INTERNATIONAL STANDARD

ISO 7708

First edition
1995-04-01

Air quality — Particle size fraction definitions for health-related sampling

Qualité de l'air — Définitions des fractions de taille des particules pour l'échantillonnage lié aux problèmes de santé

Reference number
ISO 7708:1995(E)

Contents

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 7708 was prepared by Technical Committee ISO/TC 146, *Air quality*.

This first edition cancels and replaces the Technical Report ISO/TR 7708:1983, of which it constitutes a technical revision.

Annexes A, B and C of this International Standard are for information only.

Introduction

The fraction of airborne particles which is inhaled into a human body depends on the properties of the particles, the speed and direction of air movement near the body, the rate of breathing, and whether breathing is through the nose or mouth. Inhaled particles can then deposit somewhere in the respiratory tract, or can be exhaled. The site of deposition, or probability of exhalation, depends on the properties of the particles, respiratory tract, breathing pattern and other factors.

Liquid particles or soluble components of solid particles can be absorbed by the tissues wherever they deposit. Particles can cause damage close to the deposition site if they are corrosive, radioactive, or capable of initiating some other type of damage. Insoluble particles can be transported to another part of the respiratory tract or body, where they can be absorbed or cause a biological effect.

There is a wide variation from one person to another in the probability of particle inhalation, deposition, reaction to deposition, and clearance. Nevertheless, it is possible to define conventions for size-selective sampling of airborne particles when the purpose of sampling is health-related. These are relationships between the aerodynamic diameter and the fractions to be collected or measured, which approximate to the fractions penetrating to regions of the respiratory tract under average conditions. Measurement conducted according to these conventions will probably yield a better relationship between measured concentration and risk of disease. For further information on the factors affecting inhalation and deposition and their application in standards, see Stuart et al. [12], Phalen et al. [9], Lippmann et al. [5], Heyder et al. [3], Miller et al. [7], Rudolph et al. [10], Vincent [13], Ogden and Birkett [8] and Soderholm [11].

Air quality — Particle size fraction definitions for health-related sampling

1 Scope

This International Standard defines sampling conventions for particle size fractions for use in assessing possible health effects of airborne particles in the workplace and ambient environment. Conventions are defined for the inhalable, thoracic and respirable fractions; extrathoracic and tracheobronchial conventions may be calculated from the defined conventions. (The inhalable fraction is sometimes called inspirable — the terms are equivalent. The nomenclature of the fractions is discussed in annex A.) Assumptions are given in clause 4. The convention chosen will depend on the region of effect of the component of interest in the airborne particles (see clause 3). In this International Standard, conventions are expressed in terms of mass fractions, but they may also be used when the intention is to evaluate the total surface area or the number of particles in the collected material. The conventions should not be used in association with limit values defined in other terms, for example for limit values of fibres defined in terms of their length and diameter.

2 Definitions

For the purposes of this International Standard, the following definitions apply.

2.1 sampling convention: Target specification for sampling instruments which approximates to, for each particle aerodynamic diameter,

— in the case of the inhalable convention, the ratio of the mass concentration of particles entering the respiratory tract to the corresponding mass concentration in the air before the particles are affected by the presence of the exposed individual and by inhalation;

— in the case of other conventions, the ratio of the mass concentration of particles entering the specified region of the respiratory tract to the mass concentration of particles entering the respiratory tract. (These other conventions can also be expressed as ratios to the mass of total airborne particles.)

2.2 particle aerodynamic diameter: Diameter of a sphere of density 1 g/cm^3 with the same terminal velocity due to gravitational force in calm air as the particle, under the prevailing conditions of temperature, pressure and relative humidity (see clause 4).

NOTE 1 For particles of aerodynamic diameter less than 0,5 µm, the particle diffusion diameter should be used instead of the aerodynamic diameter. The particle diffusion diameter means the diameter of a sphere with the same diffusion coefficient as the particle, under the prevailing conditions of temperature, pressure and relative humidity.

2.3 inhalable fraction: Mass fraction of total airborne particles which is inhaled through the nose and mouth.

NOTE 2 The inhalable fraction depends on the speed and direction of the air movement, on the rate of breathing and other factors.

2.4 inhalable convention: Target specification for sampling instruments when the inhalable fraction is the fraction of interest.

2.5 extrathoracic fraction: Mass fraction of inhaled particles which fail to penetrate beyond the larynx.

2.6 extrathoracic convention: Target specification for sampling instruments when the extrathoracic fraction is of interest.

2.7 thoracic fraction: Mass fraction of inhaled particles which penetrate beyond the larynx.

2.8 thoracic convention: Target specification for sampling instruments when the thoracic fraction is of interest.

2.9 tracheobronchial fraction: Mass fraction of inhaled particles which penetrate beyond the larynx, but which fail to penetrate to the unciliated airways.

