LIGHT & LIGHTING for OSH Professionals

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VISIBLE LIGHT IS ALL AROUND US, from sunlight to street lighting and automobile headlights to the backlight on a smartphone and in nearly every indoor space. Humans are so accustomed to working and living in artificial light that many of us have not stopped to consider the implications. Most OSH professionals' experience with light and artificial lighting is likely limited to assessing whether sufficient light exists for people to see where they are going or carry out a task, or whether a light is too bright. This article aims to provide a current review of lighting for OSH professionals. Such a review is timely due to emerging issues including energy efficiency, human health impacts (e.g., blue light hazard, circadian rhythm disruption, fatigue), human performance (e.g., visual performance, visual comfort) and environmental impacts (e.g., light pollution).

Visible Light

The visible light spectrum (VLS) is typically considered the portion of the electromagnetic spectrum from approximately 400 to 700 nm wavelength (Figure 1; Elert, 2019; IUPAC, 1997). The colors range from violet (~400 to 450 nm), blue (~450 to 500 nm), green (~500 to 550 nm), yellow (~550 to 600 nm), orange (~600 to 650 nm) and red (~650 to 700 nm). However, there can be some significant variation in exact wavelength ranges reported for colors (Elert, 2019; Helmenstine, 2020; Jones, 2020). The radiant energy of light is characterized by the direct relationship with frequency (Brune, 2020); that is, the shorter wavelength range of the VLS (e.g., violet/purple) has more intrinsic energy than longer wavelengths (e.g., red). The radiant flux (power) of a light source is a function of the frequency of the emitted radiation and time over which the energy is transmitted (DiLaura, Houser, Mistrick et al., 2011; Sliney, 2016).

Lighting Units & Definitions

Common light sources currently used in commercial and industrial applications include incandescent, fluorescent, high intensity discharge (metal halide and sodium vapor) and solid state lighting (SSL) [e.g., light-emitting diodes (LED) and organic LED; Table 1, p. 24]. Lighting metrics are used to predict and compare how a lighting system will behave. Luminaires (lighting fixtures) can be characterized by many metrics, including the total quantity and directional intensity, visual color appearance and brightness, and electrical and fixture efficiency (ANSI/IES, 2017; DiLaura et al., 2011; Rea, 2013). An important point is that some metrics can be classified depending on them having a radiometric or a photometric basis. Radiometric quantities are associated with measurements of radiant energy and power. Photometric quantities were developed to measure light in a manner consistent with the human eye's vision by using, for example, the International Commission on Illumination (CIE) 1924 photopic (P) luminosity [V(λ)], or the CIE 1951 scotopic (S) luminosity [V`(λ)] functions (CIE, 2011; Figure 2, p. 24). Table 2 (p. 26) provides additional key metrics used to characterize lighting.

Although the photopic luminosity function is known to underestimate the contribution of short wavelength light to perceived illuminance (Rea, Figueiro, Bierman et al., 2012), lumens and lux remain widely used lighting metrics. This issue has important implications because the relative proportions of the spectral power distribution (SPD) for LEDs are different from incandescent or fluorescent light or sunlight (Figure 3, p. 27). Illuminating Engineering Society (IES, 2013) has published a technical memorandum (TM-24-13) that provides a method to factor in the differences in SPD from various luminaires while still achieving similar apparent light levels (also referred to as visually equivalent lumens) within a space. The formula used in TM-24-13 factors in these contributions through the use of the S/P ratio, which is the ratio of the scotopic (S) lumens/photopic (P) lumens. Practically, LEDs typically have higher S/P ratios than the light source being replaced, allowing designers to reduce the total lumens required in the system.

