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2013-03

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Proceedings of SPIE, Bellingham, v. 8567, 85671K, 2013
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Ocular UV Protection: Revisiting Safe Limits for Sunglasses Standards

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ABSTRACT

The *International Commission on Non-Ionizing Radiation Protection (ICNIRP)* establishes that the safe limits regarding ultraviolet radiation exposure in the spectral region 180nm–400nm incident upon the unprotected eye(s) should not exceed 30 Jm^{-2} effective spectrally weighted (spectral weighting factors are provided by ICNIRP); and the total (unweighted) ultraviolet radiant exposure in the spectral region 315nm–400nm should not exceed 10^4 Jm^{-2} . However, it should be considered that the spectral range from 180nm–280nm does not reach the surface of the Earth, since it is absorbed by the ozone layer of the atmosphere. The Brazilian Standard for sunglasses protection, NBR15111(2004), as well as the British Standard BSEN1836(2005) and American Standard ANZI Z80.3(2009), requires the UV protection in the spectral range 280nm–380nm, but does not take into account the total (unweighted) UVA radiant exposure. These limits are discussed in this work and calculations have been made for 27 state capitals of Brazil to understand the limits that should be involved in order to protect the eyes of the Brazilian population. These calculations and considerations may be extended to other countries as well. As a conclusion, we show that the upper limit for the UVA protection of 400nm should be included in the Brazilian standard, as well as the irradiance limits. Furthermore, the parameters for the resistance to irradiance test required on the Brazilian standard are also discussed herein as well the significance of this test. We show that the test should be performed by the sun simulator for a longer period than currently required.

Keywords: sunglasses UV protection, sunglasses standard, NBR15111 (2004), BSEN1836 (2005).

1. INTRODUCTION

Ultraviolet light (UV) is divided into three regions of the spectrum: UV-A (315-400nm), UV-B (280-315nm), UV-C (240-280nm). A series of recent studies shows that exposure of the cornea to UV irradiation induces pathological changes in its structure [1]. Ultraviolet rays may cause inflammation of the cornea, opacity of the lens (cataract) and harms to the retina. UV exposure of the cornea to high levels or low levels repeatedly, may cause irreversible damage resulting in keratopathies affecting the epithelium and anterior part of the stroma.

For the ocular health, sunglasses should have different levels of UV protection (280nm-400nm) depending on the lens categories - degree of darkening of the lens - established by the sunglasses standards. The categories range from 0-4, depending on transmittance in the visible, ultraviolet and protection (UVA and UVB) should be in accordance with tables 1 and 2, from Brazilian and British standards for UV protection on sunglasses [2, 3].

The sun protection filters for general use are divided into five categories described in Table 1.

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Tabela 1: Transmittance for sunglare filters for general use (Brazilian Standard - NBR15111/2004 [2] and British Standard - BSEN1836 (2005) [3]).

Filter category	Requirements				
	Ultraviolet spectral range		Visible spectral range		
	Maximum value of spectral transmittance $\tau^F(\lambda)$	Maximum value of solar UVA transmittance τ_{SUA}	Range of luminous Transmittance (380 – 780nm) τ^V		
	280 – 315 nm	> 315 – 350 nm	315 – 380 nm	from over %	to %
0	0.1 · τ_V	τ_V	τ_V	80.0	100
1				43.0	80.0
2				18.0	43.0
3				8.0	18.0
4				3.0	8.0

τ_V is the luminous transmittance of sunscreen filter for the standard illuminant D65 CIE. The transmittance τ_V is defined by the equation (1):

$$\tau_V = \frac{\int_{380 \text{ nm}}^{780 \text{ nm}} \tau_F(\lambda) \cdot V(\lambda) \cdot S_{D65\lambda}(\lambda) \cdot d\lambda}{\int_{380 \text{ nm}}^{780 \text{ nm}} V(\lambda) \cdot S_{D65\lambda}(\lambda) \cdot d\lambda} \quad (1)$$

$V(\lambda)$ is the spectral luminous efficiency for daylight vision [4].

