

## Article

# The Health Risk of Ultraviolet Radiation and Its Intensity in Shielded Metal Arc Welding

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## Abstract

In gas-shielded arc welding, selecting the appropriate gas mixture is crucial not only for welding quality but also for reducing harmful UV radiation, which poses an occupational health risk. The aim of this research was to investigate the intensity of UV-A and UV-B radiation (290–390 nm) in the low-current range (10–45 A) using pure argon (Ar), helium (He), nitrogen (N<sub>2</sub>), and a 70% Ar/30% He gas mixture. The measurements demonstrated that the composition of the shielding gas drastically affects UV emission. Under identical parameters, pure argon generates around three times higher radiation levels than pure helium. But when 30% helium was added to argon, the UV emission was significantly reduced by approximately 30%. The highest UV values were recorded with pure nitrogen. The tests revealed that the main reason is severe arc instability: the expanding plasma surface area significantly increases radiation. Overall, it can be concluded that in the low-current welding range, arc stability determines the magnitude of UV radiation to a greater extent than the emission characteristics of the gases. However, further measurements are needed to draw conclusions for higher amperages.

**Keywords:** ultraviolet radiation; gas radiation; argon radiation; nitrogen radiation; helium radiation; welding safety; radiation safety

## 1. Introduction

Ultraviolet (UV) radiation is an important topic in many scientific and industrial fields. Numerous sectors either utilise its beneficial properties or focus on protecting themselves from its harmful effects [1,2]. The UV radiation can be both useful and dangerous, depending on how it is viewed. It can be highly beneficial, such as in deliberate applications like sterilisation and disinfection, or it can pose a significant hazard when emitted as an unintended byproduct of other processes. It is necessary to understand firstly what UV radiation is and how it works, so it can be decided which category it falls into and from what perspective each type of UV should be examined. UV radiation is a type of electromagnetic (EM) energy that can be classified along with other forms of radiation, such as X-rays or infrared light [3]. It is part of the electromagnetic spectrum, as illustrated in Figure 1, based on the literature [4–6]. Within this spectrum, the properties of the radiation vary depending on its wavelength. For example, the range from approximately 380 nm to 750 nm corresponds to visible light, which enables human vision. Adjacent to this region are the infrared wavelengths slightly longer than visible light and, on the other side, the



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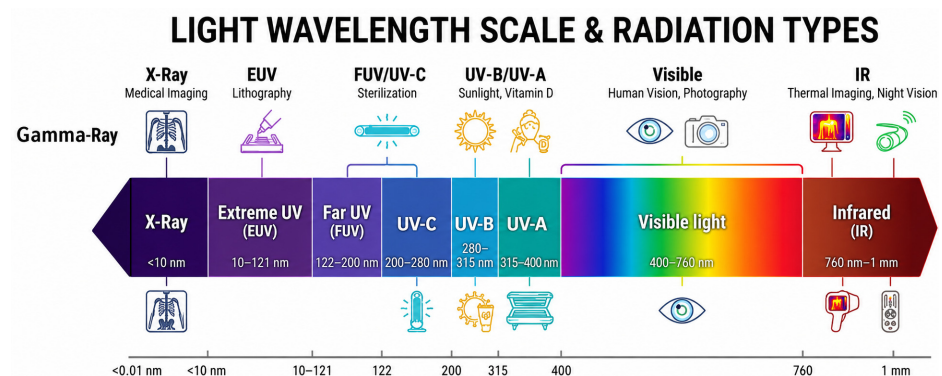
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ultraviolet range [3,5], which is the focus of this research. The UV range extends roughly from 100 nm to 380 nm, which is entirely outside the visible spectrum for the human eye, although in some rare cases, people may perceive light near the upper limit of UV radiation of around 350 nm. There are some discrepancies in the literature regarding the exact length of UV radiation, with 400 nm being the end of the range in many cases and 380 nm in other cases [7,8]. The reason for this debate is the way it is measured; it changes based on what it is measured for, visibility or wave properties [1,9,10]. UV radiation is considered non-ionising because its photon energy is generally insufficient to remove electrons directly from atoms or molecules. In the 290–390 nm range investigated in this study, UV radiation can cause serious biological damage through photochemical and oxidative mechanisms, but it does not act in the same way as ionising radiation such as X-rays or gamma rays.