The OSH professional should also consider that two light sources can have similar correlated color temperature (CCT) and color rendering index (CRI) while having vastly different SPDs. As a result, a standard (photometric) light meter alone cannot provide the necessary expanded metrics required to make an informed decision regarding lighting from LEDs (Ferrero, Velázquez, Pons et al., 2018; Nilsson, 1981). Therefore, a spectroradiometer (often incorrectly referred to as a spectrometer) is re-

KEY TAKEAWAYS
- LED lighting is being rapidly adopted in all industries and homes due to energy and cost reductions and longer product life.
- Current research has provided new insight on numerous impacts of lighting on human health and productivity.
- New metrics and instruments are needed to monitor and manage these issues. This article provides a review of the emerging issues regarding lighting that are important to the OSH professional.

quired in lieu of the photometric light meter that the OSH professional typically utilizes (CIE, 2011). Spectroradiometers are more complicated instruments and are typically more expensive than photometers (ScienceDirect, 2019).

Lighting Standards & Regulations

In 2019, the U.S. Energy Information Administration (EIA, 2019) estimated that about 6% of total U.S. electricity consumption is used by lighting in the residential and commercial sectors. Although currently being reviewed, the second phase of the U.S. Energy Independence and Security Act was scheduled to take effect Jan. 1, 2020 (Energy Independence and Security Act of 2007). While the standards are technology neutral, the required 25% increase in lighting energy efficiency for general service lamps in the 40 to 100 W range would serve only to increase the adoption of LEDs. Regardless of the outcome, it is not expected to have an impact on the long-term adoption of LEDs. The Clean Energy for All Europeans package of legislative acts directs EU countries to transpose the set of new energy directives into national law with the next 2 years (EU, 2019). These include the Energy Performance of Buildings Directive Update of 2018 that sets a target of all new buildings to be nearly net zero energy by 2020 resulting in adoption of new lighting technologies (EU, 2018).

The U.S. has few national legal requirements for lighting levels beyond OSHA (2011a;b) requiring minimum illuminance related to avoiding slips, trips and falls, and safe egress routes and exit lighting. In response, lighting systems in the U.S. are typically designed following various adopted codes, standards and guidelines based on jurisdiction or organization policy. The acceptable metric values within these codes, standards and guidelines provided by IES and other organizations (e.g., Canadian Center for Occupational Health and Safety, CCOHS) are typically categorized based on building type or task. In contrast, national level legislation, codes, standards and guidelines such as Energy Policy Act of 2005; Energy Independence and Security Act of 2007; American Society of Heating, Refrigerating and Air-Conditioning Engineering (ASHRAE) standards 90.1-2016 and 189.1-2017 focus on specifying lighting watts/area or lumens/watt based on area usage or luminaire type.

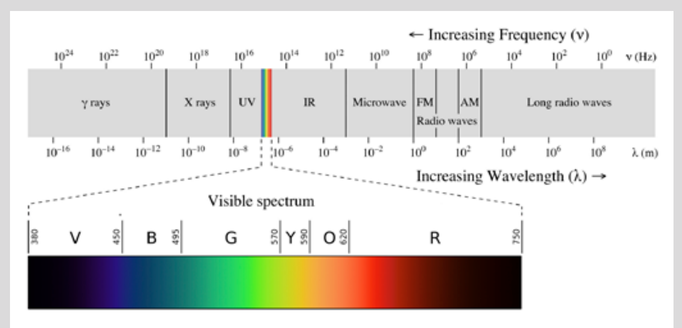
Useful lighting concepts and standards can obtained from a number of organizations including the U.S. Department of Energy, ASHRAE, CIE, IES, U.S. Green Building Council, International WELL Building Institute, CCOHS, EPA Energy Star Program, American Council of Governmental Industrial Hygienists (ACGIH) and International Commission on Non-Ionizing Radiation.

Anatomy of the Eye

The two primary vision related photoreceptor cells found in the eye include about 40 million cones and 100 million rods (DiLaura et al., 2011) with differing sensitivities to the VLS. The cones function at higher illumination levels initiating photopic vision, while the rods function at lower light levels initiating scotopic vision. The two receptors work together over a range known as the mesopic region (Barbur & Stockman, 2010). Three classes of cones exist: long wavelength (L type), medium wavelength (M type) and short wavelength (S type) with peak photopigment sensitivities of 575, 525 and 450 nm, respectively (DiLaura et al., 2011). The fovea is densely packed with L- and M-type cones, giving the center of the eye the best visual acuity (i.e., the spatial resolving capacity of the visual system) and color differentiation (DiLaura et al., 2011). S-type cones, which are not usually found in the fovea, and rod photoreceptors dominate the periphery regions (DiLaura et al., 2011). Rods are more than 1,000 times as sensitive to light as cones and act as a much better motion sensor. For the OSH professional, the two major implications are 1) tasks requiring higher levels of target detection, recognition or localization need higher illumination levels (Kalloniatis & Lu, 2007); and 2) at

