TECHNICAL REPORT

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Nanotechnologies — Characterization of carbon nanotube and carbon nanofibre aerosols to be used in inhalation toxicity tests

Nanotechnologies — Caractérisation des aérosols de nanotubes de carbone et de nanofibres de carbone à utiliser dans les tests de toxicité par inhalation

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 229, *Nanotechnologies*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Inhalation is the primary route of exposure to aerosolised carbon nanotubes (CNTs) and carbon nanofibres (CNFs). Exposure to CNTs or CNFs can occur in consumer settings as well as in occupational settings. Occupational exposure to CNTs or CNFs can occur at all phases of the manufacturing, handling, and formulation of the material into final products[1,2]. Consumers are potentially exposed to CNTs or CNFs released as products of degradation, weathering, or mechanical processes (e.g. grinding or polishing) from consumer products that contain CNT or CNF embedded into a matrix[3,4].

Similar to other nanomaterials, the physicochemical properties of CNTs or CNFs are greatly diverse in terms of diameter, length, shape, arrangement of carbon atoms, surface chemistry, defects, and impurities. Their different physicochemical characteristics are responsible for different functional properties such as mechanical, electrical, optical, and thermal properties. Many previous inhalation toxicity studies of CNT and CNF aerosols reported various hazards from acute inflammation to carcinogenicity and the toxicological responses to CNT and CNF aerosols vary depending on their physicochemical characteristics[5].

Among the various physicochemical characteristics, morphological factors such as length and rigidity have been suggested as key parameters related to the toxicity of CNT and CNF aerosols[6,7]. CNT and CNF aerosols can consist of individual primary fibres in the nanoscale[8] and aggregated or agglomerated structures, including those with diameters larger than 100 nm[9]. Among various types of CNT and CNF, the asbestos-like pathogenicity has been observed only in long (>5 µm) and rigid fibres, but not in short or tangled CNT[6]. Thus, a better understanding of the characteristics of generated CNT or CNF aerosols in relation to toxicity end points is key for risk assessment and safer-by-design approaches.

The framework for material characterization for inhalation studies consists of (1) characterization of as-produced (pristine) or supplied material, (2) characterization of administered material, (3) characterization of material following administration, and (4) human exposure characterization[10]. This document focuses on the first two characterization needs, which include physicochemical properties (e.g. size, size distribution, aggregation/agglomeration, and shape) and measurement of concentration (e.g. mass, number, surface area, and volume). These parameters can be measured by direct (online) or indirect (off-line) methods and each technique needs specific sampling procedures. However, the limited technologies in the generation and characterization of nanofibres make it difficult to perform inhalation toxicity studies, although the inhalation exposure to CNT and CNF is highly likely in the workplace[9,11], and research facilities[8], where they are in use. In this regard, this document provides the current status of CNT and CNF aerosol characterization used in the inhalation toxicity tests as well as the physicochemical properties of CNTs and CNFs and their relationship with toxicity end points.

This document complements the work of other international organizations including the Organization for Economic Co-operation and Development (OECD) which has published guidelines and guidance on the performance of inhalation toxicity studies[12,13]. ISO 10808 describes the characterization of nanoparticles in inhalation exposure chambers for inhalation toxicity testing. This document is different from ISO 10808 and focuses on different types of nanomaterials (nanotubes and nanofibres opposed to nanoparticles) because many characterization methods and important physicochemical parameters related to the toxicity of CNT and CNF are different from those of nanoparticles. Recommendations and guidelines to assist investigators in making appropriate choices for the characterization of CNT and CNF aerosols to be studied are presented in this document.

Nanotechnologies — Characterization of carbon nanotube and carbon nanofibre aerosols to be used in inhalation toxicity tests

1 Scope

This document reviews characterization of CNT and CNF aerosols for inhalation exposure studies. The document also provides useful information on appropriate characterization of CNT and CNF, which is required to evaluate and understand the inhalation toxicity of CNT and CNF aerosols. This document neither provides guidance on aerosol characterization for other carbon nanomaterials, nor provides guidance for characterization of carbon nanotube and nanofibre aerosols in the workplace or ambient air.

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.

ISO 80004 (all parts), *Nanotechnologies — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given ISO 80004 (all parts), and the following apply.

ISO and IEC maintain 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
carbon nanotube
nanotube composed of carbon

Note 1 to entry: Carbon nanotubes usually consist of curved graphene layers, including single-wall carbon nanotubes and multiwall carbon nanotubes.

[SOURCE: ISO/TS 80004-3:2020, 3.3.3]

3.2
multiwall carbon nanotube
MWCNT
multi-walled *carbon nanotube* (3.1) composed of nested, concentric or near-concentric graphene sheets with interlayer distances similar to those of graphite

Note 1 to entry: The structure is normally considered to be many single-wall carbon nanotubes nesting each other, and would be cylindrical for small diameters but tends to have a polygonal cross-section as the diameter increases.

[SOURCE: ISO/TS 80004-3:2020, 3.3.6]