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SHORT REPORT

Dosimetry Assessment of Potential Hazard from Visible Light, Especially Blue Light, Emitted by Screen of Devices in Daily Use

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Abstract: Visible light has been considered to have minimal impact on the skin. However, the increasing use of electronic devices has led to a significant increase in exposure to visible light, especially blue light. We measured the irradiance (mW/cm^2) and estimated dose (J/cm^2) of visible light and blue light emitted from various electronic devices including smartphones, tablets and computers. The measurement was done in normal screen mode and night shift mode at different brightness levels and distances across six screens. The irradiance and dose of visible light and blue light corresponded to the brightness, distance, and screen size of the devices. This study has shown that the irradiance and dose of visible light and blue light emitted from electronic devices in daily use are small and unlikely to be harmful to human skin.

Keywords: visible light, blue light, electronic devices

Background

Visible light is a part of electromagnetic radiation visible to the human eye, representing wavelengths from 400 to 700 nm.[1] It constitutes roughly 44% of sunlight.[2] The light-emitting diode (LED) source that emits visible light wavelengths can also be found in electronic devices in daily use, such as smartphones, computers, and tablets.[1] Regular use of electronic devices has led to a significant increase in the exposure of human skin to visible light, and there is a growing concern about the safety of light sources such as LEDs with peak emissions in the blue light range (400–490 nm).[3]

Generally, visible light has been regarded as having minimal impact on the skin due to its low energy.[2] However, previous studies have shown that visible light can induce indirect DNA damage through the generation of reactive oxygen species, suppression of innate immunity, and premature photoaging.[2,4,5] Photoaging seen in Fitzpatrick skin types I–III and pigmentation seen in Fitzpatrick skin types IV–VI have been implicated as being linked to visible light exposure.[6]

Understanding the distinction between photopic and melanopic wavelengths is important in evaluating the potential impacts of light exposure on both skin health and vision. Photopic wavelengths relate primarily to human visual perception and follow the CIE photopic luminous efficiency curve, with peak sensitivity at 555 nm.[7] These wavelengths are critical for assessing light exposure in terms of visual comfort and vision health because they primarily stimulate the cone cells responsible for color vision.

In contrast, melanopic wavelengths peak around 480 nm and influence non-visual biological processes,[8] including circadian rhythms and melatonin regulation. Melanopic wavelengths are particularly relevant to skin health, as they can activate melanocytes and lead to hyperpigmentation and photoaging, particularly in darker skin types. This melanopic

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sensitivity to blue light has a more direct biological impact on skin cells, such as inducing oxidative stress and triggering pigmentation responses.

Given the specific impacts of melanopic wavelengths on skin, this distinction clarifies why blue light exposure—especially at melanopic wavelengths—is increasingly scrutinized for potential dermatological effects. Although photopic wavelengths are primarily tied to visual health, blue light in the melanopic range is relevant when assessing the risk of skin-related conditions caused by light exposure.

While previous studies have focused mainly on the melanopic effects of blue light, the present study aims to measure the irradiance and dose of both visible and blue light emitted from electronic devices at varying distances and brightness levels. By evaluating both photopic and blue light wavelengths, the study seeks to better understand their potential impact on skin health, particularly with respect to blue light, which may be implicated in hyperpigmentation and other cutaneous disorders.

Visible light-induced pigmentation in pigmentary disorders such as melasma or post-inflammatory hyperpigmentation, especially in darker skin types, results from activation of opsin 3, which further activates extracellular signal-regulated kinase, eventually resulting in expression of microphthalmia-associated transcription factor, tyrosinase activity, and the melanogenesis process.[9] A previous study showed that only blue light with a peak emission of 415 nm could induce pigmentation in darker skin types, while red light with peak emission of 630 nm did not lead to any pigmentary changes.[10] While another two studies demonstrated that blue light wavelengths at peak 450 nm could affect human dermal fibroblasts to generate reactive oxygen species, causing cellular damage.[11,12]

