YouVeeShield
think health beauty

WHY THIS DOCUMENT MATTERS

ICNIRP Guidelines

GUIDELINES ON LIMITS OF EXPOSURE TO ULTRAVIOLET RADIATION OF WAVELENGTHS BETWEEN 180 NM AND 400 NM (INCOHERENT OPTICAL RADIATION)

The International Commission on Non-Ionizing Radiation Protection

Please refer to the content of the highlighted paragraphs page 171:

"The Committee recognized that when standards or exposure limits (ELs) are established, various value judgments are made."

"However, the limits represent conditions under which it is expected that nearly all individuals may be repeatedly exposed without acute adverse effects and, based upon best available evidence, without noticeable risk of delayed effects."

"...it is not possible to provide a single exposure limit that applies to all skin phototypes. Additional guidance is required for applying guidelines for skin protection."

Please refer to highlighted content on page 175.

"It should be emphasized that many individuals who are exposed to photosensitizing agents (ingested or externally applied chemicals, e.g., in cosmetics, foods, drugs, industrial chemicals, etc.) probably will not be aware of their heightened sensitivity."

WHY SHOULD YOU CARE?

"Sadly, most people have no idea that they have increased UV sensitivity—whether it is due to a medication, supplement, or medical state. They may or may *see* the potential damages immediately after an exposure to a UV lamp, but will suffer the consequences from the cumulative exposures at an accelerated rate as compared to an individual without UV sensitivity." Dr. Chris Adigun.

GUIDELINES ON LIMITS OF EXPOSURE TO ULTRAVIOLET RADIATION OF WAVELENGTHS BETWEEN 180 NM AND 400 NM (INCOHERENT OPTICAL RADIATION)

The International Commission on Non-Ionizing Radiation Protection*

INTRODUCTION

SINCE THE publication of the ICNIRP *Guidelines on UV Radiation Limits* (ICNIRP 1996),[†] recent research has made it appropriate to update the guidelines for protection. While no significant changes are made in the values, the biological basis can be strengthened, and the limitations on use can be clarified.

A document titled *Environmental Health Criteria 160, Ultraviolet Radiation* (UNEP 1994), was published in 1994 under the joint sponsorship of the United Nations Environment Programme (UNEP), ICNIRP, and the World Health Organization (WHO). The document contains a review of the biological effects reported from exposure to ultraviolet radiation (UVR) and serves as the scientific rationale for the development of these guidelines. In addition, the International Agency for Cancer Research (IARC) published a monograph on UVR in 1992 (IARC 1992) and published a monograph on sunscreens more recently (IARC/WHO 2001). Furthermore, the National Radiological Protection Board (NRPB) has recently published a scientific review of the health effects of UVR (NRPB 2002). Reviews of relevant UVR biological action spectra were published in a monograph on the measurement of optical radiation hazards (ICNIRP/CIE 1998). The important publications that relate most directly to the guidelines [some of which have appeared since the Environmental Health Criteria (EHC) document was drafted] are referenced in the rationale (Appendix).

The purpose of these guidelines is to provide basic principles of protection against non-coherent ultraviolet radiation, so that they may serve as guidance to the various international and national bodies or individual experts who are responsible for the development of regulations, recommendations, or codes of practice to protect workers and the general public from the potentially adverse effects of UVR.

The Committee recognized that when standards or exposure limits (ELs) are established, various value judgments are made. The validity of scientific reports has to be considered, and extrapolations from animal experiments to effects on humans have to be made. Costs vs. benefit analyses are necessary, including economic impact of controls. The limits in these guidelines were based on the scientific data, and no consideration was given to economic impact or other non-scientific priorities. However, the limits represent conditions under which it is expected that nearly all individuals may be repeatedly exposed without acute adverse effects and, based upon best available evidence, without noticeable risk of delayed effects (see paragraph on Special Considerations). Although a single set of limits can apply for exposure of the eye, it is not possible to provide a single exposure limit that applies to all skin phototypes. Additional guidance is required for applying guidelines for skin protection.

ICNIRP Subcommittee IV (Optical Radiation) prepared the initial update of these guidelines after an extensive review of the current scientific evidence. The IRPA Associate Societies as well as a number of competent institutions and individual experts were consulted in the preparation of the guidelines and their cooperation is gratefully acknowledged.