FIGURE 1

RELATIONSHIP OF VISIBLE SPECTRUM TO ELECTROMAGNETIC SPECTRUM



Note. Reprinted from EM spectrumrevised.png (File), by P. Ronan, 2013.

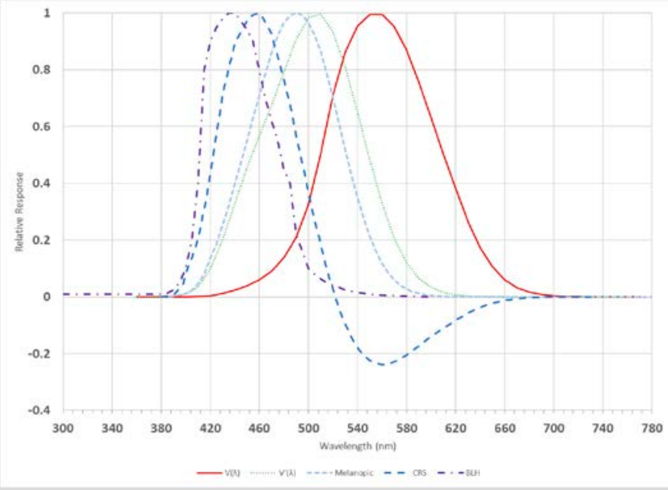
TABLE 1
COMMON LIGHTING TYPES

Luminaire type		Efficacy	CRI rating	CCT range	Average lifetime
Incandescent		15 lm/W	95	2500 K	1,000 hours
High-intensity discharge	Metal halide	70 to 115 lm/W	65 to 90	3000 to 4200 K	5,500 to 20,000 hours
	High-pressure sodium	50 to 125 lm/W	25	1900 to 2100 K	16,000 to 24,000 hours
Fluorescent	Compact	65 to 70 lm/W	77 to 88	2700 to 6500 K	8,000 to 10,000 hours
	T5 HO	92 to 108 lm/W	50 to 95	2700 to 6500 K	30,000 hours
	T8	92 to 95 lm/W	50 to 95	2700 to 6500 K	30,000 hours
Induction		70 lm/W	80 to 90		≥ 100,000 hours
LED current (phosphor-converted)		160 to 170 lm/W (current) 255 lm/W (future)	90		≥ 50,000 hours
LED future (color mixed)		350 lm/W			

Note. Adapted from "LED Lighting Efficacy: Status and Directions," by Morgan Pattison, Hansen, & Tsao, 2018; "LED efficacy: What America stands to gain," by U.S. DOE, 2017.

FIGURE 2
RELATIVE RESPONSE FUNCTION

Relative response functions for V(λ), V′(λ), melanopic lux, circadian rhythm stimulus and blue light hazard.



typical indoor lighting levels the rods are saturated, which can be a major safety hazard when going from higher to lower lighting levels (e.g., indoors to outdoors) as it takes time for the rods to begin to function. A third class of non-vision-related photoreceptor called an intrinsically photosensitive retinal ganglion cell (ipRGC) was formally identified in 2002 (Hattar, Liao, Takao et al., 2002). However, their existence was alluded to in research on mice dating back to the 1920s (Keeler, 1928).

