21st International Conference Man and Working Environment

SEMSIE

Safety Engineering & Management - Science, Industry, Education

REVIEW PAPER

DOI: 10.46793/SEMSIE25.067L

ALEKSANDAR LAZAREVIĆ[1]
JELENA ZVEZDANOVIĆ[2]
SANJA PETROVIĆ[3]
DRAGAN CVETKOVIĆ[4]
TATJANA GOLUBOVIĆ[5]

[1,2,3,4]University of Niš,
Faculty of Technology, Leskovac, Serbia
[5]University of Niš,
Faculty of Occupational Safety, Serbia

[1]*acalazarevic92@hotmail.com*
[2]*jelite74@yahoo.com*
[3]*milenkovic_sanja@yahoo.com*
[4]*dragancvetkovic1977@yahoo.com*
[5] *tatjana.golubovic@znrfak.ni.ac.rs*

EFFECTS OF ULTRAVIOLET RADIATION ON OCCUPATIONAL HEALTH AND SAFETY

Abstract: *Occupational exposure to ultraviolet (UV) radiation poses a significant health risk, particularly for workers in outdoor professions. Prolonged UV exposure is associated with a range of acute and chronic conditions, including erythema, photoaging, cataracts, and an increased risk of non-melanoma skin cancers. Despite growing awareness, protective behaviour among workers often remains inadequate. This paper examines the biological effects of UV radiation, identifies high-risk occupational groups, and discusses preventive strategies aimed at minimizing exposure. The emphasis is placed on the importance of implementing protection policies in the workplace, including the use of personal protective equipment (PPE), education campaigns, and organizational measures. Recognizing UV radiation as an occupational hazard is essential for safeguarding the health and well-being of exposed workers in light of climate change and ongoing ozone depletion.*

Keywords: UV radiation, occupational exposure, photoprotection, workplace safety

ORCID iDs:		
	Aleksandar Lazarević	https://orcid.org/0000-0002-8784-3769
	Jelena Zvezdanović	https://orcid.org/0000-0002-3640-2111
	Sanja Petrović	https://orcid.org/0000-0001-9493-8355
	Dragan Cvetković	https://orcid.org/0000-0002-3228-3573
	Tatjana Golubović	https://orcid.org/0000-0001-6725-752X

INTRODUCTION

Ultraviolet (UV) radiation is a form of non-ionizing radiation, which constitutes a non-visible segment of the electromagnetic spectrum, characterized by wavelengths shorter than visible light. The main source of UV radiation that reaches Earth is sunlight. Some industrial processes, such as electric arc welding and plasma cutting equipment, germicidal UV lamps in hospitals and laboratories, mercury vapour lamps, metal halide lamps, etc., can also generate artificial (anthropogenic) UV radiation.

Ultraviolet radiation provides several important benefits, particularly in controlled or natural low-dose exposures. For most people, UV radiation from sunlight is the main source of vitamin D production. However, foods and supplements also contribute to circulating vitamin D. This process is essential for maintaining calcium homeostasis, bone health, and immune system function. Adequate vitamin D levels have been linked to reduced risks of osteoporosis, certain autoimmune diseases, and even some cancers (Ross et al., 2011). Vitamin D levels typically exhibit significant seasonal variation, particularly in regions located at higher latitudes. Research indicates that during the winter months, approximately 50% of the UK population may experience vitamin D insufficiency (Hyppönen & Power, 2007). In addition to these naturally significant roles, UV radiation has been used since ancient times to treat various diseases, and this phenomenon is scientifically grounded in the presence of numerous chromophores within various layers of the skin, which are capable of interacting with and absorbing UV radiation. Nowadays, in clinical and cosmetic practice, UV radiation is utilized for a wide range of purposes, including cosmetic tanning, the therapeutic management of several dermatological disorders, such as psoriasis, vitiligo, atopic dermatitis, and localized scleroderma, as well as in medical applications like photodynamic therapy (PDT) (Krutmann & Morita, 1999).