$S_{D65\lambda}(\lambda)$ is the spectral distribution of radiation of CIE standard illuminant D 65 [4,5,6].

Solar UV-transmittance τ_{SUV} is the mean of the spectral transmittance between 280 nm and 380 nm weighted with the solar radiation $E_{s\lambda}(\lambda)$ at sea level for air mass 2 and the relative spectral effectiveness function for UV radiation $S(\lambda)$ [2,3], as shown in Table 2.

The complete weighting function $W(\lambda)$ is the product of both, as given by equation (2):

$$W(\lambda) = E_{s\lambda}(\lambda) \cdot S(\lambda) \quad (2)$$

Solar UVA transmittance is given by equation τ_{SUA} 3:

$$\tau_{SUA} = \frac{\int_{315 \text{ nm}}^{380 \text{ nm}} \tau_F(\lambda) \cdot E_{s\lambda}(\lambda) \cdot S(\lambda) \cdot d\lambda}{\int_{315 \text{ nm}}^{380 \text{ nm}} E_{s\lambda}(\lambda) \cdot S(\lambda) \cdot d\lambda} = \frac{\int_{315 \text{ nm}}^{380 \text{ nm}} \tau_F(\lambda) \cdot W_\lambda(\lambda) \cdot d\lambda}{\int_{315 \text{ nm}}^{380 \text{ nm}} W_\lambda(\lambda) \cdot d\lambda} \quad (3)$$

Solar UVB transmittance is given by equation τ_{SUVB} 4:

$$\tau_{\text{SUVB}} = \frac{\int_{280 \text{ nm}}^{315 \text{ nm}} \tau_F(\lambda) \cdot E_{s\lambda}(\lambda) \cdot S(\lambda) \cdot d\lambda}{\int_{280 \text{ nm}}^{315 \text{ nm}} E_{s\lambda}(\lambda) \cdot S(\lambda) \cdot d\lambda} = \frac{\int_{280 \text{ nm}}^{315 \text{ nm}} \tau_F(\lambda) \cdot W_\lambda(\lambda) \cdot d\lambda}{\int_{280 \text{ nm}}^{315 \text{ nm}} W_\lambda(\lambda) \cdot d\lambda} \quad (4)$$

Table 2. Transmittance for sunglare filters for general use of NBR15111(2004) and BSEN1836 (2005) [2,3].

Filter category	Requirements				
	Ultraviolet spectral range			Visible spectral range	
	Maximum value of spectral transmittance $\tau_F(\lambda)$	Maximum value of solar UVA transmittance τ_{SUA}		Range of luminous Transmittance (380 – 780nm) τ_V	
	280 – 315 nm	> 315 – 350 nm	315 – 380 nm	from over %	to %
0				80.0	100
1	0.1 · τ_V	τ_V	τ_V	43.0	80.0
2				18.0	43.0
3		0.5 · τ_V	0.5 · τ_V	8.0	18.0
4				3.0	8.0

As one wears sunglasses, the eyes become unprotected from its natural response of limiting the light entering the ocular medium. Therefore, if sunglasses are not properly protected from UV rays, the eyes may be harmed.

Furthermore, it also important to be acknowledged on the UV protection lifetime, since it deteriorates as sunglasses are exposed to the sun.

One of the requirements of the Brazilian standard NBR15111 is to perform a test irradiating for 25 hours the sunglasses with a solar simulator (450W arc xenon lamp) and then spectroscopically compare the UV protection before and after artificial sun radiation exposure for a predetermined period.

Therefore, the challenge is to determine the correlation of natural Sun exposure period with the standard's requirement simulation period. The correlation may vary from different locations on the Earth and even from different places in the same country, such as in Brazil (continental sized).

2. METHODOLOGY

One of the requirements from the *International Commission on Non-Ionizing Radiation Protection (ICNIRP)* described on the its guidelines for exposure limits of the eyes [7] is that, ultraviolet radiant exposure in the

spectral region 180 nm to 400 nm incident upon the unprotected eye should not exceed 30 J/m² effective spectrally weighted using spectral weighting factors[3, 8, 9, 10] as shown in figure 1[18], and the total (unweighted) ultraviolet radiant exposure in the spectral region 315nm to 400 nm should not exceed 10⁴ J/m².

