Transmittance Variations Analysis in Sunglasses Lenses Post Sun Exposure

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Abstract. The hypothesis that sunglass ultraviolet (UV) protection can degrade with Sun exposure has never been proven experimentally. No sunglasses standards take into account UV transmittance changes after long Sun exposure. We selected 12 sunglass lenses and measured transmittance values from 280 nm to 780 nm. After 50 hours of exposure, new transmittance measurements were taken and transmittance variations inferior to 0.2% were observed. The exposition continues longer and more lenses will be tested to obtain conclusive results. We hope to obtain experimental data to confirm UV protection loss hypothesis and obtain a relation between Sun and solar simulator exposition.

1. Introduction
Sunglasses are widely used fundamentally for visual comfort, fashion and protective issues. There is a strong association between UV light exposure and at least 6 different diseases involving 3 different ocular structures (eyelid, cornea and crystalline lens) [1]. Eye’s natural response to intense visible light is to reduce its exposure by closing the eyelid and constricting the pupil. When wearing dark lenses, visible light is attenuated and the natural response is not activated, with less visible light reaching the eye, the pupil does not constrict increasing eye’s exposure, thus sunglasses with improper UV protection are dangerous [2]. There is a hypothesis that after long exposition to Sun sunglasses lenses may lose their UV protection.

The brazilian standard NBR ISO 12312-1:2015 specifies physical characteristics (mechanical, optical etc) for sunglasses and sunglare filters for general use [3].

The luminous transmittance or visible transmittance, $\tau_V$, is defined as the mean of the spectral transmittance, $\tau_F(\lambda)$, between 380 nm and 780 nm weighted with the spectral distribution of radiation of daylight (CIE Standard illuminant D65), $S_{D65}(\lambda)$, and relative spectral visibility function of daylight vision, $V(\lambda)$, and it is calculated using Equation (1) [3].

$$\tau_V = \frac{\int_{380}^{780} \tau_F(\lambda)V(\lambda)S_{D65}(\lambda)d\lambda}{\int_{380}^{780} V(\lambda)S_{D65}(\lambda)d\lambda}$$

The solar UV transmittance, $\tau_{SUV}$, is the mean of the spectral transmittance, $\tau_F(\lambda)$, between 280 nm and 380 nm weighted with the solar radiation, $E_{\lambda}(\lambda)$, at sea level for air mass 2 and the relative spectral effectiveness function for UV radiation, $S(\lambda)$, and it is calculated using Equation (2) [3].
The solar UVA transmittance, $\tau_{SUVA}$, and the UVB transmittance, $\tau_{SUVB}$, are calculated using Equation 2 but using integration interval between 315 nm and 380 nm, and between 280 nm and 315 respectively.

Depending on visible spectral transmittance, lenses are classified into different categories and for each category there is a minimum required UV protection (table 1) [3]. For being improper for general use, lenses with visible transmittance less than 3% are not classified into any category.

Table 1. Transmittance requirements for sunglass lenses for general use [3].

| Lens category | Visible spectral range | UV spectral range | Maximum value of solar UVB transmittance ($\tau_{SUVB}$) | Maximum value of solar UVA transmittance ($\tau_{SUVA}$) |
|---------------|------------------------|------------------|--------------------------------------------------------|--------------------------------------------------------|
|               | Range of luminous transmittance ($\tau_V$) | from over (%) to (%) | 280 nm to 315 nm | 315 nm to 380 nm |
| 0             | 0% to 80%              | 0.05 $\tau_V$    | $\tau_V$ |
| 1             | 43% to 80%             | 1.0% absolute or 0.05 $\tau_V$ (the greater) | 0.5 $\tau_V$ |
| 2             | 18% to 43%             | 1.0% absolute or 0.05 $\tau_V$ (the greater) | 1.0% absolute or 0.25 $\tau_V$ (the greater) |
| 3             | 8% to 18%              | 1.0% absolute or 0.25 $\tau_V$ (the greater) |
| 4             | 3% to 8%               | 1.0% absolute or 0.25 $\tau_V$ (the greater) |

Brazilian standard proposes a resistance-to-irradiation test in which lenses’ category and UV requirements could not change after 50 uninterrupted hours of irradiation by 450 W solar simulator. There are not any sunglasses standards that take into account UV transmittance changes after long Sun exposure or any previous experimental studies about transmittance variation by solar exposition.

