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Leo Smith
Board of Directors
International Dark Sky Association
1060 Mapleton Avenue
Suffield, CT 06078

May 31, 2008

Dear Mr. Smith:

This letter is in response to your inquiry as to whether light levels produced by streetlights might adversely affect sleep, hormone levels and potentially health in people living in a dense urban environment.

By way of introduction, I am a faculty member in the Division of Sleep Medicine, Brigham and Women's Hospital and Harvard Medical School and I have been studying the effects of light on human circadian rhythms, including sleep, hormones, alertness and performance rhythms, for 15 years. Among other roles, I am the Chair of the Commission Internationale de l'Eclairage (CIE) Division 6 Technical Committee TC6-63 'Photobiological strategies for adjusting circadian phase to minimize the impact of shift work and jet lag' and a Member of the Light and Health Committee, Illuminating Engineering Society (IES) of North America. I am also on the Editorial Boards of the journal *Sleep* and the Sleep and Health Education Program, Harvard Medical School.

Our studies aim to understand the 'non-visual' effects of light on human physiology. About 10 years ago, a novel photoreceptor was discovered in the mammalian eye, including humans, which is anatomically and functionally different from the rod and cone photoreceptors that we use for vision. This new photoreceptor cells are located in a different part of the eye to rods and cones, in the ganglion cell layer, and these cells are 'hard-wired' to the parts of the brain that control our daily sleep and hormone rhythms, particularly the suprachiasmatic nuclei in the hypothalamus, the site of the central circadian pacemaker or 'body clock'. Light information from the environment is detected by these cells to synchronize the internal circadian clock with the external time of day and day-night changes to ensure that our physiology and behavior is properly synchronized with the external environment. The importance of this regular, daily light-dark cycle exposure is readily observed if this light-dark information is altered. For example, shift-workers who stay awake at night and try and sleep in the day, or those flying across multiple time zones, experience sleep, alertness, performance and metabolic disorders because their internal clock cannot readjust quickly enough to the change in light-dark cycle and consequently becomes desynchronized from the environment.

In addition to resetting the biological clock, light also acutely suppresses the production of the pineal hormone melatonin. Melatonin is the internal biochemical signal of darkness and night duration and its production changes in response to season and light exposure. Under a natural light environment, light would never be seen when melatonin is produced and would therefore be unaffected. With the invention of artificial light, however, light exposure now often occurs during the night, stopping the production of melatonin and increasing alertness. In animal studies, melatonin can act as an oncostatic – can slow down the growth of cancerous tumors – and suppression of melatonin speeds up some types of tumor growth. While such studies have not been repeated in humans, there is good epidemiological evidence that female shift-workers, who are often exposed to light at night when their melatonin production occurs, have higher rates of breast cancer than non-shift working women. Notably, totally blind women, who have less light exposure, have reduced rates of breast cancer. While we have yet to understand fully the environmental and health impact of being exposed to light at night, these preliminary data suggest a detrimental effect of prolonged exposure to light at night.

While early research into the effects of light on sleep and hormones suggested that bright light exposure was necessary to stimulate a response, over the past 20 years ours' and others' research has shown that the sleep and circadian systems are exquisitively sensitive to light, and that very dim light is capable of eliciting measurable effects on human physiology. There are many papers detailing the effects of light levels equivalent to that experienced indoors in artificial room light, down to light as dim as 1.5 lux. Below I will review briefly the results from several papers from our own laboratory (copies of the papers are enclosed). There are other papers which I would be happy to provide if necessary.

The first studies describe the effects of different intensities of light on the circadian pacemaker, melatonin levels, alertness and brain activity (see Zeitzer et al., *Journal of Physiology* 2000 and Cajochen et al. *Behavioral Brain Research* 2000, enclosed). Subjects were exposed to one intensity of white light ranging from 3 lux to 9100 lux for 6.5 hours during the night. During the light exposure, blood samples were drawn to measure levels of the pineal hormone melatonin, they were asked to rate their alertness levels, and electrodes were placed in their face and head to measure the rate of slow eye movements and brain activity. The circadian rhythms of melatonin were measured the day before and the day after the light exposure to assess the effects on the biological clock.