In recent decades, photoprotection against visible light has become more of a focus. However, there are no established guidelines regarding visible light photoprotection and no consensus standard for measuring the visible light protection factor.[13] Photoprotection against visible light nowadays includes avoiding sunlight, seeking shade, and using photoprotective clothing. Most organic and inorganic sunscreen filters that protect against ultraviolet radiation do not provide coverage for visible light, except for non-micronized titanium oxide, zinc oxide, and ferrous oxide, which can only be found in tinted sunscreen.[13,14]

Artificial light is inevitably becoming more pervasive in our daily lives. Humans spend a significant amount of time in front of digital screens that emit visible light, especially blue light. Exposure to everyday light sources, including a range of LED lighting products and smartphone display screens, could affect the quality of sleep, well-being, and long-term health.[15] Growing evidence showed that eye strain and fatigue were related to blue light with a wavelength of 400–490 nm.[16] Likewise, the harmfulness of visible light to the skin is also possible, as mentioned, and is becoming more of a concern in the field of dermatology.

A study of the American population showed that the average screen time per day was six to nine hours, and the percentage of adults who spend more than 10 hours in front of electronic devices was increasing.[2] However, the irradiance and dose of visible light, especially blue light, have not been thoroughly measured. Therefore, this study aims to measure the irradiance and dose of visible light, especially blue light, at different brightness levels and distances from electronic devices.

Methods

This study was exempted from Siriraj ethical review due to non-human research. Irradiance (mW/cm^2) and dose (J/cm^2) of visible light and blue light were measured using a portable broadband radiometer; PMA 2100 (Solar Light, Glenside, PA, USA). The radiometer was equipped with a sensor.

Two sensors were used for measuring visible light and blue light. Irradiance and dose of visible light were measured by PMA2130 Digital Photopic Light Sensor, having a CIE Photopic Luminous Efficiency Curve between 360 and 830 nm with a peak wavelength at 555 nm and following the SI definition of 683 lm/W at 555 nm. It has a Teflon diffuser, assuring an angular response close to the cosine function. This detector is designed to have a spectral response like that of the human eye's visual response in the photopic region. The sensor can measure intensity in the range of 0–2,000 $\mu W/cm^2$, with a display resolution 0.01 $\mu W/cm^2$. Irradiance and dose of blue light were measured using the PMA2121 Digital Blue Light Safety Sensor, which has a spectral responsivity function based on the blue-light hazard function. The sensor detected blue light wavelengths between 400 and 530 nm, with a peak sensitivity at 460 nm. The sensor can measure

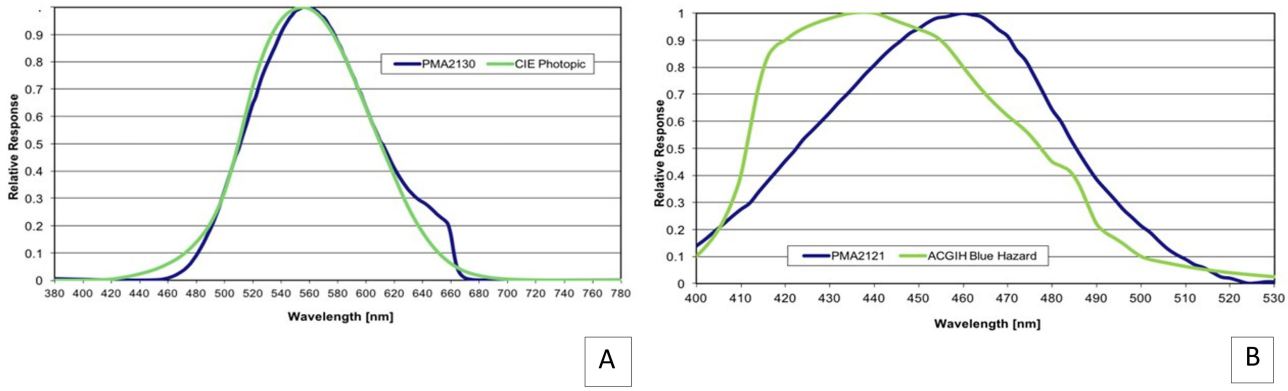

Figure 1 Spectral Response of (**A**) Model PMA2130 Digital Photopic Light Sensor follows CIE Photopic Luminous Efficiency Curve (360–830nm), and (**B**) Model PMA2121 Digital Blue Light Safety Sensor follows ACGIH blue hazard action spectrum.
Note: Courtesy from Solar Light Company. Copyright 2022 by Solar Light Company, LLC.

