Genotoxicity and carcinogenicity of the light emitted by artificial illumination systems

Silvio De Flora

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Abstract The light delivered by artificial illumination systems, and in particular by halogen quartz bulbs, contains UVA, UVB, and UVC radiation, is genotoxic to both bacterial and human cells and is potently carcinogenic to hairless mice. Since IARC has classified UV radiation in Group 1, any source of UV light poses a carcinogenic hazard to humans. Suitable regulations would be needed in order to control the safety of the light emitted by artificial light sources.

The recent Volume 100 (Part D) of the International Agency for Research on Cancer (IARC) Monographs (2012) focussed on the carcinogenic risks to humans resulting from exposures to UV-containing light. Not only solar radiation was reaffirmed to be causally associated with all major types of skin cancer, but it was also concluded that UV-tanning devices are carcinogenic to humans, thereby being allocated in IARC Group 1.

I would like to draw the attention on the possible carcinogenic risks associated with exposure to UV-emitting artificial light sources, such as fluorescent lamps and especially halogen quartz lamps. More than 20 years ago, while investigating the light-induced formation of reactive oxygen species, by serendipity, we made the discovery that not only sunlight but also the light emitted by artificial illumination systems is genotoxic to bacteria (De Flora et al. 1990). Using filters cutting various UV wavelengths, it was apparent that the potent genotoxicity of halogen lamps is due to delivery of UV light encompassing not only

UVA and UVB but also UVC, which is not present in the solar irradiation reaching the earth crust (De Flora et al. 1990). Furthermore, in another laboratory, it was shown that the mutational specificity in bacteria had the same characteristic features as those seen after irradiation with 254-nm UV light (Wójcik and Janion 1997). These patterns are due to the fact that the quartz bulb of halogen lamps is permeable to the UV radiation delivered by the incandescent tungsten filament, which covers a wide spectrum of wavelengths not only in the UVA region but also in the UVB and UVC regions (McKinlay et al. 1989). This is likely to be the range of wavelengths inducing melanoma (Swerdlow et al. 1988). At 1 cm distance, the 254-nm light output of a 50-W quartz halogen lamp was 3×10^{-7} W/cm²/nm, while solar radiation was undetectable on the earth's surface at the same wavelength. Radiation from these light sources can cause damage to human skin due to their UVC and UVB output (Bloom et al. 1996). It has also been demonstrated that, at a distance of 10 cm, a 100-W quartz halogen bulb can elicit erythema in 15 min, which represents a 3.4-fold increase in the lifetime risk of developing a cutaneous malignancy (Cesarini and Muel 1989).

The results obtained in bacteria were confirmed by evaluating in cultured human lymphocytes both the frequency of micronuclei (D'Agostini et al. 1993) and an array of chromosomal abnormalities, including breaks and interchanges between chromatids (D'Agostini et al. 1999). In addition, halogen light induced anchorage-independent growth in neonatal human fibroblasts. In particular, maximum transformation frequencies were observed at fluences of 5–8 J/m² for a 254-nm germicidal lamp, 6,300 J/m² for a fluorescent lamp, and 300 J/m² for an unfiltered 20 W quartz halogen lamp (West et al. 1995). Interestingly, no genotoxic effect could be detected when the quartz bulbs

S. De Flora (✉)
Department of Health Sciences, University of Genoa,
Via A. Pastore 1, 16132 Genoa, Italy
e-mail: sdf@unige.it

were shielded with a simple glass cover (De Flora et al. 1990; D'Agostini et al. 1993).

Thereafter, we provided evidence that halogen lamp light is potently carcinogenic to hairless mice (De Flora and D'Agostini 1992; D'Agostini and De Flora 1994). In few months, the 100 % of exposed mice developed multiple squamocellular carcinomas and other skin tumors of various histopathological nature, which were totally absent in unexposed controls. The carcinogenic response even occurred by reducing the daily exposure time from 12 to either 6 or 3 or 1.5 h and by decreasing the illuminance levels from 10,000 to 3,333, or 1,000 lx, corresponding to distances of approximately 50, 100, or 200 cm. These are quite realistic exposure conditions. Again, carcinogenicity was totally prevented by covering the lamps with glass covers (De Flora and D'Agostini 1992; D'Agostini and De Flora 1994).