While UV radiation offers several recognized health and therapeutic benefits, it also poses significant risks to human health. According to the International Agency for Research on Cancer (IARC), all forms of ultraviolet radiation – UVA, UVB, and UVC, as well as solar radiation, are classified as Group 1 carcinogens, indicating confirmed carcinogenicity in humans, based on robust epidemiological and experimental evidence (El Ghissassi et al., 2009). Among the acute effects, UVB radiation in particular can trigger erythema, commonly manifested as skin redness, and may stimulate a compensatory increase in melanin production, particularly in individuals with lighter skin. On a molecular level, UV exposure can lead to genetic damage, including mutations in the p53 tumour suppressor gene, which compromises its role in preventing malignant transformation. Additionally, ultraviolet radiation facilitates the generation of reactive oxygen species (ROS), which are closely linked to various stages of skin cancer development, from initiation to progression (Lee et al., 2020).

Given the potential health hazards associated with UV radiation, it is crucial to investigate its impact in terms of occupational safety, with special emphasis on worker safety. Addressing this issue involves identifying sources of exposure, evaluating associated risks, and implementing effective preventive measures to avoid negative health effects of UV radiation on employees.

UV RADIATION INTERACTIONS AND BIOLOGICAL EFFECTS

The ultraviolet radiation spectrum is conventionally divided into three bands based on their wavelengths and the interaction between the radiation matter and human cells (Figure 1):

- UVC – 100-280 nm wavelength
- UVB – 280-320 nm
- UVA – 320-400 nm

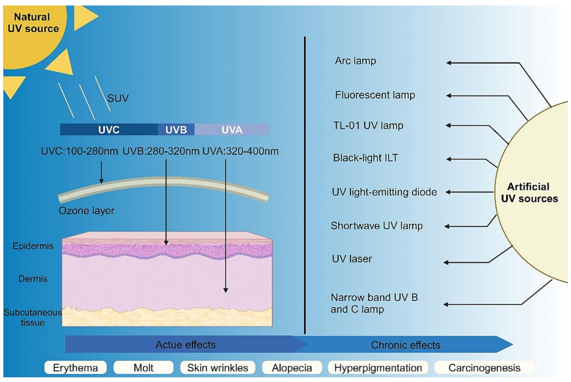

Figure 1. *Distribution of UV radiation. Source: Tang et al. (2004)*

Among the different types of UV radiation, UVC possesses the highest energy and poses the greatest potential risk to biological tissues. However, under natural conditions, UVC radiation is entirely absorbed by the stratospheric ozone layer, making it largely irrelevant as a health hazard except in the cases of accidental exposure to artificial sources (Trevisan et al., 2006). UVB radiation is also partially absorbed by the atmosphere, yet approximately 5% reaches the Earth's surface. Due to its shorter wavelength, UVB primarily affects the superficial layers of the epidermis and is associated with acute and chronic skin damage such as sunburns (Narayanan et al., 2010). UVA rays have the longest wavelength within the ultraviolet spectrum and constitute the majority of UV radiation that reaches the Earth's surface, between 90% and 95%. UVA radiation is minimally absorbed by atmospheric components and thus penetrates more deeply into the skin, reaching the dermal layer where collagen fibres are located. UVA radiation exerts harmful effects on both epidermal keratinocytes and dermal fibroblasts, contributing to progressive alterations in skin structure and function over time. Upon absorption of UVA photons by skin chromophores, ROS are generated, initiating oxidative stress. This oxidative imbalance and deeper penetration explain UVA's role in photoaging (Pittayapruek et al., 2016). The typical UVA to UVB ratio in solar radiation that reaches the ground is approximately 20:1, although this proportion fluctuates depending on geographic latitude, time of day, season, and atmospheric conditions such as cloud cover, which disproportionately attenuate UVB relative to UVA (WHO, 2016; Romanhole et al., 2015).

