RISKS ASSOCIATED WITH BLUE LIGHT

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UV light is not the only danger for vision.

Blue light is the most energetic part of the visible light spectrum and thus can lead to retinal toxicity, all the more as it is not blocked by physiological filters like tear film, cornea, crystalline lens and vitreous body, except when you have reached a certain age (figures 1, 2).

Figure 1: Transmission of light through the different ocular structures

- UVC is completely absorbed by the atmospheric ozone layer.
- The majority of UVB is absorbed by the cornea, while a small fraction of UVB reaches the lens.
- UVA is largely absorbed by the lens, but can reach the retina particularly in children.
- **Visible light**, containing the energy-rich short wavelengths, **reaches the retina**.

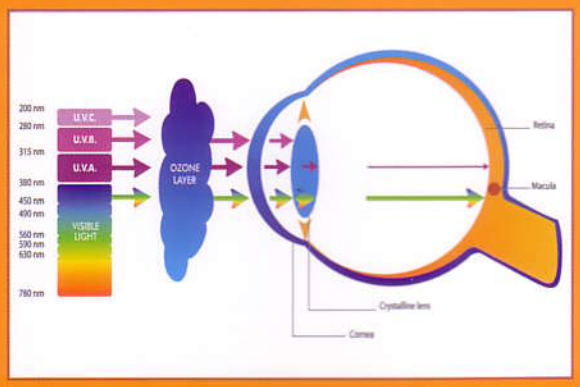
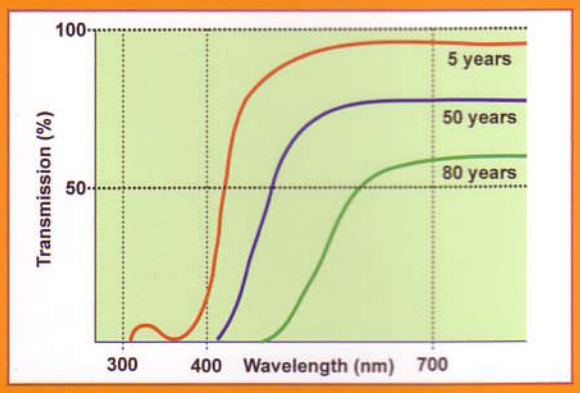


Figure 2: Transmission of the ocular media as a function of age

Note the high HEV-transmission in the young eyes, and the reduced transmission as well as the shift towards longer wavelengths in older ages.



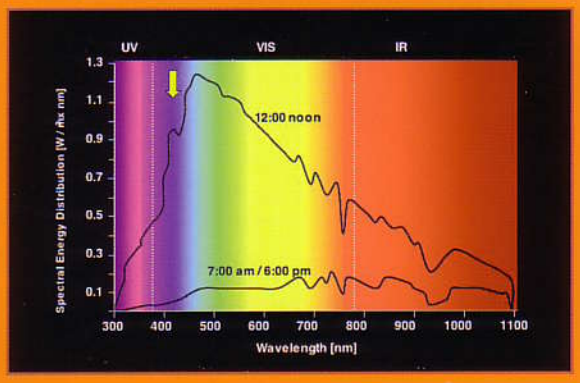
What is blue light ?

Also called "HEV" (High Energy Visible), **blue light covers wavelengths from 380 to 500 nm.**

Due to its high energy, blue light is more scattered than the other wavelengths of the visible spectrum (Rayleigh diffusion), that is why a clear sky appears blue to our eyes. Blue light is also emitted by a great number of artificial light sources as well as by direct sunlight (figure 3).

Figure 3: Spectrum of sunlight reaching the earth at different times of the day

Highest level of UV and blue radiations occurs around noon time (yellow arrow).



"Blue light" is a simplified expression because it designs both violet visible light, which extends from 380 to 420 nm, and blue light, which extends from 420 to 500 nm. Strictly speaking, we should say "violet-blue light".

Blue Light:
Why it is essential to protect oneself from it

1. Experimental studies: Blue light severe effects on the retina

It must be first pointed out that blue light hazard on retinal tissues was revealed through different experimental studies on animals. By exposing monkeys to very high doses of blue light, researchers Harwerth and Perling discovered, in 1971, that it would lead to a prolonged loss of spectral sensitivity in the blue region, resulting from **retinal lesions** [1].

Such observations were confirmed in the Eighties by other researchers who, from their own experimental studies on animals, discovered that high concentrated blue light could cause photochemical lesions on the retina, **especially in the Retinal Pigment Epithelium (RPE) and photoreceptors** [2, 3].

Thorough quantitative studies on Primates have brought to light **the action spectrum of light rays on the retina.**

The relationship between the radiation spectrum and the risk of retinal damage was established by Young, in 1988 [3], from an analysis of Ham and co's works dating back to the early Seventies.