In its review of the whole database, ICNIRP noted that a substantial number of studies have been published since 1989, when the last detailed rationale for the guidelines was published, and since the UNEP/ICNIRP/WHO EHC was published in 1994. Many of the biological effects, where only tentative data were available in 1994, have now been clarified. In particular, the understanding of UVA-induced damage to DNA by indirect mechanisms, the involvement

* ICNIRP, c/o BfS—R. Matthes, Ingolstaedter Landstr. 1, 85764 Oberschleissheim, Germany.

[†] The initial guidelines were published in Health Phys 49:331–340; 1985, amended in Health Phys 56:971–972; 1989, and reconfirmed by ICNIRP in Health Phys 71:978; 1996.

For correspondence or reprints contact: R. Matthes at the above address or email at info@icnirp.org.

(*Manuscript received* 5 *February* 2004; *accepted* 30 *April* 2004)
0017-9078/04/0

of new mechanisms for cell protection against the harmful effects of photosensitized reactions, and the participation of UVA in the chain of events believed to play a role in melanocytic and non-melanocytic skin cancer provide a better understanding of the risk of human exposure to UVR. There is further evidence for the importance of early life (childhood and adolescence) irradiation for melanocytic skin cancer (IARC/WHO 2001) and probably for basal cell carcinoma (Kricker et al. 1995; Gallagher et al. 1995a, b). There has been significant improvement in the understanding of the complex chain of events involved in photocarcinogenesis, e.g., the discovery of a UVR signature at the molecular level (i.e., the p53 gene mutation) (Mukhtar and Elmets 1996; IARC 1992). Progress has also been made in standardizing several action spectra including those for photocarcinogenesis and erythema by the International Commission on Illumination (CIE 1999, 2000, 2002).

It was noted, however, that a number of issues still need further research before a more complete health risk assessment can be made. These include the modulation of the immune system by both UVA and UVB and their interaction with several chromophores; the apparent role of UVA in the development of melanocytic skin cancer; and the role of both UVA and UVB in the development of different types of cataract (UNEP 1994). The International Agency for Research on Cancer (IARC) of the WHO recently reviewed the impact of sunscreens (IARC/WHO 2001).

ICNIRP concludes that, while significant clarification has occurred with respect to health risk assessment from exposure to UVR, recent data do not provide any results suggesting that the exposure limit values contained in Table 1 of the 1989 guidelines need to be amended. This conclusion is supported by a review conducted by the National Radiological Protection Board (NRPB 2002). Thus, ICNIRP reaffirms the 1989 guidelines on exposure limits to UVR as valid for current use. ICNIRP will continue to monitor the scientific literature and amend the guidelines on exposure limits as necessary.

BACKGROUND

Ultraviolet radiation (UVR) occupies that portion of the electromagnetic spectrum from at least 100 to 400 nanometers (nm). In discussing UVR biological effects, the International Commission on Illumination (CIE) has

Table 1. UV exposure limits and spectral weighting function.