**Figure 1.** UV spectrum in the wavelength scale (figure made by the author based on [1,9,10]).

As previously stated, although this radiation falls outside the visible spectrum, it significantly affects the human body, posing severe risks to the skin and eyes depending on its specific wavelength. UV radiation can be categorised into various classifications based on the field of application (e.g., healthcare, astronomy, or occupational safety). The most widely accepted wavelength range classifications are summarised in Table 1, based on the literature [5,6]. In everyday contexts, ultraviolet radiation is primarily generated by the Sun as thermal radiation and is commonly referred to as UV-A, UV-B, and UV-C. In contrast, during welding, UV radiation is generated by an electrical discharge that creates an extremely hot, ionised arc plasma; as excited atoms and ions return to their lower energy states, they emit high-energy photons across the entire optical spectrum [11,12]. Furthermore, there are additional regions, such as Far-UV and Extreme-UV (EUV); the latter is strongly absorbed by atmospheric oxygen and typically propagates only in a vacuum [5,12]. Among these, the UV-A, UV-B, and UV-C ranges are of primary practical and occupational safety significance in manufacturing technologies, particularly within the welding industry, which is the focal point of this article.

**Table 1.** Radiation spectrum from X-ray to Infrared [5,6].

| Radiation Range Designation | Wavelength Range |
|-----------------------------|------------------|
| X-Ray                       | <10 nm           |
| (Extreme UV) EUV            | 10–121 nm        |
| (Far UV) FUV                | 122–200 nm       |
| UV-C                        | 200–280 nm       |
| UV-B                        | 280–315 nm       |
| UV-A                        | 315–400 nm       |
| Visible light               | 400–760 nm       |
| Infrared (IR)               | 760 nm–1 mm      |

While UV-A and UV-B radiation pose significant occupational health risks, such as direct DNA damage and severe erythema [3,13], UV radiation also has highly beneficial industrial applications. For instance, the high energy and germicidal properties of the UV-C range are intentionally utilised in various industries for the disinfection and sterilisation of materials, surfaces, and environments [10]. However, in the welding industry, the emission of these powerful UV radiations is not the objective; rather, it is an entirely unwanted and hazardous byproduct that requires strict protective measures.

### *1.1. The Effect of UV on the Skin*

Ultraviolet (UV) radiation emitted by the sun and artificial sources has profound effects on skin cells and molecules, and understanding these effects is essential. These effects can induce both acute and chronic changes in the skin, depending on the wavelength and the degree of exposure. From biological and dermatological perspectives, the most active parts of the UV spectrum are UV-B (280–315 nm), which damages the deeper layers of the epidermis; the more deeply penetrating UV-A (315–400 nm); and the high-energy UV-C (100–280 nm). Although natural solar UV-C radiation is almost entirely filtered out by the Earth's ozone layer, artificial sources, particularly welding arcs, emit significant amounts. This range, including the upper zone of far-UV radiation (far-UV-C, 122–200 nm), has the lowest penetration power; thus, its energy is almost entirely absorbed in the outermost layer of the skin (stratum corneum). Consequently, it is extremely destructive to this upper layer and, without adequate protection, can rapidly cause severe acute damage, such as intense erythema [3,6,10].

The most common and visible acute effect is erythema, commonly known as sunburn, which represents a distinct inflammatory response of the skin. This process involves the dilation of superficial blood vessels, accompanied by sensations of warmth, tenderness, and pain. Although erythema often appears during or immediately after exposure, its intensity and associated pain typically peak 6–24 h after exposure. In cases of more severe exposure and inflammation, blistering may also occur, indicating significant damage to the deeper layers of the skin [3,6].