The spreading of these scientific findings through the international press, without our awareness, gave rise to a violent reaction by lamp manufacturers who denied by all means that halogen lamps could emit UV radiation and be carcinogenic. However, after few years, they had to bow to the facts and introduced new types of halogen lamps on the market, having commercial names such as UV-Stop or UV-Block, in which the quartz bulb is “doped” in such a way to become less permeable to UV radiation. Our further studies showed that the light emitted by these lamps is almost negative for genotoxicity (Camoirano et al. 1999), although treated bulbs have been found to emit low residual amounts of UVA, UVB, and UVC light (Sayre et al. 2004). Ironically, the new lamps were not advertised to avoid risks to humans but to prevent discoloring of cloth, paintings, or other materials in shops and museums.

It is hard to achieve an epidemiological evidence for the carcinogenicity of artificial illumination systems due to a variety of reasons and especially due to the confounding role of sunlight exposure. Nevertheless, both in vitro and in vivo experimental data converge in demonstrating the potential carcinogenicity to humans of traditional, uncovered halogen lamps. This conclusion is further supported by the evidence that these lamps emit all types of UV radiation as well as by mechanistic data. In fact, the molecular alterations detected in the skin of mice exposed to halogen light are the same that are known to occur after exposure to UV light or sunlight (Balansky et al. 2003). Since IARC (2012) has now classified UV radiation in Group 1, exposure to UV radiation via halogen quartz bulbs is expected to involve a carcinogenic hazard.

When covering halogen quartz bulbs with UVC filters, exposure of hairless mice becomes a model mimicking the effects of solar irradiation. The use of this model led us to the unexpected discovery that UVA- and UVB-containing light not only has local effects in the skin but it also has

systemic effects as well. In fact, exposure of hairless mice caused an increase in DNA adduct levels both in lung and in bone marrow along with cytogenetic damage both in bone marrow and in peripheral blood (Balansky et al. 2003). The effects of light on mouse lung were confirmed by multigene expression analysis (Izzotti et al. 2004). Furthermore, exposure to light of albino mice, especially early in life, induced oxidatively generated DNA damage even in heart and aorta (Izzotti et al. 2008). Epidemiological studies have suggested an association between exposure to solar UV radiation and occurrence of lymphoid malignancies, whose incidence has substantially increased worldwide during the last decades. Experimental studies in genetically susceptible mice have disproved the hypothesis that UV-related immunosuppression may be responsible for the development of these tumors (Jiang et al. 2001). Rather, as supported by our studies, a systemic effect of light is likely to be ascribed to formation, in the irradiated skin, of as yet unidentified genotoxic derivatives that can travel to distant organs.

In my country, even in the absence of any specific regulation, I cannot find halogen lamps that are not either “doped” or covered with a glass. There is concern, however, that these safety measures may not be respected in other countries, or with products imported from other countries, and that a large number of traditional, non-protected lamps are still in use in houses, offices, and commercial areas.

The potential toxicological hazards of the light emitted by artificial illumination systems are often disregarded. This issue is of particular concern for the general population, taking into account that most of our time is nowadays spent in indoor environments and that exposure of human populations to these lighting sources is extremely widespread. Moreover, the output of wavelengths in the UV region may be particularly harmful in subjects suffering from certain dermatoses, such as lupus erythematosus (Klein et al. 2009) and xeroderma pigmentosum, which are particularly susceptible to UV light. For instance, examination of light sources in the home and school of a child affected by xeroderma pigmentosum revealed that they emitted high levels of UV radiation (Sayre et al. 2004). Therefore, suitable regulations should be made available in order to control the output of UV light and the biological safety of the light emitted by artificial light sources.

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