Executive Summary:
Report on Health Canada Survey of Ultraviolet Radiation and Electric and Magnetic Fields from Compact Fluorescent Lamps

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Background

This report presents the results of tests to determine the levels of ultraviolet and electromagnetic emissions from a sample of 30 Compact Fluorescent Lamps (CFLs). For the ultraviolet radiation (UVR), spectral irradiance data was measured and times to achieve minimum erythemal (skin reddening) dose (MED) and recommended maximum daily UVR exposure were calculated. The parameters measured for the electromagnetic emissions (EMF) were the electric field intensity and magnetic flux density produced by the lamps. In addition, the subject of "dirty electricity" produced by CFLs was examined in terms of its potential to produce electromagnetic exposures in the home.

The impetus for this survey came from the proposed phasing out of energy-inefficient lighting by the Canadian Government by the year 2012 [NRCan, 2007]. This action is expected to result in the more widespread use of CFLs as alternatives to standard incandescent lamps. The need to assess whether the ultraviolet radiation and electromagnetic emissions from CFLs exceeded current exposure guidelines was therefore deemed important.

The selection and procurement of lamps for the survey was carried out by a consulting firm under contract to the federal department of Natural Resources (NRCan). Final criteria for selection were that the lamps have integrated electronic ballasts and were of the screw-in type or could be used with a screw-in adapter. Of the sample group of 30 lamps, 21 were of the familiar bare spiral type while 9 were double envelope lamps and reflector (flood) lamps. Manufacturers wattage ratings ranged from 4 watts to 27 watts. Two incandescent lamps were also purchased (60 Watts and 100 Watts) for comparison purposes.

NRCan provided funding support for this work and all testing and evaluation was carried out by Health Canada staff or under the direction of HC staff as additional technical assistance was required. Testing was performed at Health Canada labs in the National Capital Region.

A. UVR Hazard Assessment

According to the *Radiation Emitting Devices (RED) Act*, no person shall sell, lease or import into Canada a radiation emitting device if the equipment creates a risk to any person of genetic or personal injury, impairment of health or death from radiation by reason of the fact that it emits radiation that is not necessary in order for it to accomplish its claimed purpose. It has been claimed that UV emissions from CFLs have the potential to induce rashes, blistering and photokeratitis. As there are not many peer-reviewed studies available on this topic, more research is needed to explore whether CFLs can indeed induce these adverse health effects

To characterize the UVR from the lamps, the stabilization time and 'hotspot' (or maximum irradiance) for each model was determined using a NIST calibrated radiometer with a UV radiation safety detector. Spectral irradiance characteristics (250-700nm, 1 nm increments) were then measured using a NIST calibrated spectroradiometer while voltage was stabilized at 115VAC. Long-term eye exposure at close proximity to a bulb is unlikely due to aversion responses to a bright source. However, unintentional long-term skin exposure is foreseeable at close distances to the CFLs (i.e. hands under a desk lamp or short-term activity near the source). Measurements were therefore performed at distances of 3, 10 and 30 cm from each bulb. Nine models were chosen for further analysis, looking at the variance of spectral output.

The current recommended Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents issued by the American Conference of Governmental Industrial Hygenists (ACGIH) were used to verify if the general requirements of the *RED Act* are met. Spectral irradiance data was also used to calculate the time to achieve an MED for each bulb.

Results (UVR)

To simplify the summarization of the UVR results, three of the bulbs will be compared and discussed: a) incandescent bulb AG60 (the ‘benchmark’ for hazard analysis), b) CFL N15 (which emits the most UV), and c) CFL Z14 (which demonstrated the least amount of risk). Results for all lamps tested are in the body of the full report.