In addition to its damaging effects on the skin, UV radiation is also implicated in the development of several ocular disorders, including cataracts, macular degeneration, and premature aging of periocular tissues. Notably, cataracts account for approximately 48% of global cases of blindness.

Our experiments demonstrate that UV radiation affects certain naturally occurring biological compounds, including chlorophylls, bacteriochlorophylls, and porphyrins, with a particular emphasis on protoporphyrin IX. The data indicate that UV exposure induces degradation of these molecules, obeys a first-order rate, and is highly dependent on the used-energy input and the used solvents. These compounds may serve as biomarkers for UV-induced biological damage in humans. Additionally, these compounds can potentially be applied in fields such as cosmetology and PDT therapy (Zvezdanović et al., 2009; Lazarević et al., 2025).

The ozone layer within the stratosphere functions as an essential protective shield, filtering out a substantial portion of the sun's UV radiation, thus limiting its harmful impact on the Earth's surface. Over the past century, anthropogenic activities, particularly the release of chlorofluorocarbons (CFCs) and other ozone-depleting substances (ODSs), have led to considerable depletion of the ozone layer, consequently elevating the levels of UV radiation that penetrate the atmosphere and reach ground level (Bernhard et al., 2023). Climate change, characterized by rising global temperatures, also influences the levels of UV radiation exposure. Scientific studies indicate that with each 1 °C increase in ambient temperature, the carcinogenic potential of UV radiation may rise by approximately 5%, suggesting a compounding effect between thermal and UV-related environmental stressors (Umar & Tasduq, 2022).

WORKPLACE EXPOSURE TO UV RADIATION AND HEALTH RISKS

Although a slight recovery of the polar ice caps has been noted, the ozone layer continues to experience depletion. This ongoing deterioration has contributed to increased levels of UV radiation reaching the Earth's surface, accompanied by extended periods of elevated temperatures during summer months (Ball et al., 2019). From a primary prevention perspective, it is crucial to identify occupations with a high risk of solar UV exposure, as well as to determine sectors where sun-protective behaviours in the workplace are notably inadequate.

Outdoor workers are particularly vulnerable to these adverse environmental changes and they are the ones who suffer the most. Ultraviolet radiation exposure among outdoor workers is not restricted only to bright, sunny conditions. Dosimeter-based studies reveal that on cloudy or overcast days, UV levels can still reach approximately 30% of those observed under clear skies. Moreover, during the spring season, when skin typically lacks protective thickening, UV intensity averages around 80% of that seen in the summer months. Prolonged occupational exposure to UV radiation is well documented as a risk factor for various adverse health outcomes, including squamous cell carcinoma, multiple actinic keratoses, cataract formation, and accelerated cutaneous aging (Wright et al., 2004; Schmitt et al., 2011). The World Health Organization has estimated that between 2 million and 3 million squamous cell carcinomas, 10 million basal cell carcinomas, and 200,000 melanomas are diagnosed globally each year, most of them among outdoor workers. It is estimated that about 15 million workers in Europe are exposed to solar UV, the vast majority of whom (90%) are generally male. Examples of occupations characterized by prolonged outdoor activities and consequently significant direct and indirect exposure to solar ultraviolet radiation UVR include construction workers, agricultural workers, gardeners, childcare providers, firefighters, police officers, lifeguards, athletes, street vendors, etc. (EU-OSHA, 2009).

The link between outdoor occupations and the incidence of skin cancers, as well as other dermatological conditions, is primarily connected with prolonged exposure to solar radiation, often combined with insufficient implementation of sun protection measures.

In industrial environments, UV radiation exposure primarily arises from artificial sources rather than natural sunlight. Common industrial applications involving artificial UV sources include electric arc welding, UV curing in the printing and textile industries, sterilization processes in pharmaceutical and laboratory settings, and photolithography in electronics manufacturing. Workers in these sectors may be regularly exposed to high-intensity UVA and UVB radiation, sometimes without adequate protective measures (Diepgen et al., 2012; WHO, 2016).