Physiological & Psychological Impacts

The photochemical risk of short-wavelength radiation (~400 to 500 nm) is collectively referred to as blue light hazard. This consists of three major effects: 1) retinal burns; 2) cataracts; and 3) macular degeneration (sometimes referred to as age-related macular degeneration; Neelam, Au & Zhou, 2014; Sliney, 1994). Light sources utilizing the blue light portion of the VLS have caused retinal damage and cell death in albino rats (Lougheed, 2014) and lesions in the human eye (Ham, Mueller & Sliney, 1976). In response, retinal photochemical injury weighting functions (with maximum responses at 435 to 440 nm) were established to protect against blue light hazard (ACGIH, 2001; Ham, 1983; ICNIRP, 2013; Lund, Stuck & Edsall, 2006; Sliney, 2016) with corresponding exposure limits established (Figure 2). For most OSH professionals, the blue light hazard exposure guidelines have only been of concern in specific limited operations such as welding or dental curing (Briggs, Parker, Miller et al., 1992; Council on Dental Materials, Instruments and Equipment, 1986; Okuno, Ojima & Saito, 2010). Although LEDs have an increased relative amount of shorter wavelength light, CIE (2019) has issued a position statement indicating that it does not expect blue light hazard to be a major issue with LED replacements. However, reports in the scientific literature demonstrate that replacement LED fixtures can result in exceedance of the blue light hazard exposure guidelines (Leccese, Vandelanotte, Salvadori et al., 2015) and other issues (Mou & Peng, 2013; O'Hagan, Khazova & Price, 2016; Point, 2018; Rebec, Klanjšek-Gunde, Bizjak et al., 2015).

The suprachiasmatic nucleus located in the hypothalamus plays a pivotal role in regulating daily oscillations of organ functions (including melatonin production) and synchronizing them to day and night body states (Gillette & Tischkau, 1999). This near 24-hour sleep-wake cycle is referred to as the body's circadian rhythm. Several studies from the 1980s to present have shown that the setting of the circadian rhythm is impacted by the ipRGCs' response to light (Crowley, Lee, Tseng et al., 2003; Pauley, 2004; Pickard & Sollars, 2010; Sollars & Pickard, 2015; Wahl, Engelhardt, Schaupp et al., 2019). These ipRGCs account for less than 1% of all ganglion cells and have peak sensitivities to light between 459 and 484 nm (Bedrosian & Nelson, 2013). Subsequently research has shown that several types of ipRGC exist with slightly different responses (Stabio, Sabbah, Quattrochi et al., 2018). These cells are an area of ongoing research. The absence of a light/dark cycle or a distinct noncyclical event (e.g., jet lag, shift work) can cause circadian rhythm disruption leading to a misalignment between physiology, behavior and the environment (Bedrosian & Nelson, 2013). Singular events of circadian rhythm disruption can result in short-term fatigue. Fatigue has been linked to many OSH incidents and worker performance issues (Filtness & Naweed, 2017; Lerman, Eskin, Flower et al., 2012; Marcus & Rosekind, 2017; McCormack, O'Shea, Doran et al., 2018). Overall, the nonvisual effects of lighting are beginning to be recognized as important factors to be considered as the impacts can be recorded at relatively low light levels, including from electronic devices (Figueiro & White, 2013; Kozaki, Kubokawa, Taketomi et al., 2016; Stevens & Zhu, 2015; Vartanian, Li, Chervenak et al., 2015). Currently, two principal metrics are used to characterize the impacts of light on human circadian rhythms (Figure 2): the circadian rhythm stimulus (Rea, Figueiro, Bierman et al., 2012) and melanopic lux (Enezi, Revell, Brown et al., 2011; Lucas, Peirson, Berson et al., 2014).

Although exposure of humans to light can be beneficial for photo entrainment, long-term exposure to light at night can result in long-term circadian rhythm disruption, which has other potential impacts. This disruptive method is of unique importance to the roughly 20% of the worldwide population that is involved in night shift work (Bedrosian & Nelson, 2013). Shift work has previously been classified by International Agency for Research on Cancer (IARC, 2007) as Group 2A, probably carcinogenic to humans. Although light at night is not definitively connected to night shift work, night shift work specifically was recently classified in Group 2A (IARC Monographs Vol. 124 Group, 2019). Of particular concern regarding this issue are the potential heightened circadian rhythm disruption impacts of LED-based light at night. OSH professionals must understand that lighting choices go deeper than cost savings. OSH professionals must understand the important considerations involving light exposure and how it can have beneficial or detrimental impacts on human health and performance. The specific effects depend on many factors including prior light exposure history, hours awake, time of day, SPD, duration and intensity. Workers, especially night shift workers, must be educated on this issue and proper precautions must be taken to ensure that shift workers have proper sleeping conditions.

