

Scientific Committee on Emerging and Newly Identified Health Risks

SCENIHR

Light Sensitivity



The SCENIHR adopted this opinion at the 26th Plenary on 23 September 2008.

Light Sensitivity

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They are: the Scientific Committee on Consumer Products (SCCP), the Scientific Committee on Health and Environmental Risks (SCHER) and the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) and are made up of external experts.

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In particular, the Committee addresses questions related to potential risks associated with interaction of risk factors, synergic effects, cumulative effects, antimicrobial resistance, new technologies such as nanotechnologies, medical devices, tissue engineering, blood products, fertility reduction, cancer of endocrine organs, physical hazards such as noise and electromagnetic fields and methodologies for assessing new risks.

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¹ Declared interest (see the minutes of the SCENIHR's 25th Plenary:
http://ec.europa.eu/health/ph_risk/committees/04_scenihr/scenihr_minutes_en.htm)

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ABSTRACT

Within the context of the promotion of wide-spread use of energy saving lamps, such as compact fluorescent lamps (CFLs), and the possible phase-out of incandescent lamps, it has been claimed that the symptoms of several diseases may be aggravated in the presence of energy saving lamps (mainly CFLs).

SCENIHR did not find suitable direct scientific data on the relationship between energy saving lamps and the symptoms in patients with various conditions (i.e. xeroderma pigmentosum, lupus, migraine, epilepsy, myalgic encephalomyelitis, Irlen-Meares syndrome, fibromyalgia, electrosensitivity, AIDS/HIV, dyspraxia, and autism). Therefore, SCENIHR examined whether three lamp characteristics (flicker, electromagnetic fields, and UV/blue light emission) could act as triggers for disease symptoms. Due to lack of data on CFLs, existing data on traditional fluorescent tubes were extrapolated to situations when compact fluorescent lamps may be used.

While for some conditions either flicker and/or UV/blue light could exacerbate symptoms, there is no reliable evidence that the use of fluorescent tubes was a significant contributor. Of all compact fluorescent lamps properties, only UV/blue light radiation was identified as a potential risk factor for the aggravation of the light-sensitive symptoms in some patients with such diseases as chronic actinic dermatitis and solar urticaria.

The committee wishes to draw attention of the Commission Services to the fact that it has been observed that some single-envelope CFLs emit UVB and traces of UVC radiation. Under extreme conditions (i.e. prolonged exposures at distances <20 cm) these CFLs may lead to UV exposures approaching the current workplace limit set to protect workers from skin and retinal damage.

Due to the lack of relevant data, the number of all light-sensitive patients in the European Union, who might be at risk from the increased levels of UV/blue light radiation generated by CFL is difficult to estimate. However, a preliminary rough estimation of the worst-case scenario yields a number of around 250,000 individuals (0.05% of the population) in the EU.

The committee notes that the use of double-envelope energy saving bulbs or similar technology would largely or entirely mitigate both the risk of approaching workplace limits on UV emissions in extreme conditions and the risk of aggravating the symptoms of light-sensitive individuals.

Keywords: Light sensitivity, CFL, fluorescent lamps, risk assessment, SCENIHR.

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EXECUTIVE SUMMARY

The European Commission has requested SCENIHR to determine whether the claims of the "light sensitive" citizens' associations that their symptoms are aggravated by energy saving lamps are justified and, if any of the claims is valid, to determine which lamp characteristics (e.g. light wavelength, lamp frequency, electromagnetic fields emitted, etc.) are responsible as well as to estimate the size of the population affected.

The Scientific Committee established a scientific rationale which is necessary for providing an opinion in response to the request to the Committee. The rationale summarizes physical, engineering, biological, and medical scientific knowledge which is relevant for evaluating if there are specific health risks associated with compact fluorescent lamps (CFLs) compared to conventional forms of lighting. Based on this rationale, the Scientific Committee reached the following conclusions:

A wide range of symptoms have been claimed to be aggravated by the use of energy saving lamps (and CFLs in particular) in patients with: xeroderma pigmentosum, lupus, migraine, epilepsy, myalgic encephalomyelitis, Irlen-Meaers syndrome, fibromyalgia, electrosensitivity, AIDS (HIV), dyspraxia, and autism. No suitable direct data on the relationship between energy saving lamps and any of these conditions have been identified which may be related to the fact that the widespread introduction of such bulbs is a relatively recent development. Therefore, SCENIHR performed a wider examination of the relevant available literature describing correlations between the properties of fluorescent tubes and the appearance of the symptoms of these conditions because such tubes display very similar properties to those of energy saving lamps. The data found for fluorescent tubes was then extrapolated to situations when compact fluorescent lamps may be used.

Flicker and/or UV/blue light from various sources other than lamps can in principle exacerbate the symptoms of certain diseases (epilepsy, migraine, retinal diseases, chronic actinic dermatitis, and solar urticaria). However, there is no evidence that use of traditional fluorescent tubes does.

The concerns identified for energy saving lamps have been attributed to one or more of the following lamp properties: flicker, electromagnetic fields, and UV and blue light radiation. The Committee identified only UV/blue light radiation as a potential risk factor for the aggravation of the light-sensitive symptoms in some patients with such diseases as chronic actinic dermatitis and solar urticaria. No evidence was found that would indicate that either EMF or flicker could be a significant contributor.

The committee wishes to draw attention of the Commission Services to the fact that it has been observed that some single-envelope CFLs emit UVB and traces of UVC radiation. Under extreme conditions (i.e. prolonged exposures at distances <20 cm) these CFLs may lead to UV exposures approaching the current workplace limit set to protect workers from skin and retinal damage.

Due to the lack of relevant data, the number of all light-sensitive patients in the European Union, who might be at risk from the increased levels of UV/blue light radiation generated by CFL is difficult to estimate. However, a preliminary rough estimation of the worst-case scenario yields a number of around 250,000 individuals (0.05% of the population) in the EU.

The committee notes that the use of double-envelope energy saving bulbs or similar technology would largely or entirely mitigate both the risk of approaching workplace limits on UV emissions in extreme conditions and the risk of aggravating the symptoms of light-sensitive individuals

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1. BACKGROUND

Within the context of the promotion of the wide-spread use of energy saving lamps such as compact fluorescent lamps, and the possible concurrent phase-out of incandescent lamps, citizens' associations such as Right to Light, Spectrum Alliance and Lupus UK claim that the symptoms of the following diseases are or could be aggravated in the presence of energy saving lamps (mainly compact fluorescent lamps):

xeroderma pigmentosum, lupus, migraine, epilepsy, myalgic encephalomyelitis (also known as chronic fatigue syndrome), Irlen-Mearns (also known as scotopic syndrome), fibromyalgia, electro-sensitivity, HIV/AIDS, dyspraxia and autism/aspergers Syndrome.

According to physicians and other experts cited by these associations, symptoms can be aggravated by the following technical parameters of the lamps:

- a. Light spectrum specificities;
- b. The air "ionised" by the fluorescent bulbs;
- c. The electromagnetic fields generated by fluorescent bulbs;
- d. Potentially other, so far not identified technical parameters differing from incandescent bulbs.

The "light sensitive" citizens' associations have not provided objective evidence or any up-to-date research papers on these issues, but professors from the British Skin Care Foundation and the British Dermatological Association say that such papers exist.

The associations advocate the precautionary principle and their right for a social life as disabled people. In this context, they are firmly opposed to the phasing out of traditional incandescent bulbs as long as no alternative technology is available for which proper testing has proved that they are harmless to "light sensitive" people.

The Spring European Council in 2007 requested the Commission to adopt by 2009 the latest energy efficiency requirements leading to the phasing out of incandescent bulbs.² In this context, the Commission is planning to adopt measures in early 2009 under the Ecodesign of Energy Using Products Directive (2005/32/EC) that are very likely to phase out incandescent bulbs.

The following documents have been submitted by the associations of "light sensitive" citizens in the framework of an ongoing preparatory study on the planned Ecodesign implementing measure:³

- Right to Light position paper on the preparatory study's draft Chapter 3 and 8
- Spectrum Alliance's submission with 3 annexes
- Lupus UK written contribution to the stakeholder meeting on 23 November 2007 organised by the preparatory study consultant

² Brussels European Council 8/9 March 2007, Presidency Conclusions, 7224/07.

³ www.eup4light.net

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2. TERMS OF REFERENCE

Against the above background, SCENIHR is requested:

- A. To determine whether the claims of the "light sensitive" citizen's associations that their symptoms are aggravated by energy saving lamps are justified, based on solid and up-to-date scientific evidence.
- B. If any of the claims is valid, to determine which lamp characteristics (e.g. light wavelength, lamp frequency, electromagnetic fields emitted, etc.) are responsible.
- C. If any of the claims are valid, to estimate the size of the population affected.