2.10 tracheobronchial convention: Target specification for sampling instruments when the tracheobronchial fraction is of interest.

2.11 respirable fraction: Mass fraction of inhaled particles which penetrate to the unciliated airways.

2.12 respirable convention: Target specification for sampling instruments when the respirable fraction is of interest.

2.13 total airborne particles: All particles surrounded by air in a given volume of air.

NOTE 3 Because all measuring instruments are size-selective to some extent, it is often impossible to measure the total airborne particle concentration.

3 Principle

The sampling conventions recognize that only a fraction of the airborne particles which are near to the nose and mouth is inhaled. This fraction is called the inhalable fraction (2.3). For some substances, the subfractions of this which penetrate beyond the larynx, or to the unciliated airways, are of special significance for health.

This International Standard presents conventionalized curves approximating to the fraction inhaled and the subfractions penetrating beyond the larynx or to the unciliated airways. These curves are called the inhalable convention (2.4), the thoracic convention (2.8) and the respirable convention (2.12). The extrathoracic (2.6) and tracheobronchial (2.10) conventions may be calculated from these. Instruments used for sampling should conform with the sampling convention appropriate to the region of the respiratory tract where deposition of the substance being measured might lead to a biological effect. For example, the inhalable convention would be chosen if the substance might lead to an affection wherever it is deposited, the thoracic convention would be chosen if the region was the lung conductive airways (bronchi), and the respirable convention if the region was the gas exchange region extending from the respiratory bronchioles to the alveoli.

In children and in adults with certain chest diseases, the tracheobronchial region is more effective at collecting particles of small aerodynamic diameter than it is in healthy adults. This is accounted for in the conventions by a second respirable convention, centred at smaller aerodynamic diameters, which gives a coresponding tracheobronchial convention extended to smaller aerodynamic diameters. This tracheobronchial convention should be used when the exposed population includes these "high-risk" groups, and the "high-risk" respirable convention may be used in these circumstances.

Instruments can be used to collect individual fractions according to the conventions, or to collect several fractions simultaneously. For example, an instrument could collect particles from the air according to the inhalable convention, and then separate this material into portions according to the thoracic, tracheobronchial and respirable conventions. Alternatively, an instrument might just collect the respirable fraction from the air. In this case, the design would have to ensure that selection at the entry due to aerodynamic effects, and subsequently within the instrument, was such that the overall selection was in accordance with the conventions. (The performance requirements of instruments are summarized in clause 9.)

4 Assumptions and approximations

Approximations and assumptions are unavoidable when simulating, by sampling conventions, the very complex interaction of variables that governs respiratory tract entry and penetration.

The conventions are necessarily only approximations to respiratory tract behaviour, and the following assumptions should be noted.

a) The inhalable fraction depends on air movement — speed and direction — on the rate of breathing, and on whether breathing is through the nose or mouth. The values given in the inhalable convention are for representative values of the rate of breathing, and are averaged for all wind directions. This is appropriate for an individual uniformly exposed to all wind directions or predominantly exposed to wind from the side or from behind, but the convention would usually underestimate the inhalable fraction of larger particles for an individual who usually faced the wind.

b) The respirable and thoracic fractions vary from individual to individual and with the breathing pattern, and the conventions are necessarily approximations to the average case.

c) Each convention approximates to the fraction penetrating to a region, and not to the fraction

depositing there. In general, particles must deposit to have a biological effect. In this respect, the conventions will lead to an overestimate of the potential biological effect. The most important example is that the respirable convention overestimates the fraction of very small particles which are deposited in the unciliated airways, because a fraction of these particles is exhaled without being deposited. In many workplaces, these very small particles do not contribute much to the sampled mass.

d) The thoracic convention approximates to the thoracic fraction during breathing through the mouth, which is greater than the thoracic fraction during breathing through the nose. The extrathoracic convention may therefore underestimate the "worst case" extrathoracic fraction, which occurs during breathing through the nose.

5 Inhalable convention

The target sampling curve for instruments collecting the inhalable fraction, when averaged over all wind directions, shall be as follows for windspeeds $u < 4$ m/s. The percentage E_I of airborne particles of aerodynamic diameter D (µm) which are to be collected is given by the equation

$$E_I = 50\,(1 + \exp\,[-0{,}06\,D]) \quad \ldots (1)$$

Some values of E_I are given in table B.2 and illustrated in figures B.1 and B.2.