In addition to outdoor occupations and industrial environments, some indoor professions, particularly in the healthcare and cosmetic sectors, are also associated with notable exposure to artificial UV radiation. Healthcare workers may be exposed during procedures involving UV-emitting devices, such as phototherapy for dermatological conditions, UV disinfection systems, and in operating rooms or catheterization suites where UV-based sterilization is utilized. Similarly, workers in beauty salons and cosmetic clinics are often exposed to UVA radiation during procedures such as gel nail curing and skin tanning. Although these exposures are generally controlled and minimal, repeated exposure without appropriate protective measures may pose long-term risks to the skin and eyes (Marchbein & Campbell, 2022).

Prolonged or repeated exposure to artificial UV radiation can cause both acute and chronic health effects. These include erythema, photokeratitis ("welder's flash"), cataracts, photoaging, and an increased risk of skin cancers such as squamous cell carcinoma. Welding, in particular, is associated with intense UVC exposure, which, although typically filtered out by the atmosphere, poses significant hazards when generated artificially. To minimize these risks, it is essential to implement a combination of technical controls (e.g. shielding and enclosure of UV sources), administrative measures (e.g. training and restricted access), and personal protective equipment (e.g. UV-filtering goggles, gloves, and protective clothing). Regular monitoring of exposure levels and adherence to safety standards are crucial for preventing long-term health consequences among industrial workers (EU-OSHA, 2009; WHO, 2016; Modenese et al., 2018).

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has established a recommended exposure limit for artificial UV radiation affecting unprotected skin and eyes, set at 30 J/m² over an 8-hour work period. To assess compliance with this limit, effective irradiance (measured in W/m²) is calculated by weighting the spectral irradiance across the wavelength range of 180 to 400 nm using the ICNIRP action spectrum. The resulting value allows for the determination of the maximum permissible exposure duration, which is obtained by dividing the recommended maximum dose (30 J/m²) by the effective irradiance, under the assumption that exposure remains constant over time (ICNIRP, 2004).

PREVENTION OF OCCUPATIONAL UV DISEASES

Effective prevention of adverse skin and ocular diseases among outdoor and other workers exposed to UV radiation requires the implementation of a comprehensive set of preventive strategies. These include collective technical and organizational measures aimed at minimizing exposure, dissemination of targeted information, and provision of specific training programs for employees. Additionally, the consistent use of appropriate personal protective equipment (PPE), promotion of protective behavioural practices, and regular medical surveillance of exposed individuals are essential components of occupational health management in UV-exposed professions (Modenese et al., 2018). There are four main examples of preventive measures that can be applied to reduce UV exposure in the workplace, as follows (Modenese et al., 2018):

(1) *Collective Technical / Organizational measures*: These measures include both artificial and natural shading of workspaces, as well as scheduling structured breaks in UV-protected environments during peak radiation hours. Additionally, reorganizing work routines to limit or entirely avoid outdoor tasks during midday, initiating work earlier in the morning, or extending lunch breaks, can significantly reduce cumulative UV exposure, particularly during periods of elevated UV index values throughout the year (ICNIRP, 2010; Alfonso et al., 2017; Modenese et al., 2016).

(2) *Health and safety information and training*. Educational and informational initiatives should be introduced as early as possible, possibly in all schools preparing individuals for outdoor professions, as well as among all current outdoor workers.