The radiation-induced defence process of pigmentation, also known as tanning, is a complex, multiphase biological mechanism activated differently by various wavelengths. UV-A radiation rapidly induces immediate pigment darkening (IPD) within minutes, which persists for only a few hours. This is followed by persistent pigment darkening (PPD), lasting up to 24 h, which then gradually leads to delayed tanning (DT). Delayed tanning develops 3–5 days postirradiation and remains visible for weeks or months [3]. There is a physical rationale for this difference: UV-A increases melanin density in the deeper, basal layers of the skin, resulting in more durable pigmentation. In contrast, UV-B acts primarily on the superficial layers of the epidermis, where damaged cells are shed more rapidly [3].

The damaging effects of radiation at the cellular and molecular levels are highly hazardous. Due to its short wavelength, UV-B radiation causes direct DNA damage, for example, by forming cyclobutane pyrimidine dimers and thymine dimers. In parallel, UV-A radiation acts indirectly via oxidative stress: melanin facilitates the formation of reactive oxygen species (such as cytotoxic hydrogen peroxide), which can induce DNA strand breaks and ultimately lead to cell death [1–3]. The body employs molecular defence mechanisms: upon exposure to UV-B, it activates the p53 protein, which stimulates melanin production, while it counteracts UV-A-induced oxidative stress by increasing levels of the heme oxygenase 1 (HO-1) enzyme [3].

Long-term, repeated UV exposure leads to cumulative chronic changes, such as photoaging, immunosuppression, and carcinogenesis [1,13]. During photoaging, the skin loses its elasticity, its texture coarsens, and deep wrinkles, dilated blood vessels, and permanent

pigment spots appear. However, the most serious consequence is the development of skin cancer and melanoma, in which UV-B has been shown to play a more significant and aggressive role than UV-A [1,14,15]. It is a critical medical fact that the harmful, DNA-damaging effect of UV-B is independent of skin pigmentation: the extent of DNA damage depends almost exclusively on the magnitude of the radiation dose [3,15].

Although individual responses are significantly influenced by genetics and the Fitzpatrick skin phototype scale, where lighter skin types (Types I and II) burn easily and face a higher risk of malignancy, while darker skin types (Type V) exhibit faster DNA repair and reduced UV penetration, protection remains essential [16]. Since the skin's natural pigmentation primarily provides protection against longer wavelengths, shorter, more insidious UV-B radiation poses a critical risk to all skin types [3,15].

### *1.2. The Effect of UV on the Eye*

The most common consequence of acute UV exposure is photokeratitis (also known as welder's flash), an inflammatory reaction of the cornea. Symptoms include severe pain, a foreign body sensation, photosensitivity, lacrimation (tearing), and eyelid spasms (blepharospasm). Clinical signs manifest as conjunctival hyperemia, corneal oedema, and epithelial detachment. These symptoms peak after a latency period of 30 min to 24 h (averaging 6–12 h) and typically resolve within 48 h [6]. Although the condition is largely reversible, it causes serious temporary visual impairment. Because many individuals attribute the gritty sensation in the eyes to fatigue or general working conditions, the condition remains significantly underdiagnosed [6,17].

The extent of ocular damage is physically closely related to the wavelength of UV radiation, as the cornea acts as a filter. The UV-C range is almost completely absorbed by the corneal surface. Furthermore, 40–70% of environmental or artificial UV-B is also absorbed by the anterior surface, with only 3–8% penetrating the inner structures of the eye. In contrast, the longer-wavelength UV-A can penetrate the cornea to a much greater extent, approximately 40–60%, and thereby reach the lens. This explains why, while UV-C and UV-B primarily damage the superficial layers of the cornea, UV-A can also induce pathological changes in deeper structures [6].

At the cellular level, radiation causes drastic damage once the exposure threshold is reached. It is estimated that as little as 200 s of unattenuated UV-B radiation is sufficient to induce photokeratitis. Cell death (apoptosis) and desquamation are accelerated in the outermost layer of the cornea (epithelium). In severe cases, the entire epithelial layer can detach down to the basement membrane, exposing nerve endings and causing excruciating pain. While the outer epithelial layer can regenerate, the inner monolayer of cells responsible for fluid balance (endothelium) cannot divide. Due to UV-induced damage in this region, the tissue can swell by up to 200%, and the organised arrangement of collagen fibres is disrupted, leading to temporary myopia [6]. Furthermore, endothelial cell destruction is permanent; small nodules (guttae) may form under the membrane, potentially progressing to Fuchs' dystrophy, which can ultimately lead to blindness [6].