NOTE 4 Experimental data on the inhalable fraction do not yet exist for $D > 100$ µm, and the convention should not be applied to larger particles. For windspeeds $u > 4$ m/s, equation (2) is tentatively suggested. Equation (2) should not be applied for $D > 90$ µm or $u > 9$ m/s, which are the limits of the experimental data.

$$E_I = 50\,(1 + \exp\,[-0{,}06\,D]) + 10^{-3}\,u^{2,75}\exp\,[0{,}055\,D] \quad \ldots (2)$$

6 Thoracic convention

The target sampling curve for instruments collecting the thoracic fraction shall be as follows. The percentage E_T of the inhalable convention which is to be collected at an aerodynamic diameter D (µm) is given by a cumulative log-normal distribution with a median of 11,64 µm and a geometric standard deviation of 1,5. A numerical approximation for ease of calculation is given in annex B. Note that E_T is calculated from the inhalable convention. The fraction of the total airborne particles (2.13) at an aerodynamic diameter D is obtained by multiplying E_T by 0,01 E_I from equation (1). The values obtained are given in tables B.1 and B.2 and illustrated in figure B.1. It will be seen from the tables that 50 % of total airborne particles with $D = 10$ µm are in the thoracic fraction.

7 Respirable conventions

7.1 Target population: sick and infirm, or children

When the population that it is desired to protect are children, or the sick or infirm (the "high risk" group), the target sampling curve for instruments used for collecting the respirable fraction is as follows. The percentage E_R of the inhalable convention which is to be collected at an aerodynamic diameter D (µm) is given by a cumulative log-normal distribution with a median diameter of 2,5 µm and a geometric standard deviation of 1,5. A numerical approximation for ease of calculation is given in annex B. Note that E_R is a fraction of the inhalable convention. The fraction of the total airborne particles (2.13) at an aerodynamic diameter D is obtained by multiplying E_R by 0,01 E_I from equation (1). The values obtained are given in tables B.1 and B.2 and illustrated in figure B.1.

NOTE 5 When the population is the "high risk" group, the healthy adult respirable convention may be used and will then give an extra safety margin. The chief purpose of the "high risk" respirable convention is to generate a "high risk" tracheobronchial convention (see clause 8) which provides better protection for this group.

7.2 Target population: healthy adults

The percentage E_R of the inhalable convention which is to be collected at an aerodynamic diameter D (µm) is given by a cumulative log-normal distribution with a median diameter of 4,25 µm and a geometric standard deviation of 1,5. A numerical approximation for ease of calculation is given in annex B. Note that E_R is a fraction of the inhalable convention. The fraction of the total airborne particles (2.13) at an aerodynamic diameter D is obtained by multiplying E_R by 0,01 E_I from equation (1). The values obtained are given in tables B.1 and B.2 and illustrated in figure B.1.

8 Extrathoracic and tracheobronchial conventions

The extrathoracic convention is calculated as $(E_I - E_T)$ (see clauses 5 and 6) at each aerodynamic diameter D. The tracheobronchial convention is calculated as $(E_T - E_R)$ (see clauses 6 and 7) at each aerodynamic diameter D. The two tracheobronchial conventions corresponding to the two respirable conventions are

given in tables B.1 and B.2 and illustrated in figure B.2. The "high risk" tracheobronchial convention should be used when the exposed population includes children or the sick or infirm.

9 Performance of instruments

It may not be possible to construct instruments whose characteristics exactly match the conventions given in clauses 5 to 8. In any case, experimental error in the testing of instruments, and possible dependence on factors other than aerodynamic diameter, mean that it is only possible to make a statement of probability that an instrument's characteristic falls within a certain range. The comparison of instruments with the conventions is dealt with in another ISO publication. Among other possibilities, this allows verification over restricted ranges of variables if this is all that is necessary. For example, for ambient air instruments, it may be satisfactory to assess performance for a particle size range terminating below 100 µm, and then to restrict use to atmospheres where larger particles are not present.

Annex A
(informative)

Nomenclature of inhalable and respirable fractions

The term "inhalable" is used in this International Standard because it is the word which most naturally describes the meaning of the fraction for which it is used. There has been some confusion over terminology in the past. "Inhalable" was used in the late 1970's in European English-language literature with the same meaning as in this International Standard. ISO/TR 7708:1983[4] and the amended European directive 88/642/EEC used the term "inspirable" for this fraction, and the terms "inspirable" and "inhalable" are equivalent. For a time, the US Environmental Protection Agency (EPA) used "inhalable" for what is now called "total thoracic particulate" or "PM_{10}". EPA no longer uses the term "inhalable", and this International Standard has therefore readopted the term with its original meaning.

The term "respirable" has been used in English since at least 1952 for the fraction penetrating to the unciliated airways (Hamilton and Walton[1]; Lippmann and Harris[6]). ISO/TR 7708:1983 adopted the term "alveolar", partly because of the similarity of the terms "respirable" and "inspirable"; but as this International Standard uses the term "inhalable", this argument no longer applies, and the familiar term "respirable" has been readopted.

There has been no such confusion in French and German, but for clarity the following terms are recommended:

German	French	English
einatembar	inhalable	inhalable
alveolengängig	alvéolaire	respirable
thorakal	thoracique	thoracic