intensity in the range of 0–150,000 Lux, with display resolution 1 Lux. The maximum exposure limit for a source subtending an angle of less than 0.011 radians should not exceed 10 mJ/cm² over 10,000 seconds of exposure. The spectral responses of two sensors were shown in Figure 1. Due to the screen time limitation of some devices, the measurement was carried out for 10 minutes for each setting of devices then the number was converted to estimated dose in one hour.

The radiometer and two sensors were calibrated and traceable to the National Institute of Standards and Technology. The standard used for PMA 2100 radiometer was the Fluke Model 189 multimeter, S/N 85500008 with the calibration level of 0.3 V for the low range and 3 V for the high range. The standard used for PMA 2130 sensor was Optronic Laboratories Model OL220M, a 200 W quartz-halogen, coiled-coil tungsten filament lamp, S/N M1553 with the calibration level of 2,000 lux. The standard used for PMA 2121 sensor was Optronic Laboratories Model OL220M 200 W quartz-halogen, coiled-coil tungsten filament lamp, S/N M1539 with the calibration level of 70 μW/cm^2.

The irradiance and dose of visible light and blue light on six screens (Samsung Galaxy A71 [height 16.3 cm, width 7.6 cm, time of used 10 months], Apple iPhone 15 Plus [height 16.1 cm, width 7.7 cm, new device], Apple iPAD Air 5 [height 24.7 cm, width 17.8 cm, time of used 6 months], Apple iPAD Pro 4 [height 28.1 cm, width 21.5 cm, time of used 4 years], HP P22 G4 monitor screen [height 49.7 cm, width 30.1 cm, time of used 1 year], and MacBook Air M2 [height 30.4 cm, width 21.5 cm, time of used 1 month]) were measured. The smartphone screens (Samsung Galaxy A71 and Apple iPhone 15 Plus) were measured at 25 cm perpendicular. Apple iPAD screens (Apple iPAD Air 5 and Apple iPAD Pro 4) were measured at 25 and 50 cm perpendicular. HP P22 G4 monitor screen and MacBook Air M2 were measured at 50 cm perpendicular.[17] All of the devices were measured without any screen protectors.

To measure the irradiance and dose of visible light and blue light from electronic devices using a photometer, we followed these steps to set up the appropriate environment: (1) the measurement was done in a dark room without any external light sources that could interfere with the measurement; (2) the sensor was placed at a fixed distance (25 or 50 cm) perpendicular to the screen; (3) the screen was set to display a uniform solid blue color; (4) the brightness was adjusted to 50% and 100% percentage; (5) the screen was measured in normal mode and night shift mode; and (6) the screen and radiometer were given some time (about 15 minutes) to warm up and stabilize to ensure consistent measurements. Figure 2 demonstrated the placement of sensors and electronic devices.

Results

Estimated dose (J/cm^2) of electronic devices obtained from photopic and blue light sensors in 1 hour was shown in Table 1. The irradiance (mW/cm^2) of electronic devices obtained from photopic and blue light sensors was shown in Table 2. The measurement of irradiance was done for three times and gave the same results. At 25 cm distance, irradiance and estimated dose emitted from tablets were greater than those from smartphones. At 50 cm distance, irradiance and estimated dose emitted from computer screens were greater than those from tablets. At 100% brightness of each distance,