λ[a] (nm)	EL[d] (J m^{-2})	EL[d] (mJ cm^{-2})	$S(\lambda)$[b]	λ[a] (nm)	EL[d] (J m^{-2})	EL[d] (mJ cm^{-2})	$S(\lambda)$[b]
180	2,500	250	0.012	310	2,000	200	0.015
190	1,600	160	0.019	313[c]	5,000	500	0.006
200	1,000	100	0.030	315	1.0×10^4	1.0×10^3	0.003
205	590	59	0.051	316	1.3×10^4	1.3×10^3	0.0024
210	400	40	0.075	317	1.5×10^4	1.5×10^3	0.0020
215	320	32	0.095	318	1.9×10^4	1.9×10^3	0.0016
220	250	25	0.120	319	2.5×10^4	2.5×10^3	0.0012
225	200	20	0.150	320	2.9×10^4	2.9×10^3	0.0010
230	160	16	0.190	322	4.5×10^4	4.5×10^3	0.00067
235	130	13	0.240	323	5.6×10^4	5.6×10^3	0.00054
240	100	10	0.300	325	6.0×10^4	6.0×10^3	0.00050
245	83	8.3	0.360	328	6.8×10^4	6.8×10^3	0.00044
250	70	7	0.430	330	7.3×10^4	7.3×10^3	0.00041
254[c]	60	6	0.500	333	8.1×10^4	8.1×10^3	0.00037
255	58	5.8	0.520	335	8.8×10^4	8.8×10^3	0.00034
260	46	4.6	0.650	340	1.1×10^5	1.1×10^4	0.00028
265	37	3.7	0.810	345	1.3×10^5	1.3×10^4	0.00024
270	30	3.0	1.000	350	1.5×10^5	1.5×10^4	0.00020
275	31	3.1	0.960	355	1.9×10^5	1.9×10^4	0.00016
280[c]	34	3.4	0.880	360	2.3×10^5	2.3×10^4	0.00013
285	39	3.9	0.770	365[c]	2.7×10^5	2.7×10^4	0.00011
290	47	4.7	0.640	370	3.2×10^5	3.2×10^4	0.000093
295	56	5.6	0.540	375	3.9×10^5	3.9×10^4	0.000077
297[c]	65	6.5	0.460	380	4.7×10^5	4.7×10^4	0.000064
300	100	10	0.300	385	5.7×10^5	5.7×10^4	0.000053
303[c]	250	25	0.120	390	6.8×10^5	6.8×10^4	0.000044
305	500	50	0.060	395	8.3×10^5	8.3×10^4	0.000036
308	1,200	120	0.026	400	1.0×10^6	1.0×10^5	0.000030

[a] Wavelengths chosen are representative; other values should be interpolated (see Eqns. 2a–c).
[b] Relative spectral effectiveness.
[c] Emission lines of a mercury discharge spectrum.
[d] EL for a monochromatic source, but also limited by a dose-rate of 10 kW m^{-2} (1 W cm^{-2}) for durations greater than 1 s as well in order to preclude thermal effects.

divided the UV spectrum into three bands. The band 315 to 380–400 nm is designated as UVA, 280 to 315 nm as UVB, and 100 to 280 nm as UVC (CIE 1987, 1999). Wavelengths below 180 nm (vacuum UV) are of little practical biologic significance since they are readily absorbed in air. Ultraviolet radiation is used in a wide variety of medical and industrial processes and for cosmetic purposes. These include photocuring of inks and plastics (UVA and UVB), photoresist processes (all UV), solar simulation (all UV), cosmetic tanning (UVA and UVB), fade testing (UVA and UVB), dermatology (all UV), and dentistry (UVA). Even though the principal operating wavelengths for most of these processes are in the UVA, almost always some shorter wavelength (UVB and UVC) radiation and violet light are emitted as well. Many industrial applications employ arc sources for heat or light (e.g., welding), which also produce UVR as an unwanted admixture for which control measures may be necessary. While it is generally agreed that some low-level exposure to UVR benefits health (UNEP 1994; Preece et al. 1975; Clemens et al. 1982; Holick 2000; Webb et al. 1988, 1989; MacLaughlin and Holick 1985), there are adverse effects (de Gruijl 1997; UNEP 1994; ICNIRP/CIE 1998) that necessitate the development and use of ELs for UVR. However, the development of UVR EL poses a real challenge to achieve a realistic balance between beneficial and adverse health effects.

Until 1980, it was generally thought that the most significant adverse UVR health effects resulted from exposures at wavelengths below 315 nm; but today these effects are recognized to be produced at longer wavelengths (UVA) at substantially higher doses. At one time, wavelengths below 315 nm were collectively known as "actinic radiation," when it was thought that these effects occurred only in the UVB and UVC. This guideline has been limited to wavelengths greater than 180 nm where UVR is transmitted through air. The most restrictive limits are for exposure to radiation having those wavelengths less than 315 nm.

