What is Human-centric Lighting?

There is more to light than what we see

BY JOHN SAMMARCO

During the early 1900s, safety was the primary driver prompting use of the new technology of electric lighting for underground mining. The Edison electric cap lamp was approved for mine use during 1915, and it eventually gained wide acceptance. Lighting technology continued to evolve over the years and, until recently, only gradual improvements occurred with incandescent lights.

The advent of light emitting diode (LED) lights revolutionized mine illumination. White LEDs are achieving about 170 lumens per watt (lm/W), the amount of visible light per unit of electrical power, in comparison to about 15 lm/W for an incandescent bulb. They can provide useful light in excess of 50,000 hours of operation as compared to about 1,000 to 3,000 hours for an incandescent light.

Now, there is a new lighting revolution taking place called human-centric lighting (HCL), also known as integrative lighting, that can help improve the safety and health of miners — especially those miners working shifts who experience disruption of their natural circadian rhythm and miners who work underground in conditions of dim artificial light. This article will give an overview of HCL, explain the need to investigate HCL to improve the safety of miners, and provide an overview of HCL research currently being conducted by the National Institute for Occupational Safety and Health (NIOSH).

Circadian rhythms are affected by light. (Image: Shutterstock)

What is HCL?

HCL enhances and promotes beneficial physiological and psychological effects for people. Specifically, it integrates the light needed for visual perception with the nonvisual aspects of light that can affect circadian entrainment, alertness, concentration and performance on cognitive tasks [1], all of which are important factors for miner safety. Light has nonvisual effects that are especially important for mining shift workers who have their natural circadian rhythms disrupted by working when they should be sleeping. Circadian rhythms are the body's various internal "clocks" that are controlled and synchronized by an internal "master body clock." Internal clocks regulate when people encounter feelings of being awake, sleepy, hungry or unhappy. "Abnormal circadian rhythms may be linked to obesity, diabetes, depression, bipolar disorder, seasonal affective disorder, and sleep disorders…" [2].

The master body clock is mainly driven by the natural day and night cycle of light; thus, light can be a very effective intervention to address the disruption of circadian rhythms. Light exposure during the mornings can advance the circadian system so that people go to bed earlier; light at night can result in a circadian rhythm delay and people will go to bed later. An effective light exposure to "resynchronize" circadian rhythm depends on many factors that include the time of day, the light's spectral distribution, the intensity and duration of light exposure, the prior light exposure, and the directionality of the light.

Light affects the synthesis of the hormone melatonin that is produced naturally by the body at night and indicates biologically that it is time to sleep. Melatonin synthesis can be heavily suppressed by light, specifically by the shorter spectral wavelengths in the visible light range of 450 nm to 490 nm (blue), which can result in an alerting effect, and some research indicates that red light during the afternoon can have an alerting effect without affecting melatonin synthesis [3].

HCL for Shift Workers

Mining operations use shift work to achieve around-the-clock production. However, one potential side effect of operating on a 24/7 basis can be worker fatigue and the disruption of circadian rhythms that can lead to sleepy and fatigued workers, who are 69% more likely to be involved in accidents [4]. Health risks include type 2 diabetes, obesity, heart disease, stroke and cancer [5]. The results of a national survey conducted by NIOSH indicate a predominance of shift work for production workers in the coal and metal sectors, where 68.3% of coal and 64.7% of metal mines have multiple shifts [6]. The high rate of shift work makes the mining industry a prime candidate for HCL interventions.

The lack of natural light is another factor for fatigue [7]. Underground miners have much less natural light exposure than other workers, even when they are on a steady daylight schedule. For instance, for a typical workday from 7 a.m. to 3:30 p.m., an underground miner in the Pittsburgh, Pennsylvania, area would at best receive 47% of nat-

ural daylight exposure on June 21 (the summer solstice) and only about 15% of natural daylight on December 21 (the winter solstice).

Secondly, underground miners work in mines with artificial lighting that provides ambient light levels that are much lower compared to other workplaces using artificial lighting. For instance, the ambient illuminance for a roof bolter operator would be about 22 lx, which is in comparison to night shift nurses' ambient lighting environment of about 300 lx [7]. Thus, there is an increased risk of circadian disruption (CD) given the low ambient light levels experienced by miners. CD symptoms include fatigue, decreased cognitive (brain) performance, sleep problems and other health issues [8]. Therefore, HCL can also benefit people who do not work shifts if their workplaces are in low ambient artificial light [8].

NIOSH Research

We are conducting HCL research within the NIOSH Mining Program study "Lighting Interventions for Improving the Health, Safety and Well-Being of Underground Mineworkers." NIOSH wants mines to participate in a field study that will evaluate the impacts of blue- and red-light treatments, given at the beginning of the work shift, on task performance, sleepiness and alertness, subjective well-being, sleep efficiency, and circadian rhythms in underground miners working steady first, second and third shifts. Specifically, the study focuses on the nonimage forming aspects of light, and it will determine the differences in CD between the blue and red-light treatments and the differences among first, second and third shifts.

The lighting treatments will be administered via commercially available, light-emitting eyewear worn for 30 minutes before the shift starts (Fig. 1). Miners will go about their regular pre-shift activities while wearing the lighted eyewear. The lighted eyewear uses LED technology to provide blue-enriched white light peaked at 468 nm and red light. The small size and low power requirements of the LEDs are well suited to be used in this lightweight, battery-powered lighted eyewear.

Figure 1—The lighted eyewear is only worn for 30 minutes during pre-shift. Miners can go about their normal activities while wearing the lighted eyewear. Shown here is lighting treatment B, the blue-enriched 'white' light.

Each miner will receive two lighting conditions: treatment A is red light and treatment B is blue-enriched white light. Half of the miners will receive treatment A for three weeks, have two weeks with no light treatment, then receive treatment B for three weeks. The other half of the miners will receive the light treatments in the reverse order.

We expect this research to lead to new HCL interventions for underground mines that will improve the safety and health of miners by reducing fatigue and CD. Our research is also designed to answer questions about the efficacy of the new HCL interventions for the mining industry.

Disclaimers

The findings and conclusions in this paper are those of the author and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of any company or product does not constitute endorsement by NIOSH.

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Coal Age

NEWS/4

RECLAMATION & BONDING/14

LONGWALL MINING/18

UAVS/20

THIS ISSUE

This month, Coal Age *reports on the changing landscape for drones and UAVs. The next chapter of this evolving story features better technology and more rules. On the cover, DJI's Phantom 4 RTK drone hovers above a haul truck on grade. (Photo: Propeller Aero)*