It is a critical physiological fact that the cornea cannot develop adaptive resistance to radiation. Repeated exposures do not increase resistance; in fact, cumulative damage significantly raises the risk of developing chronic pathologies [6,14]. This danger is particularly prevalent in the welding industry. Safety regulations often focus solely on the welder, yet surveys indicate that in 83% of cases, other workers are also present within the welding zone [18]. Since work areas in shipbuilding or on construction sites are difficult to demarcate, and research shows no close correlation between the use of personal protective equipment (PPE) and the knowledge of radiation hazards, workers are particularly vulnerable [18,19]. Therefore, precise measurement of optical radiation and accurate designation

of critical safety zones are essential to protect the vision of both welders and surrounding personnel [18–20].

### *1.3. The Effect of UV on the Immune System*

Ultraviolet (UV) radiation not only causes direct damage to skin cells but also exerts a profound systemic and local effect on the immune system. Exposure induces a drastic decrease in the number and activity of Langerhans cells in the epidermis, as well as a decline in the function of circulating T lymphocytes. This results in a general weakening of the immune response, known as immunosuppression, which compromises the body's defences against both pathogens and tumour cells [3,13,20].

At the molecular level, the mechanism of immunosuppression depends strongly on the radiation wavelength. Shorter-wavelength UV-B activates chromophores in the upper layers of the skin and causes direct DNA damage, such as the formation of cyclobutane–pyrimidine dimers. In contrast, more deeply penetrating UV-A induces oxidative stress, free radical formation, and lipid peroxidation, thereby damaging cell membranes [13]. UV exposure also induces a local “energy crisis” by inhibiting glycolysis in human keratinocytes, leading to a collapse of the cells' energy supply. Consequently, key antigen-presenting cells, such as Langerhans and dendritic cells, either undergo apoptosis or migrate to the lymph nodes. This leads to impaired antigen presentation and reduced cytokine production. Instead of mounting an effective immune response against pathogens, the immune system inhibits T-cell activation and develops long-lasting immunological tolerance [13].

This UV-induced immune tolerance has dual physiological consequences. From a homeostatic perspective, the modulation of inflammatory responses may provide therapeutic benefits in certain conditions: UV-induced immunosuppression can alleviate the symptoms and reduce the recurrence of autoimmune diseases (e.g., multiple sclerosis), asthma, and polymorphic light eruption (PLE) [13].

However, these negative effects far outweigh the potential benefits. Due to compromised immune defences, the body becomes more susceptible to infections; for instance, herpes and papillomaviruses are reactivated more frequently, and the efficacy of vaccine-induced immunological memory is also demonstrably reduced. Furthermore, the photo-sensitive skin rashes associated with various autoimmune diseases, such as systemic lupus erythematosus (SLE) and dermatomyositis, are significantly exacerbated by UV radiation. Nevertheless, the most critical consequence is oncogenesis: the combined immunosuppressive effects of UV-B and UV-A facilitate the progression of various skin malignancies, including melanoma, squamous cell carcinoma, and basal cell carcinoma, from cells harbouring DNA damage [13,20]. However, these adverse effects should be interpreted as potential occupational hazards rather than unavoidable consequences of welding work. Under normal industrial conditions, the risks associated with UV radiation can be effectively controlled by appropriate occupational safety measures, including shielding, correctly selected personal protective equipment, auto-darkening welding helmets, UV-resistant clothing, controlled access to the welding area, and the designation of safe distances. Therefore, the health risk becomes critical mainly when these preventive measures are absent, inadequate, or improperly applied.