PURPOSE AND SCOPE

The purpose of this document is to provide guidance on maximal limits of exposure to UVR in the spectral region between 180 nm and 400 nm. The limits represent conditions under which it is expected that nearly all individuals may be repeatedly exposed without acute adverse effects and, based upon best available evidence, without noticeable risk of delayed effects (see paragraph on Special Considerations). These EL values for exposure of the eye or the skin may be used to evaluate potentially hazardous exposure from UVR; e.g., from arcs, gas and vapor discharges, fluorescent lamps, incandescent sources, and solar radiation. The limits do not apply to lasers that emit UVR. Most incoherent UVR sources are broadband, although single emission lines can be produced from low-pressure gas discharges. These values should be used as guides in the control of exposure to both pulsed and continuous sources where the exposure duration is not less than 1 μs. These ELs are below levels that would be used for UV exposures of patients required as a part of medical treatment or for elective cosmetic purposes. These ELs are exceeded for exposed skin by noonday summer sunlight overhead at 0–40° latitude within 5–10 min. The ELs should be considered absolute limits for direct exposure of the eye and "advisory" for skin exposure because of the wide range of susceptibility to skin injury depending on skin type. The ELs should be adequate to protect lightly pigmented individuals.

BASIC CONCEPTS

This document makes use of the spectral band designations of the CIE. Unless otherwise stated, UVA is from 315 to 400 nm, UVB is from 280 to 315 nm, and UVC is from 100 to 280 nm (CIE 1984, 1987). It should be noted that some specialists follow this general scheme but take the dividing line between UVA and UVB at 320 nm. The UVR exposure should be quantified in terms of an irradiance E (W m^{-2} or W cm^{-2}) for continuous exposure or in terms of a radiant exposure H (J m^{-2} or J cm^{-2}) for time-limited (or pulsed) exposures of the eye and skin. The geometry of exposure to UVR is very important. For example, the eyes (and to a lesser extent the skin) are anatomically protected against UVR exposure from overhead sources such as the sun overhead (Sliney 1995; UNEP 1994). The limits should be applied to exposure directed perpendicular to those surfaces of the body facing the radiation source, measured with an instrument having cosine angular response (UNEP 1994). For highly non-uniform irradiation the irradiance and radiant exposure need not be averaged over the area of a circular measurement aperture smaller than 1 mm in diameter for pulsed exposures and 3.5 mm for lengthy exposures.

These ELs should be used as guides in the control of exposure to UV sources and as such are intended as limits for non-therapeutic and non-elective exposure. The ELs should be considered as absolute limits for ocular exposure. The ELs were developed by considering lightly pigmented populations (i.e., white Caucasian) with greatest sensitivity and genetic predisposition for skin cancer. Exposure during sun bathing and tanning under artificial sources may well exceed these limits but exposed individuals should be advised that some health risk is incurred from such activity. Eye protection is always required during therapeutic exposures. Nevertheless, occasional exposures to conditioned skin may not result in adverse effects. The rationale for the UVR exposure limits is provided in the Appendix.

EXPOSURE LIMITS

For the EL for both general and occupational exposure to UVR incident upon the skin or eye within an 8-h period, the following applies.

Exposure of the eyes

Ultraviolet radiant exposure in the spectral region 180 to 400 nm incident upon the unprotected eye(s) should not exceed 30 J m^{-2} effective spectrally weighted using the spectral weighting factors contained in Table 1, and the total (unweighted) ultraviolet radiant exposure in the spectral region 315 to 400 nm should not exceed 10^4 J m^{-2}.

Exposure of the skin

For the most sensitive, non-pathologic, skin phototypes (known as "melano-compromised"), ultraviolet radiant exposure in the spectral region 180 to 400 nm upon the unprotected skin should not exceed 30 J m^{-2} effective spectrally weighted using the spectral weighting factors contained in Table 1. This limit should be considered a desirable goal for skin exposure to minimize the long-term risk, but it must be recognized that this limit is difficult to achieve in sunlight and judgment must be used in its practical application. It has a very substantial safety factor for dark skin phototypes (known as "melano-competent") and more generally for individuals who have been conditioned by previous, repeated exposures (known as "melano-adapted," i.e., tanned).