Demonstrating that "the different components of the radiation mixture that strikes the retina are not equally hazardous", it shows that **harmfulness exponentially increases as photon energy rises (figure 4).** From the near IR through half of the visible spectrum, the injurious effects of radiation are weak and hardly increase. When the wavelength reaches around 510 nm, the curve bends and a sudden rise occurs in the risk of producing retinal damage. From this very wavelength on, a significant increase in the severity of deleterious effects is also noticed. Given that the transition takes place at the border between the perceived colours of green and blue, the phenomenon is referred to as "the blue light hazard" [3].

In short, this study reveals that, on equal concentration, **blue light is 15 times more deleterious for the retina than the rest of radiation within the visible range.**

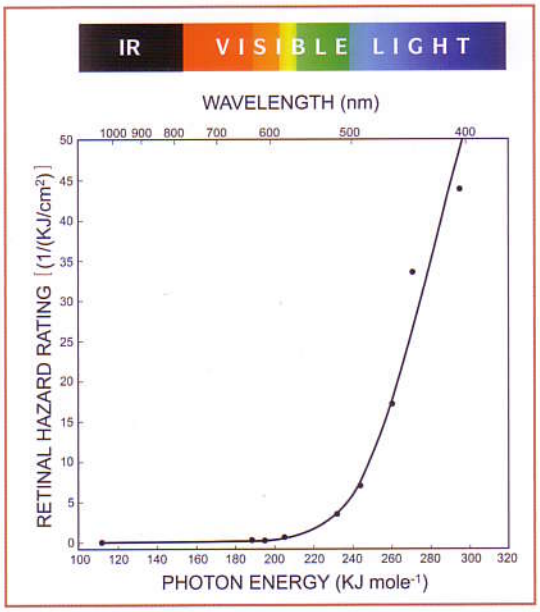


Figure 4: Action spectrum of Retinal Radiation Damage

R.W. Young, Solar Radiation and Age-related Macular Degeneration; Survey of Ophthalmology vol. 32, n°4, January-February 1988.

This curve gives an estimate of radiation damage on the retina compared to the wavelength (up) and photon energy (down).

This relationship was confirmed by other experimental studies, among them one study on rats by Pr Remé in 2000: "No apoptosis and no other light-induced lesions could be found in green light-exposed eyes, whereas massive apoptotic cell death occured after illumination with blue light." [4]

These studies have also brought out that tissue deterioration observed during long-term exposure to bright light was **the same as changes observed with AMD symptoms (Age-related Macular Degeneration)**, and that it was localized in the same structures: retinal pigment epithelium, rods and cones [3].

2. Human Epidemiological Studies: cumulative effects of blue light

It is a long time since long-term exposure to sunlight has been suspected of being a factor of ageing human retina. At the moment, no undeniable clinical evidence exists yet but more and more experts consider that cumulated exposure to blue light could be **a risk factor of developing AMD**.

Categorically demonstrating some correlation between AMD and sunlight would require epidemiological studies of a huge amplitude.

The "Beaver Dam Eye Study" [5] is one of the most significant work on the topic, some results of which support the existence of this correlation. However, it is very difficult in this kind of study, to relate with precision the cumulative sun exposure of participants over their whole life. This is different, for instance, from studying tobacco influence on AMD: most smokers are able to report fairly precisely how long they have been smoking and how much they smoke.

More than 6000 patients thoroughly observed over 5 to 10 years... in "The Beaver Dam Eye Study" (2004) [5]

An American study published in 2004 "The Beaver Dam Eye Study", aimed at examining the association between sun exposure and indicators of sun sensitivity with AMD incidence was realized on more than 6000 patients, over 5 to 10 years.

It reveals **twice higher a risk of developing early AMD** among people exposed to the summer sun (> 2 hours per day) all their life long than among those hardly exposed (< 2 hours per day). However, there is no significant association between sun exposure during the study itself and the incidence of early AMD; which would seem to prove **cumulative** sun exposure is responsible for increasing the risk in developing AMD.

In this study, the blame is put on visible light and, in particular, blue light: "*If cumulative sun exposure is related to the incidence of increased retinal pigment or early age-related maculopathy (ARM), it is hypothetically the effect of exposure to visible rather than UV light. Previous studies have not found ARM to be associated with cumulative UV-A or UV-B exposure, but support associations between ARM and ocular exposure to blue light.*" [5].

This feeling is shared by other specialists like Schepens Eye Research Institute - one of the biggest research centers in the United States regarding eye diseases -, which notes on its website "*Blue rays seem to quicken the development of AMD more than other rays of solar spectrum.*" (http ://www.theschepens.org/).

3. Blue light toxicity: a photochemical process

The damage created by blue light on photoreceptors and RPE is now well analyzed.

Regarding photoreceptors, the mechanism is as follows:

- Normally, when photopigments absorb light, the photoreceptor cell bleaches and becomes unavailable for light absorption until the photopigment is reformed through a lengthy metabolic process known as **the visual cycle**.
- However, if the intermediary formed when the photopigment absorbs light then absorbs blue light, photoreversal can cause a photoreceptor cell to rapidly become unbleached.