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Erythema reference action spectrum and standard erythema dose

Spectre d'action érythémale de référence et dose érythémale normalisée

Reference number
ISO 17166:1999(E)
CIE S 007/E-1998

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Foreword

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International Standard ISO 17166 was prepared as Standard CIE S 007/E by the International Commission on Illumination, which has been recognized by the ISO Council as an international standardizing body. It was adopted by ISO under a special procedure which requires approval by at least 75 % of the member bodies casting a vote, and is published as a joint ISO/CIE edition.

The International Commission on Illumination (abbreviated as CIE from its French title) is an organization devoted to international cooperation and exchange of information among its member countries on all matters relating to the science and art of lighting.

Annex A of this International Standard is for information only.

ISO 17166:1999(E)
CIE S 007/E-1998

Standard

Erythema Reference Action Spectrum and Standard Erythema Dose

Spectre d'action erithémale de référence et dose erithémale normalisée

Erythemale Referenzwirkungsfunktion und standardisierte Erythemdosis

CIE Central Bureau,
Kegelgasse 27, A-1030 Vienna, Austria

S 007/E

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Protection of the skin

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Foreword

Standards produced by the Commission Internationale de l'Éclairage (CIE) are a concise documentation of data defining aspects of light and lighting, for which international harmony requires such unique definition. CIE Standards are therefore a primary source of internationally accepted and agreed data, which can be taken, essentially unaltered, into universal standard systems.

The CIE undertook a major review of its official recommendations on photobiological effects, their dose relationships and measurement. Based on these investigations the present standard describes present day knowledge of the subject.

This Standard has been approved by the National Committees of the CIE and supersedes the recommendations made in Publication *CIE* **106/4** - 1993 (reprint from *CIE-Journal* **6/1** 17-22 1987) *A reference action spectrum for ultraviolet induced erythema in human skin.*

This CIE Standard reflects present day knowledge of UV radiation effect on humans, specially erythema, but does not absolve those carrying out experiments with humans from their responsibility for the safety and well being of the subjects involved.

1. 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 UVA 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 recognised 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 ultraviolet radiation. Variables which 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 end point, time of reading after exposure, and ambient illumination.

To avoid further confusing misuse of the term *MED*, we propose 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.

2. Scope

This Standard specifies the erythema reference action spectrum ($s_{er}(\lambda)$), and the Standard Erythema Dose (*SED*).

3. Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying most recent editions of the standards indicated below. Members of CIE, the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO) maintain registers of currently valid international standards.

CIE 17.4-1987: International Lighting Vocabulary - equivalent to IEC 50(845)
CIE 90-1991: Sunscreen testing (UVB).
CIE 98-1992: Personal dosimetry of UV radiation.

CIE 103/3-1993: Reference action spectra for ultraviolet induced erythema and pigmentation of different human skin (CIE Collection in Photobiology and Photochemistry).
CIE 125-1997: Standard Erythema Dose, a Review.

4. Definitions

erythema action spectrum ($s_{er}(\lambda)$)
Spectral dependence of the ability of UV radiation to produce erythema in human skin.

Note: It is usual to tabulate and plot the $s_{er}(\lambda)$ normalized to its maximum.

erythemal effective irradiance (E_{er})
Quantity defined by the equation:

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

where E_λ is the spectral irradiance in $W \cdot m^{-2} \cdot nm^{-1}$ and $s_{er}(\lambda)$ is the erythema action spectrum normalized to its maximum.

erythemal effective radiant exposure (H_{er}), also called the effective dose or erythemal dose:
The time integral of erythemal effective irradiance defined by the equation

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

where E_λ is the spectral irradiance in $W \cdot m^{-2} \cdot nm^{-1}$ and $s_{er}(\lambda)$ is the erythema action spectrum.

minimal erythema dose (MED):
A subjective measure based on the reddening of the skin; it depends on many variables, e.g. individual sensitivity to UVR, radiometric characteristics of the source, skin pigmentation, anatomic site, elapsed time between irradiation and observing the reddening (typical value: 24 hours), etc. It should be reserved solely for observational studies in humans and other animals.

standard erythema dose (SED):
Standardised measure of erythemogenic UV radiation, 1 SED is equivalent to an erythemal effective radiant exposure of $100\ J \cdot m^{-2}$.

ultraviolet radiation (UVR):
Optical radiation in the 100 nm to 400 nm wavelength range.

5. The concept of erythemal irradiance and dose

5.1 Erythemal effective irradiance

The erythemal effective irradiance (E_{er}) from a source of ultraviolet 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:

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

or

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

E_λ is the spectral irradiance in $W \cdot m^{-2} \cdot nm^{-1}$ at wavelength λ in nm and $\Delta\lambda$ is the wavelength interval used in the summation. $s_{er}(\lambda)$ is a measure of the effectiveness of radiation of wavelength λ in nm relative to some reference wavelength in producing a minimal erythema. Integration has to be carried out in the wavelength range where neither E_λ or $s_{er}(\lambda)$ equal zero. As it is a ratio, $s(\lambda)$ is of dimension unity. The effective 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 effective radiant exposure (also called the *effective dose* or *erythemal dose*).

The dose (expressed as an *erythemal quantity*) received after an exposure period of *t* seconds is

$$H_{er} = E_{er} \cdot t / \Phi \qquad (2)$$

where Φ is the numerical value in $J \cdot m^{-2}$ equivalent to one *erythemal quantity*.

5.2 The erythema action spectrum

The ability of UV radiation to produce erythema in human skin is highly dependent upon the radiation wavelength, and is expressed by the erythema action spectrum. Erythema action spectra have been the subject of experimental and theoretical interest for over 70 years. The CIE first considered the adoption of a so-called standard erythemal curve in 1935[2]. The erythema action spectrum defined in this standard was first introduced by the CIE in 1987[3] (See also [4-6]). It is represented by relatively simple functions over three clearly defined spectral regions:

$$s_{er}(\lambda) = 1{,}0 \qquad \text{for } 250 \le \lambda \le 298 \text{ nm} \qquad (3)$$

$$s_{er}(\lambda) = 10^{0{,}094(298-\lambda)} \qquad \text{for } 298 < \lambda \le 328 \text{ nm} \qquad (4)$$

$$s_{er}(\lambda) = 10^{0{,}015(140-\lambda)} \qquad \text{for } 328 < \lambda \le 400 \text{ nm} \qquad (5)$$

5.3 The standard erythema dose (erythemal quantity and radiometric equivalence)

There are many biological endpoints in photobiology in which the effectiveness varies with wavelength. For this reason the new quantity shall contain the word *erythema* to make it explicit that we are referring here only to that specific biological response. The term *standard erythema dose*[7], acronym *SED*, shall be used to express this quantity.

1 SED is equivalent to an erythemal effective radiant exposure of $100 \text{ J} \cdot \text{m}^{-2}$.

Note: When deciding upon the numerical value of the radiometric equivalence, the choice is arbitrary - there is no 'right' value. However in order to avoid confusion between *MED* and the *SED* we do not want the *SED* to be interpreted as the *MED* in some particular skin type. Consequently[8] 1 SED is equivalent to an erythemal effective radiant exposure of $100 \text{ J} \cdot \text{m}^{-2}$. The *MED*s in subjects with skin types I to IV would be expected to lie between erythemal effective radiant exposures of $150 \text{ J} \cdot \text{m}^{-2}$ to $600 \text{ J} \cdot \text{m}^{-2}$, equivalent to 1,5 SED to 6 SED.

Annex A: Bibliography (Non-normative annex)

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