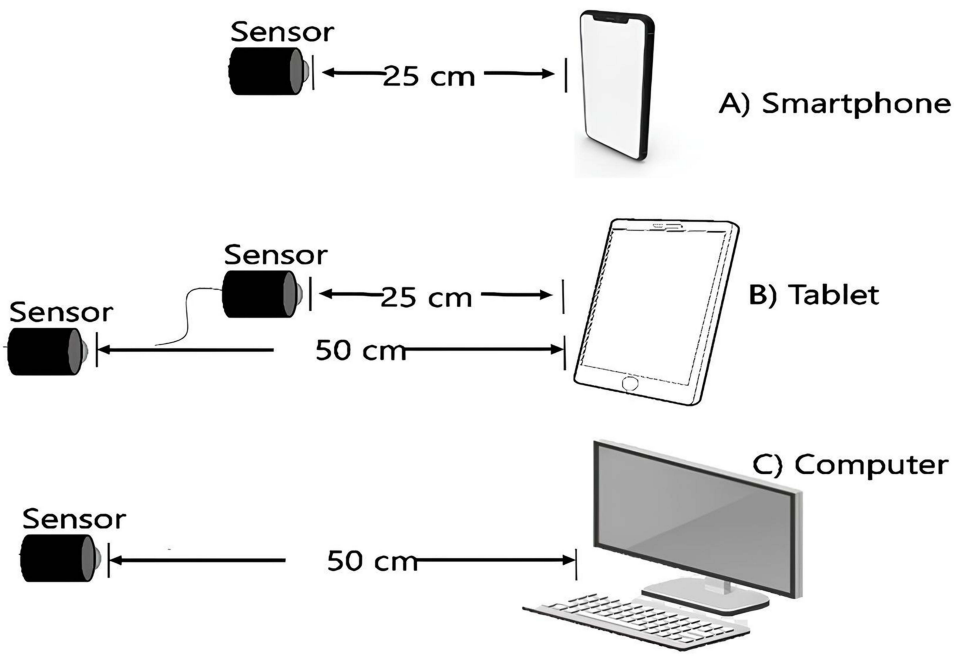

Figure 2 Measure setting demonstrating the placement of sensors and electronic devices.

the irradiance and estimated dose were greater than those from 50% brightness. Night shift mode provided the reduction of blue light dose. For example, at 100% brightness with a 25 cm distance, the percent reduction of blue light dose using a night shift mode was 33.3%, 18.2%, 44%, and 62.7% for the Samsung Galaxy A71, iPhone 15 Plus, iPAD Air 5, and iPAD Pro 4, respectively. At 50% brightness with a 25 cm distance, the percent reduction of blue light dose was 37.5%, 25%, 44%, and 41.1% for the Samsung Galaxy A71, iPhone 15 Plus, iPAD Air 5, and iPAD Pro 4, respectively.

Table 1 Estimated Dose (J/cm^2) Emitted from Electronic Devices Measured Using the Model PMA 2100 Photometer/Radiometer in 1 hour

Setting	Brightness (%)	Distance	Smartphone (J/cm^2)		iPAD (J/cm^2)		Computer (J/cm^2)	
Photopic sensor (360–830 nm, peak 555 nm)			**Samsung Galaxy A71**	**iPhone 15 Plus**	**iPAD Air 5**	**iPAD Pro 4**	**HP P22 G4 monitor screen**	**MacBook Air M2**
Normal mode	100	25 cm	0.0192	0.0066	0.0408	0.0420		
		50 cm			0.0180	0.0168	0.0372	0.0192
	50	25 cm	0.0072	0.0012	0.0162	0.0108		
		50 cm			0.0078	0.0042	0.0222	0.0060
Night shift mode	100	25 cm	0.0192	0.0048	0.0282	0.0312		
		50 cm			0.0132	0.0120	0.0132	0.0144
	50	25 cm	0.0078	0.0012	0.0114	0.0108		
		50 cm			0.0024	0.0036	0.0072	0.0060

(*Continued*)

Table 1 (Continued).

