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PERSONAL DOSIMETRY OF UV RADIATION

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Foreword

The following members of TC 6-19 "Personal Dosimetry of UV Radiation" took part in the preparation of this Technical Report. The TC comes under CIE Division 6 Photobiology and Photochemistry.

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Personal Dosimetry of UV Radiation

Summary

Natural and artificial ultraviolet radiation (UVR) can induce both beneficial and detrimental effects in man. Humans are exposed not only to natural UVR, but also may be exposed either intentionally or unintentionally to artificial UVR sources (tanning equipments, workplaces, etc.).

Normally people do not maintain a fixed position with respect to the UVR source, and so measurements using a stationary detector can be of limited value. Consequently the exposure dose of radiation can best be determined by means of personal monitoring.

A practicable personal dosimeter for UVR is a polysulphone film, which after exposure to ultraviolet radiation in the spectral range 250 to 330 nm, shows an increase in absorbance at 330 nm. In evaluating actinic radiant exposure, the action spectrum of the photobiological effect under consideration, the spectral power distribution of the UVR source and the spectral response of the personal dosimeter have to be known.

Detailed information on the practical use of polysulphone film is given, together with a description of other UV-sensitive materials that may be suitable for personal UVR dosimetry.

Personendosimetrie von UV-Strahlung

Zusammenfassung

Natürliche und künstliche UV-Strahlung kann sowohl gesundheitsfördernde als auch schädigende Wirkungen hervorrufen. Täglich ist der Mensch nicht nur der natürlichen UV-Strahlung der Sonne ausgesetzt, sondern häufig auch - gewollt oder ungewollt - künstlichen UV-Quellen (Solarien, Arbeitsplätze usw.).

Gewöhnlich befinden sich Personen, deren UV-Expositionen kontrolliert werden sollen, in ständig wechselnden Positionen zur UV-Quelle. Stationäre Messungen mit UV-Radiometern bringen nur begrenzte Aussagen über die reelle Größe der Bestrahlungsdosis. In diesen Fällen ist die Bestrahlungsdosis am sinnvollsten durch UV-Personendosimeter zu ermitteln.

Praktisch einsetzbar für den Bereich 250 bis 330 nm sind Personendosimeter mit Polysulphonfolien, die unter UV-Exposition einen Anstieg der Extinktion bei 330 nm zeigen. Zur Bestimmung der aktinischen Bestrahlungsdosis müssen das Wirkungsspektrum des betrachteten photobiologischen Effektes, die spektrale Strahllichtverteilung der UV-Strahlenquelle und die spektrale Empfindlichkeit der Personendosimeter bekannt sein.

Zur Anwendung von Polysulphonfolie-Dosimetern werden detaillierte Angaben gemacht. Weitere mögliche UV-sensible Materialien, die ebenfalls für UV-Personendosimeter anwendbar wären, werden aufgelistet.

Dosimétrie personnelle des radiations UV

Résumé

Les radiations ultraviolettes naturelles et artificielles (UVR) peuvent déterminer des effets aussi bien bénéfiques que délétères chez l'homme. Les sujets sont exposés non seulement aux UVR naturels, mais peuvent également être exposés, soit intentionnellement, soit non intentionnellement, à des sources d'UVR artificiels (solariums, travaux postés, etc.).

Normalement, les sujets ne restent pas immobiles par rapport à la source UVR, et par conséquent, les mesures utilisant un détecteur fixe ne sont que de valeur limitée. Par conséquent, les doses d'exposition aux radiations peuvent être plus précisément évaluées grâce à l'utilisation de moniteurs personnels.

Un dosimètre personnel utilisable pour l'UVR est réalisé par une feuille de polysulfone, qui, après exposition aux radiations ultraviolettes dans l'intervalle spectral de 250 à 330 nm, présente une augmentation d'absorption à 330 nm.

Outre l'exposition actinique radiante, le spectre d'action de l'effet photobiologique analysé, la distribution énergétique spectrale de la source UVR, et la réponse spectrale doivent être connus.

Des informations détaillées sur l'utilisation pratique des films polysulfone sont fournies, accompagnées d'une description d'autres matériaux sensibles aux UVR qui peuvent être adaptés à la dosimétrie personnelle des UVR.

