and workplace air — Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography — Part 2: Diffusive sampling</std>~~

~~<std>ISO 16200-1:2004ISO 16200-1, Workplace air quality — Sampling and analysis of volatile organic compounds by solvent desorption/gas chromatography — Part 1: Pumped sampling method</std>~~

~~<std>ISO 16200-2:2009ISO 16200-2, Workplace air quality — Sampling and analysis of volatile organic compounds by solvent desorption/gas chromatography — Part 2: Diffusive sampling method</std>~~

~~<std>ISO 21366:2019, Traditional Chinese medicine — General requirements for smokeless moxibustion devices</std>~~

~~<std>ISO/TR 27628:2007ISO/TR 27628, Workplace atmospheres — Ultrafine, nanoparticle and nano-structured aerosols — Inhalation exposure characterization and assessment</std>~~

~~<std>ISO/IEC 29360-1:2021, Information technology — Determination of chemical emission rates from electronic equipment — Part 1: Using consumables</std>~~

~~<std>ISO 28439:2011ISO 28439, Workplace atmospheres — Characterization of ultrafine aerosols/nanoaerosols — Determination of the size distribution and number concentration using differential electrical mobility analysing systems</std>~~

~~<std>ISO/ASTM 52900:2021, Additive manufacturing — General principles — Fundamentals and vocabulary</std>~~

3 Terms and definitions

For the purposes of this document, the terms and definitions from ISO/ASTM 52900 and the following are applied.

ISO and IEC maintain **terminological terminology** databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 volatile organic compound

VOC
organic compound that is emitted from the test specimen and all those detected in the chamber outlet air

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4 Hazardous substance targets and major factors

VOCs, aldehydes, and UFP are currently identified as some of the potentially hazardous substances emitted during operation of material extrusion type AM machines in schools and public places. The material extrusion type AM machines which are currently used for AM process with filaments (ABS, PA, PC, etc.) can change the concentration of hazardous substances depending on the process and environment of the non-industrial places. The risk of each hazardous substance can be confirmed by referring to the hazard statement of the MSDS of the substance.

Since the following factors can increase the concentration of hazardous substances in that place, appropriate countermeasures are needed. See Annex A for information on considerations to reduce the emission concentrations of hazardous substances in the non-industrial place.

The factors are specified as follows:

- ~~Printer~~printer-related factors (e.g., design - open frame, enclosed);
- ~~Feedstock~~feedstock-related factors (e.g., type of polymer, ~~color~~colour, infill materials);
- ~~Process~~process-related factors (e.g., extruder temp, bed temp, infill density);
- ~~Environmental~~environmental-related factors (e.g., room size, presence of doors/windows, ventilation, temperature, humidity).

5 Relevant test standards

This document covers three main classes (VOCs, aldehydes, and UFP) of hazardous substances that could be emitted in case of using material extrusion type 3D printers and filaments. Table 1 provides a list of these hazardous substances and the recommended sampling strategy and test methods for their analysis in a workplace or indoor environment. Users should be aware that each type of emission could vary individually depending on the duration of machine operation, type of filaments, temperature, humidity of the place, etc. As such they much each be monitored individually and proper care should be taken to ensure the monitoring plan covers the worst-case scenarios. Currently, there is no test method to measure VOCs, aldehydes, and UFP simultaneously or for an extended period (such as the entire additive manufacturing process). Therefore, the non-industrial places where material extrusion type 3D printers are in operation require an integrated analysis method to monitor each substance that is relevant to the process.

Table 1.— Relevant test standards for some hazardous substances

Requirements	VOCs	Aldehydes	UFPs
Sampling method	ISO 16000-5	ISO 16000-2	
	ISO 16000-6	ISO 16000-3	ISO/TR 27628
	ISO 16017-1	ISO 16000-4	ISO 28439
	ISO 16017-2	ISO 16200-2	
	ISO 16200-1		
Analysis method	ISO 16000-6		ISO/TR 27628
	ISO 16017-1	ISO 16000-4	ISO 28439
	ISO 16017-2		

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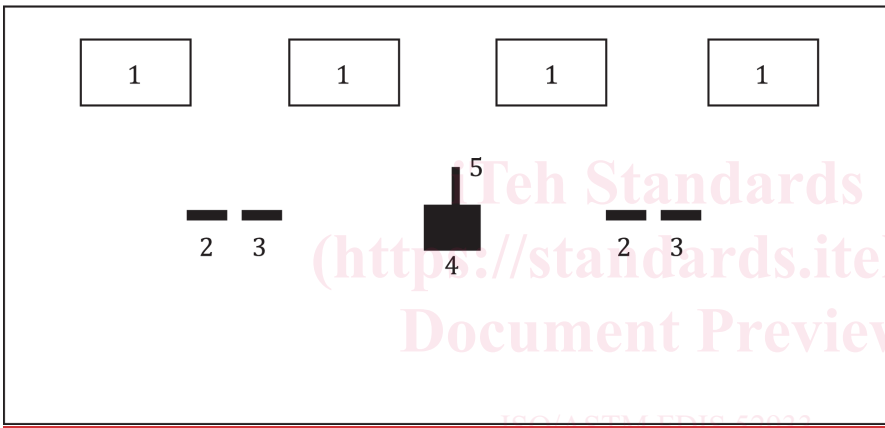
6 Sampling conditions

6.1 Sampling location

Sampling of hazardous substances during the AM process shall be carried out simultaneously and the VOCs, aldehydes sampler and the UFP analysis equipment shall be placed in separate spaces to sample each of the substances. **Figure 1** shows an example of one possible spacing of samplers relative to 3D printers. Two VOCs and aldehyde sampler shall be installed for cross-check. In addition, the sampler location is usually installed at the center of the non-industrial place and is installed at 1,0 m to 1,8 m height from the floor.

UFP sampling tube shall consist of a conductive silicon tube or stainless steel, not exceeding 3 m in length, and avoid bends in the tube.

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- Key
- 1 material extrusion 3D printer (example)
 - 2 VOCs sampler
 - 3 aldehyde sampler
 - 4 UFP analytical equipment
 - 5 UFP sampling tube

Figure 1 — Schematic diagram of the non-industrial place for sampling strategy

In case of UFP analytical equipment that condenses nanoparticles by using butanol, isopropanol, and other organic solutions, the substances could be spontaneously volatilized in the non-industrial place while the equipment is in operation. Accordingly the final concentration of VOCs would be affected. Therefore, UFP analytical equipment that uses organic solvents, should be placed outside the additive manufacturing site, ensuring no occurrence of cross-contamination from outside.

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