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Eye Disease Resulting From Increased Use of Fluorescent Lighting as a Climate Change Mitigation Strategy

Increased use of fluorescent lighting as a climate change mitigation strategy may increase eye disease. The safe range of light to avoid exposing the eye to potentially damaging ultraviolet (UV) radiation is 2000 to 3500K and greater than 500 nanometers. Some fluorescent lights fall outside this safe range.

Fluorescent lighting may increase UV-related eye diseases by up to 12% and, according to our calculations, may cause an additional 3000 cases of cataracts and 7500 cases of pterygia annually in Australia.

Greater control of UV exposure from fluorescent lights is required. This may be of particular concern for aging populations in developed countries and countries in northern latitudes where there is a greater dependence on artificial lighting. (*Am J Public Health.* 2011;101:2222–2225. doi: 10.2105/AJPH.2011.300246)

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CLIMATE CHANGE MITIGATION will involve numerous changes in the use of technology. Many people worldwide are exposed to artificial light sources both in the home and in the workplace. Until recently, this mainly entailed exposure to incandescent lights and, less frequently, to fluorescent lighting. Moves to sustainability and a low-carbon economy have involved the phasing out of incandescent lights and a shift toward more energy-efficient lighting in a number of countries, including Australia and the countries of the European Union.[1,2] In the United States, federal law stipulates that incandescent lights be phased out by 2014.[3]

Globally, increasing numbers of workers spend their work time in buildings rather than in fields or other outside locations and are thus, regularly and for extended periods, exposed to ultraviolet (UV) radiation via fluorescent lighting. This increase is partly due to rapid urbanization and the increasingly knowledge-based society (attracting workers into offices) in which we live. Although fluorescent lighting has been used in schools and offices for many years, only in recent years has it dominated UV exposure in the home, and it will continue to do so in future years.

The types of energy-efficient lighting with which incandescent lights are being replaced are high-intensity discharge (HID) lamps, light-emitting diodes (LEDs), and fluorescent lighting, including the popular compact fluorescent lamps (CFLs). All of these light sources are more efficient than the incandescent lamp, which electrically heats a tungsten filament so that it glows but loses much energy as heat.[4] CFLs, for example, use 75% less energy than do incandescent lamps.[5]

HID lamps produce intense light in a small area, and although they are less energy efficient than fluorescent lights, they are used widely for lighting large areas such as streets and sports facilities.[6] LEDs are energy efficient but not as bright, stable, or cheap as fluorescent lights. Fluorescent lighting, with its minimal energy demands, is considered to provide the most efficient form of light, one that most closely resembles daylight and provides the visual acuity necessary for task performance. Consequently, as a result of the popularity of fluorescent lighting a large number of people are now exposed to artificial sources of UV radiation emitted from these lights. Could this be a precursor to a substantial increase in future eye disease? We examine the potential for such an increase.

FLUORESCENT LIGHTING AND ULTRAVIOLET RADIATION

A fluorescent lamp or tube is a gas-discharge device that uses electricity to excite mercury vapor. The excited mercury atoms produce UV radiation, which causes the phosphorescent coating inside the tube to fluoresce, producing visible light. Manufacturers can vary the color of the light given off by the tube by manipulating the mixture of phosphors, and the spectrum of light emitted is a combination of light directly emitted by the mercury vapor and light emitted by the phosphorescent coating. The amount and wavelength of the UV radiation emitted from such lamps vary widely.[7]

The fluorescent lighting used indoors is often in the form of cool white tubes with a color temperature of about 4000K. (If each light requires 18 watts, the lamps are usually supplied as a pair of 9-watt tubes because 2 lamps cancel out any flicker.) CFLs vary in terms of color temperature, and there are variations and inconsistencies among manufacturers. However, the warmer CFLs, which are usually less than 3500K, produce light that is generally not adequate for concentration at work. Cool white CFLs, at 4000K or greater, are more commonly used in commercial settings. Table 1 describes the types of fluorescent lights and associated color temperatures.[8]

The market share of fluorescent lighting varies considerably among countries, ranging from 6% in the United States to 20% in the United Kingdom and 50% in Germany in 2007, for example.[9] In US commercial buildings, use of incandescent lamps decreased (from 58% to 54%) between 1992 and 2003, as did use of fluorescent lamps (from 91% to 83%), whereas there were increases in the use of CFLs (from 12% to 38%) and HID lamps (from 26% to 29%).[4] In many countries, there is still a high potential for increased use of fluorescent lighting.