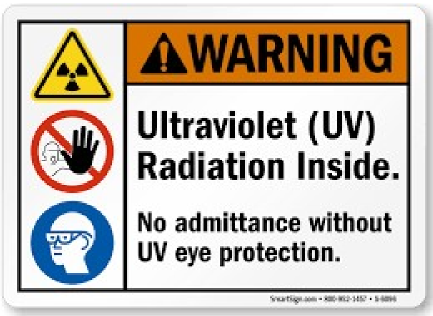

Figure 2. *Typical signs used in the work environment to warn about UV risk exposure*

Supplementary preventive tools such as instructional fact sheets, warning signs, and visual reminders can encourage workers to avoid exposure when the UV index is high (Figure 2) and to consistently apply personal protective measures, including suitable clothing, wide-brimmed hats, UV-protective eyewear, and broad-spectrum sunscreen (ICNIRP, 2010; Alfonso et al., 2017; Modenese et al., 2016)

(3) *Personal protection*. Occupational sunglasses must comply with established safety standards regarding both the UV filtering capacity of the lenses and the physical design of the frames, with sufficiently large, close-fitting lenses and broadside arms to ensure comprehensive eye protection. Suitable protective clothing should consist of long-sleeved shirts and trousers made from tightly woven, UV-opaque fabrics such as cotton blends or technical synthetic fibres, preferably with a high UV protection factor (UPF), ideally rated 50+. Proper head protection includes wide-brimmed hats or helmets equipped with neck flaps and side guards to shield vulnerable areas from solar radiation (Figure 3). For exposed skin areas, broad-spectrum water-resistant sunscreens with a minimum sun protection factor (SPF) of 50+ should be applied at least 20 minutes before sun exposure. Reapplication is necessary at regular intervals, particularly every two hours, and more frequently in cases of excessive sweating or when the UV index is high (ICNIRP, 2010; Alfonso et al., 2017; Modenese et al., 2016).

Figure 3. *Welder with appropriate personal protective equipment*

(4) *Health surveillance*. Occupational health physicians should conduct periodic medical examinations of workers to effectively prevent long-term effects on the skin and eyes. Particular attention must be given to identifying individuals with heightened sensitivity to UV radiation, such as those with prolonged use of photosensitizing medications, existing wounds, suspicious skin lesions, or UV-sensitive dermatological conditions like psoriasis. Regarding ocular health, conditions such as lens opacities and corneal injuries may increase photosensitivity. Collaboration with dermatologists, ophthalmologists, and other relevant specialists is recommended for managing specific cases (ICNIRP, 2010; Alfonso et al., 2017; Modenese et al., 2016).

Exposure measurement

Measurement of UV radiation at workplaces is the first step in worker protection, and it can be measured at fixed locations using radiometers (Figure 4). There are several devices available for UV measurements. However, all of them mostly use two primary methodologies: chemical UV dosimeters, which utilize photosensitive plastic films that change their optical characteristics upon UV exposure, and electronic UV dosimeters, which rely on semiconductor-based sensors to detect and measure UV radiation levels. Both types of devices provide valuable data for assessing occupational and environmental UV exposure (Huang et al., 2021).

Figure 4. *PCE-UV34 Radiation Meter equipped with a Photodiode with a UV correcting filter*

CONCLUSION

Occupational exposure to UV radiation poses a significant health risk, particularly for outdoor workers and those operating near artificial UV sources. Prolonged and unprotected exposure can lead to acute and chronic dermatological and ophthalmological conditions, including skin cancers, photoaging, and cataracts. Because of the growing environmental challenges and increased solar UV radiation due to climate change and ozone depletion, along with growing industry, it is imperative that UV protection becomes a standard component of occupational health policies across all sectors involving outdoor work.

ACKNOWLEDGEMENTS

This paper was supported by the Ministry of Science, Technological Development and Innovations of the Republic of Serbia, Program for financing scientific research work, numbers 451-03-137/2025-03/200133 and 451-03-137/2025-03/200148.