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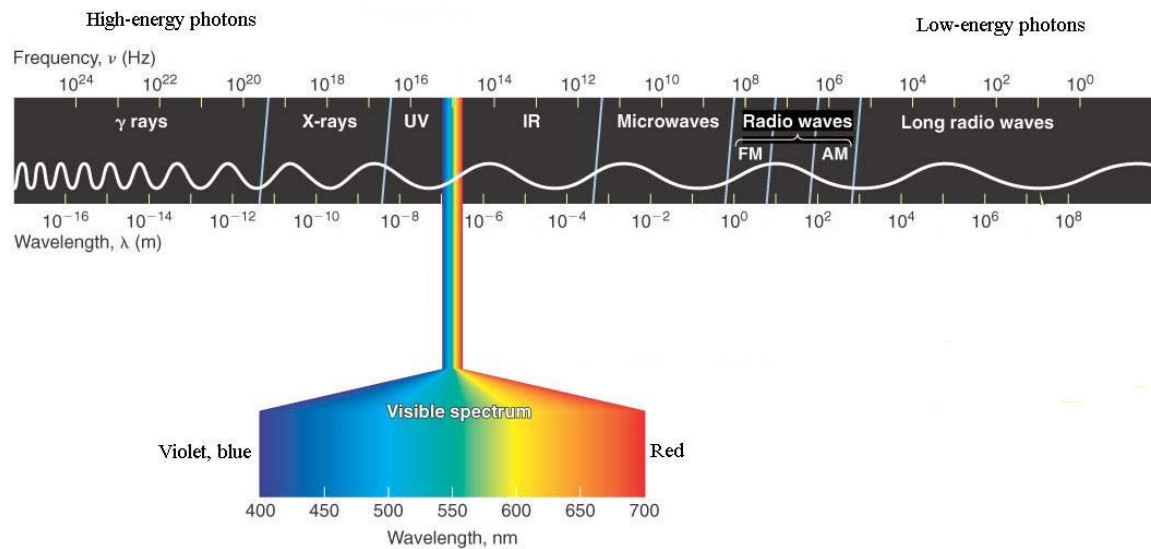
3. SCIENTIFIC RATIONALE

The purpose of this opinion is to determine if the proposed phasing out of incandescent lamps and their replacement with the more energy efficient Compact Fluorescent Lamps (CFL) can have possible health consequences for especially "light sensitive" groups of people. The CFL are technologically developed from conventional fluorescent lamps and differ mainly from those in size, in that they can directly fit into regular light bulb sockets, e.g., in desk lamps in close proximity to the user.

The objective of this section is to establish the scientific rationale which is necessary for providing an opinion in response to the request to the Committee. The section summarizes physical, engineering, biological, and medical scientific knowledge which is relevant for evaluating if there are specific health risks associated with CFL compared to conventional forms of lighting.

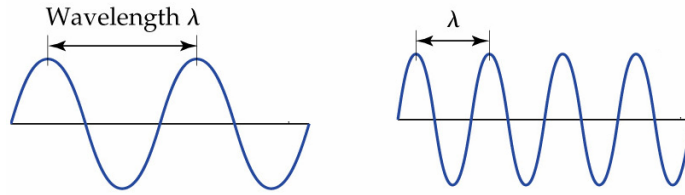
3.1. Introduction

Light is defined as the electromagnetic radiation with wavelengths between 380 and 750 nm which is visible to the human eye. Electromagnetic radiation, such as light, is generated by changes in movement (vibration) of electrically charged particles, such as parts of 'heated' molecules, or electrons in atoms (both processes play a role in the glowing filament of incandescent lamps, whereas the latter occurs in fluorescent lamps). Electromagnetic radiation extends from γ rays and X-rays through to radio waves and to the long radio waves. This is often referred to as 'the electromagnetic spectrum' which is shown on the figure below (modified from American Chemical Society 2003):



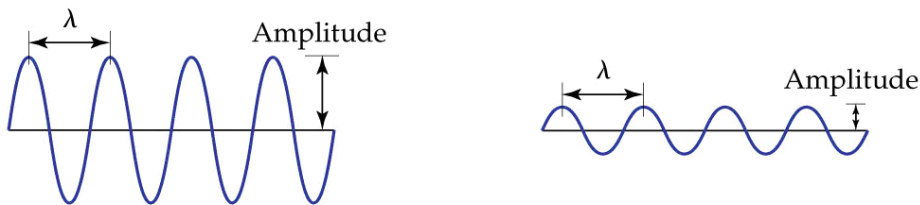
An alternative physical description of light is to consider radiation as being emitted as discrete parcels of energy, called photons, which have dual nature – that of a particle and a wave. The fundamental parameter that distinguishes one part of the electromagnetic spectrum from another is the wavelength, which is the distance between successive peaks of the radiated energy (waves). Photons' energy levels are determined by measuring their wavelength (expressed in units of length and symbolized by the Greek letter lambda λ). Of the two waves shown below, the left one has a wavelength that is two times longer than the one shown on the right:

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The energy of a photon is directly proportional to the photon's frequency, and inversely proportional to its wavelength. Frequency is measured in number of cycles (wave peaks) per second and is expressed in Hz. So, γ rays consist of very high-energy photons with shorter wavelengths and higher frequencies compared to radio waves.

In addition, light is characterized by its intensity. For example, the blindingly intensive red light on a theater stage may consist of photons of the same energy and wavelength as the red stoplight at a street corner; however, stage light is different in terms of the quantity of photons emitted. The higher the number of photons irradiated, the higher the amplitude (the height) of the wave of these photons. The figure below shows photons of the same wavelength (λ), frequency and energy which have two different levels of intensity:



The amplitude is a quantitative characteristic of light, while wavelength (intrinsically linked to photons' energy and frequency) characterises the nature of light qualitatively.

Light is a very small component of the electromagnetic spectrum and is the part that can be perceived by the human eye. Radiation just beyond the red end of the visible region is described as Infra-red (IR), and radiation of shorter wavelength than violet light is called Ultra-violet (UV). The UV portion of the spectrum is divided into three regions:

UVA (315 – 400 nm)

UVB (280 – 315 nm)

UVC (100 – 280 nm)

(Some investigators define UVB as the waveband 280 – 320 nm.)

Sunlight is attenuated as it travels through the earth's atmosphere. This means that all radiation with a wavelength below 290nm is filtered out before it reaches the earth's surface.

Characteristic for every light source is its spectrum, i.e. a graph of the radiant energy emitted at each wavelength. Depending on the characteristics of the light emitting system, the emitted spectrum can be broad or it can have sharp 'lines' at certain wavelengths; the former is the case for the sun, for incandescent and halogen lamps, and is related to the temperature of the source. The latter is usually related to specific changes in energy levels of electrons in certain atoms. Lamps used in lighting applications need to cover the visible range of wavelengths for proper white perception. By the physical principles of light generation, thermal sources like heated filaments of different types [historically C-fibre, W-filament, 'Halogen' protected W-filaments, and electrically induced high temperature plasmas (arc lamps)], as well as the sun and other stars, generate a spectrum of a so called 'black body radiator' which peaks at a certain characteristic frequency corresponding to the temperature of the emitter and follows a

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well described spectrum between the reddish glow of charcoals ($\sim 1000^{\circ}\text{C}$) and the white light corresponding to the surface temperature of the bright sun ($\sim 6000^{\circ}\text{C}$). Various spectra are generally recognised by their characteristic colour by a human observer. For example, due to an increase in scattering of short wavelengths (i.e. blue light) with an increased path length of the sunrays through the atmosphere, the sun takes on more and more of a red hue as it sinks toward the horizon.

Light is indispensable to life on the planet and consequently affects humans and other creatures alike. Notably there are important physical effects through the interaction of light with our skin and our eyes leading to the 'warm' (red light) and 'cold' (blue light) sensation as well as the side effects through our accommodation to the periodic changes each day and with the season which contribute to the regulation of activity/rest cycles.

3.2. Methodology

In general, only scientific reports that are published in English language peer-reviewed scientific journals are considered. Due to the specific questions and the sparseness of primary scientific literature in certain areas, we considered other sources of information. We have furthermore included some information regarding certain additional conditions, and their possible link to fluorescent lighting, beside the ones specifically mentioned in the Terms of Reference.

To evaluate the scientific evidence supporting the various claims of correlations between fluorescent light from traditional fluorescent tubes and CFL and disease conditions, a set of criteria were used. These criteria are:

- (i) case-control study, cohort study or provocation test involving a number of individuals, published in the peer reviewed literature;
- (ii) findings confirmed by other studies in the scientific literature;
- (iii) biological plausibility of cause/contributor and effect;
- (iv) observations by a health professional in the relevant area;
- (v) experiences described by individuals;
- (vi) experiences by individuals reported by others;
- (vii) substantial exposure and no evidence of adverse effects.

These criteria were then used to perform the ranking of evidence according to the following:

Ranking	A	B	C	D	E
	sufficient evidence	some evidence	inadequate evidence	anecdotal evidence only	no reported effects
Criteria	(i), (ii) & (iii)	(i) & (iii)	(iii) & (iv)	(iv), (v) or (vi)	(vii)

3.3. Physical and biophysical background to light sensitivity

3.3.1. Physical background

The power (energy emitted per second) of a radiant source is expressed in watts (W), but light is expressed in lumens (lm) to account for the varying sensitivity of the eye to different wavelengths of light. The derived relevant units are the radiance (luminance) of a source in W/m^2 (lm/m^2) in a certain direction per steradian (unit of solid angle); all

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around is 4π steradians), and the irradiance (illuminance) of a surface in W/m^2 (lm/m^2 or lux).