ABBREVIATIONS AND DEFINITIONS

A	- optical absorbance, $A = \log T$
A_{330}	- optical absorbance at 330 nm
$E_e(\lambda)$	- spectral irradiance
E_{eff}	- actinic irradiance
F	- equivalent dose of monochromatic radiation λ_c , which would produce the same response in the dosimeter as the actual radiation exposure
g	- weighting factor to transform F into H_{eff}
H_e	- radiant exposure, radiant dose
H_{eff}	- actinic radiant exposure, actinic dose
PSF	- polysulphone film
$s(\lambda)_{\text{rel}}$	- relative spectral response of the dosimeter
$s(\lambda)_{\text{eff,rel}}$	- relative action spectrum of the observed biological effect
$s(\lambda)_{\text{ery,rel}}$	- relative action spectrum of skin erythema
$s(\lambda)_{\text{hd,rel}}$	- relative action spectrum of UV health damage of men also called UV hazard spectrum
T_o	- transmittance at 330 nm before UV exposure
T_{exp}	- transmittance at 330 nm after UV exposure
t	- exposure time
UV	- ultra violet
UVA	- UV, $\lambda = 315\ldots 400$ nm
UVR	- ultra violet radiation
ΔA_{330}	- alteration of optical absorbance at 330 nm $\Delta A = -\log(T_{\text{exp}}/T_o)$
λ	- wavelength
λ_c	- wavelength at which the dosimeter has been calibrated
λ_o	- wavelength where the relative action spectrum is normalized to unity
λ_1, λ_2	- wavelength interval of interest

The additivity law of van Krefeld:

The effects of single wavelength bands can be added to an overall effect, as far as the single effects turn out to be independent from each other - even if the blackening curves (or dose response curves) for different wavebands are different.

(This means at the same time that no conductive, i.e. catalytic, or hindering, i.e. antagonistic effects occur.)

Bunsen-Roscoe Law:

If the product of a reaction of a receiver depends only upon the number of absorbed photons, it is unimportant whether the same amount of photons is absorbed within a shorter or a longer time interval.

Therefore in many photochemical reactions the released effect depends on the defined spectral power distribution of the incident radiation and on the product of irradiance E_e and exposure time t ; this means it depends upon the radiant exposure H_e .

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1. INTRODUCTION

Natural and artificial ultraviolet radiation (UVR) can induce both beneficial and detrimental effects in humans. The severity of these effects depends not only on the quantity but also on the quality, or spectral distribution, of the incident radiation. Since many biological species, including man, do not maintain a fixed position with respect to the UVR source, the exposure dose of radiation can best be determined by means of personal monitoring. This report summarizes the recommendations of CIE Division 6 (TC 6-19) for personal monitoring of exposure to UVR.

2. APPLICATIONS OF PERSONAL MONITORING TO UVR

The main areas of application for personal monitoring are in occupational medicine, particularly in the control of exposed workplaces (with respect to maximum permissible radiation exposure limits) and special problems in UV phototherapy, diagnosis and medical research (e.g. dermatology, ophthalmology).

Humans are exposed to UVR either intentionally or unintentionally.

2.1 Intentional exposure

- Sunbathing for relaxation and tanning.
- Cosmetic tanning with artificial sources of UVR.
- Medical therapy mainly in the treatment of skin diseases, particularly psoriasis (sources include both UV lamps and sun exposure in climatotherapy).
- Prophylactic UV exposure in certain UV-deprived groups e.g. housebound elderly.

2.2 Unintentional exposure

- Outdoor occupations including agricultural workers, construction workers, fishermen, gardeners, oil field workers, road workers, police officers, sailors, lifeguards, mountain guides and ski instructors.
- Industrial photoprocesses including electronics industry (photoresists), printing industry (UV drying) and plastics industry (photopolymerization).
- Germicidal applications including disinfection of sewage effluents, drinking water, air in operating theatres, water for the cosmetics industry and swimming pools.
- Electric arc welding.
- Leisure industry including discotheques and cosmetic tanning salons.
- Hospitals including staff working with phototherapy lamps and lamps used for photodermatological and fluorescence diagnosis.
- Dentistry including fluorescence diagnosis and UV curing of dental resins.
- Scientific laboratories, particularly for photophysics and photochemistry.
- Offices including UV component of visible light emitting fluorescent lamps and desk top lamps incorporating tungsten halogen bulbs, and UV lamps used for signature verification by fluorescence.

3. PHOTOBIOLOGICAL EFFECTS OF UV EXPOSURE

3.1 UV-Induced biological processes

Personal monitoring is normally carried out to determine the extent to which a subject has been exposed to UVR causing a particular photobiological response. These responses include:

- UV erythema;
- pigmentation (immediate and delayed);
- skin carcinogenesis;
- cataract formation;