REFERENCES

Alfonso, J. H., Bauer, A., Bensefa-Colas, L., Boman, A., Bubas, M., Constandt, L., ... & Giménez-Arnau, A. M. (2017). Minimum standards on prevention, diagnosis and treatment of occupational and work-related skin diseases in Europe–position paper of the COST Action StanDerm (TD 1206). *Journal of the European Academy of Dermatology and Venereology*, *31*, 31-43. https://doi.org/10.1111/jdv.14319

Ball, W. T., Alsing, J., Mortlock, D. J., Staehelin, J., Haigh, J. D., Peter, T., ... & Rozanov, E. V. (2018). Evidence for a continuous decline in lower stratospheric ozone offsetting ozone layer recovery. *Atmospheric Chemistry and Physics*, *18*(2), 1379-1394. https://doi.org/10.5194/acp-18-1379-2018

Bernhard, G. H., Bais, A. F., Aucamp, P. J., Klekociuk, A. R., Liley, J. B., & McKenzie, R. L. (2023). Stratospheric ozone, UV radiation, and climate interactions. *Photochemical & Photobiological Sciences*, *22*(5), 937-989. https://doi.org/10.1007/s43630-023-00371-y

Buys, D. G., & Brown, S. C. (2021). Radiation exposure protection: Small things matter. *Cardiovascular Journal of Africa*, *32*(5), 235-236. DOI: 10.5830/CVJA-2021-052.

Diepgen, T. L., Fartasch, M., Drexler, H., & Schmitt, J. (2012). Occupational skin cancer induced by ultraviolet radiation and its prevention. *British Journal of Dermatology*, *167*(s2), 76-84. https://doi.org/10.1111/j.1365-2133.2012.11090.x

El Ghissassi, F., Baan, R., Straif, K., Grosse, Y., Secretan, B., Bouvard, V., & Cogliano, V. (2009). A review of human carcinogens, part D: radiation. *The Lancet Oncology*, *10*(8), 751-752. https://doi.org/10.1016/S1470-2045(09)70213-X

European Agency for Safety and Health at Work. (2009). Outlook 1: New and emerging risks in occupational safety and health. Available online: https://osha.europa.eu/en/node/6842/file_view (accessed on 26 July 2018).

Huang, X., & Chalmers, A. N. (2021). Review of wearable and portable sensors for monitoring personal solar UV exposure. *Annals of biomedical engineering*, *49*(3), 964-978. https://doi.org/10.1007/s10439-020-02710-x

Hyppönen, E., & Power, C. (2007). Hypovitaminosis D in British adults at age 45 y: nationwide cohort study of dietary and lifestyle predictors. *The American journal of clinical nutrition*, *85*(3), 860-868. https://doi.org/10.1093/ajcn/85.3.860

International Commission on Non-Ionizing Radiation Protection. (2004). Guidelines on limits of exposure to ultraviolet radiation of wavelengths between 180 nm and 400 nm (incoherent optical radiation). *Health Physics*, *87*(2), 171-186.

International Commission on Non-Ionizing Radiation Protection. (2010). ICNIRP statement protection of workers against ultraviolet radiation. *Health Physics*, *99*(1), 66-87. *DOI:* 10.1097/HP.0b013e3181d85908

Krutmann, J., & Morita, A. (1999, September). Mechanisms of ultraviolet (UV) B and UVA phototherapy. In *Journal of Investigative Dermatology Symposium Proceedings* (Vol. 4, No. 1, pp. 70-72). Elsevier. https://doi.org/10.1038/sj.jidsp.5640185

Lazarević, A., Petrović, S., Cvetković, D., Stanojević, J., Anđelković, T., & Zvezdanović, J. (2025). Protoporphyrin IX response to ultraviolet and white light treatments in different mediums. *Monatshefte für Chemie-Chemical Monthly*, *156*(4), 431-442. https://doi.org/10.1007/s00706-025-03306-8

Lee, J. W., Ratnakumar, K., Hung, K. F., Rokunohe, D., & Kawasumi, M. (2020). Deciphering UV-induced DNA damage responses to prevent and treat skin cancer. *Photochemistry and photobiology*, *96*(3), 478-499. https://doi.org/10.1111/php.13245

Marchbein, D., & Campbell, C. (2020). "Is UV Light for Nails Safe? Dermatologists Weigh in on New Cancer Study." *Teen Vogue*. Retrieved from https://www.teenvogue.com/story/uv-light-for-nails-safety

Modenese, A., Bisegna, F., Borra, M., Grandi, C., Gugliermetti, F., Militello, A., & Gobba, F. (2016). Outdoor work and solar radiation exposure: Evaluation method for epidemiological studies. *Medycyna Pracy. Workers' Health and Safety*, *67*(5), 577-587.