The human eye does not register the exact spectral composition of light, but perceives colour on the basis of three kinds of receptors with different spectral sensitivities. Due to the importance of the sun, as a broad spectrum light source, all technical sources can be characterised by their 'Correlated Colour Temperature' which corresponds to the surface temperature of 'black body radiator' (sun or star) which generates a similar colour sensation on the human observer. Typical incandescent lighting is 2700K which is yellowish-white. Halogen lighting is 3000K and daylight is around 5000K.

The Correlated Colour Temperature is an important characteristic for the impact of light on the human observer and on the way the human observer film or digital cameras captures images of objects and scenery. Obviously, through vision, this also affects the recognition and perception of external stimuli which leads to a wealth of effects in humans.

Electromagnetic radiation such as light can, through a number of processes, interact with matter where elastic processes (i.e. without loss of energy in movement) are of very limited effect on the atoms and molecules, whereas inelastic processes will transfer photon energy ("photon absorption"), which may excite electrons to higher energy levels in atoms and thus lead to secondary processes such as:

Heat Formation ("dissipation")

Fluorescence / Phosphorescence / Radical Formation / Light induced chemical reaction

Ionisation (electron emission from an atom or molecule)

Absorption of electromagnetic radiation is typically related to warming of the tissue exposed which has mostly indirect consequences. However, radiation of shorter wavelengths, due to the higher characteristic photon energy, can excite electrons such that chemical processes are initiated which may have detrimental side effects. A well known mechanism is the detrimental effect of UV radiation on living cells.

Ionizing radiation consists of high-energy photons that can detach (ionize) at least one electron from an atom or molecule. Ionizing ability depends on the energy of individual photons, and not on their number. The ability of photons to ionize an atom or molecule varies across the electromagnetic spectrum. X-rays and gamma rays can ionize almost any molecule or atom; far ultraviolet light can ionize many atoms and molecules; near UV, visible light, IR, microwaves and radio waves are non-ionizing radiation.

Ionisation starts with wavelengths shorter than 200 nm and needs at least 6 eV, but more likely up to 33 eV (Hall and Giaccia 2006). An exception is the ionisation by (pulsed) lasers with high intensities ($>10^{11} \text{ W}/\text{cm}^2$; Robinson 1986). There are significant biological effects of ionisation where the most critical target is the DNA (strand breaks and chromosomal aberrations). Such DNA damage may lead to mutations and therefore cancer induction. **Importantly however, ionisation is not generally produced by radiation in the visible/IR/UV range at wavelengths that are longer than 200 nm.**

3.3.2. Light-tissue interactions

Like sunlight on water, UV, visible and IR radiation can be partially reflected from the outer surface of the skin and eyes, and as it penetrates the tissue it can be scattered in various directions (including backwards) from microscopic particles and structures such as fibers (e.g., present in the dermis of the skin). In the tissue, radiation may also be absorbed by various molecules. In comparison to UV and long-wavelength IR radiation, visible radiation is generally not strongly absorbed by the bulk tissue, but it is strongly absorbed by certain components like pigments and blood. The net result of backscattered

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and absorbed visible radiation determines skin color, the white of our eyes, and the multi-colored irises that we see (too little light re-emerges from the pupil, except on photographs taken with a strong flash light directed straight into the eyes). The long-wavelength IR radiation is not scattered but strongly absorbed by water – the main constituent of soft tissues – and this contributes to the heat sensation when the skin is exposed to sunlight. Ultraviolet radiation, especially with short wavelengths, is strongly absorbed by bulk tissue, i.e. by organic molecules like proteins, lipids and DNA. Most of the UV-B radiation is therefore absorbed in the outermost superficial layer (the epidermis of the skin). The absorbed energy from UV radiation is not only converted into 'heat' (i.e. thermal energy from increased movement of molecules), as is the case with IR radiation, but it can also drive photochemical reactions. In the eye, visible radiation is absorbed by special photo-pigments that trigger electrochemical stimuli to optical nerves, enabling us to see, but potentially also mediating adverse effects.

With a few exceptions (most notably the formation of pre-vitamin D3), most photochemical reactions caused by UV radiation in the skin and eyes are detrimental: proteins and DNA become damaged and dysfunctional, either by directly absorbing UV radiation or by being damaged through an intermediary step, such as reactive oxygen species generated from another UV-absorbing molecule. Hence, UV radiation can be considered harmful. Overly damaged cells will die and disassemble in a well-orchestrated manner (a process dubbed apoptosis). Large numbers of cells in apoptosis may cause notable defects that literally surface after a few days in a process we know as 'peeling'. Fortunately, our skin is well adapted to UV-induced damage which also arises upon exposure to the sun. Cells react, alarm signals are produced (i.e. stress responses mediated through cascades of molecular reactions), and the damaged molecules and cells are repaired or replaced. The UV-induced damage and alarm signals can evoke an inflammatory reaction (attracting immune cells from the blood to the site of the toxic insult) as part of a normal sunburn reaction in the skin, or snow blindness (or welder's flash) in the eyes (the redness is caused by widening of superficial blood vessels, and some swelling occurs because of a higher permeability of the vessel walls facilitating the trafficking of white blood cells). In some cases such sunburn reactions may already arise after extremely low UV exposures, revealing an enhanced UV toxicity. Alternatively abnormal allergy-like skin reactions may occur, indicating a pathologic immune response to UV exposures.

3.4. Physical characteristics of lamps

Principles of operation

A fluorescent lamp generates light from collisions in a hot gas ('plasma') of free accelerated electrons with atoms – typically mercury – in which electrons are bumped up to higher energy levels and then fall back while emitting at two UV emission lines (254 nm and 185 nm). The thus created UV radiation is then converted into visible light by UV excitation of a fluorescent coating on the glass envelope of the lamp. The chemical composition of this coating is selected to emit in a desired spectrum.

Construction

A fluorescent lamp tube is filled with a gas containing low pressure mercury vapour and noble gases at a total pressure of about 0.3% of the atmospheric pressure. In the most common construction, a pair of filament emitters, one at each end of the tube, is heated by a current and is used to emit electrons which excite the noble gases and the mercury gas by impact ionisation. This ionisation can only take place in intact light bulbs. Therefore, adverse health effects from this ionisation process are not possible. Furthermore, lamps are often equipped with two envelopes, thus dramatically reducing the amount of UV radiation emitted.

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Electrical aspects of operation

A special electronic circuitry is needed to start the lamp and maintain currents at adequate levels for constant light emission. Specifically, the circuitry delivers high voltage to start the lamp and regulates the current flow through the tube. A number of different constructions are possible. In the simplest case only a resistor is used, which is relatively energy inefficient. For operation from alternating current (AC) mains voltage, the use of an inductive ballast is common and was known for failure before the end of the lamp lifetime inducing flickering of the lamp. The different circuits developed to start and run fluorescent lamps exhibit different properties, i.e. acoustic noise (hum) emission, lifetime (of the lamp and the ballast), energy efficiency and light intensity flicker. Today mostly improved circuitry is used, most especially with compact fluorescence lamps where the circuitry can not be replaced before the fluorescence lamps. This has reduced the occurrence of technical failures inducing effects as those listed above.

EMF

The part of the electromagnetic spectrum that comprises static fields, and fields up to 300 GHz is what is here referred to as electromagnetic fields (EMF). The literature on which kinds, and which strengths of EMF that are emitted from CFLs is sparse. However, there are several kinds of EMF found in the vicinity of these lamps. Like other devices that are dependent on electricity for their functions, they emit electric and magnetic fields in the low-frequency range (the distribution frequency 50 Hz and possibly also harmonics thereof, e.g. 150 Hz, 250 Hz etc. in Europe). In addition, CFLs, in contrast to the incandescent light bulbs, also emit in the high-frequency range of the EMF (30-60 kHz). These frequencies differ between different types of lamps.

Flicker

All lamps will vary their light intensity at twice the mains (line) frequency, since the power being delivered to the lamp peaks twice per cycle at 100 Hz or 120 Hz. For incandescent lamps this flickering is reduced compared to fluorescence lamps by the heat capacity of the filament. If the modulation of the light intensity is sufficient to be perceived by the human eye, then this is defined as flicker. Modulation at 120 Hz cannot be seen, in most cases not even at 50 Hz (Seitz et al. 2006). Fluorescent lamps including CFLs that use high-frequency (kHz) electronic ballasts are, therefore, called "flicker free". However, both incandescent (Chau-Shing and Devaney 2004) and "flicker free" fluorescent light sources (Khazova and O'Hagan 2008) produce hardly noticeable residual flicker. Defective lamps or circuitry can in some cases lead to flickering at lower frequencies, either only in part of the lamp or during the start cycle of some minutes.