### *1.4. The UV Radiation in the Welding Industry*

The most common and intense sources of artificial optical radiation in industrial environments are welding arcs. The welder needs to protect themselves with personal protective equipment, but visitors, engineers, and others who pass by a welding area are at risk of injury if they do not wear protective equipment, depending on the amperage used and the welding shielding gas. In contrast to natural radiation, the radiation generated

by welding plasma is not filtered by the atmosphere; consequently, the entire spectrum, ranging from the entire UV spectrum (10–400 nm), including extreme and far UV, to the visible (VIS) and infrared (IR) regions, reaches the environment in extremely high doses [11,21,22]. Although the welding arc plasma also produces UV radiation below 200 nm (FUV and EUV), this range is almost immediately absorbed by the surrounding air and the shielding gas (frequently leading to ozone formation). As a result, the biologically critical radiation range that actually reaches the skin and eyes of the welder is limited to the spectrum between 200 and 400 nm, comprising UV-C, UV-B, and UV-A [8,10,12].

The lack of adequate protection is reflected in alarming health statistics: surveys indicate that 86% of workers experience UV-induced keratoconjunctivitis, 92% have suffered flash burns, and 40% experience neck erythema [23,24]. These injuries frequently occur even when welding helmets are utilised, largely due to the critical moment of arc ignition. At this instant, extremely intense UV emissions are generated within a fraction of a second, often before traditional shields are properly positioned [12,21,25]. Modern, auto-darkening sensor-controlled welding helmets that react within milliseconds offer a solution to this issue. Their parameters, such as shade level, sensitivity, and delay, can be fine-tuned for specific arc types and currents, thereby drastically reducing radiation exposure [26]. The auto-darkening welding helmet designation is DIN 3/11 EW (the designation indicates the optical state: '3' is inactive, and '11' is the safety-active dark, while the EW sign is the suit of the European standard). In the default setting of the welding helmet, i.e., in the light state, the mask transmits approximately 5–14% of visible light with a value of '3', while during welding, when switched to the dark state, which can be adjusted to '11', this ratio drops to below 0.1%, and at the maximum level of '13', it drops to as low as 0.0003%.

From a physical and chemical perspective, the spectrum and intensity of UV radiation generated during welding depend largely on the specific technology employed. Research has demonstrated that the presence of metal vapours within the arc plasma is a critical factor: even concentrations of less than 1% can drastically increase visible and UV radiation. Furthermore, at extremely high temperatures, the most hazardous short-wave UV-C radiation becomes dominant [11]. Radiation levels are also determined by factors such as the arc-plasma geometry, the type of shielding gas, and the plasma's self-absorption capacity. When metal atoms entering the plasma return from an excited state, they emit photons at characteristic wavelengths (metallic resonance); in the case of optically thinner plasmas, nearly all of this radiation is emitted into the surrounding environment [11,22,27].

The emission dynamics also vary across the different stages of the welding process, a phenomenon that is particularly pronounced during non-contact arc ignition in tungsten inert gas (TIG) welding. During this process, a high-voltage pulse ionises the shielding gas, initiating an electron avalanche and creating conductive plasma channels (streamers) between the workpiece and the electrode [12,28]. The return of excited gas atoms and ions to their ground state releases a massive quantity of high-energy UV photons. Consequently, the initial stage of arc ignition produces an extremely intense and hazardous UV emission peak, followed by the continuous, stable emission of the arc [12,28]. Because different shielding gases and operating parameters yield vastly different UV spectra, precise exposure measurement and technology-specific protection are essential to ensure the safety of those in the vicinity [22,27,28].

## 2. Measuring Methods and Daily Limit of Ultraviolet Radiation

### 2.1. The Daily Limit of the Ultraviolet Radiation

The daily UV limit is a unit set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) to limit the amount of UV radiation a person can be exposed to on a given day [8]. The daily threshold is 3 mW/cm<sup>2</sup>; above this, the body is no

longer able to regenerate effectively with only a night's sleep, leading to accelerated and permanent cell damage. To put this into perspective, if an instrumental measurement is  $0.001 \text{ mW/cm}^2$ , that means a human can stay in that emission range up to 60 min a day. The calculation method is given by Equation (3). However, it is important to note that radiation varies with wavelength, as the UV-A, UV-B, and UV-C ranges cause different levels of biological damage. But the correct equation can be calculated with it [21].