Modenese, A., Korpinen, L., & Gobba, F. (2018). Solar radiation exposure and outdoor work: an underestimated occupational risk. *International journal of environmental research and public health*, *15*(10), 2063. https://doi.org/10.3390/ijerph15102063

Narayanan, D. L., Saladi, R. N., & Fox, J. L. (2010). Ultraviolet radiation and skin cancer. *International journal of dermatology*, *49*(9), 978-986. https://doi.org/10.1111/j.1365-4632.2010.04474.x

Pittayapruek, P., Meephansan, J., Prapapan, O., Komine, M., & Ohtsuki, M. (2016). Role of matrix metalloproteinases in photoaging and photocarcinogenesis. *International journal of molecular sciences*, *17*(6), 868. https://doi.org/10.3390/ijms17060868

Romanhole, R. C., Ataide, J. A., Moriel, P., & Mazzola, P. G. (2015). Update on ultraviolet A and B radiation generated by the sun and artificial lamps and their effects on skin. *International journal of cosmetic science*, *37*(4), 366-370. https://doi.org/10.1111/ics.12219

Ross, A. C., Manson, J. E., Abrams, S. A., Aloia, J. F., Brannon, P. M., Clinton, S. K., ... & Shapses, S. A. (2011). The 2011 report on dietary reference intakes for calcium and vitamin D from the Institute of Medicine: what clinicians need to know. *The Journal of Clinical Endocrinology & Metabolism*, *96*(1), 53-58. https://doi.org/10.1210/jc.2010-2704

Schmitt, J., Seidler, A., Diepgen, T. L., & Bauer, A. (2011). Occupational ultraviolet light exposure increases the risk for the development of cutaneous squamous cell carcinoma: a systematic review and meta-analysis. *British Journal of Dermatology*, *164*(2), 291-307. https://doi.org/10.1111/j.1365-2133.2010.10118.x

Tang, X., Yang, T., Yu, D., Xiong, H., & Zhang, S. (2024). Current insights and future perspectives of ultraviolet radiation (UV) exposure: Friends and foes to the skin and beyond the skin. *Environment International*, 108535. https://doi.org/10.1016/j.envint.2024.108535

Trevisan, A., Piovesan, S., Leonardi, A., Bertocco, M., Nicolosi, P., Pelizzo, M. G., & Angelini, A. (2006). Unusual high exposure to ultraviolet-C radiation. *Photochemistry and photobiology*, *82*(4), 1077-1079. https://doi.org/10.1562/2005-10-27-RA-728

Umar, S. A., & Tasduq, S. A. (2022). Ozone layer depletion and emerging public health concerns – an update on epidemiological perspective of the ambivalent effects of ultraviolet radiation exposure. *Frontiers in Oncology*, *12*, 866733. https://doi.org/10.3389/fonc.2022.866733

World Health Organization. (2016). *Radiation: Ultraviolet (UV) Radiation*. Geneva.

Wright, C., Diab, R., & Martincigh, B. (2004). Anatomical distribution of ultraviolet solar radiation. *South African journal of science*, *100*(9), 498-500.

Zvezdanović, J., Cvetić, T., Veljović-Jovanović, S., & Marković, D. (2009). Chlorophyll bleaching by UV-irradiation in vitro and in situ: Absorption and fluorescence studies. *Radiation Physics and Chemistry*, *78*(1), 25-32. https://doi.org/10.1016/j.radphyschem.2008.07.006