Light Emission, UV radiation and blue light

There are characteristic differences between spectra emitted by fluorescent lamps and incandescent lamps because of the different principles of operation. Incandescent light bulbs are tuned in their colour temperature by specific coatings of the glass and are often sold either by the attribute 'warm' or 'cold' or more specifically by their colour temperature for professional lighting applications (photographic studios, clothing stores etc.). In the case of fluorescent lamps, the spectral emission depends on the phosphor coating. Thus, fluorescent lamps can be enriched for blue light (wavelengths 400-500 nm) in order to simulate daylight better in comparison to incandescent lamps. Like fluorescent lamps, CFL emit a higher proportion of blue light than incandescent lamps. There are internationally recognized exposure limits for the radiation (200-3000 nm) emitted from lamps and luminaries that are set to protect from photobiological hazards

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(International Electrotechnical Commission 2006). These limits also include radiation from CFLs.

The UV content of the emitted spectrum depends on both the phosphor and the glass envelope of the fluorescent lamp. The UV emission of incandescent lamps is limited by the temperature of the filament and the absorption of the glass. Some single-envelope CFLs emit UV-B and traces of UV-C radiation at wavelength of 254 nm, which is not the case for incandescent lamps (Khazova and O'Hagan 2008). Experimental data show that CFLs produce more UVA irradiance than a tungsten lamp. Furthermore, the amount of UVB irradiance produced from single-envelope CFLs, from the same distance of 20 cm, was about ten times higher than that irradiated by a tungsten lamp (Moseley and Ferguson 2008).

3.5. Potential mechanisms for impact on users

3.5.1. Effects of fluorescence light vs. normal incandescent light on non-skin pre-existing conditions

Here we discuss the influence of flicker, blue light, "light" in general, and EMF, as emanating from conventional and compact fluorescence lamps on non-skin related pre-existing conditions. The various conditions are discussed separately and the possible influence of the physical factors is evaluated using the criteria outlined in section 3.2.

3.5.1.1. Epilepsy

Five percent of the total world population has single seizures, and the annual incidence is 50 in 100.000 (WHO 2001). About 5 in 100 of epileptic people have photosensitive epilepsy (Epilepsy Action 2007). Photosensitive epilepsy is a form of epilepsy in which seizures are triggered by visual stimuli that form patterns in time or space, such as flashing lights, bold, regular patterns, or regular moving patterns. Often persons with photosensitive epilepsy have no history of seizures outside of those triggered by visual stimuli.

The visual trigger for a seizure is generally cyclic, forming a regular pattern in time or space. Flashing or flickering lights or rapidly changing or alternating images are an example of patterns in time that can trigger seizures (Harding et al. 2005). Epilepsy Action (2007) states that fluorescent lights should normally not cause a problem, except for faulty lamps, which may flicker at a lower frequency. However, much higher risks are connected with television and video games.

While photosensitivity of epileptics is scientifically proven (Steinkruger 1985, Wilkins et al. 1999, Wilkins et al. 2004), it is not analyzed if the flicker frequency range > 120 Hz causes seizures, as do frequencies of 15 – 18 Hz (Hughes 2008) and of 3 Hz (Harding et al. 2005). Although an old study of flicker (50 and 100 Hz) from fluorescent lighting with aging lamps did not suggest a hazard to photosensitive patients (Binnie et al. 1979), a more recent study reports that flicker from screens with 50 Hz repetition frequency causes discharges in the investigated subjects, whereas 100 Hz screens appear to be safe (Ricci et al. 1998).

Conclusion

Seizures are induced by flicker but can be accurately correlated to the frequency only for a small range (3 Hz, 15 – 18 Hz) [Evidence level A]. There is no scientific evidence that fluorescent lamps including CFL induce seizures [Evidence level E].

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3.5.1.2. Migraine

As defined on the website of the National Institute of Neurological Disorders and Stroke, migraine is an intense pulsing or throbbing pain in one area of the head. It is often accompanied by extreme sensitivity to light and sound, nausea, and vomiting. Migraine is three times more common in women than in men. Some individuals can predict the onset of a migraine because it is preceded by an "aura," visual disturbances that appear as flashing lights, zig-zag lines or a temporary loss of vision. People with migraine tend to have recurring attacks triggered by a lack of food or sleep, exposure to light, or hormonal irregularities (only in women). Anxiety, stress, or relaxation after stress can also be triggers. For many years, scientists believed that migraines were linked to the dilation and constriction of blood vessels in the head. Investigators now believe that migraine is caused by inherited abnormalities in genes that control the activities of certain cell populations in the brain (National Institute of Neurological Disorders and Stroke, 2008).

It is estimated that 14% of the adults in Europe have migraine (Stovner et al. 2006). According to self-reported information, certain visual patterns can reliably trigger a migraine attack, such as high contrast striped patterns or flickering lights (Shepherd 2000).

Fluorescent lamps can cause eye-strain and headache (Wilkins et al. 1991). Patients with migraine show somewhat lowered flicker fusion thresholds during migraine-free periods (Kowacs et al. 2004). In addition, photophobia, which is an abnormal perceptual sensitivity to light experienced by most patients with headache during and also between attacks, is documented in many studies (Main et al. 2000).

People with migraine claim to be particularly sensitive to blue light (European Lamp Companies Federation).

Conclusion:

Migraine can be induced by flicker in general (up to about 50 Hz) and patients are light sensitive during and between attacks [Evidence level A]. Scientific support for aggravating symptoms by flicker from fluorescent tubes was not found [Evidence level D]. There is anecdotal evidence of problems with blue light [Evidence level D].

3.5.1.3. Irlen-Meares (Dyslexia; Scotopic Syndrome)

Irlen-Meares is a learning disability that manifests itself primarily as a difficulty with reading and spelling which may be improved by use of coloured lens or overlays. The Irlen-Meares syndrome is also known as Meares-Irlen syndrome and closely linked to Scotopic Syndrome. There is no consensus reached within the scientific community about its actual distinctiveness from other forms of dyslexia. It is separate and distinct from reading difficulties resulting from other causes, such as non-neurological deficiency with vision or hearing, or from inadequate reading instruction. Evidence also suggests that dyslexia results from differences in how the brain processes written and/or spoken language. Although dyslexia has a neurological basis, it is not an intellectual disability. Dyslexia occurs at all levels of intelligence and causes fatigue, headache and word-scrambling, and is considered a learning disability. Dyslectics show impaired flicker detection at 10 Hz (Evans et al. 1994) and do not react uniformly to a flickering stimulus (5, 10, 15, 20, and 25 Hz) (Ridder et al. 1997).

Irlen-Meares is a problem associated with the brain's ability to process visual information. The scientific literature, however, states that due to a deficit in the visual magnocellular pathway, impaired sensitivity to both drifting and flickering gratings exist (Ben-Yehudah et al. 2001), as well as to flickering or moving visual stimuli (Cornelissen et al. 1998).

Self-reporting suggests that fluorescence lighting in contrast to incandescent light aggravate the symptoms of dyslexia. Probably the main problems are caused by UV radiation and blue light, emitted by cool white tubes (Irlen method 2008).

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Conclusion:

It has been shown that dyslectics and Irlen-Meares patients tend to have difficulties detecting flicker. Therefore, flicker from fluorescent tubes should not be a problem [Evidence level A]. There are self-reported indications that the condition is aggravated by mainly UV and blue light [Evidence level D].

3.5.1.4. Ménière's Disease

Ménière's disease is a disorder of the inner ear. Although the cause is unknown, it probably results from an abnormality in the fluids of the inner ear. Ménière's disease is one of the most common causes of dizziness originating in the inner ear. In most cases only one ear is involved, but both ears are affected in about 15 percent of patients.

The symptoms of Ménière's disease are episodic rotational vertigo (attacks of a spinning sensation), hearing loss, tinnitus (a roaring, buzzing, or ringing sound in the ear), and a sensation of fullness in the affected ear. Tinnitus and fullness of the ear in Ménière's disease may come and go with concomitant changes in hearing, occur during or just before attacks, or be constant. There may also be an intermittent hearing loss early in the disease, especially in the low pitches, but a fixed hearing loss involving tones of all pitches commonly develops in time. Loud sounds may be uncomfortable and seem distorted in the affected ear. From all the Ménière's disease's symptoms, vertigo is usually the most troublesome. Vertigo may last for 20 minutes to two hours or longer. During attacks, patients are usually unable to perform activities normal to their work or home life. Sleepiness may follow for several hours, and the off-balance sensation may last for days. The symptoms of Ménière's disease may be only a minor nuisance, or can become disabling, especially if the attacks of vertigo are severe, frequent, and occur without warning (Ménière's disease 2008). Increased sensitivity to physical stimuli like flickering or fluorescent lights during the attacks of Ménière's disease (e.g. vertigo) is self-reported (Vestibular Disorder Association 2005). A recommendation for vertigo is to provide an alternative to fluorescent lighting (Job Accommodation Network 2005).

Conclusion:

Light conditions are not associated with Ménière's disease. However, the attacks may be aggravated by flicker [Evidence level D].

3.5.1.5. HIV/AIDS

The Human immunodeficiency virus (HIV) is a retrovirus that kills the T-helper cells which are essential components of the human body's immune system. Therefore, HIV decreases the ability of the body to fight infection and disease which usually leads to the development of the so-called acquired immunodeficiency syndrome (AIDS).

