Research Note

Prophylactic UV Radiation and CIE Standard on Photobiological Safety of Lamps and Lamp Systems

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ABSTRACT

Two aspects of UV photobiology have come up almost simultaneously for discussion. On the one hand, the CIE has, for all practical purposes, completed discussions of a new standard "CIE S 009/E: 2002 Photobiological Safety of Lamps and Lamp Systems"¹⁾, and it was adopted without any amendments. On the other hand, some national standards (for example, in Russia) have for decades insisted on UVA+UVB radiation being used for prophylactic purposes at actinic erythema doses (around 140 J m⁻² per 8 hours of irradiation), which are significantly higher than prohibitive doses of actinic UV hazard (30 J m⁻²) suggested in the CIE standard.

It seems that this arisen situation is to be thought about more carefully.

KEYWORDS : prophylactic UV radiation, erythema, UV hazard exposure limit for the skin, exposure time

1. Introduction

The problems of standards for irradiation units and of the safety of their use are as topical as ever. The new standard CIE S 009/E: 2002 Photobiological Safety of Lamps and Lamp Systems²⁾ should be applied competently and with caution, with careful amendments introduced on a number of points.

2. Description of problem

2.1 Analysis of the CIE standard

It is known that the dependence of photoreaction of the biological receiver on a level of influence of optical radiation (OR) in all spectral range of the near earth sun has the universal feature: from a threshold level through favorable influence of different intensity of radiation up to levels of unfavorable and even harmful action³⁾. Therefore attempts are quite natural to introduce the well-founded restrictions on level of illumination (irradiation) in terms of unfavorable influence of OR on the men. An example of such *restrictive* standard is the CIE standard S 009/E: 2002.

According to this standard the recommended effective exposure limit should not exceed 30 J m⁻² for the 200-400 nm range:

$$E_{st} = \sum_{200}^{400} \sum_t E_{\lambda}(\lambda, t) S(\lambda) \Delta \lambda \Delta t < 30 \text{ J m}^{-2} \quad (1)$$

where $E_{\lambda}(\lambda, t)$ is the spectral irradiance, W m⁻²nm⁻¹;

$S(\lambda)$ is the actinic ultraviolet hazard weighting function (fig.1a); $\Delta \lambda$ is the bandwidth in nm;

Δt is the exposure time in sec.

E_s is the effective ultraviolet irradiance in W m⁻².

If exposure to radiation is in the course of eight hours, a maximum of permissible irradiance shall be $E_s = 30/8 \cdot 3600 = 1,04 \text{ m W m}^{-2}$.

Figure 1 Proposed CIE action spectra: UV erythema and actinic UV hazard

- a) — actinic UV hazard
b) — erythema

It is known that the most different photoprocesses, proceeding in human organism, get in such wide range lengths of waves³⁾. So, for example, photoceratitis and photoconjunctivitis it is necessary to relate to undoubtedly harmful, irrespective of whether they are shown at a level of a threshold doses (50-100 J m⁻²) or at higher ones. The same reasons are correct for any destructive influence of short-wave UV radiation on a cell level.

Erythema and sunburn are treated as *harmful* in⁴⁾. However, considering erythema influence, follows to mean as a minimum the two spectral range qualitatively different from each other. One of them with $\lambda < 280(300)$ nm should be related to particularly *harmful* range, inclusive a cancer action. This range rather long ago has been included in the USA and Netherlands national standards as dangerous with the threshold dose 30 J m⁻². Photoceratitis and photoconjunctivitis get here too. It is necessary to note that the realization of such levels of short wave UV irradiation in mass lighting installations can be applied to extreme situations, that as a rule do not last long.

Other range with $\lambda > 280$ nm at adequate regulations can be useful for human health.

So it is absolutely not occasionally that from a regulation according to (1) in the standard¹⁾ considered the UV-A range (315-400 nm), which is widely used

recently in solariums, was removed with its appropriate dose of irradiation. For this spectral region by us, the total radiant exposure for unprotected eye should not exceed 10000.

J m⁻² for exposure time less than 1000 s. For exposure time greater than 1000 s the UVA irradiance for unprotected eye should not exceed 10 W m⁻².

These specification can be expressed as follows:

$$E_{\text{UVA}} t = \sum_{315}^{400} \sum_t E_{\lambda}(\lambda, t) \Delta \lambda \Delta t \leq 10000 \quad (\text{J m}^{-2}) \quad (t < 1000 \text{ s}) \quad (2a)$$

$$E_{\text{UVA}} \leq 10 \quad (\text{W m}^{-2}) \quad (t \geq 1000 \text{ s}) \quad (2b)$$

where $E_{\lambda}(\lambda, t)$ is the spectral irradiance in W m⁻² nm⁻¹; $\Delta \lambda$, Δt are the same as in (1).

The dose in spectral region 315 nm to 400 nm (UVA) in 300 times exceeds the norm in region (200-400 nm) according to (1) and more than 10 years is used in solariums.

Table1 Effective radiant exposure from erythematous fluorescent lamps

Kind of premises	Exposure time, hour/day	Erythema irradiance, E_{er} , * mer m ⁻² *** (recommended)	Dose, $E_{\text{er}} t$, ** mer hour m ⁻² J m ⁻² (effective)
Work room of industrial and public buildings	8	5.0	40/144
Collective premises of children's institutions, classrooms and studies in schools, hospital and sanatorium wards	4-6	5.0	20-30/72-108

* On the horizontal plane on the level of 1 meter above the floor, in children's institutions
— on the level of 0.8 meter above the floor.