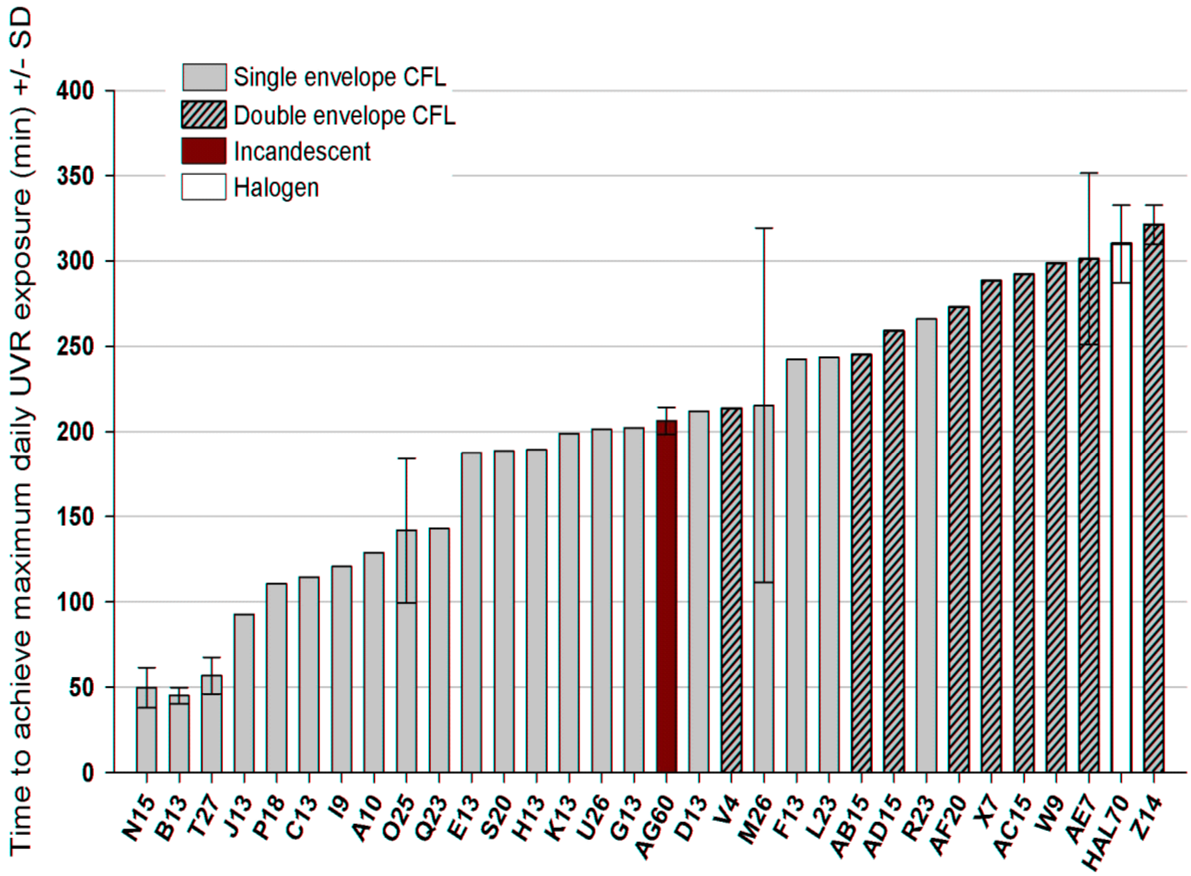

Figure 1. Calculated UVR T_{max} for various bulbs at an exposure distance of 3 cm.

- At a distance of 3 cm from a 60W incandescent bulb (see AG60 in Figure 1), you do not risk skin and eye damage for 3.4 hr/day, repeated exposure.
- In comparison, the maximum daily UVR exposure for a single-envelope CFL (i.e. N15) is only 50 min.
- A double-envelope CFL (i.e. Z14), on the other hand, can be used for 5.4 hrs/day without adverse health effects (the extra glass layer blocks out most of the UVB radiation).
- At a distance of 3cm, skin reddening can occur after 55.2 hrs (AG60), 3.3 hrs (N15) and 81.3 hrs (Z14) continuous exposure (data not shown on graph).