HIV-positive persons with retinal damage (see the Retina diseases section below) have been shown in one study to have increased sensitivity to flickering light (Plummer et al. 1998). Problems with fluorescent tubes are not reported.

Conclusion:

No risk from flicker concerning other symptoms than retinal diseases has been found for HIV-positive persons [Evidence level E].

3.5.1.6. Retinal diseases

Photochemical damage from blue light may induce several harmful effects to the retina mainly by the production of singlet oxygen (Rózanowska et al. 1995, 1998). Therefore filters are recommended to protect lens and retina from blue light (Ham 1983), if the antioxidant defence mechanisms and the presence of melanin cannot protect against the damage (Sarna et al. 2003). HIV-positive patients may have retinal damage such as

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infectious retinopathies and noninfectious complications, which makes them more sensitive to blue light (Plummer et al. 1998).

Conclusion:

Blue light may be harmful to those with retinal diseases [Evidence level B]. There is also some evidence that prolonged exposure to blue light may reduce the colour sensitivity of the intact retina [Evidence level B].

3.5.1.7. Autism/Aspergers Syndrome

Autism is a neuro-developmental disorder characterized by deficiencies in social interactions and communication skills, as well as repetitive and stereotyped patterns of behavior. Recent epidemiological data show that autism is a frequent disorder, observed in 1 child in 500. The cumulated prevalence of diseases belonging to the spectrum of autism (autism, Aspergers syndrome) and pervasive developmental disorders not otherwise specified, has been estimated at 1/167 (Orphanet 2008).

The studies of Colman et al. (1976), which suggested that repetitive behavior can be aggravated by the flickering nature of fluorescent illumination, had interpretative problems and could not be replicated (Turner 1999). However, a putative relationship between autism and migraine is still suggested by similarities between the two conditions, including the presence of sensory over-stimulation (Casanova 2008). This suggestion is however made without any further investigation into the importance of flicker.

Conclusion:

There is no evidence showing negative effects of fluorescence light on autistic behavior, however, an influence cannot be excluded [Evidence level D].

3.5.1.8. Myalgic encephalomyelitis (Chronic Fatigue Syndrome)

Chronic fatigue syndrome is one of several names given to a potentially debilitating disorder characterized by profound fatigue which lasts for at least six months. It has a prevalence that varies from 0.2% to above 2% (Wyller 2007). According to the US Centers for Disease Control and Prevention, persons with chronic fatigue syndrome most often function at a substantially lower level of activity than they were capable of before the onset of illness. In addition to these key defining characteristics, patients report various nonspecific symptoms, including weakness, muscle pain, impaired memory and/or mental concentration, insomnia, and post-exertional fatigue lasting more than 24 hours. In some cases, CFS can persist for years. The cause or causes of CFS have not been identified and no specific diagnostic tests are available (Centers for Disease Control and Prevention, 2008) A number of illnesses have been described that have a similar spectrum of symptoms to CFS. These include fibromyalgia syndrome, myalgic encephalomyelitis, neurasthenia, multiple chemical sensitivities, and chronic mononucleosis.

According to self-reporting, about 52,500 people in the UK (= 21% of myalgic encephalomyelitis) have increased sensitivity to light (Action for M. E. 2008). Patient studies have also indicated excessive light sensitivity (Söderlund et al. 2000). This is in contrast to other studies, where reduced sensitivity towards sunny, dry, and long days compared to controls can be found (García-Borreguero et al. 1998), and which suggested a disturbance of the biological clock (Durlach et al. 2002).

Conclusion:

There is conflicting evidence regarding patient's sensitivity towards light.

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Symptoms may be aggravated by many factors, including light conditions as stated by self-reporting [Evidence level D]. There is no evidence for a link between chronic fatigue syndrome and fluorescent lighting [Evidence level E].

3.5.1.9. Fibromyalgia

According to the National Institute of Arthritis and Musculoskeletal and Skin Diseases, Fibromyalgia is a disorder that causes muscle pain and fatigue (feeling tired). People with fibromyalgia have “tender points” on the body. Tender points are specific places on the neck, shoulders, back, hips, arms, and legs. These points hurt when pressure is put on them. People with fibromyalgia may also have other symptoms, such as: trouble sleeping; morning stiffness; headaches; painful menstrual periods; tingling or numbness in hands and feet; and problems with thinking and memory (sometimes called “fibro fog”) (National Institute of Arthritis and Musculoskeletal and Skin Diseases, 2007).

Conclusion:

Light conditions do not play a role in fibromyalgia [Evidence level A]. Problems with fluorescent lamps are not investigated but are very unlikely [Evidence level E].

3.5.1.10. Dyspraxia (apraxia)

Developmental dyspraxia is a developmental (e.g. spastic) coordination disorder which is a life-long condition that is more common in males than in females; the exact proportion of people with the disorder is unknown since the disorder is hard to detect. Current estimates range from 5% - 20% with at least 2% being affected severely.

Conclusion:

No evidence in the scientific literature is found regarding any influence of light conditions on dyspraxia [Evidence level E].

3.5.1.11. Photophobia

Photophobia is eye discomfort in bright light, which occurs in many diseases including migraine (see above). Photophobia is a symptom most often associated with pathological eye conditions such as cataracts, corneal damage, burns, infections, inflammation, injury, retinal detachment, etc. People with lighter-coloured eyes and albinism often suffer from photophobia. Since only general studies about effects of light are found, it is concluded that the main problem is the light intensity; irrespective of modulation of other light parameters.

Conclusion:

Any effect of flicker, blue light and fluorescent tubes has not been investigated, but cannot be ruled out [Evidence level C].

3.5.1.12. UV radiation, snow-blindness and cataract

With adequate blocking of UVC and UVB radiation, the CFL do not pose a risk for inducing snow-blindness (sunburn on the exposed surface of the eye ball). However, recent measurements (see section 3.4.) show that some commercially available CFL emit traces of UVC and significant amounts of UVB radiation, which could conceivably cause snow-blindness if the lamp is in close proximity to the eye for an extended period of time (the eye is far more sensitive to UVC radiation than the skin). However, preliminary measurements (personal communication De Gruijl) showed that threshold limits are not easily exceeded. Long-term exposure of the eye to UV radiation (wavelengths lower than 320 nm) may contribute to cataract formation (opacity of the lens). With overhead positioning of lamps this should not pose a significant risk in comparison to sun

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exposure, but with UV emitting lamps at eye level contributions may become important. There are no indications that fluorescent tubes used in room illumination cause either snow-blindness or cataract.

Conclusion:

Fluorescent light does not cause snow-blindness [Evidence level B] or cataract [Evidence level C]. This holds true for CFL, provided that UVC and UVB radiations are adequately filtered out.

3.5.1.13. Electromagnetic hypersensitivity

An in-depth description of the characteristics and occurrence of EMF, as well as the current view on possible health effects after exposure to these EMF can be found in the SCENIHR Opinion: Possible effects of electromagnetic fields (EMF) on human health (SCENIHR, 2007). The limit of exposure to the general public from EMF is based on guidelines by the International Committee on Non Ionising Radiation Protection (ICNIRP, 1998). In short, the levels are frequency dependent and set to avoid acute harmful effects, which in the low frequency part of the spectrum may lead to nerve excitation, and in the radio frequency part of the spectrum tissue heating.

There have been claims that the electromagnetic fields (EMF) emitted from CFL could cause symptoms among persons that consider themselves sensitive to CFL. Furthermore, it has also been reported that persons experiencing symptoms from mobile phones are also "sensitive" to CFL. The subjective symptoms that are mentioned include dermatological symptoms like reddening, tingling and burning sensations, but also headache, fatigue, dizziness, concentration difficulties and nausea. The question is thus if these symptoms can be triggered by EMF, and if CFL irradiate such EMF.

Those that attribute specific health problems like the ones mentioned above to any kind of EMF are often termed "electromagnetic hypersensitive" (WHO 2005). This refers to exposure to extremely low frequency (ELF) electromagnetic fields, as well as to fields of the high frequency kind. The former fields are typically generated from power lines and from various electric devices. Examples of high frequency fields are the fields emitted from devices used for mobile communication (mobile phones and their base stations). These fields have frequency components that belong to the so called radiofrequency part of the spectrum (RF fields).

The symptoms that are attributed to ELF and to RF fields are similar. Many patients also claim that both types of exposure trigger their symptoms. The question whether there exists a real correlation between exposure to EMF and the reported symptoms has been studied in epidemiological studies as well as in provocation studies. The former studies allow for finding possible statistical connections between field exposure and long-term, chronic effects, whereas the provocation studies can reveal if there are any immediate effects by a specific type of exposure. There are a number of published provocation studies, mostly on ELF fields, but also on RF fields to an extent. Recent extensive reviews of these studies clearly show that there is no connection between acute EMF exposure (ELF and RF) and perceived symptoms (WHO 2005, Seitz et al. 2004, Rubin et al. 2005, Rössli 2008). However, these studies do not contribute knowledge regarding any long-term effect. There are few studies with appropriate methodology that address long-term effects of RF exposure and symptoms, whereas a somewhat higher number of studies have focused on ELF effects on symptoms. Most studies have not found any correlation between exposure and symptoms. One RF study related to base stations was performed by Hutter et al. (2006) who found a connection between exposure to higher power densities (1.3 mW/m^2) and some, but not all, of the investigated self-reported symptoms.

