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Erythema reference action spectrum and standard erythema dose

Spectre d'action érythémale de référence et dose érythémale normalisée

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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 the International Commission on Illumination (CIE) in cooperation with Technical Committee ISO/TC 274, *Light and lighting*.

This first edition of ISO/CIE 17166 cancels and replaces ISO 17166:1999 | CIE S 007-1998, of which it constitutes a minor revision. The document has been editorially revised as per current ISO rules and the references have been updated.

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

Introduction

The problem of dosimetry in skin photobiology lies in the fact that the ability of ultraviolet (UV) radiation to elicit erythema in human skin depends strongly on wavelength, encompassing a range of four orders of magnitude between 250 nm and 400 nm. Thus, a statement that a subject received an exposure dose of 1 $J \cdot cm^{-2}$ (10^4 $J \cdot m^{-2}$) of UV radiation conveys nothing about the consequences of that exposure in terms of erythema. If the radiation source was a UV-A fluorescent lamp, no erythemal response would be seen apart from in people exhibiting severe, abnormal pathological photosensitivity. The same dose delivered from an unfiltered mercury arc lamp or fluorescent sun-lamp would result in marked violaceous erythema in most white-skinned individuals. Consequently, photobiologists have long recognized the need to express the exposure as an erythemally weighted quantity[1].

Recently, the term "minimal erythema dose (MED)" has been used widely as a measure of erythemal radiation. This is unreasonable because the MED is not a standard measure of anything but, on the contrary, encompasses the variable nature of individual sensitivity to UV radiation. Variables that affect the MED include: optical and radiometric characteristics of the source; determinants of the exposure, such as dose increment and field size; nature of the skin, such as pigmentation, previous light exposure and anatomical site; and observational factors, such as definition of the endpoint, time of reading after exposure and ambient illumination.

To avoid further confusing misuse of the term MED, it is proposed that this term be reserved solely for observational studies in humans and other animals, and that a new term, the "standard erythema dose (SED)", be used as a standardized measure of erythemogenic UV radiation.

Erythema reference action spectrum and standard erythema dose

1 Scope

This document specifies the erythema reference action spectrum, $s_{er}(\lambda)$, and the standard erythema dose (SED).

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.

CIE S 017:—,[1] *ILV: International Lighting Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in CIE S 017 and the following apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
erythema spectral weighting function
erythema action spectrum
$s_{er}(\lambda)$
function representing the spectral dependence of the ability of *ultraviolet radiation* (3.6) to produce just perceptible actinic erythema in human skin

[SOURCE: CIE S 017:—, entry 17-26-065]

3.2
erythemal irradiance
E_{er}
effective irradiance with the spectral irradiance, E_λ, spectrally weighted with the *erythema spectral weighting function*, $s_{er}(\lambda)$, (3.1)

Note 1 to entry: This definition is based on the assumption that an action spectrum is adopted for the actinic effect considered, and that its maximum value is 1.

Note 2 to entry: It is essential to specify which action spectrum is used, as the unit is the same.

Note 3 to entry: The erythemal irradiance is expressed in watts per square metre ($W \cdot m^{-2}$).

[SOURCE: CIE S 017:—, entry 17-26-067]

1) Under preparation. Stage at the time of publication: CIE DIS 017:2016.

3.3
erythemal dose
erythemal radiant exposure
H_{er}
time integral of *erythemal irradiance* (3.2) defined by the formula:

$$H_{er} = \int\int E_{\lambda}(\lambda, t) s_{er}(\lambda) \mathrm{d}\lambda \, \mathrm{d}t$$

where

$E_{\lambda}(\lambda, t)$ is the spectral irradiance at wavelength λ and time t;

$s_{er}(\lambda)$ is the *erythema spectral weighting function* (3.1) normalized to 1 at its maximum

Note 1 to entry: This definition is based on the assumption that an action spectrum is adopted for the actinic effect considered, and that its maximum value is 1.

Note 2 to entry: It is essential to specify which action spectrum is used, as the unit is the same.