Another lighting impact of increasing concern is light pollution (Chepesiuk, 2009; Falchi, Cinzano, Duriscoe et al., 2016; Tähkämö, Partonen & Pesonen, 2019). More than 99% of individuals living in the U.S. and Europe, and 80% of the world population experience nighttime light pollution (Falchi et al., 2016). Light pollution can come from many sources, including streetlights, interior lighting, or the use of computers, televisions or cell phones. As light and dark often signals when to eat, sleep, hunt, migrate or reproduce, light pollution can have many negative effects on humans, flora and fauna (Aubé, 2015; Deynego, Elizarov & Kaptsov, 2016; Ouyang, Davies & Dominoni, 2018; Tähkämö et al., 2019).

In addition to the physiological impacts of light, psychological impacts also must be considered. Not only do ipRGCs communicate with the suprachiasmatic nucleus, their signals also reach the prefrontal cortex, hippocampus and amygdala, all of which are areas involved in mood regulation (Bedrosian & Nelson, 2013; Fernandez, Fogerson, Lazzerini Ospri et al., 2018). Circadian rhythm disruption has also been shown to have psychological connections such as mood fluctuations (Haynes, Gengler & Kelly, 2016; Lockley, Dijk, Kosti et al., 2008), fatigue (Caldwell, Caldwell, Thompson et al., 2019), insomnia (Figueiro & White, 2013; Smolensky, Hermida, Reinberg et al., 2016), lack of appetite (Poggiogalle, Jamshed & Peterson, 2018) and generally impaired performance (Figueiro, Sahin, Wood et al., 2016; Naismith, Hickie, Terpening et al., 2014).

Productivity

When utilized properly, lighting choices can also produce benefits beyond those associated with visual acuity. Using lights with higher CCTs can improve employees' feelings of well-being and boost overall productivity (Mills, Tomkins & Schlangen, 2007; Price, Udovicic, Behrens et al., 2019). In addition, other studies have demonstrated positive influences on depressive symptoms, alertness, psychomotor vigilance and task performance (Askaripoor, Motamedzade, Golmohammadi et al., 2019; Mills et al., 2007). While short wavelengths can promote alertness by suppressing melatonin production, it has also been shown that a 630 nm light can produce a wakefulness response (Sahin & Figueiro, 2013).

Temporal Light Modulation Effects

Temporal light modulation (TLM), known colloquially as flicker, refers to the temporal pattern of light output. TLM in light sources is a function of 1) electrical input voltage fluctuation; 2) technology type (e.g., LED vs. incandescent); 3) power source technology (e.g., driver, ballast); 4) light regulation (e.g., dimmers); and 5) visible light communication technologies (e.g., LiFi). Currently, there is wide variation in TLM among luminaires. TLM is known to affect human visual perception, neurobiology and performance, sometimes in adverse ways (CIE, 2016b; 2017; Jaen, Sandoval, Colombo et al., 2005). Undesired effects in visual perception of TLM are referred to as temporal light artifacts (CIE, 2016b). CIE (2016b) identifies three major types of temporal light artifacts: flicker, stroboscopic effect and phantom array effect, often referred to as ghosting.

Without proper ballasts, drivers or capacitors, a light source will exhibit flicker (Lau, 2014). When light flickers at a frequency greater than 50 Hz, most people cannot distinguish between individual flickers; however, the sensory system of some individuals can still detect flicker (ASSIST, 2012; Lau, 2014). Flicker is associated with eye strain and fatigue. A common office complaint associated with flicker is headaches (Karanovic, Thabet, Wilson et al., 2011), however, seizures can be induced in sensitive individuals (Smedley, Webb & Wilkins, 2010; Wilkins, Veitch & Lehman, 2010). When the flicker frequency is from 100 to 500 Hz, it is possible to encounter a stroboscopic effect when working with rotating machinery, which causes it to appear stationary or rotating at a slower speed (Poplawski & Miller, 2013). This could have safety implications in a workplace. The phantom array effect was recently recognized and is primarily visible in outdoor nighttime situations where high contrast is present. Currently, the two most common metrics for TLM are percent flicker and flicker