The literature on the kinds and strength of EMF that are emitted from CFL is sparse. However, there are several kinds of EMF found in the vicinity of these lamps. Like other devices that are dependent on electricity for their functions, they emit electric and

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magnetic fields in the ELF range (mainly 50 Hz in Europe). In addition, CFL, in contrast to the incandescent light bulbs, also emit in the high frequency range (30-60 kHz). These frequencies differ between different types of lamps. A Swiss study (Bundesamt für Energie, 2004), is one of the few available studies where correct measurements of CFL and their EMF have been performed. In this work, eleven different energy saving lamps were investigated and compared with two types of ordinary incandescent light bulbs. All measured values were far below any limits set by guidelines of international organizations like ICNIRP.

The 50 Hz magnetic field that was measured 30 cm from the lamps was in the nT range, which is very low and comparable to the background fields in any room without electric appliances that are using strong electric currents. The high frequency magnetic fields differed to some extent between different types of lamps, but were still in the nT range 30 cm from the source.

The 50 Hz electric field was also measured and found to be somewhat higher in CFL than from normal lamps, but lower than from other electric appliances. Finally, the high frequency electric fields (which are not present from incandescent bulbs) are measurable but at very low intensity.

Conclusion:

Although there is scarce literature in the area, it seems that the electromagnetic fields generated from CFL are not unique to these lamps, and also not strong in comparison with EMF from any other devices.

It has never been conclusively and convincingly shown that there exist any connections between EMF and the symptoms that are reported by persons with so-called electromagnetic hypersensitivity, although their symptoms are real and in many cases very severe. Thus, based on current scientific knowledge, there do not seem to be any correlation between EMF from CFL, and symptoms and disease states [Evidence level A].

3.5.1.14. Conclusions regarding non-skin pre-existing conditions

There are several self-reported statements about adverse health effects of fluorescent lamps, partly based on subjective perception and psychological effects and lacking scientific evidence. There is a need for additional experimental and epidemiological studies before final conclusions can be drawn regarding several of the conditions that are mentioned in the mandate for this Opinion.

There is evidence showing that flicker can cause seizures in patients with photosensitive epilepsy [Evidence level A], although there are no reported effects of CFL having such effects [Evidence level E].

Migraine can be induced by flicker [Evidence level A], but no evidence has been provided that CFL do that [Evidence level E].

Blue light can aggravate retinal diseases in susceptible patients [Evidence level B], or possibly aggravate migraine [Evidence level D].

It cannot be excluded that Photophobia is induced or aggravated by different light conditions, but it is not even mentioned in self-reports [Evidence level C].

People with Autism/Aspergers syndrome have reported problems which they attributed to fluorescent lighting.

There is sufficient evidence [Evidence level A] that the conditions of patients with Irlen-Meaers syndrome are not influenced by CFL. No reported effects [Evidence level E] indicate that symptoms in patients with ME, fibromyalgia, dyspraxia, and HIV would be aggravated by CFL.

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It is unlikely that fluorescent lamps can cause snow-blindness or cataracts [Evidence levels B, C].

It is unlikely that any EMF emitted from CFL or other fluorescent lamps would contribute to electromagnetic hypersensitivity [Evidence level A].

However, any possible health problems related to flicker and UV/blue light emission are minimized, if CFL are equipped with functional high-frequency electronic ballasts, double envelopes and adequate coating.

3.5.2. Effects of fluorescence light vs. normal incandescent light on photosensitive skin related conditions

The photodermatoses are a group of skin conditions induced by light which include the idiopathic (of unknown mechanism) photodermatoses, drug/chemical induced photosensitivity, the porphyrias, and the genetically determined photosensitive skin conditions, the genophotodermatoses. Fluorescent light has been identified as a risk factor (Rihner and McGrath 1992, Sayre et al. 2004). This section also mentions those disorders that are aggravated by sunlight.

3.5.2.1. Idiopathic photodermatoses

Although idiopathic, this group of conditions are believed to have an immunological basis.

Polymorphic Light Eruption

This condition, which is the commonest of all the photodermatoses presents in spring or early summer as a pruritic erythematous papular rash on sunlight exposed sites. The skin eruption usually develops within half to a few hours of sunlight exposure. The condition usually remits over the winter months. The prevalence increases with the distance from the Equator (5% in Australia; 21% in Sweden; 15% in England)(Pao et al, 1994) and also with altitude (Dang et al. 2006). The overall European estimate is 10-20% (Stratigos et al. 2002, Bock et al. 2005, Hönigsmann 2008). Age of onset is variable with 60% arising in the first three decades, with a two to three fold higher prevalence among females (Bock et al. 2005). Polymorphic light eruption is thought to be a delayed hypersensitivity response to cutaneous neo-antigens induced in susceptible individuals by UVA and UVB sunlight containing exposure. It may be provoked by exposure to high output artificial sources.

Conclusion:

It is possible that in the most severely affected, CFL could produce the eruption [Evidence level C].

Chronic Actinic Dermatitis

Most of the patients have a long history of recurrent contact allergy to defined allergens with features of dermatitis on photoexposed sites. Some have semi-translucent nodules termed actinic reticuloid. It occurs mainly in males over the age of 50 years with a prevalence in Scotland of 16.5:100,000 population (Dawe 2008). The skin is abnormally sensitive to UVB/UVA and frequently also visible radiation. A new type of chronic actinic dermatitis (also uncommon), associated with atopic dermatitis, has been identified in patients in their teens and 20s. Photosensitivity can be severe and broad extending from UVB to the visible region.

Conclusion:

Degree of photosensitivity suggests there may be a problem with CFL (Moseley 2008) [Evidence level C].

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Actinic Prurigo

This is an uncommon condition that particularly affects American Indians and less frequently Caucasian and Asian populations. Age of onset is usually before 10 years and it predominantly affects females. Patients complain of a perennial problem with deterioration during spring and summer. Pruritic, patchy, oedematous erythema with papules is evident following exposure to sunlight. Repetitive UVA provocation testing usually induces lesions. Management of actinic prurigo is more difficult than that of polymorphic light eruption. Its prevalence is estimated at 3.3 per 100,000 of the general population (Dawe 2008).

Conclusion:

Severe cases may potentially be at risk from CFL (Moseley 2008) [Evidence level C].

Solar Urticaria

This is an uncommon photosensitive skin disorder that affects both males and females. It may arise in any age group but is particularly common in the first four decades of life. The condition is persistent and about one-third of patients show no response to treatment. Its wavelength dependency is most commonly in the UVA region extending into the visible and occasionally also affecting the UVB region. The prevalence has been estimated to be 3.1 per 100,000 (Beattie 2003). Provocation of the lesions is relatively easy in the most sensitive group.

Conclusion:

It is possible that some patients could be at risk from CFL. It should be noted that incandescent light sources also cause problems in some patients [Evidence level C].

3.5.2.2. Drug/chemical induced photosensitivity

Many drugs are recognised as capable of inducing photosensitivity. They do so by a variety of mechanisms, commonly phototoxicity, which means that any individual exposed to a sufficient quantity of a drug and appropriate irradiation will be affected. Other mechanisms of action result in only a small number of individuals being affected. Some photosensitising drugs are listed below (Ferguson 2002). Much less common is the mechanism of drug-induced photoallergy which involves a sensitised immune system.

Phototoxicity

Amiodarone

Amiodarone is a cardiac antidysrhythmic agent that causes a burning, prickling sensation with erythema in approximately 50% of individuals on high dose. The wavelengths responsible are UVA and visible light. Unsightly slate-grey skin pigmentation may also develop.

Phenothiazine

Phenothiazine-derivative drugs have an antipsychotic action, thought to act by blocking dopaminergic transmission within the brain. They produce skin discomfort, erythema and blistering elicited by exposure to UVA. Unsightly skin discolouration may also occur.

Fluoroquinolone Antibiotics

This is a large group of drugs that exhibit variable degrees of phototoxicity. Symptoms include erythema and blistering; wavelengths responsible are mainly UVA.

Conclusion:

Given the degree of photosensitivity, it is not anticipated that drug induced photosensitivity to the above will be a particular problem when patients are exposed to CFL vs. incandescent sources [Evidence level C].

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Photofrin and other Anti-cancer Agents

Photofrin and Foscan are potent intentional visible wavelength dependent photosensitisers used in photodynamic therapy of internal cancers. Photodynamic therapy can elicit skin phototoxic responses when exposed to visible light (Hettiaratchy et al, 2000).

Conclusion:

Photosensitivity might be expected to arise with CFL to a greater extent than that seen currently with incandescent light sources because of the greater amount of blue light. However, these patients are closely managed because of their known temporary phototoxicity, and so in practice this is not likely to constitute a significant problem [Evidence level C].