Note 3 to entry: See also *minimal erythema dose* (3.4) and *standard erythema dose* (3.5).

Note 4 to entry: The erythemal dose is expressed in joules per square metre ($J \cdot m^{-2}$).

[SOURCE: CIE S 017:—, entry 17-26-066]

3.4
minimal erythema dose
MED
actinic dose, using the *erythema spectral weighting function* (3.1), that produces a just noticeable actinic erythema on a single individual's previously unexposed skin

Note 1 to entry: The minimal erythema dose is a subjective measure based on the reddening of the skin; it depends on many variables, e.g. individual sensitivity to *ultraviolet radiation* (3.6), radiometric characteristics of the source, skin pigmentation, anatomic site, elapsed time between irradiation and observing the reddening (typical value: 24 h), etc. Since it varies with each individual, it should be reserved solely for observational studies in humans and other animals.

Note 2 to entry: See also *standard erythema dose* (3.5).

Note 3 to entry: The minimal erythema dose is expressed in joules per square metre ($J \cdot m^{-2}$).

[SOURCE: CIE S 017:—, entry 17-26-068]

3.5
standard erythema dose
SED
standardized unit of measure of erythemal radiation

Note 1 to entry: One standard erythema dose (1 SED) is equivalent to an erythemal radiant exposure of 100 $J \cdot m^{-2}$.

Note 2 to entry: See also *minimal erythema dose* (3.4).

[SOURCE: CIE S 017:—, entry 17-26-069, modified — Note 3 to entry has been omitted.]

3.6
ultraviolet radiation
UV radiation
optical radiation for which the wavelengths are shorter than those for visible radiation

Note 1 to entry: The range between 100 nm and 400 nm is commonly subdivided into:

— UV-A: 315 nm to 400 nm;

— UV-B: 280 nm to 315 nm;

— UV-C: 100 nm to 280 nm.

Note 2 to entry: A precise border between "ultraviolet radiation" and "visible radiation" cannot be defined, because visual sensation at wavelengths shorter than 400 nm is noted for very bright sources.

Note 3 to entry: In some applications, the ultraviolet spectrum has also been divided into "far", "vacuum" and "near" ultraviolet; however, the borders necessarily vary with the application (e.g. in meteorology, optical design, photochemistry, thermal physics).

[SOURCE: CIE S 017:—, entry 17-26-008]

4 Concept of erythemal irradiance and dose

4.1 Erythemal irradiance

The erythemal irradiance, E_{er}, from a source of UV radiation is obtained by weighting the spectral irradiance of the radiation at wavelength λ (in nm) by the effectiveness of radiation of this wavelength to cause a minimal erythema and summing over all wavelengths present in the source spectrum. This can be expressed mathematically as shown in Formulae (1) and (2):

$$E_{er} = \int E_{\lambda}(\lambda) \cdot s_{er}(\lambda) \mathrm{d}\lambda \tag{1}$$

or

$$E_{er} = \sum E_{\lambda}(\lambda) \cdot s_{er}(\lambda) \cdot \Delta\lambda \tag{2}$$

where

$E_{\lambda}(\lambda)$ is the spectral irradiance at wavelength λ;

$\Delta\lambda$ is the wavelength interval used in the summation;

$s_{er}(\lambda)$ is the erythema spectral weighting function (see 4.2) normalized to 1 at its maximum.

Integration has to be carried out in the wavelength range where neither $E_{\lambda}(\lambda)$ nor $s_{er}(\lambda)$ equal zero. As it is a ratio, $s_{er}(\lambda)$ has unit one. The erythemal irradiance is equivalent to a hypothetical irradiance of monochromatic radiation having a wavelength at which $s_{er}(\lambda)$ is equal to unity. The time integral of effective irradiance is the erythemal dose.

The erythemal dose, H_{er}, (in $J \cdot m^{-2}$) received after an exposure period of t (in s) is shown in Formula (3):

$$H_{er} = E_{er} \cdot t \tag{3}$$

where E_{er} is the erythemal irradiance (in $W \cdot m^{-2}$).