** If the exposure time is different, UV irradiance is estimated with account of the need to observe the essential dose.

*** E_{er} , quantitatively equal to the erythematous UV-flux with the length of a wave $\lambda = 297$ nm and capacity 1 W⁷⁾.

The note: In the further consideration the dimension E_{er} is replaced on effective W, as it is accepted in the international standards¹⁾.

Table 2 Summary (various documents)

Document	Dose (effective exposure limit) 200-400 nm, J m ⁻²	Effective UV irradiance, (per 8 hours) 200-400 nm, mW m ⁻²	UVA irradiance (≥ 1000 s exposure) 315-400 nm, W m ⁻²
CIE S 009 / E:2002	30	1,04	≤ 10
MI 5046-89 (USSR)	144 *	5,0 *	-
CIE S 007 / E:1998	100 **	-	-

2.2 Healthy UV radiation

Yet for more long time the prophylactic UV installations are used for compensation of *solar hunger*⁵⁾. The extensive researches, conducted since the 1930s in Europe and the USSR, including in the sphere of space medicine⁶⁾, shows that light exposure to UV radiation in the region 280 - 400 nm have a favorable effect on human health.

Under influence of UV radiation hydrocarbon and albumen metabolism in organism changes. The positive influence of UV radiation on respiratory processes, circulation of the blood, increasing haimaglobus in blood, strengthening immunis is known. The activity of many functions of organism as a result of absorption of UV radiation ensure improve and tonic influence on the man. The photosynthesis of vitamin D concerns to the important photobiological processes realized under influence of UV radiation with $\lambda < 315$ nm. The lack of vitamin D in men organism, arising frequently in northern areas as a result of ultra-violet insufficiency (*solar hunger*), causes frustration of phosphorus-calcium metabolism and other pathological shifts, that is accompanied by sharp decrease of resistance of organism, making it susceptible to unfavorable condition of an environment³⁾.

2.3 The contradictions among standards

The standard for prophylactic (erythematous) radiant exposure (dose), adopted in this country in 1989⁵⁾, are shown in Table 1.

The dose (prophylactic exposure limit $E_{er}t$) in Table 1 is determined as follows:

$$E_{er}t = \sum_{\lambda=280}^{400} \sum_t E_{\lambda}(\lambda, t) S_{er}(\lambda) \Delta t \Delta \lambda, \quad (3)$$

where E_{er} is the effective (erythema) irradiance in $W m^{-2}(er m^{-2})$;

$E_{\lambda}(\lambda, t)$ is the spectral irradiance in the range from $\lambda = 280nm$ to $\lambda = 400 nm$

in $W m^{-2} nm^{-1}$

(bactericidal irradiation with $\lambda < 280 nm$ shall be completely excluded from the radiant spectrum of lamp);

$S_{er}(\lambda)$ is the erythema action spectrum normalized to its maximum (fig.1b), (see CIE S 007/E:1998);

Δt , $\Delta \lambda$ the same as in (1).

The effective (erythema) irradiance, recommended in Table 1, substantially exceeds the effective ultraviolet irradiance E_s magnitude, determined by the standard CIE S 009/ E-2002¹⁾.

The data from few documents is brought together in Table 2.

Before to pass to concrete proposals we shall specify three serious circumstances:

Firstly, as follows from the reference⁸⁾ practically all people suffer from UV shortage in Russia from 1,5 to 5 months in a year.

Secondly, operation and introduction of new prophylactic installations require considerable resources, and consequently any direct or indirect instructions on an opportunity of decrease of quality of the installations or exception them will be perceived not in interests of health of the nation.

So, for example, observance of the CIE standard¹⁾ can result in reduction recommended prophylactic irradiance down to 1-1,5 mW/m^2 that is much lower than the threshold level and it makes these installations practically useless.

Thirdly, it must be taken into account that in the prophylactic installations of long action (about 8 hours and more) erythema lamps are used simultaneously with usual lighting lamps, and in this connection the these installations may be under the action of the CIE S 009/E: 2002 "Photobiological Safety of Lamps and Lamp systems"¹⁾.

3. Conclusion

- (1) To improve CIE S 009/E: 2002 by introduction in it of differentiated standards of safe radiation for at least two zones: UVC and UVB.
- (2) Standards elaborated earlier⁵⁾ for beneficial (prophylactic) UV radiation shall be recognized as standards for UVB+UVA.
- (3) The data of photoconjugativity threshold limits shall be used in the current stage of our knowledge as the differentiated radiation standard for UVC by reducing the former by one order of magnitudes, i.e., to accept the threshold time of some 5 $J m^{-2}$.
- (4) With account of the growing importance of fundamental knowledge in the sphere of effect of radiation on man (higher lighting standards, alarming information about the ozone layer and so on), it shall be deemed expedient to conduct further research for the improvement of radiation (lighting) standards in certain, more detailed, spectrum regions.
- (5) It seems that it would be expedient to further elaborate CIE Standard for prophylactic UV radiation on the basis of the Russian standard⁵⁾ with account of its operation with a positive result over a long period of time.

References

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