Brazilian standard NBR15111(2004) is a mirror standard of BS-EN1836(1997)+A1:200[19] Besides considering the UVA range from 280 nm – 380 nm and not up to 400 nm, as required by ICNIRP, only the limits from Tables 1 and 2 are required, not referring to the established exposure limits, as previously described [7].

Figure 1 refers to the relative spectral effectiveness function for UV radiation range 280 nm – 400 nm.

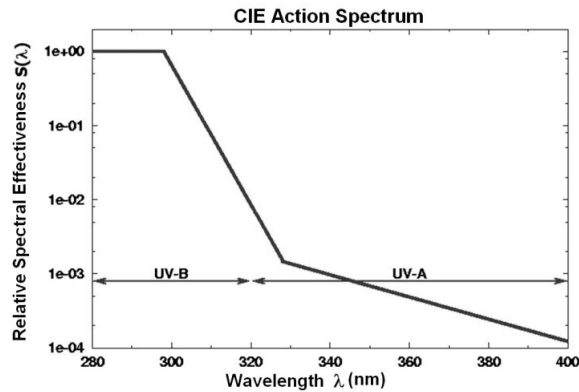


Figure 1. The spectral effectiveness of UVR as a function of wavelength as defined by CIE [11].

Figure 2 shows the total UV radiant exposure (kJ/m²) for Sao Carlos city in Brazil, at the GPS latitude -22°01'03" S, longitude -47°53'27" W and altitude of 854 m for each day of the year 2012. Calculations were carried out using SMARTS2 [20] freeware software with the required adjustments for this study.

3. RESULTS

Statistically, in San Carlos (SP), the amount of radiation that reaches this city considering the integration up to 400nm is on average 46% more than the irradiation when integrating up to 380nm.

One of the standard tests also required by Brazilian standard - NBR15111 (2004) - requires that the lenses of sunglasses are irradiated for 25±0.h, using a xenon arc lamp, free of ozone, as XBO OFR-450. This lamp along with a cut off filter for UVC simulates the solar spectrum. To compare the irradiance of this lamp with irradiance of the sun that reaches the Earth's surface, one must consider the air mass 1.

The air mass one (AM1) is defined by the air mass traversed by radiation to the surface, which angle of incidence - the zenith angle - is equal to zero. For this mass of air, solar irradiance is 1000 W/m² [7].

Using the irradiance data of the lamp XBO450 OFR - OSRAM obtained from a chart provided by the manufacturer for a distance of 500 mm from the lamp, Table 3 was generated, and it determines the equivalence between the irradiance of light that reaches the sunglasses, focusing at 0°, i.e. orthogonal to the lens, and the irradiance of sunlight which reaches the spectacles, when they are positioned in the same condition, i.e. orthogonally to the lamp.

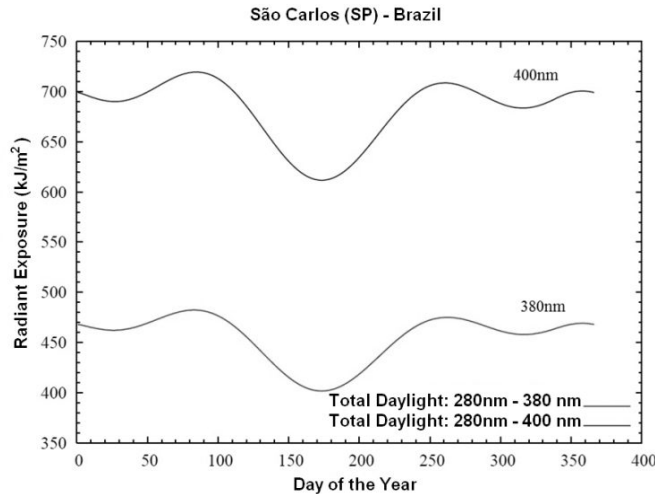


Figure 2. Radiant Exposure expected for São Carlos (SP) city for each day of the year. The 380 nm and 400 nm profiles refer to the entire radiant exposure for Sao Carlos (SP) considering the UV range from 280 nm – 380 nm and from 280 nm – 400 nm, respectively.