To determine the effective irradiance of a broadband source weighted against the peak of the spectral effectiveness curve (270 nm), the following weighting formula should be used:

$$E_{eff} = \Sigma\, E_\lambda \cdot S(\lambda) \cdot \Delta\lambda, \quad (1)$$

where:

E_{eff} = effective irradiance in μW cm^{-2} (μJ s^{-1} cm^{-2}) or W m^{-2} (J s^{-1} m^{-2}) normalized to a monochromatic source at 270 nm;

E_λ = spectral irradiance from measurements in μW cm^{-2} nm^{-1} or W m^{-2} nm^{-1};

$S(\lambda)$ = relative spectral effectiveness (unitless); and

$\Delta\lambda$ = bandwidth in nanometers of the calculation or measurement intervals.

Permissible exposure time in seconds for exposure to UVR incident upon the unprotected skin or eye may be computed by dividing 30 J m^{-2} by the value of E_{eff} in W m^{-2}. The maximal exposure duration may also be determined using Table 2, which provides representative exposure durations corresponding to effective irradiances in W m^{-2} or μW cm^{-2}.

Values of $S(\lambda)$ for wavelengths that are not listed in Table 1 may be interpolated through the application of the following three formulas (Wester 2000). The three simple mathematical expressions apply in the range only from 210–400 nm:

For the region

$$210 \le \lambda \le 270 \text{ nm } S(\lambda) = 0.959^{(270-\lambda)} \quad (2a)$$

For the region

$$270 < \lambda \le 300 \text{ nm } S(\lambda) = 1 - 0.36x\left(\frac{\lambda - 270}{20}\right)^{1.64} \quad (2b)$$

For the region

$$300 < \lambda \le 400 \text{ nm } S(\lambda) = 0.3 \times 0.736^{(\lambda-300)} + 10^{(2-0.0163\lambda)}. \quad (2c)$$

The formulae interpolate between and substitute with reasonable accuracy the points along the action spectrum.

SPECIAL CONSIDERATIONS

These EL values are intended to apply to UVR exposure of the working population, but with some precaution also apply to the general population. However, it should be recognized that some rare, highly

Table 2. Limiting UV exposure durations based on exposure limits.

Duration of exposure per day	Effective irradiance	
	E_{eff} (W m^{-2})	E_{eff} (μW cm^{-2})
8 h	0.001	0.1
4 h	0.002	0.2
2 h	0.004	0.4
1 h	0.008	0.8
30 min	0.017	1.7
15 min	0.033	3.3
10 min	0.05	5
5 min	0.1	10
1 min	0.5	50
30 s	1.0	100
10 s	3.0	300
1 s	30	3,000
0.5 s	60	6,000
0.1 s	300	30,000

photosensitive individuals exist who may react adversely to exposure at these levels. These individuals are normally aware of their heightened sensitivity. Likewise, if individuals are concomitantly exposed to photosensitizing agents (Fitzpatrick et al. 1974; Johnson 1992), a photosensitizing reaction can take place. It should be emphasized that many individuals who are exposed to photosensitizing agents (ingested or externally applied chemicals, e.g., in cosmetics, foods, drugs, industrial chemicals, etc.) probably will not be aware of their heightened sensitivity. Phototoxic reactions apply to all individuals and depend upon the quantity of photosensitizing chemicals and the UVR exposure, whereas photoallergic reactions will be observed for much lower quantities of the substance in sensitized individuals. Lightly pigmented individuals conditioned by previous UVR exposure (leading to tanning and hyperplasia) and heavily pigmented individuals can tolerate skin exposure in excess of the EL without erythemal effects. However, repeated tanning may increase the risk for those persons later developing signs of accelerated skin aging and even skin cancer. Such risks should be understood prior to the use of UVR for medical phototherapy or cosmetic exposures.

PROTECTIVE MEASURES

Protective measures will differ depending upon whether the UVR exposure results from sunlight or from artificial sources. The use of hats, eye protectors, clothing, and sun-shading structures are practical protective measures to reduce sunlight exposure. When these measures are inadequate, topical sunscreens should be applied to the skin. However, the value of sunscreens has been questioned, and an IARC Working Group on the Evaluation of Cancer-Preventive Agents concluded that there was inadequate epidemiological evidence in humans for a cancer-preventive effect of topical use of sunscreen formulations against cutaneous malignant melanoma, or basal-cell carcinoma, despite the experimental evidence in animal studies (IARC/WHO 2001).