Psoralen Phototoxicity from Plants and Diet

Phytophotodermatitis is a group of conditions which appear following psoralen skin contact from plants along with UVA wavelength exposure. This is unlikely to be a significant problem with CFL. Psoralens are also present in foodstuffs.

Conclusion:

The amount of psoralen in the diet (celery, parsnip, limes, etc.,) when combined with fluorescent lighting is unlikely to be either an acute or chronic problem [Evidence level D].

Photo-allergic contact dermatitis

Photo-allergic contact dermatitis is an uncommon delayed-type hypersensitivity reaction elicited by low doses of UV radiation in susceptible individuals. The main groups of photocontact allergens current in the environment are sunscreen chemicals, and topical non-steroidal anti-inflammatory drugs. When the diagnosis is made, patients can quickly avoid the provoking wavelengths, usually in the UVA region.

Conclusion:

CFL are unlikely to be a significant inducing factor in this group of patients [Evidence level D].

3.5.2.3. Genophotodermatoses

This group of inherited photosensitive skin diseases include Xeroderma Pigmentosum, Cockayne's, Bloom's and Rothmund-Thomson Syndrome, which are quite rare. Xeroderma pigmentosum is reported as occurring in 1 of 250,000 in Europe and the USA (Robbins et al. 1974) while the other disorders are even rarer. The best understood of these is xeroderma pigmentosum. In its classical excision repair defective form, there is a marked photosensitivity to UVB wavelengths. Childhood development of skin cancer makes photoprotection against these wavelengths a priority.

Conclusion:

It is possible that unfiltered CFL could be associated with increased disease activity. Patients are currently advised to avoid unfiltered fluorescent lighting. There could be assumed to be a similar problem with other members of the group [Evidence level C].

3.5.2.4. Porphyrrias

This group of mixed inherited and environmentally induced photosensitivity skin diseases relates to an accumulation of a photosensitive porphyrin within the skin. Examples of these diseases include erythropoietic protoporphyria, the main feature of which is burning or prickling pain in the skin exposed to sunlight. A few minutes of intense visible light are usually enough to elicit symptoms causing the individual to try to escape from

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the light source and seek relief, for example, using cold water compresses. Erythropoietic protoporphyria develops in childhood, or even during infancy. It should be noted that cutaneous porphyrias are particularly sensitive to the blue light region so there would be a theoretical argument when comparing tungsten bulbs (which have less blue light). Porphyrias are rare disorders. For example, the prevalence of congenital erythropoietic porphyria (Günther's disease) in the UK is approximately 2 per 3,000,000 live births. Erythropoietic protoporphyria prevalence has been reported at around 1 to 2 per 100,000 inhabitants (Burns 2004, Marco et al. 2007).

Conclusion:

CFL in extremely sensitive patients could possibly produce a slight increase in the problem compared to tungsten light sources, although there is published evidence against this (Chingwell et al, 2008, in press) [Evidence level C].

Porphyria Cutanea Tarda

The prevalence of porphyria cutanea tarda is estimated to be 1:5,000. It is caused by excessive alcohol intake, chronic hepatitis infection and other factors. It produces blisters, skin fragility and hypertrichosis. It is mainly produced by visible wavelengths rather than ultraviolet A.

3.5.2.5. Photo-aggravated Dermatoses

Ten percent of patients with atopic dermatitis are aware of exacerbations triggered by sunlight. This may be due to infrared exposure and perspiration, but in other patients this does not seem to be the case.

Conclusion:

It seems unlikely that CFL would contribute significantly to this problem and might even be preferred to incandescent light sources [Evidence level D].

3.5.2.6. Lupus Erythematosus

Lupus erythematosus is a chronic autoimmune disease that is often exacerbated by sunlight exposure. Its prevalence is estimated at 27.7 per 100,000 of the general population with a much higher prevalence reported for females of Afro-Caribbean ethnicity (Hopkinson et al. 1993, Johnson et al. 1995). Some patients do describe artificial light causing problems. Provoking wavelengths seem to be predominantly in the UVB extending into UVA2. A range of skin presentations include butterfly rash, a polymorphic light eruption presentation and lupus erythematosus tumidus are examples.

Conclusion:

Through their UV component, chronic exposure to CFL could possibly be a problem. Systemic lupus is an important condition in that skin flares can be associated with internal disease activity [Evidence level C].

3.5.2.7. Skin Cancer

Ultraviolet radiation is a major environmental risk factor for skin cancers. Hence, UV radiation from artificial illumination sources should be reduced to a minimum. The UVC and UVB radiations are especially effective in damaging DNA, and in causing gene mutations and cancerous transformation of cells. Although the carcinogenic UV dose from fluorescent lighting in offices is minor (~ 1%) when compared to equal exposure times in the summer sun, old risk assessments showed that actual annual exposures of office workers could increase by 10 to 30% from the fluorescent lighting, which over a lifetime was estimated to increase the risk of squamous cell carcinomas by around 4 % with a baseline risk much lower than that for outdoor workers who dominate incidences (Lytle et al 1992). Some recent measurements (see section 3.4) showed that some commercially available CFL emit short wavelength UV radiation down to the UVC (254 nm) which is

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unnecessary and undesirable, and leaves room for improved lamp engineering. The most effective wavelengths in causing or stimulating skin melanoma – the most aggressive skin cancer – are not known, but UVA and longer wavelengths may be relatively more important than for skin carcinomas. It should be noted that UVA exposure from fluorescent lamps for indoor illumination is still far lower than from the sun (or artificial tanning lamps). A case-control study in a population with low sun exposure showed that melanoma risk was not associated with fluorescent lighting in the home or offices (Swerdlow et al 1988).

Conclusion:

Fluorescent lamps do not contribute significantly to the melanoma risk [evidence level A] and by analogy CFL will not [Evidence level B]. Fluorescent lamps, including CFL, are estimated to contribute insignificantly to UV doses effective in causing skin carcinomas [Evidence level B].

3.5.2.8. Conclusions regarding skin diseases

Although good quality clinical data associating fluorescent light induction (and by inference CFL) of these photosensitive diseases, is lacking, there are some experimental data supporting the belief that exposure to CFL (particularly when the source is close to the skin) may induce problems in those patients with severe photosensitivity in the ultraviolet B/A spectrum namely, xeroderma pigmentosum, and other genophotodermatoses as well as the idiopathic photodermatoses (chronic actinic dermatitis, severe solar urticaria, polymorphic light eruption and actinic prurigo). It is also possible that in cutaneous systemic lupus erythematosus problems could be induced by the UV mercury vapour lines emitted by unfiltered CFL.

It is also feasible that in some skin conditions particularly sensitive to blue light, e.g., photodynamic therapy administered patients, there could be a marginally greater reaction with CFL than seen with incandescent light sources. It does seem that these adverse reactions will occur in a relatively small number of patients and could, to a degree, be avoided by UV filtering of CFL.

Peer reviewed definitive test data comparing incandescent vs. CFL in these diseases is required to provide a clear answer to the question being asked in this report.

- There is sufficient evidence to show that UV and in some cases visible radiation from lamps can provoke a clinically significant skin reaction in light-sensitive patients [Evidence level A].
- Fluorescent lamps, including CFL emit UV radiation that may be harmful to a subset of particularly sensitive patients [Evidence level C].
- CFL may be harmful when in close proximity to the skin (around 20 cm or less) [Evidence level B].

3.6. Risk Assessment

The concerns identified for energy saving bulbs have been attributed to one or more of the following properties:

- Flicker
- Electromagnetic field radiation
- UV and blue light emission.

It is essential to recognise that energy saving light bulbs are similar in nearly all respects to fluorescent tubes which have been in widespread use in the Member States for many decades. However, from the limited data available to us, some energy saving lamps appear to emit UV-B and traces of UV-C in contrast to the previously most widely used

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types of fluorescent tubes. These data also indicate that lamps are different regarding both the emitted wavelengths of UV and UV intensity. Incandescent lamps do not emit significant quantities of UV radiation. A hazard assessment that considers the possible effects of these three properties is set out in the preceding sections of this report.

The modulation of light intensity from energy saving lamps is of a much higher rate than that may be perceived as flicker. Flicker, observed with low frequencies, is associated with adverse health effects in the small percentage of individuals with certain pre-existing diseases (epilepsy, migraine, and photophobia). There is no evidence that these conditions are exacerbated by normally functioning fluorescent tubes. It can therefore be concluded that the flicker from energy saving bulbs is most unlikely to produce significant adverse health effects even in flicker susceptible individuals.

The SCENIHR has addressed the issue of the claimed hypersensitivity of a few individuals to electromagnetic fields (SCENIHR 2007). It is noted that such claimed effects could not be reproduced in controlled provocation tests. There are no supporting data on the possible contribution of fluorescent tubes or energy saving lamps to such claimed hypersensitivity. As the SCENIHR will provide a further opinion in November on the possible health effects of EMF, further risk assessment of the EMF contribution from energy saving lamps is not considered here.