Our team has developed an online survey to evaluate the sunglasses use conditions by the Brazilian population. Over 2000 people have been surveyed. Some questions were asked, for example where the person lives, person’s degree of education and the time one takes to change or buy new sunglasses. Another important asked question was about how long was the daily wearing time of sunglasses. The results have shown that people used to wear the sunglasses for 22 days and 8 hours in summer, and 52.6% buy new sunglasses every 2-4 years. Based on the answers and estimations, it is reasonable to assume that the UV protection of sunglasses should last at least 2 years [4].

Our team has also developed a device capable of automatically expose sunglasses lenses to the Sun [5]. The project consists of a panel with cover, housing 100 lenses fixed on a rotating axis, which will be irradiated by the Sun from sunrise until sunset. The lid opens and turns the panel towards the Sun automatically, so that the lens will always be facing the Sun. Humidity, dust, time and UV index sensors, as well as a video camera are part of the system. The exposure time and UV index will be recorded and automatic opening or closing the lid may also be controlled by a PC using online software.
In this study, we analyze UV and visible spectral range transmittance variation in sunglass lenses after long Sun exposition. We aim to obtain experimental data to confirm the hypothesis that sunglass lenses lose their UV protection after solar exposition. As secondary goal, we aim to compare Sun exposition and solar simulator exposition from transmittance variations.

2. Methodology
Twelve dark sunglasses (categories 3, 4 and without category) were selected for this study. Once our goal is to analyze variation in UV (280 nm - 380 nm) and visible transmittance (380 nm - 780 nm), initial transmittance values from 280 nm to 780 nm of the left lenses were measured using VARIAN Cary 5000 spectrophotometer. The right lenses were saved for future exposition on solar simulator. An acrylic frame and metal base panel as shown in figure 1 were mounted to hold left lenses for exposition.

![Figure 1. Lenses during Sun exposure.](image)

Every 50 hours of solar exposition new transmittance measures are performed. The transmittance measures were performed in 5 different points of each lens. Lenses transmittance variation analyses are calculated using the free software GNU Octave v.3.8.2 [6].

3. Results
After 50 hours of exposition small transmittance variations were observed. These variations were inferior to 0.2% of initial value for all wavelengths from 280 nm to 780 nm. Figure 2 illustrates percentage transmittance variation for measured wavelengths. This figure shows one lens’ percentage transmittance variation for every wavelength from 280 nm to 780 nm. A negative value means transmittance increase in some wavelength and a positive one means transmittance decrease.
In 7 lenses, transmittance values increased for all wavelengths. In 4 lenses, transmittance values increased for some wavelengths and decreased for others. In only 1 lens, transmittance values decreased for all wavelengths. This short solar exposition (50 hours) produced small transmittance variations.

4. Conclusion
In almost all lenses, transmittance values increased slightly for every wavelength. However, we could not trace a variation behavior trend because not only the variations measured were little and number of lenses small but also we encountered different responses.

With more exposition time and more lenses tested, we hope acquire enough data to confirm the hypothesis that lenses lose their UV protection after long natural solar exposition. Furthermore, with these data and spectroscopy measures after solar simulator expositions of right lenses, we will be able to compare experimentally solar exposition and solar simulator exposition. Therefore we will obtain experimental data to analyze whether UV protection is lost after 2 years (1460 hours of use).

We are also developing an automated panel [5] to facilitate the exposure of the lens and the control over exposure.

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