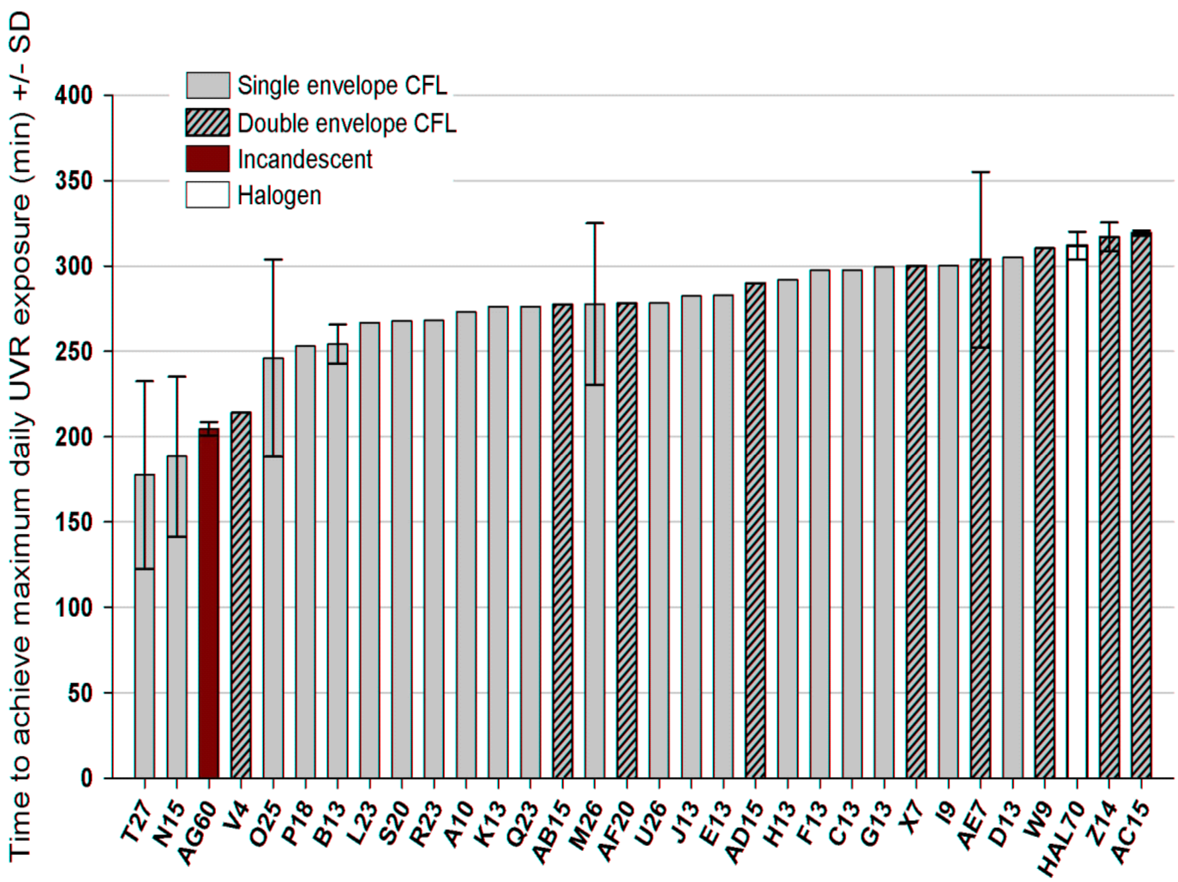

Figure 2. Calculated UVR T_{max} for various bulbs at an exposure distance of 30 cm.

- At a distance of 30 cm from a 60W incandescent bulb (see AG60 in Figure 2), UVR damage to unprotected skin or eyes may result if the bulb is repeatedly used for longer than 3.4 hr/day.
- In comparison, the maximum daily UVR exposure for a single-envelope CFL (i.e. N15) has been increased to 3.0 hr (this is not significantly different from the incandescent T_{max} when you consider the error bars).
- A double-envelope CFL (i.e. Z14) can be used for 5.3 hrs/day without adverse health effects.
- At a distance of 30 cm, skin reddening can occur after 56.1 hrs (AG60), 31.6 hrs (N15) and 87.0 hrs (Z14) continuous exposure (data not shown on graph).

The TLVs used in this hazard assessment represent conditions under which it is believed that nearly all healthy individuals using fluorescent light may be repeatedly exposed without adverse health effects such as those mentioned previously. The results should be used only as guides in the control of exposures to UV radiation and should not be regarded as fine lines between safe and dangerous levels. Moreover, these values do not apply to photosensitive individuals (i.e. patients with polymorphic light eruption, chronic actinic dermatitis, actinic prurigo, solar urticaria, lupus, porphyrias, etc.) or to individuals concomitantly exposed to photosensitizing agents. Among the hundreds of agents that can cause UV hypersensitivity are certain antibiotics, antidepressants, diuretics, cosmetics, antipsychotic drugs, coal tar distillates, dyes and lime oil. As such, certain plants, chemicals and prescription drugs mixed with exposure to UVR sources can result in skin and eye damage at sub-TLV exposures. Lastly, these values do not apply to persons who have had the lens of the eye removed in cataract surgery.

B. EMF Hazard Assessment

All CFLs were tested in two frequency bands, the Extra Low Frequency (ELF, 60 Hz to 2 kHz) and the Low Frequency (LF, 30 kHz to 300 kHz) bands. Each lamp was characterized for its magnitude of the electric field intensity and magnetic flux density at a reference distance of 20 cm and the rate of attenuation of the fields with distance. Also, characterization of the different field waveforms and determination of the operating frequency of the ballast circuitry was carried out. In addition to the field measurements, electrical performance tests consisting of power consumption, power factor and load current distortion were conducted on each lamp. Incandescent lamps were tested only in the ELF band.

The ability of CFLs to produce “dirty electricity” and dirty electricity-generated electric fields was investigated. The instrument promoted by proponents for measuring "dirty electricity", the Graham-Stetzer Microsurge meter, was evaluated in order to understand the unit of dirty electricity, the Graham-Stetzer Unit or GSU. The GSU was translated into traditional electrical units in common usage by the scientific community in order to be able to estimate field strengths. A case study of a selected CFL was examined in terms of the contribution made by dirty electricity to the total exposure in the home.