Exposure to UV/blue light radiation provides both some health benefits (e.g. boosting vitamin D levels and psychological effects) and some health risks (e.g. skin cancer). It is important from a public health viewpoint that the exposure to UV radiation, particularly UV-C is limited. In the workplace, limits have been set for exposure to UV radiation (Directive 2006/25/EC). The principal source of exposure of the great majority of the public to UV radiation is the sun. However, there is also widespread exposure from fluorescent tubes and a number of types of spot lights. These light sources are the predominant form of lighting in offices and other workplaces, shops, public transport vehicles, hospitals, and places of entertainment. They are also increasingly used in areas of domestic premises such as kitchens. It is in domestic premises where by far the greatest change in lighting will occur as a result of the switch from incandescent bulbs to energy saving lamps. This change may result in both increased duration of exposure of the public to some UV radiation wavelengths over a 24-hour period and perhaps also an increased intensity of exposure due to the closer proximity (and possibly increased area of skin exposure) to certain light sources, e.g. table lamps.

In terms of the potential health risk it is appropriate to consider separately two population groups: a) the general population and b) individuals who have demonstrable hypersensitivity to UV light.

a) **General population.**

As noted above UV radiation from energy saving lamps is just one source of exposure to UV radiation. In the case of light sources such as table lamps to which individuals may be in close proximity (around 20 cm or less) the exposure to UV radiation, if the use of such sources is prolonged, might approach but is not likely to exceed the workplace limit. Thus, for this particular use, there may be a health risk for the general public. The committee notes that the use of double envelope bulbs or similar technology for such lighting devices would remove this risk (Khazova and O'Hagan 2008). In other use situations the risk is considered negligible. Compact fluorescent lamps could create a risk of blue light over-exposure contributing to some retinal damage when in close proximity to the eye.

b) **Individuals who have demonstrable hypersensitivity to UV/blue light radiation.**

There are a number of individuals across Europe who suffer from a variety of disorders which renders them exceptionally sensitive to UV/blue light radiation. The prevalence of these conditions is extremely low (ranging from one case per 3,000,000 to 0.0004% and

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0.02% of the general population). The prevalence of only polymorphic light eruption represents a sizable portion (up to 20%) of the general population. However, due to the nature of the condition, the likelihood of patients with polymorphic light eruption to be affected by CFL is rather low. The number of all patients in Europe, who might be at risk from the increased levels of UV/blue light radiation generated by CFL, is estimated at around 250,000 individuals. Hypersensitive patients are constantly at risk of exposure to much higher levels of UV/blue light radiation from sources other than CFL. Therefore, those patients are usually closely monitored and provided advice by health care professionals. The committee notes that the use of double envelope energy saving bulbs or similar technology in the dwellings of such individuals would largely or entirely mitigate this increased risk.

4. OPINION

The widespread introduction of energy-efficient compact fluorescent lamps (CFL) and the suggested phasing out of incandescent lamps has caused concerns among patient groups that this would aggravate certain disease conditions. The CFL are technologically developed from conventional fluorescent lamps and differ mainly from those in size, in that they can directly fit into regular light bulb sockets, and in that they are generally equipped with electronic ballasts that stabilize the lamp and provide initial striking voltage which is required to start the lamps arc discharge.

The European Commission has requested SCENIHR the following:

- A. To determine whether the claims of the "light sensitive" citizens' associations that their symptoms are aggravated by energy saving lamps are justified, based on solid and up-to-date scientific evidence.
- B. If any of the claims is valid, to determine which lamp characteristics (e.g. light wavelength, lamp frequency, electromagnetic fields emitted, etc.) are responsible.
- C. If any of the claims is valid, to estimate the size of the population affected.

The Scientific Committee established a scientific rationale which is necessary for providing an opinion in response to the request to the Committee. The rationale summarizes physical, engineering, biological, and medical scientific knowledge which is relevant for evaluating if there are specific health risks associated with CFL compared to conventional forms of lighting. Based on this rationale, the Scientific Committee has the following answers to the above-listed three questions:

Answer to question A

Based on the mode of operation of the lamps, the Committee identified that the following three lamp characteristics had to be examined in order to determine whether they should be considered as potential triggers for aggravation of some disease-related symptoms:

- Flicker
- Electromagnetic fields
- UV and blue light radiation.

A wide range of symptoms have been claimed to be aggravated by the use of energy saving lamps (and CFL in particular) in patients with: xeroderma pigmentosum, lupus, migraine, epilepsy, myalgic encephalomyelitis, Irlen-Meaers syndrome, fibromyalgia, electrosensitivity, AIDS (HIV), dyspraxia, and autism. However, the Committee was not able to identify suitable direct data on the relationship between energy saving lamps and any of these conditions because the widespread use of such bulbs is a relatively recent development. Therefore, SCENIHR performed a wider examination of the association between these conditions and the three properties of energy saving lamps. Namely:

- (i) the relevant available literature was collected and ranked for its suitability for risk assessment purposes
- (ii) associations between lamp properties and the above health conditions were identified
- (iii) an extrapolation was made from situations where a correlation was identified that was likely to pertain also for lamp saving bulbs. In doing this, the committee drew

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particularly on information relating to fluorescent tube use since such tubes display very similar properties to that of compact fluorescent lamps.

Flicker and/or UV/blue light from various sources other than lamps can in principle exacerbate the symptoms of certain diseases (epilepsy, migraine, retinal diseases, chronic actinic dermatitis, and solar urticaria). However, there is no evidence that use of traditional fluorescent tubes does.

Answer to question B

Of all CFL properties, only UV/blue light radiation was identified as a potential risk factor for the aggravation of the light-sensitive symptoms in some patients with such diseases as chronic actinic dermatitis and solar urticaria. No evidence was found that would indicate that either EMF or flicker could be a significant contributor.

Answer to question C

The committee wishes to draw attention of the Commission Services to the fact that it has been observed that some single-envelope CFLs emit UVB and traces of UVC radiation. Under extreme conditions (i.e. prolonged exposures at distances <20 cm) these CFLs may lead to UV exposures approaching the current workplace limit set to protect workers from skin and retinal damage.

Due to the lack of relevant data, the number of all light-sensitive patients in the European Union, who might be at risk from the increased levels of UV/blue light radiation generated by CFL is difficult to estimate. However, a preliminary rough estimation of the worst-case scenario yields a number of around 250,000 individuals (0.05% of the population) in the EU⁴.

The committee notes that the use of double-envelope energy saving bulbs or similar technology would largely or entirely mitigate both the risk of approaching workplace limits on UV emissions in extreme conditions and the risk of aggravating the symptoms of light-sensitive individuals.

⁴ For explanation of calculation methodology see Annex 1.

5. MINORITY OPINION

None.

6. LIST OF ABBREVIATIONS

AIDS	Acquired immunodeficiency syndrome
CFLs	Compact fluorescent lamps
ELF	Extremely low-frequency
EMF	Electromagnetic fields
HIV	Human immunodeficiency virus
IR	Infra-red
RF	Radiofrequency
UV	Ultra-violet
WHO	World health organization

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Annex 1

Methodology of calculating the number of patients suffering from pre-existing conditions who might be at risk due to CFL UV radiation.

The number of patients who suffer from radiation-sensitive, pre-existing conditions and who might be at an increased risk from exposure to UV radiation emitted from CFL has been estimated roughly to be around 250,000 individuals. This estimate has been derived from the equation described in the methodology section (3.2) and the scientific-literature-based prevalence data for each of the conditions which are provided in the skin-diseases part of the opinion (section 3.5.2).

Methodology:

The number of individuals who might face an additional risk due to CFL UV radiation (N) is estimated using the following formula:

$$N = \sum_i prevalence_i \cdot EUPOP \cdot f = EUPOP \cdot f \sum_i prevalence_i$$

where

EUPOP is the EU population (rounded at 500,000,000 individuals);

i is an index referring to a given radiation-sensitive skin condition;

prevalence_{*i*} is the prevalence of each radiation-sensitive skin condition *i* expressed as fractions which are listed with the description of each of the conditions;

f is the likelihood of an individual with a radiation-sensitive skin condition of being affected by CFL UV light expressed as a fraction (estimated at 0.3 for all conditions except for polymorphic light eruption whose likelihood, due to its nature, is estimated at 0.001; estimates by SCENIHR members).

example:

20% x 0.1% x 500 000 000 = 100 000 individuals with Polymorphic Light Eruption
(prevalence b/n 10-20%)

0.0165% x 30% x 500 000 000 = 24 750 individuals with Chronic Actinic Dermatitis

0.0033% x 30% x 500 000 000 = 4950 individuals with Actinic Prurigo

0.0031% x 30% x 500 000 000 = 4650 individuals with Solar Urticaria

0.002% x 30% x 500 000 000 = 3000 individuals with Erythropoietic protoporphyria

0.02% x 30% x 500 000 000 = 30 000 individuals with Porphyria Cutanea Tarda

0.0277% x 30% x 500 000 000 = 41 550 individuals with Lupus Erythematosus

0.0004% x 30% x 500 000 000 = 600 individuals with Xeroderma Pigmentosum

Total 209 500 rounded at 250 000 to estimate for the worst-case scenario and possible undiagnosed patients.