TABLE 2

RADIOMETRIC & PHOTOMETRIC LIGHTING TERMS/METRICS

Term	Definition	Unit
Radiant intensity	The radiant flux per unit solid angle	W/sr
Radiant flux	Total radiant energy per unit of time	W
Radiant efficiency	Ratio of radiant flux to power consumed	Unitless
Luminous intensity	The luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 x 10^{12} hertz and that has a radiant intensity in that direction of 1/683 W per steradian (sr)	Candela (cd) 1 cd = 1/683 W/sr
Luminous flux	The amount of light emitted per second in a unit solid angle of one steradian from a uniform source of one candela	Lumen (lm) = cd·sr
Illuminance	The area density of the luminous flux from a source divided by the area over which the flux is received	lux (lx) = lm/m^2 (foot-candle)
Luminance	The intensity of light emitted from a surface per unit area in a given direction	Cd/m^2
Lumen maintenance/ lamp lumen depreciation (LLD) factor	A ratio of the mean lumens over the lifetime compared to initial lumen output of a given lamp	LLD = mean lumens/ initial lumens
Luminous source efficacy	The total luminous flux emitted by the total luminaire versus power input	lm/W
CCT	CCT is the absolute temperature a blackbody has when it has approximately the same color appearance as the source. CCT rating for a lamp is a general "warmth" or "coolness" measure of its appearance	Kelvin (K). Typically between 2000K (warm) and 6500K (cool)
Color rendering index (CRI)	A measure of a light source's ability to show object colors realistically or naturally compared to a familiar reference source such as daylight	Scale of 0 to 100, 100 being perfect rendering
Spectral power distribution (SPD)	The collective data of radiant power emitted by a light source at each wavelength or band of wavelengths in the visible region of the electromagnetic spectrum	Unitless (relative) or W/cm^2 (absolute)

Note. Shaded terms denote radiometric quantities.

index (CIE, 2011). Flicker index (Eastman & Campbell, 1952) is most commonly used, and indicates the amount of modulation (reduction) in light output over a single on/off cycle. A value of 100% would indicate that at some point in the cycle there is no light, while a value of 0 would indicate a completely steady source (Bullough & Marcus, 2015; Eastman & Campbell, 1952). Pacific Northwest National Laboratory (PNNL, 2016) has published information on characterizing flicker (Poplawski & Miller, 2011; 2013) and more recently a performance review of some currently available handheld flicker meters (PNNL, 2018). Other measurement metrics for TLM include modulation depth (CIE, 2016b), short-term-flicker indicator (also called short-term flicker severity; CIE, 2016b) or short-term flicker perceptibility (Synergy Systems, 2019), long-term flicker perceptibility (Synergy Systems, 2019) flicker visibility measure (Perz, Sekulovski, Vogels et al., 2017) and the time domain flicker visibility measure (Perz, 2019). For the OSH professional, TLM will primarily be of concern due to flicker, especially in an office environment or heavily computerized environment, and the stroboscopic effect around moving machinery.

Glare

The term *glare* refers to a bright surface or object in the field of view. There are two common types of glare (CIE, 2011; Yang, Luo & Huang, 2018a;b; Yang, Luo & Ma, 2017; Yang, Luo, Ma et al., 2017). Disability glare results in temporary visual impairment caused by intense light sources in the field of view (Epitropoulos, Fram, Masket et al., 2015; Patterson, Bargary & Barbur, 2015). Discomfort glare is a subjective feeling of discomfort due to excessive contrast in the field of view. One of the most common examples of glare is from streetlights, but it is not limited to outdoor situations. Glare is typically measured with luminance meters or luminance cameras (Aslam, Haider & Murray, 2007). Recent advances in sensor technologies have allowed digital cameras to also be used for measurement (Hsu, Chen & Jiaan, 2012). There are several measures of glare, with CIE (1995) recommending the unified glare rating (UGR) as a quantitative measure of glare (Scheir, Hanselaer & Ryckaert, 2017). Other glare calculation methods include CIBSE glare index (CLEAR, 2020a), IES glare index (CLEAR, 2020b; Robinson, Bellchambers, Grundy et al., 1962) and the daylight glare index (Kent, Fotios & Altomonte, 2019). California's Building Energy Efficiency Standards (Title 24, Part 6; CEC, 2019) specifies a maximum lumens rating for backlight, uplight and glare based on IES (2011) TM-15-11. For the OSH professional, the primary implication is reducing contrast between illumination levels in the field of view.

