

LED Lights and Eye Safety

This Eco Design Note examines safety issues related to LED lights and the consumers who use them. Specifically, it explores three basic questions: Can off grid LED lights be too bright, posing a hazard to people looking at them? Alternately, can they be too dim, harming adults and children who use inadequate light to read and work? Finally, does the light produced by LEDs disturb sleep patterns and hormone levels?

Introduction

Advances in LED lighting technology have brought promising new opportunities to enhance people’s lives and enable new activities. Markets and merchants can stay open later into the evening. Children can read at night and have more opportunity to do schoolwork. Homes can be better lit without the risks and costs of fuel based kerosene lamps or candles.

Yet any new technology also brings new questions, and possible health concerns should be discussed and investigated to ensure that one problem (from fuel based lighting) isn’t replaced by another (from LED lighting). For off grid LED lighting, several key questions should be explored concerning possible health risks associated with this new technology.

Are off grid LED lights bright enough to pose a risk to adults or children who look directly at them? Can reading in the dim light provided by some lights be harmful for children doing homework? Does the bluish light provided by many off grid lights cause harm or disturb the sleeping patterns of people who use them? These questions will be discussed, and possible answers given in this Eco Design Note.

This article will make frequent reference to the term **illuminance**. Illuminance is basically a measure of the amount of light, from any light source, that reaches a given surface. For example, one could talk about the illuminance on the ground (from the sun and sky) during the day, or the illuminance on a desk from a desk light, candle, and/or kerosene lantern.

Can off grid LED lights be *TOO* bright?

The first and probably most important question to consider is whether off grid LED lights can be bright enough to pose an immediate risk to adults or children who look directly at them.

There are many lights and lighting technologies in a typical environment that could potentially cause harm. Indeed, the sun itself is technically considered a hazardous source, and would harm anyone who stares directly at it. The reason the sun doesn’t regularly harm people, of course, is that we have a natural “aversion” response where we don’t tend to look directly at bright lights and when we do, we quickly look away. This aversion response helps limit the amount of time, and consequently the amount of harmful light, that enter’s the eye, passes though the lens, and is focused on the retina. (Figure 1)

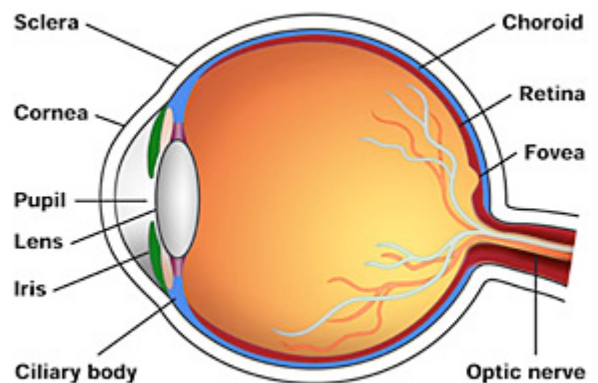


Figure 1. A diagram of the human eye.

Exposure to large amounts of light can damage the eye in several ways. The lens, for example, can be damaged

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by exposure to infrared light (IR) or ultraviolet (UV) light – this has been linked to certain kinds of cataracts (clouding of the eye’s lens). The retina can be damaged by strong doses of blue light, and though the evidence is inconclusive, there may be a link to macular degeneration: a disease that leads to blindness that predominantly affects older people.

LEDs currently used in off grid lights do not emit large amounts of UV or IR light and do not pose a risk for these wavelengths. They do, however, emit blue light (Figure 2) in a wavelength range (400-500 nm) that could harm the eye if viewed at sufficient intensity and duration. Blue light has enough energy to cause chemical changes in the retina and may damage cellular DNA. This blue light hazard is generally considered the area of most concern for LED lights.

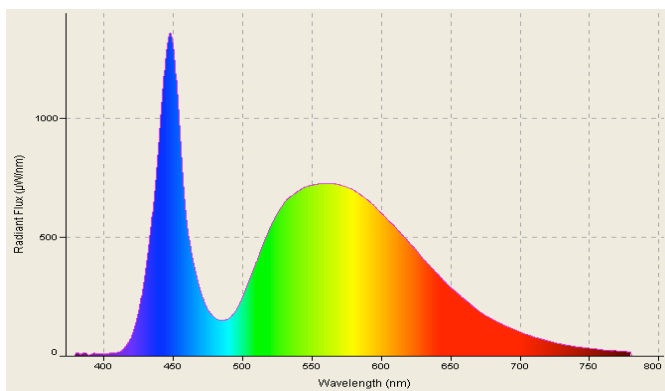


Figure 2. A graph showing the spectral output of a white LED within the visible spectrum. The LED emits light at different wavelengths including a sharp blue spike at 460 nanometers.

LEDs, blue light hazards and IEC 62471¹

IEC 62471 “Photobiological Safety of Lamps and Lamp Systems” is a test method used to measure and report hazard levels of different lighting products. The standard is still under development as of 2012 as committee members seek to better define risk categories and test details. IEC 62471 establishes

¹ Lyons, L. “LED products must meet photobiological safety standards” LEDs Magazine (Feb 2012)

light exposure limits and duration levels and classifies the results into the different Hazard Groups summarized in Table 1.