Setting	Brightness (%)	Distance	Smartphone (J/cm^2)		iPAD (J/cm^2)		Computer (J/cm^2)	
Blue light sensor (400–530 nm, peak 460 nm)								
Normal mode	100	25 cm	0.0108	0.0066	0.0150	0.0260		
		50 cm			0.0066	0.0121	0.0210	0.0096
	50	25 cm	0.0048	0.0024	0.0054	0.0056		
		50 cm			0.0024	0.0026	0.0132	0.0036
Night shift mode	100	25 cm	0.0072	0.0054	0.0084	0.0097		
		50 cm			0.0030	0.0044	0.0024	0.0048
	50	25 cm	0.0030	0.0018	0.0030	0.0033		
		50 cm			0.0012	0.0013	0.0012	0.0018

Table 2 Irradiance (mW/cm^2) Emitted from Electronic Devices Using the Model PMA 2100 Photometer/Radiometer

Setting	Brightness (%)	Distance	Smartphone (mW/cm^2)		iPAD (mW/cm^2)		Computer (mW/cm^2)	
Photopic sensor (360–830 nm, peak 555 nm)			**Samsung Galaxy A71**	**iPhone 15 Plus**	**iPAD Air 5**	**iPAD Pro 4**	**HP P22 G4 monitor screen**	**MacBook Air M2**
Normal mode	100	25 cm	0.0055	0.0019	0.0115	0.0109		
		50 cm			0.0049	0.0047	0.0105	0.0052
	50	25 cm	0.0021	0.0004	0.0045	0.0030		
		50 cm			0.0020	0.0012	0.0062	0.0016
Night shift mode	100	25 cm	0.0054	0.0014	0.0080	0.0086		
		50 cm			0.0036	0.0032	0.0038	0.0040
	50	25 cm	0.0022	0.0004	0.0032	0.0029		
		50 cm			0.0013	0.0010	0.0021	0.0016
Blue light sensor (400–530 nm, peak 460 nm)								
Normal mode	100	25 cm	0.0032	0.0019	0.0041	0.0073		
		50 cm			0.0018	0.0032	0.0061	0.0028
	50	25 cm	0.0014	0.0007	0.0015	0.0015		
		50 cm			0.0006	0.0007	0.0037	0.0010

(*Continued*)

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Table 2 (Continued).

Setting	Brightness (%)	Distance	Smartphone (mW/cm^2)		iPAD (mW/cm^2)		Computer (mW/cm^2)	
Night shift mode	100	25 cm	0.0020	0.0015	0.0024	0.0027		
		50 cm			0.0008	0.0011	0.0007	0.0013
	50	25 cm	0.0009	0.0004	0.0009	0.0009		
		50 cm			0.0003	0.0004	0.0004	0.0005

Discussion

The widespread use of smartphones, tablets, laptops, and desktop computers has led to a significant increase in exposure to visible light sources, which raises concerns regarding potential side effects on the skin. Specifically, the effect of blue light has become the main focus, as growing evidence shows that it can induce hyperpigmentation.[9]

In this study, we measured the irradiance and dose of visible light, especially blue light, emitted from electronic devices from various distances and brightness levels. The result showed that the irradiance and dose emitted from electronic devices were proportional to brightness, distance, and screen size. This implied the use of the dimmest light possible within a reasonable distance.

The devices tested included both new and used models, with some screens having been in use for several months as mentioned earlier. For OLED screens, the potential degradation over time was considered, and future studies will explore how screen health influences light emission in more detail.

Cutaneous photosensitivity has been primarily focused on UV radiation. While visible light is regarded to be safe, it should be noted that there might be a complex and unknown aspects of interaction between human skin and visible light.[18] Visible light can damage melanocytes through melanin photosensitization and singlet oxygen generation. These process lead to decreasing cell viability, increasing membrane permeability, and causing both DNA photo-oxidation and cell death.[19] Involvement of reactive oxygen species in the formation of aging-associated changes in human cells has been established.[20] This indicates a solid role of singlet oxygen in photoaging of human skin.

Exposure of the skin to a certain amount of visible light could induce immediate pigment darkening, immediate erythema, and delay tanning.[1,21] The threshold dose for immediate pigment darkening with visible light was between 40 and 80 J/cm^2, and the threshold dose for delayed tanning was between 80 and 120 J/cm^2.[21] Given this number, the dose of visible light obtained from our study was much smaller in magnitude. This can help guide the appropriate behavior for patients with photodermatoses that can be aggravated by exposure to visible light, such as solar urticaria, chronic actinic dermatitis, and cutaneous porphyrias, as well as for patients with pigmentary disorders such as melasma and post-inflammatory hyperpigmentation.[22,23]