Dynamic Lighting

In general terms, dynamic lighting refers to changing light source characteristics (e.g., intensity, SPD, CCT, distribution of light) based on the needs of the environment (CIE, 2016a). This emerging field is also referred to as tunable-dimmable, smart lighting, intelligent lighting, spectral tuning, circadian lighting, health and well-being lighting and human-centric lighting. OSH professionals should note that the term *adaptive lighting* is also sometimes used, but this term is best reserved for describing automobile headlights (UNECE, 2019), as the term's use in the U.S. dates back to the 1960 Citroen DS (Perkins, 2015). Dynamic lighting is gaining interest among manufacturers, researchers and standards bodies as a method to increase lighting efficacy and manage light exposure for maximum benefits. Dynamic lighting is often characterized as mimicking the natural rhythm of night and day lighting conditions that the body naturally responds to. For example, a dynamic light system could be used in night shift settings to reduce worker exposure to blue light as the shift nears the end, while keeping workers awake and supporting circadian function by utilizing other VLS regions. Before implementing any dynamic lighting scheme in the workplace, OSH professionals are cautioned to ensure that the project team includes the proper expertise and that empirical evidence exists to support any vendor claims.

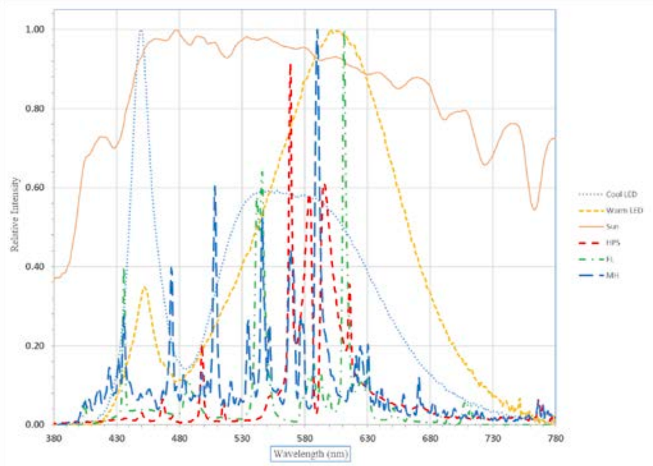
Conclusion

The adoption of LED is ever growing; therefore, OSH professionals must update their knowledge on the characteristics of this light source and its potential implications. Understanding lighting in 2020 requires more than just preventing slips, trips and falls, and providing exit lighting and visibility for safe egress routes. With greater understanding of the impacts of lighting on humans and the environment (e.g., circadian rhythm disruption, light at night) several new metrics have been developed, many of which require the measurement of the luminaire's SPD. This is achieved using a spectroradiometer instead of the basic photometric light meter that has been the standard instrument used by OSH professionals in the past. The confluence of lower cost LEDs, development of Internet of Things technologies and advances in the understanding of VLS on humans translates to the potential wide adoption of dynamic lighting systems in the near future. For OSH professionals, this provides both opportunities and challenges, as the lighting system characteristics in a workplace can easily change without undergoing a thorough internal review, which can result in worker complaints, reduced productivity and other unintended consequences. **PSJ**

FIGURE 3

SPECTRAL POWER DISTRIBUTION

SPD for sunlight, incandescent, HPS, metal halide, florescent, cool LED and warm LED.



Note: Adapted from "LSPDD: Lamp Spectral Power Distribution Database," by J. Roby, 2020.

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