Our sun, for example, is classified as an RG2 (moderate risk) source. Typical outdoor exposure levels include UV, IR and blue light wavelengths with the potential to cause harm. What about off grid LED lights? Do off grid lights contain LEDs with the ability to exceed safe exposure limits as defined by IEC 62471? If so, are the LEDs operated at sufficient power levels and with optics that would allow a user to be exposed to this hazard?

Group	Risk	Philosophical Basis
Exempt	None	No photobiological hazard
RG1	Low	No photobiological hazard under normal behavioral limitation
RG2	Moderate	Does not pose a hazard due to aversion response to bright light or thermal discomfort
RG3	High	Hazardous even for momentary exposure

Table 1. Hazard Groups defined by IEC 62471

To answer these questions, we can start by looking at the LED source itself. A review of available manufacturer data shows that some commercially available LEDs, tested with the IEC 62471 standard, fall within RG1 (low) and RG2 (moderate) risk categories. No LEDs were found to be RG3. Some of the RG1 and RG2 LEDs are very high power types that are unlikely to be used in off grid LED products. Others, however, are smaller single chip type LED devices that *could* be used in off grid products.

The next question relates to the amount of electrical power used to run the LEDs in an off grid product. Just because an LED is capable of posing a risk does not mean that it does – LEDs can be run at higher or lower power and this determines how much light the LED produces. Of the LEDs surveyed for this Eco Note, none

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with a rating higher than “Exempt” produced less than 100 lumens and all were operated at 1.5 watts or more of LED power.^{2,3}

In general, off grid products with the highest chance of posing a blue light hazard will be those that have a single, small, high power LED with a clear cover that allows direct viewing of the LED source. Some types of torches (flashlights), with focusing optics used to produce very bright light beams, may also achieve RG1 or RG2 levels. The light in these products comes from a very small concentrated area – this concentration puts the most stress on the eye’s retina. And because the risk is from the blue portion of the spectrum, high color temperature white LEDs (a bluish white light) will have somewhat higher levels of blue light emissions that could pose a hazard.

Measurement distances and IEC 62471

When determining the hazard posed by a light source, IEC 62471 uses different measurement distances for different product categories. There is still some debate concerning this issue but there are assumptions that can be used to determine the worst case scenario risks for a product.

A 200 mm measurement distance is used to determine the maximum risk from a light source. The eye cannot focus an image closer than 200 mm; this corresponds to the maximum light concentration, projected by the lens onto the retina, achieved by the optics of the eye. Under normal circumstances people typically do not directly view light sources at this distance, and so using 200 mm as the basis for a risk assessment may overestimate the hazard. Many off grid products are, however, portable and easily accessible by people and curious children, and so using a worst case scenario for the measurement distance may indeed be appropriate.

² Cree “LED EyeSafety” Xlamp_eyesafety.pdf www.cree.com

³ Lumileds “LUXEON Rebel Photobiological Safety report” AB60.pdf www.lumileds.com

IEC 62471 Test Cases

Lighting Global contracted an independent laboratory to perform a hazard risk assessment of several commercially available off grid products. The products were chosen, based on Lighting Global’s experience with products in the Quality Assurance program, to cover a range of ‘worst case’ to ‘best case’ candidates regarding light safety levels. All had light outputs in excess of 100 lumens. Some had a single, high-powered LED while others had multiple smaller LED emitters. The lens covers varied from clear to translucent (milky, diffused light output).

The products were tested at several distances to cover different exposure scenarios. The results ranged from Exempt (best case product) to RG2 for the worst case.

An RG2 (moderate risk) hazard rating was obtained for a product with a single high power LED and a clear cover lens. The test used a 200 mm direct viewing distance and it took a 58 second exposure time to trigger the RG2 result. The risk fell in the bottom 1% of the RG2 hazard range.

An RG1 rating was obtained for a product with multiple low power LEDs and a translucent diffuser.

An Exempt (no risk) rating was obtained for another product with a high power LED and a translucent cover lens. The product had a similar lumen output to the product that test RG2.

Optics can eliminate blue light hazards

Many off grid products use diffusers to soften the light from the LEDs – people typically find this type of diffused light much less harsh. In addition to improving the product’s appearance, a diffuser also lowers the hazard from high power LEDs used in the product design. Diffusers spread the light out and shield the very bright point source, creating a larger ‘emissive surface’. The same amount of light is less hazardous if it comes from a large emissive source (and more

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hazardous if it comes from a very small, concentrated spot). Some light is, however, absorbed by the diffuser, so there is a tradeoff with product efficiency. Well-designed diffusers, made with high quality optical materials, can be both efficient and effective at shielding bright point sources.

Low light concerns for off grid products

Reading in low light conditions does not appear to pose short term risks to users of off grid lights. The available data suggest that insufficient illumination (low light) conditions can cause some degree of eye strain, and reading in these conditions over long periods of time may have the potential to increase the development of nearsightedness (myopia) in children and adults.