Results (EMF)

Electromagnetic Emission Frequencies and Waveform Characteristics

Measurements of LF band electric and magnetic field waveform characteristics showed an approximately constant amplitude waveform that was frequency modulated in most cases with widely varying FM bandwidth. The center frequencies range from 43 kHz to 77 kHz and the FM bandwidths ranged from 0 kHz to 14 kHz. The center frequencies of the emitted LF-band fields are assumed to be the same as the ballast operating frequencies.

At the ELF band, the magnetic field waveforms mimicked the load current waveforms and were of a pulse-like nature, characteristic of currents drawn by a full-wave rectifier circuit. The ELF electric field waveforms were approximately sinusoidal at the mains frequency (60 Hz). The frequency content of both electric and magnetic field waveforms were well within the 2 kHz limit that was taken as the upper limit of the ELF band.

Electric Field Intensity

The worst-case ELF electric field intensity at 20 cm distance from the lamp was under 2.5% of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) limit of 4167 Volts per meter [ICNIRP, 1998]. The worst-case LF electric field intensity at 20 cm distance was below 45% of Health Canada's Safety Code 6 (2009) limit of 280 Volts per meter [Health Canada, 2009]. Both the ELF and LF electric fields attenuate with distance away from the lamps so that the margin of compliance with the respective limits is greater at larger distance. The rate of attenuation with distance was measured to be inverse square for the LF electric fields and on average, inverse power of 1.3 for the ELF electric fields. The LF electric field intensity at 20 cm was correlated with the manufacturers wattage rating, allowing the conclusion that lamps with lower wattage ratings have proportionately lower LF electric field emission. (The proportionality coefficient was 0.9% of the guideline limit per watt at 20 cm distance.) For ELF electric fields the correlation was weak (not significant).

Magnetic Flux Density

The worst-case ELF magnetic flux density at 20 cm distance was 0.14% of the ICNIRP limit of 83000 nanoTesla. The worst-case LF magnetic flux density at 20 cm distance was below 0.6% of Health Canada's Safety Code 6 (2009) limit of 2750 nanoTesla. Both the ELF and LF magnetic flux densities attenuate with distance away from the lamps so that the margin of compliance with the respective limits is greater at larger distances. For the LF magnetic field, the rate of attenuation with distance was estimated from calculations to be inverse square. For the ELF magnetic fields, the rate was measured to be inverse power of 2.2. The LF magnetic flux density at 20 cm was correlated with the manufacturers wattage rating, allowing the conclusion that lamps with lower wattage ratings have proportionately lower LF magnetic field emission. (The proportionality coefficient was 0.015% of the guideline limit per Watt at 20 cm.) For ELF magnetic fields the correlation was weak (not significant).

Dirty Electricity

Close examination of the operational characteristics of the GS Microsurge meter revealed that it measures a voltage residing between the phase and neutral conductors of common house wiring. The meter's output quantity, the GS unit, is dependent on both frequency and voltage. For the mean ballast frequency of the CFLs examined (56 kHz), it was found that it took 100 millivolts to produce a reading of 900 GSU (or a conversion factor of 0.11 millivolts per GSU). In the case study of a selected CFL, multiple readings from two separate homes gave a maximum of 650 GSU. This translated to a voltage of 75 millivolts at a frequency of 54 kHz on the house wiring due to the CFL.

Measurement of electric fields produced by standard house wiring allowed the estimation of the electric field intensity produced by 75 millivolts on the wires. This resulted in a value of less than 0.04 V/m at a distance of 20 cm or more from the wiring. This is less than the LF electric field intensity produced by the gas tube of the CFL at most common ranges, and being at the same frequency, would be indistinguishable from the latter. In short, the contribution of the dirty electricity-generated fields to the total produced by CFLs in a home is estimated to be minor or insignificant.

Conclusions

CFLs as demonstrated by the test results do not pose a health hazard to the general population from either the ultraviolet radiation or the associated electric and magnetic fields.

UVR At 30 cm, single-envelope CFLs have a maximum daily UVR exposure similar to the test results for a 60W incandescent lamp. Therefore, it is recommended that single envelope CFLs not be used at distances less than 30 cm to avoid any long-term health effects in the general population.

Based on an analysis of the spectral irradiance data for CFLs at a distance of 30 cm, (and by extension greater distances), the bulbs do not pose a significant risk of acute injury to the eyes or skin, as compared to traditional incandescent lamps. As such, CFLs tested and currently available on the Canadian market do not have issues of non-compliance with the *RED Act*.

EMF The results of the testing of the CFLs demonstrated that the electric and magnetic fields arising from the use of these lamps are below exposure standards that are based on established effects and thus should not be an issue of health concern.