Blue light emitted from electronic devices could affect visual performance by stimulating melanopsin.[24] Melanopsin is important to spatial pattern representation and contrast sensitivity. Moreover, blue light could also change the level of retinal dopamine.[25] With growing evidence suggesting the involvement of retinal dopamine in myopia development,[26] the impact of blue light emitted from electronic devices over visual performance remains to be explored. The non-visual influences of blue light on the circadian rhythm is of other concern. Blue light has a significant effect on melatonin suppression, leading to changes in sleepiness, sleep onset, ratio of deep sleep and overall sleep quality.[27] While blue light during the day has a benefit on alertness, mood, and productivity, blue light exposure at night could interfere with sleep quality.[28] This overall effect of blue light could potentially affect skin conditions as well. Recent evidences indicate that blue light-blocking filters could provide protective effects in controlling dry eyes and providing ocular comfort.[29] Using blue light-blocking devices at night also improves sleep quality and circadian rhythm disturbances.[30]

The wavelength of blue light could induce pigmentation and photoaging.[6,9] In previous clinical studies, blue light-induced pigmentation in darker skin types through activation of opsin 3 occurred at 90 J/cm^2, while blue-violet light at 50–100 J/cm^2 decreased the antioxidant concentration found in human skin.[9,31] The dose of electronic devices at the peak

wavelength of 460 nm in our study suggested that they are unlikely to cause any harm with daily use. In every distance and brightness level, the night shift mode provided benefits in reducing blue light dose. The largest monitor screen showed the greatest percent reduction in dose.

Even though the 1-hour period of dose from electronic devices was still far from reaching the threshold level that could cause any skin changes, it should be noted that the longer exposure of electronic devices could lead to an increasing dose of visible light, especially blue light. A previous study showed that maximal use of light (between 420 and 490 nm) from a high-intensity computer screen for 8 hours per day for a 5-day period does not worsen melasma lesions.[32] Moreover, given that most electronic devices are used indoors, spending more time in front of electronic devices could potentially lead to less time outdoors, where exposure to visible light could be much higher. Even though it is quite unlikely that daily exposure to visible light, especially blue light, would cause any effects, the possibility cannot be entirely excluded. A reasonable amount of exposure time coupled with some protection, such as a screen protector, can be applied.

This study had some limitations. The visible light spectrum ranged from 400–700 nm,[1] while the peak sensitivity of the used photopic sensor was 555 nm. Therefore, the results might not be an overall representation of the whole spectrum of visible light. The particular spectral irradiance distribution in the blue spectral region that caused opsin 3 activation and immediate pigment darkening was 415 nm.[10] In this study, the peak wavelength for the blue light sensor was 460 nm, which might not accurately represent the spectrum that caused the damage. However, some studies have indicated that the wavelength of 450 nm, which was closer to the sensor used in our study, could cause human dermal fibroblasts to produce reactive oxygen species, leading to collagen changes as well.[11,12] The results should be interpreted with caution.

In conclusion, this study has shown that measured irradiance and estimated dose emitted from electronic devices at various distances and brightness levels using a photopic sensor (peak wavelength of 555 nm) and a blue light sensor (peak wavelength of 460 nm) are small and are unlikely to cause any harm with daily use. However, the results should be interpreted with caution, as the used sensors might not represent the exact spectrum of visible light, especially blue light, that caused damage to the skin. The night-shift mode offered the advantage of reducing the dose of blue light. Future studies could focus on a wider range of devices with a potential direct effect on human skin.

While this study offers valuable information on the irradiance and dose of blue light emitted from electronic devices, the limitations discussed above highlight the need for more comprehensive models that incorporate spectral resolution, biological responses, and weighting factors. The potential effects of light on skin health are complex and depend on numerous factors, including wavelength, intensity, and the biological sensitivity of tissues. As such, further research is needed to refine our understanding of these effects and to develop more accurate guidelines for minimizing light-related skin damage, particularly in the context of the widespread use of electronic devices.

Data Sharing Statement

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Disclosure

All authors declare no conflicts of interest in this work.

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