In low light conditions, the pupil dilates to allow more light to enter the eye and reach the retina. The eye's ability to auto focus is challenged by lower image contrast, and eye strain can result from continued flexing to bring the image into focus. Another possible consequence is the elongation of the eye to maintain the retinal image, and over repeated long term exposure could encourage the development and progression of nearsightedness. The same mechanism is also present, though less extreme, in reading in good light conditions; over long periods of time, users who read for extensive periods on a daily basis have shown an increase in the prevalence of myopia.⁴

Other factors also factor in predicting the development of nearsightedness. Heredity seems to be a major contributing factor, with gender, level of education, and family income as additional influences.

The Illuminating Engineering Society (IES) has light level recommendations for different tasks and applications.

⁴ Kittle, J. "Reading in Close-up Settings Will Damage Your Vision – A Myopic Understanding?" (Oct 2008) <http://healthpsych.psy.vanderbilt.edu/2008/ReadingVision.htm>

These range from 20 – 1000 lux for typical activities, with reading tasks generally ranging from 300-750 lux.⁵

Fuel based lighting from candles or kerosene lamps often results in much lower illuminance levels than those available from LED based products.

Physiological response to blue light

The eye, in addition to allowing normal vision, also helps to control a person's circadian rhythm (sometimes referred to as a person's internal clock). The normal day/night cycle triggers and regulates certain hormones and biological functions including our daily sleep patterns.⁶

One of the principal hormones involved in the sleep cycle is melatonin. Melatonin is released during the dark evening hours and suppressed during the day. It is believed that melatonin tells the body when to sleep and when to stay awake. Another hormone, melanopsin, is involved in the suppression of melatonin.

The cell structures in the retina responsible for melanopsin release (and melatonin suppression) primarily respond to blue light. This peak sensitivity matches the 'blue spike' found in many white LEDs, and there is evidence to suggest that exposure to LED light does in fact suppress the release of melatonin. The level of suppression remains in doubt, and small exposures typical of those found in off grid products are far below levels seen in industrialized countries. Some experts suggest that exposure to sunlight during the day may mitigate the effects of artificial light at night, implying that illumination contrast in a daily routine plays a role in regulating the circadian cycle.⁷

⁵ IESNA 9th Edition Handbook

⁶ Beil, L. "In Eyes, a Clock Calibrated by Wavelengths of Light" New York Times (July 4, 2011)

⁷ US Department of Energy "Light at Night: The Latest Science" [ssl_whitepaper_nov2010.pdf](#)

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Research in this area is still in its infancy and more study is warranted concerning the effects of nighttime illumination on a person's circadian cycle. The topic has recently received more attention as researchers include the effects of computer screens and personal electronics that also emit a strong blue light component. Possible negative effects of blue light exposure and melatonin disruption include sleep cycle disturbances and links to some diseases.

Summary

Lighting Global believes that the illumination from off grid LED products is a safe, effective, and superior alternative to fuel based lighting. A review of available literature and specific product testing has not shown large cause for concern regarding off grid LED lights and eye safety issues, but has identified an issue where some caution is warranted. Laboratory measurements of actual products, believed to represent a range from best to worst case scenarios, resulted in a maximum (worst case) RG2 hazard rating. The specific issues under consideration can be summarized as follows:

Too Bright?

Some high power LEDs are capable of posing a moderate risk to users who stare at them. Many off grid products on the market today do not contain this type of high power LED, and those that do may or may not operate the LEDs with enough power to create a hazard. In a worst case scenario, an off grid product with a high power LED and clear cover lens could, under specific circumstances, pose a moderate risk (RG2) to users. This risk is mitigated by our aversion response to bright light and is no more dangerous (much less, in fact) than the hazard posed from staring at our sun.

LEDs continue to improve in both brightness and efficiency, and it is likely that manufacturers will take advantage of these improvements. As brighter products become available, attention should be given to prevent direct viewing of high powered LEDs. Though risks are

likely to be small, prudence is wise and manufacturers should consider designing products with:

- diffusing optics to soften light output
- shields to block direct LED viewing
- warmer color temperature LEDs to reduce the proportion of blue light emissions

Consumers are encouraged to favor these types of products, and of course children should be taught not to stare directly at very bright lights.

Too Dim?

Reading and performing tasks in low light conditions can cause eye strain but will not harm the eye in the short term. Long term chronic eye strain has been linked to the development of nearsightedness (myopia), although data to support this theory remains inconclusive. Prudence, again, suggests using adequate light levels for reading and other tasks. It is likely that typical light levels off grid products are below those recommended in industrialized countries, but above levels achieved with fuel based lighting, and so LED based off grid products represent a step in the right direction.

Too blue?

Some evidence exists that the blue light component from an LED may disrupt melatonin regulation and consequently sleep patterns. Research in this area is ongoing and no information has been found by Lighting Global to suggest that blue light from off grid products poses a physiological hazard. Given the prevalence of artificial light and illuminated electronic devices in the industrialized world, a reasonable assumption would expect to see circadian disruption issues much more pronounced, and likely detected, in these industrialized countries before they became problematic in the off grid lighting community.