Fluorescent lighting operating above a color temperature of 4000K, which is associated with wavelengths of less than 380 to 500 nanometers within the UV range, is hazardous to the ocular tissues. Clarkson identified the 6000K and 400- to 500-nanometer combination as a particularly hazardous one, causing damage to the retina.[10] The safe range of light, to avoid exposing the eye to potentially damaging UV light, is approximately 2000 to 3500K and greater than 500 nanometers. The warmer incandescent lights are usually less than 3500K and are less damaging to the eye, but they often produce light that is inadequate for concentrating at work.

Fluorescent lights emit UV radiation whose irradiance is equal to or greater than that of sunlight at wavelengths of approximately 290 to 295 nanometers but not at longer wavelengths.[11,12] However, there is a fair amount of variation in UV emissions between lamps of similar voltage. Hartman and Biggley studied 15-watt fluorescent lamps used in homes and detected greater than 10-fold differences in ultraviolet-B (UV-B) and ultraviolet-C (UV-C) emissions between lamps (ranging from 0.9 and 0.4 $\mu W/cm^2$ to 21.0 and 1.5 $\mu W/cm^2$ for UV-B and UV-C emissions, respectively), with a 23-fold variance for UV-B.[7] Other studies have also revealed wide variances in fluorescent light UV emissions.

The sensitivity of the eye to short electromagnetic wavelengths not perceived as visible light is important. Absorption of too much short-wavelength UV light can damage ocular tissues by changing the chemical structure of biomolecules.[13] UV wavelengths less than 500 nanometers (and certainly less than 380 nm) are capable of irreparable damage to the eye.[10]

TABLE 1—Types of Fluorescent Lights and Associated Color Temperatures

Type of Light	Example	Approximate Color Temperature, K
Warm (< 3200K)	Incandescent fluorescent	2750
	Deluxe warm white	2900
	Warm white	3000
Medium (3200–4000K)	White	3450
	Natural white	3600
Cool (> 4000K)	Deluxe cool white	4100
	Lite white	4150
	Cool white	4200
	Daylight	6300
	Deluxe daylight	6500
	Octron Skywhite (Sylvania)	8000

Note. Daylight is approximately 6000K (although with considerable variation).
Source. Information was adapted from Sizes Inc.[8]

Cumulative dose is also an important component of UV exposure. Literature based on occupational exposures generally assumes exposures of between 8 and 12 hours per day, or 40 hours per week. Such durations are also well within the normal range for domestic exposures.

ULTRAVIOLET RADIATION AND EYE DISEASES

UV radiation has been considered a cause of cataracts and pterygia.[14] There is also now a significant body of literature describing an association between UV radiation from the sun and degenerative eye diseases such as age-related macular degeneration (AMD).[10,13–21] Early reports suggested that the high-energy segment of the visible region (400–500 nm) is markedly more hazardous than the low-energy portion (500–700 nm).[22] Andley and Chylack reported that the risk of light damaging the retina increases with decreasing wavelength from 500 to 400 nanometers.[23] In Canada, it was reported that AMD, the most common cause of blindness in the developed world, is likely to be associated with chronic exposure to ultraviolet-A (UV-A) radiation.[16]

Shaban and Richter reported that the photoreceptors in the retina are susceptible to damage by light, particularly UV light, and that this damage can lead to cell death and disease.[24] Paskowitz et al. also suggested such photoreceptor damage, reporting that rods are affected earlier than cones.[25] Norval et al. linked acute or long-term eye damage to ozone depletion, which leads to an increase in UV radiation reaching the Earth's surface.[26]

There is also a general public awareness that UV radiation from the sun, sustained in normal daylight conditions, can damage the eye. For example, most people are aware of the importance of not looking directly at the sun, and operators of arc welders know to wear protective goggles.[16,27,28]

Less attention has been paid to the potentially damaging effects of

UV radiation people are exposed to indoors, in particular fluorescent lighting, even though such exposures are a significant source of potentially hazardous UV light. In the past, welding processes and lasers have been the indoor sources of UV radiation of most concern. In a recent report, however, Sharma et al. warned against the use of close-range fluorescent lighting, such as desk lamps, to obviate the risks posed by UV-A.[29]

FLUORESCENT LIGHTING AND IMPACT ON RATES OF EYE DISEASE

The elimination of incandescent lighting and the move worldwide to fluorescent lighting in recent years can be attributed to more acute awareness regarding future climate change concerns.[2] In Australia, it has been estimated that with this change in lighting type there will be a reduction of approximately 30 terawatt hours of electricity and 28 million tons of greenhouse gas emissions between 2008 and 2020. Because Australia accounts for only about 1.8% of greenhouse gases worldwide, a global move toward fluorescent lighting in the home will lead to significant reductions in greenhouse gases.[30]