When exposure is to artificial sources, as in some industrial hazard situations, engineering control measures are preferable to protective clothing, goggles, and procedural safety measures. Glass envelopes for arc lamps will filter out most UVB and UVC. Where lengthy exposure to high power glass-envelope lamps and quartz halogen lamps will occur at close proximity, additional glass filtration may be necessary (McKinlay et al. 1989). Light-tight cabinets and enclosures and UVR absorbing glass and plastic shielding are the key engineering control measures used to prevent human exposure to hazardous UVR produced in many industrial applications such as the fade testing of materials, solar simulation, photoresist applications, and photocuring. For arc welding, cabinets are not practical. Shields, curtains, barriers, and a suitable separation distance are used to protect individuals against the UVR emitted by open-arc processes such as arc welding, arc-cutting, and plasma spraying. Dynamic-filter welding helmets and see-through curtains have improved the safety of welding operations in recent decades. There is a need for operational rules to protect potentially exposed individuals. Operators should be trained to follow these general rules properly. Ventilation may be required to exhaust ozone and other airborne contaminants produced by UVC radiation.

MEASUREMENT

UV measurements for health risk evaluation are sometimes of value for indoor exposure assessment. However, they are generally not routinely performed for outdoor exposure conditions, except with regard to the use of the Global UV Index (ICNIRP/WHO/WMO/UNEP 2002; Gies et al. 1995).

Although direct-reading UVR radiometers exist, attempts to produce relatively inexpensive field safety survey meters that respond directly to UVB and UVC radiation [following the $S(\lambda)$ function] have not been fully successful. However, relatively expensive instruments exist which respond to UVB and UVC radiation according to the relative spectral effectiveness, $S(\lambda)$. Spectroradiometric measurements of the source which can then be used with the $S(\lambda)$ weighting function to calculate E_{eff} are often necessary for measurements more accurate than those with simple, direct-reading safety meters. Whichever measurement technique is applied, the geometry of measurement is important. All the preceding ELs for UVR apply to exposures that are measured with an instrument having a cosine-response detector oriented perpendicular to the most directly exposed surfaces of the body when assessing skin exposure. The detector is oriented along (or parallel to) the line(s) of sight of each exposed individual when assessing ocular exposure. The use of UV film badges makes it possible to integrate UV exposure on specific body sites which move with respect to the UVR source (Diffey et al. 1977; Saunders and Diffey 1995); however, the spectral response of such film badges still does not accurately follow $S(\lambda)$.

For outdoor exposure, environmental UVR measurements may be of limited use for individual dose assessment because of geometrically changing exposure conditions and human behavioral considerations. Personal dosimeters must properly take into consideration the exposed sites of the individual, time of exposure, sun angle, etc. The Global UV Index can be a useful tool in educating persons who are outdoors as to the changing level of overhead UVR. It is, however, not very predictive of ocular exposure since it is a measure of the overhead UVR incident on a horizontal surface. Ocular exposure is highly dependent upon ground reflectance factors and the upper lid and brow-ridge block most overhead UVR (Sliney 1995).

CONCLUDING REMARKS

Greater attention should be paid to the potential hazards of UVR exposure. The increasing socially driven solar exposure as well as the increasing use of artificial UVR sources is a cause for concern. In many populations, skin cancer incidence continues to rise, due in large part to a poor appreciation of the risk among the general population. Reduction of risk by avoidance of needless sunlight exposure and by physical means of protection should be an important public health goal. Improved educational programs are needed for school children, for outdoor workers and the general public. The present understanding of injury mechanisms and long-term effects of exposure to UVR is incomplete, and awaits further research. The above guidelines will be subject to periodic review and amendment as appropriate.

Acknowledgments—The support received by ICNIRP from the International Radiation Protection Association, the World Health Organization, the International Labor Office, the European Commission, and the German Government is gratefully acknowledged.