Table 3: Equivalence of Irradiance Lamp XBO450 OFR with the Sun, for air mass 1 as a function of distance (d) of the spectacles placed orthogonally from the lamp.

1 Sun = 1000 W/m ²		
XBO450 OFR OSRAM irradiance (W/m ²)	Distance from the bulb d (mm)	Equivalent Number of Suns AM1
466.868	300	0.47
672.289	250	0.67
1050.452	200	1.05
1867.471	150	1.87
4201.809	100	4.20
16807.237	050	16.81

4. DISCUSSION

The Brazilian standard requirement for sunglasses to be irradiated at a distance of 300mm, for 25 hours from the solar simulator is equivalent to 11 hours and 45 minutes of solar irradiation, directly onto the lens of the sunglasses. However it's important to be aware that when sunglasses are worn, the spectacles are not exposed directly to the sun. Most of the time sunglasses are orthogonally exposed to the sun, in another words, the angles of incidence of solar radiation are different in these lens as a function of the daytime, as in the situation when irradiated by the solar simulator.

In effect, it is not at noon or around this time that the sunglasses receive most of the radiation, but in the early hours of the morning and late afternoon - and this time range, as well as the amount of radiation varies with the season.

For illustrating this scenario, Figure 4 shows four situations related to the greater amount of radiation that reaches the sunglasses on specific days of the year there, based on the city of São Carlos (SP) - Brazil. It has been taken into account the geographical position of the city, its respective altitude and angulation of the Earth at this time of year. Moreover, typical atmospheric data as column ozone, water vapor and others were considered. Data for 5500 locations in Brazil

have also been collected and charts for 27 Brazilian state capitals and the city of São Carlos (SP) are also available, for each day of the year, always considering clear sky.

Thus, if a summer day is considered in this particular city, and one wears sunglasses for the periods coincident with the half bandwidth of each of the peaks of the presented bands on figure 4, the radiance that reaches the sunglasses is 1046.303 W/m^2 . In this situation, the irradiance of the lamp (solar simulator) for 25 hours is equivalent to 26 hours and 10 minutes of continuous exposure of sunglasses in the summer sun, i.e., it is equivalent to 11.15 days of use in the summer sun, for the simulated conditions. This means that the test under these conditions for the current Brazilian standard is ineffective without practical significance.