However, such shifts may increase the population burden of eye disease, and a crude estimate of the number of excess cases of eye disease in Australia caused by fluorescent lighting can be calculated. The prevalence of cataracts in the Australian population is approximately 31% among individuals 55 years old or older,[31] and the prevalence of pterygia is about 7.3% among those 49 years old or older.[32] In 2007, approximately 6.5 million residents of Australia were older than 49 years, and 5.1 million were older than 55 years.[33] Recently, Lucas et al.[14] reported population-attributable fractions of 0.05 for cataracts associated with UV radiation and at least 0.42 for pterygia associated with UV radiation.

Unfortunately, there are no published estimates of the percentage increase in UV exposure with increased exposure to fluorescent lighting, but previously published estimates for workplace exposures may provide a guide. Lytle et al. estimated that, among indoor workers in the United States, lifetime exposure to typical fluorescent lighting (unfiltered) at an average intensity of 1.2 kilojoules per square meter per year (although Lytle et al. reported uncertainties in indoor UV exposures) may increase the risk of solar UV radiation by 3.9% (95% confidence interval [CI] = 1.6%, 12.0%).[34] Lifetime exposure was defined as that occurring over two thirds of a lifetime (40 years of employment and 16 years of schooling, where 1 school year is approximately 0.6 of a work year, that is, 1200 hours vs 2000 hours). Thus, conservative estimates of the number of additional annual cases of cataracts and pterygia in Australia associated with UV radiation from fluorescent lighting would be 2970 and 7480, respectively.

RECOMMENDATIONS

The replacement of incandescent lamps with fluorescent lighting appears to be a global trend. However, this change in lighting sources may lead to an increase in eye diseases unless there is greater control of UV exposures from many of the fluorescent lights currently in use or technological advances enabling efficient lighting from other sources. For Australia alone, we estimate at least 10 000 additional cases of eye disease each year. Our estimates are conservative and crude in that they are limited by the poor information currently available with regard to the incidence and etiology of many eye diseases. We have not included in our estimates possible increases in AMD because there is not yet universal agreement in the literature regarding causality with UV radiation. But if a link between UV radiation and AMD is firmly established in the future, this would have significant public health implications.

Kitchel commented that "serious consideration as to how we light environments of persons with visual problems cannot come too soon" and suggested that such individuals should avoid environments where the predominant light waves are of a color temperature greater than 3500K or a wavelength less than approximately 500 nanometers.[35] Clarkson supported this 500-nanometer threshold limit.[10] Kitchel also suggested that UV light causes irreparable damage over time to the human retina, especially in young children,[35] a public health issue that has not been investigated.

The evidence suggests that the least hazardous approach to lighting is to use warm-white tubes or incandescent bulbs of lower color temperature and longer wavelength light rather than fluorescent lamps. With incandescent bulbs and warm-white tubes, the eye is not subject to potentially damaging UV radiation from fluorescent lighting. The difficulty is that anything other than fluorescent lighting is considered inadequate for many workplaces and in the home. UV filters, available for some fluorescent lights that are manufactured with UV diffusers, should become a required standard. Furthermore, we support the suggestion of Hartman and Biggley that lamp manufacturers should not allow current levels of emission of UV light from fluorescent lighting to increase and should work toward reductions in emissions.[7]

The safe range of light, to avoid exposing the eye to potentially damaging UV radiation, appears to be between 2000 and 3500K and a wavelength of greater than 500 nm. Some fluorescent lights currently fall outside this safe range. This may increase UV-related eye diseases by up to 12% (estimate of 3.9%; 95% CI = 1.6%, 12.0%) and result in unforeseen adverse public health consequences. There is a conflict between climate change mitigation through elimination of incandescent lights and the unregulated use of primarily fluorescent lighting.

In our experience, lighting supply wholesalers and retailers are generally not adequately aware of the full characteristics of their products, such as color temperature and wavelengths of emitted light. Consumers and users of fluorescent lights are relatively unaware of the fact that these lights emit UV light and that this light could be harming their eyes.

In response, we advocate for the use of incandescent and warm-white lamps instead of cool-white fluorescent lamps, as well as for further research into improving lighting from such sources. This public health issue may be of particular concern for aging populations, such as those of many developed countries and countries in northern latitudes where there is a greater dependence on artificial lighting. ■

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Contributors

H. L. Walls and K. L. Walls drafted the original article. G. Benke provided further interpretation. All of the authors helped formulate concepts and contributed to drafts of the article.

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