During the preparation of these guidelines, the composition of the International Commission on Non-Ionizing Radiation Protection was as follows:
A.F. McKinlay, Chairman (UK)
J.H. Bernhardt, Vice-chairman (Germany)
A. Ahlbom (Sweden)
J-P. Césarini (France)
F. R. de Gruijl (The Netherlands)
M. Hietanen (Finland)
R. Owen (USA)
D.H. Sliney (USA)
P. Söderberg (Sweden)
A.J. Swerdlow (United Kingdom)
M. Taki (Japan)
T.S. Tenforde (USA)
P. Vecchia (Italy)
B. Veyret (France)
R. Matthes, Scientific Secretary (Germany)
M.H. Repacholi, chairman emeritus (Switzerland)

During the preparation of this document, the composition of the ICNIRP Standing Committee IV and task group was:
D.H. Sliney (USA), Chairman
J-P. Césarini (France)
F. R. de Gruijl (The Netherlands)
B. Diffey (U.K.)
M. Hietanen (Finland)
M.A. Mainster (USA)
T. Okuno (Japan)
P. Söderberg (Sweden)
B.E. Stuck (USA)

REFERENCES

Anders A, Petry H, Fleming C, Petry K, Brix P, Luke W, Groger H, Schneider E, Kiefer J, Anders F. Increasing melanoma incidence: Putatively explainable by retrotransposons—Experimental contribution of the Xiphophorine Gordon-Kosswig Melanoma System. Pigment Cell Res 7:433–450; 1994.

Anders A, Altheide H, Knalmann M, Tronnier H. Action spectrum for erythema in humans investigated with dye lasers. Photochem Photobiol 61:200–205; 1995.

Andreassi K, Simoni S, Fiorini P, Fiamiani M. Phenotypic characters related to skin type and minimal erythema dose. Photodermatol 4:43–46; 1987.

Armstrong BK, Kricker, A. How much melanoma is caused by sun exposure? Melanoma Res 3:395–401; 1993.

Armstrong BK, Kricker A. Cutaneous melanoma. Cancer Surveys 19:219–240; 1994.

Azizi E, Lusky A, Kushelevsky AP, Schewach-Millet M. Skin type, hair colour, and freckles are predictors of decreased minimal erythema ultraviolet radiation dose. J Am Acad Dermatol 19:32–38; 1988.

Bastiaens MT, ter Huuren JA, Kielech C, Gruis NA, Westendorp RG, Vermeer BJ, Bavinck JN. Melanocortin-1 receptor gene variants determine the risk of non-melanoma skin cancer independently of fair skin and red hair. Am J Hum Genet 68:884–894; 2001.

Berger D, Urbach F, Davies RE. The action spectrum of erythema induced by ultraviolet radiation (Preliminary Report XIII). In: Jadassohn W, Schirren CG, eds. Proceedings of the Congressus Internationalis Dermatologiae-Munchen 1967. New York: Springer-Verlag; 1968: 1112–1117.

Brash DE, Rudolph JA, Simon JA, Lin A, McKenna GJ, Baden HP, Halperin AJ, Ponten J. A role for sunlight in skin cancer: UV-induced p53 mutations in squamous cell carcinoma. Proc Natl Acad Sci USA 88:10124–10128; 1991.

Cesarini JP. Ultraviolet radiation: Biological effects and health consequences. In: Matthes R, Bernhardt JH, Taki M, eds. Non-ionizing radiation, Proceedings of the 3rd International Non-Ionizing Radiation Workshop, Baden (Austria), April 22–26, 1996. Munich: ICNIRP; 1996: 55–76.

CIE. Comptes Rendues de la Commission Internationale de l'éclairage. Berlin: CIE; 9:596–625; 1935.

CIE. The spectroradiometric measurement of light sources. Vienna: Commission Internationale de l'Eclairage; Pub. No 63; 1984.

CIE. International lighting vocabulary. Vienna: Commission Internationale de l'Eclairage (International Commission on Illumination); Publication CIE No 17 (E-1.1); 1987.

CIE. Erythema reference action spectrum and standard erythema dose. Vienna: CIE; 1998.

CIE. Erythemal reference action spectrum and standard erythemal dose. Vienna: CIE; CIE Standard S007–1998; also available as ISO 17166; 1999a.

CIE. Standardization of the terms UV-A1, UV-A2 and UV-B. Vienna: CIE; Report CIE-134/1; 1999b.