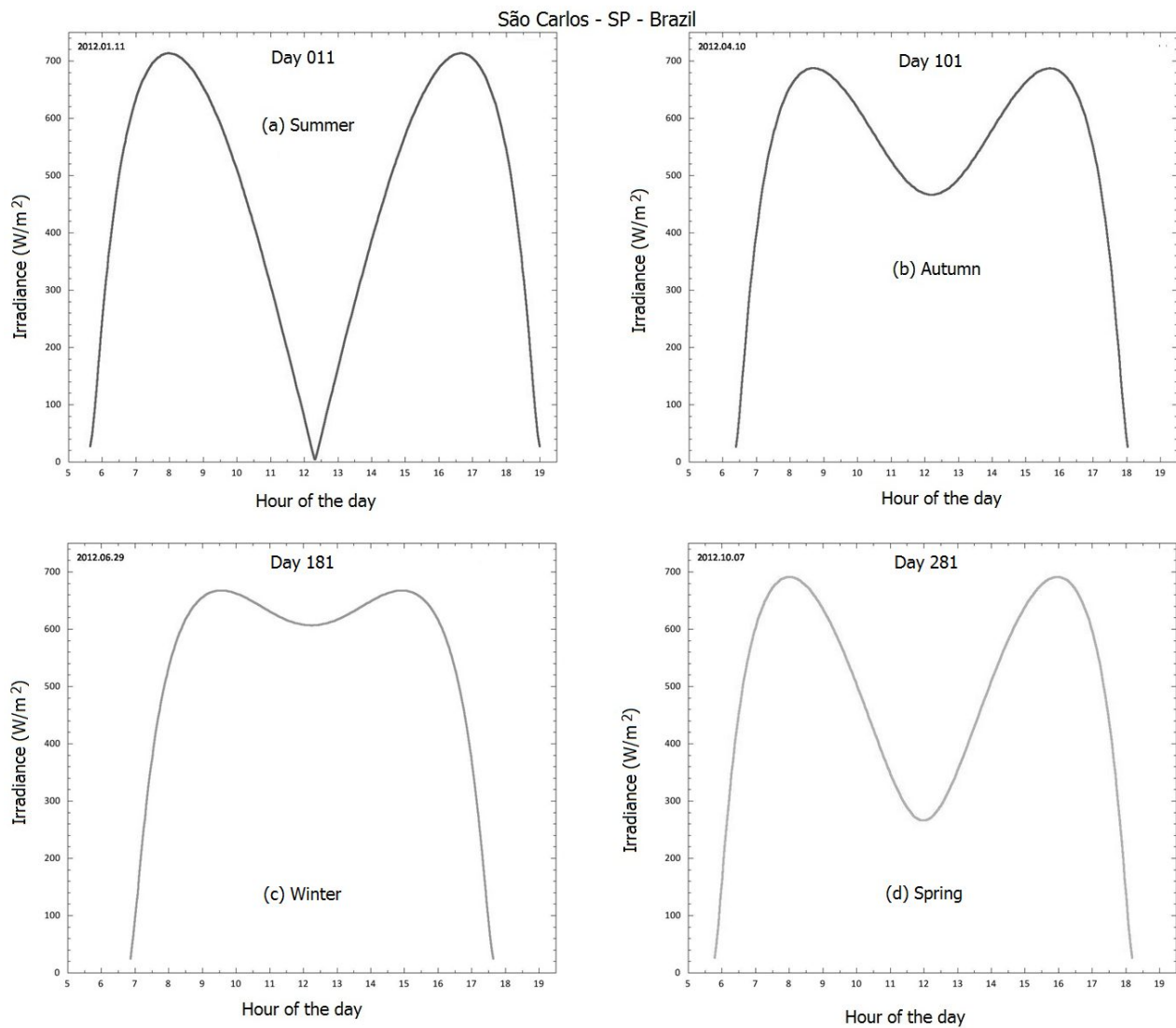


Figure 4. Four particular days (one of each season of the year) in Sao Carlos, state of Sao Paulo, in Brazil, showing the irradiance as a function of the elevation of the Sun at every hour of the day, that reaches the sunglasses lenses. Considering Day 1 as January 1st, the charts refer to: (a) Day 11 – Summer; (b) Day 101 – Autumn; (c) Day 181 – Winter; (d) Day 281 – Spring.

5. CONCLUSION

The parameters presented herein suggest that the requirements of ICNIRP should be incorporated in the Brazilian standard NBR15111, since the amount of irradiance in Brazil is dramatically higher - around 45% - if considering integration up to 400nm. Furthermore, it is suggested that the analysis regarding the UVA irradiance limits should be

included additionally without the weighting factor. One should always take into account that the UV indexes in Brazil as a whole are much greater than those in Europe and therefore the nationalization of this standard should be considered for protection of the ocular health in Brazil.

The parameters for the resistance to solar irradiation test for sunglasses to be worn in Brazil should be more clearly defined so that tests become effective in order to assure the validity of the UV protection for an average usage of sunglasses in Brazil for a longer period than 26 hours and 10 minutes. The exposure time for this particular test, which establishes the UV protection lifetime on sunglasses is still being investigated and, therefore, we are conducting a national survey to assist in defining such data. Trial registration: Approved by the Ethical Brazilian Committee: UFSCar 160.248/2012.

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ACKNOWLEDGMENTS

The authors are thankful for FAPESP, process number 2012/11171-8 (Prof. Liliane Ventura – coordinator) for the financial support.