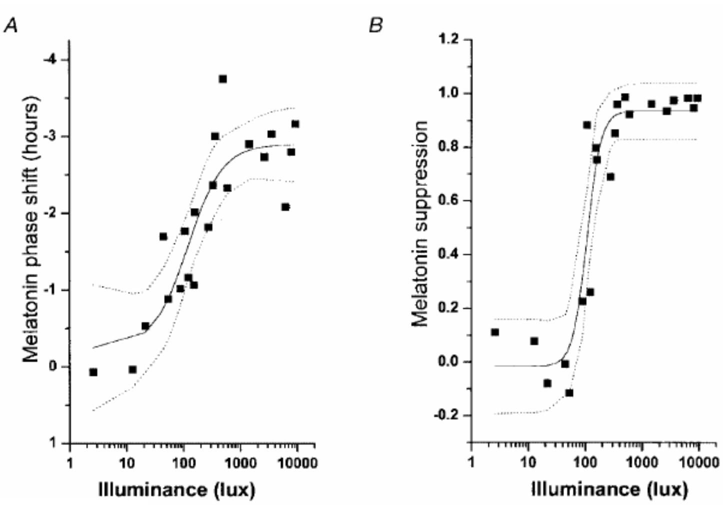


Figure 1

Figures 1 and 2 show the dose-response effect of light on the physiological and behavioral responses. Figure 1 shows the effect of light on circadian rhythm resetting (A, left panel) and suppression of melatonin production (B, right panel). The first thing to note is that the dose-response function is such that about 100 lux of light causes ~50% of the maximum response to very bright 10,000 lux light. Secondly, light from 20-100 lux is still capable of causing a 0.5 -1 h shift in the timing of the circadian pacemaker (A) and suppressing melatonin by up to 20% (B).

Figure 2 shows the results from the same study but for the dose-dependent alerting effects of light. The left panel shows subjective ratings of alertness and the middle panel shows the rate of slow eye movements, considered a reliable objective marker of fatigue. The right panel shows the power density in the electroencephalogram (EEG) recordings in the theta-alpha range (5-9 Hz); high brain activity at these frequencies is indicative of sleepiness. As Figure 2, shows, all three measures of alertness showed a dose-dependent change with light intensity such that higher intensities caused a more alerting effect. Even a low intensities (100 lux and lower), however, light was still able to induce a measurable change in fatigue.

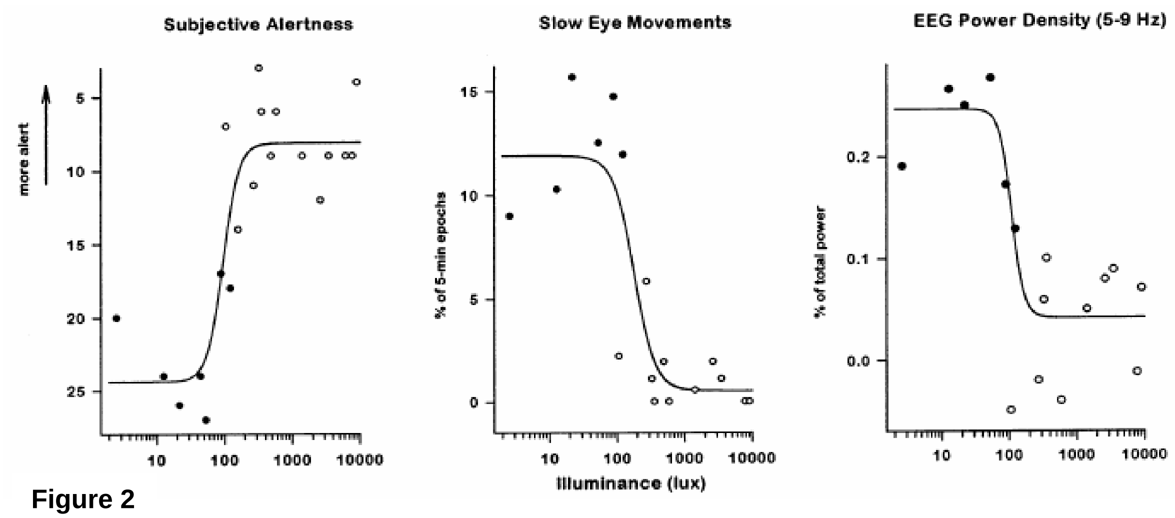


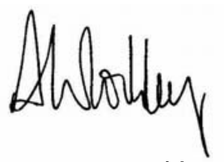
Figure 2

The final laboratory study was conducted to test the power of dim candle-light (~1.5 lux in the vertical angle of gaze) to keep the circadian system synchronized to 24 hours (Wright et al., *Proceedings of the National Academy of Sciences USA*, 2001; attached). Subjects lived in the laboratory for up to 55 days and were scheduled to live on one of three different 'day'-lengths; 23.5 h, 24.0 h and 24.6 h under dim light while awake and darkness when asleep. Although the dim light was unable to reset the circadian pacemaker enough to remain synchronized to the 23.5 h and 24.6 h days, candlelight was sufficient to keep the subjects entrained to 24 hours. Notably, most totally blind people are unable to remain synchronized to 24 hours, again highlighting the importance of even dim light on affecting human physiology and behavior.

These and other studies have shown that dim light is capable of stimulating effects on human sleep and hormonal levels. While brighter light elicits larger effects, we cannot consider dim light an inert stimulus and must keep it in mind when reviewing the appropriateness of light environments. Studies are underway to measure the actual light levels that people are exposed to while indoors and I anticipate that these levels will be significant in urban environments, and even higher when individuals live closer to intrusive street lighting. There is absolutely no need for any horizontal or vertical light to be emitted from street lamps; focusing light solely downward will provide better, more focused lighting for traffic and pedestrians and allow sufficient lighting to be produced with lower energy usage and at a reduced cost. Fixtures which permit horizontal and vertical light are not only inefficient and unnecessary but also emit light inappropriately into living spaces, particularly bedrooms. This light intrusion, even if dim, is likely to have measurable effects on sleep disruption and melatonin suppression, particularly in those whose bedrooms might be in close proximity to streetlights. Even if these effects are relatively small from night-to-night, continuous chronic sleep and hormonal disruption may possibly have longer-term health risks. For example, recent epidemiological studies have shown increased rates of obesity and cancer are associated with decreased nightly reported sleep duration. Intrusive street lighting, as well as wasting money and energy, is likely to have an adverse effect on human health, effects which are entirely avoidable with better planning of urban lighting fixtures. Short- and long-term measures to reduce light pollution will reduce energy demands, reduce reliance on carbon-based fuels and improve the health of the urban environment.

With these consequences in mind, I applaud your efforts to have intrusive street lighting abolished and I wholeheartedly support your campaign. Please let me know if I can be of further assistance.

Yours sincerely,



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Encl.

Zeitzer JM, Dijk DJ, Kronauer R, Brown E, Czeisler C. Sensitivity of the human circadian pacemaker to nocturnal light: melatonin phase resetting and suppression. *Journal of Physiology* 2000;526 Pt 3:695-702.

Cajochen C, Zeitzer JM, Czeisler CA, Dijk DJ. Dose-response relationship for light intensity and ocular and electroencephalographic correlates of human alertness. *Behavioral Brain Research* 2000; 115(1):75-83.

Wright KP Jr, Hughes RJ, Kronauer RE, Dijk DJ, Czeisler CA. Intrinsic near-24-h pacemaker period determines limits of circadian entrainment to a weak synchronizer in humans. *Proceedings of the National Academy of Sciences USA*, 2001; 98(24):14027-32.