The term “light” is used in a very broad sense to describe any electromagnetic wave, whether out of the visible spectrum (such as IR or UV) or in the visible spectrum (red, green, blue, etc.). Based on the fundamentals of quantum mechanics, starting from the work of Max Planck, the energy of an elementary unit of optical radiation (the energy of a photon) can be determined by the following Equation (1) [29].

$$Q = (h \cdot c) / \lambda, \quad (1)$$

where  $Q$  denotes the photon energy (J), while  $h$  is Planck's constant ( $6.623 \times 10^{-34} \text{ J}\cdot\text{s}$ ) and  $c$  is the speed of light ( $3 \times 10^8 \text{ m/s}$ ), respectively. The wavelength  $\lambda$  (m) can be derived from the  $\nu$  (Hz) frequency calculated using Equation (2) [29].

$$\lambda = c / \nu, \quad (2)$$

To determine the daily UV radiation intensity representing the health or safety value for a full 24-h cycle, the formulas presented in Equations (3) and (4) are required [21]:

$$t_{\max} = X / E_{\text{eff}}, \quad (3)$$

Equation (3) represents the exposure limit ( $t_{\max}$ ) of the UV radiation for a 24-h period to which someone can be exposed, while Equation (4) describes the efficiency of radiated energy. The formula describes the maximum amount of exposure in the subject; if this is calculated for the human body,  $X$  needs to be chosen as  $3 \text{ mJ/cm}^2$  as a WHO suggestion. This is the maximum amount recommended by health regulations for one day [30].

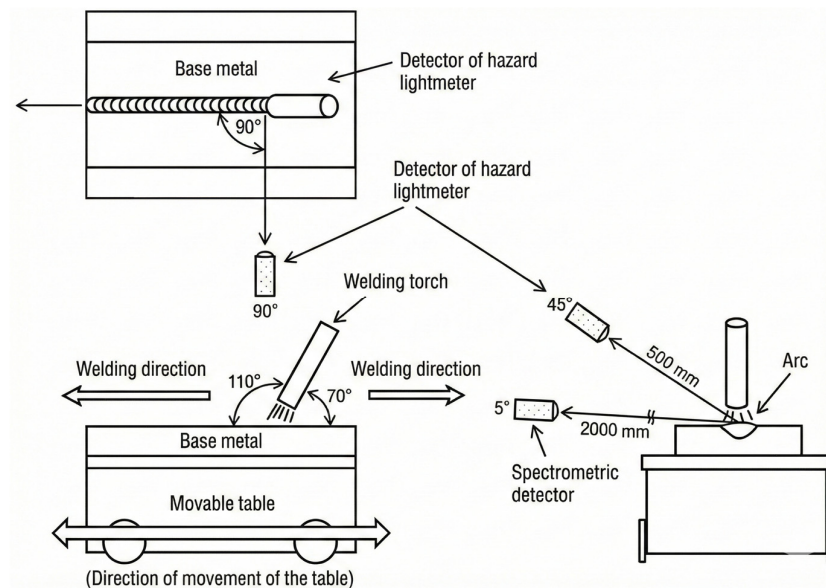
$$E_{\text{eff}} = \sum_{180}^{400} E_{\lambda} \cdot S(\lambda) \cdot \Delta\lambda, \quad (4)$$

To get the time for the exposure, it is divided by the effective exposure  $E_{\text{eff}}$  ( $\text{mW/cm}^2$ ), and with that, it is known how much time can be spent in that radiation range. If the exposure is  $1 \text{ mW/cm}^2$ , then 3 s is available to leave before any long-standing damage. The variables in Equation (4) are  $E_{\lambda}$  (spectral radiated energy in  $\text{W}/(\text{cm}^2 \cdot \text{nm})$ ),  $S(\lambda)$  (relative spectral efficiency), and  $\Delta\lambda$  (the average wavelength in nm). Equation (4) describes the calculation model for the measured radiation intensity in an area. With the knowledge of the previous equations, how much the welder is exposed to in daily work can be measured [31].

## 2.2. Industrial UV Radiation Measurement

Usually, in the welding industry, two main polluting components are measured: the fume and the light emission. In the safety standards, the parameters usually measured are fumes, electric shock, mechanical crushing by movable parts in pressure processes, or jig systems, etc. [12]. In this research, the two most important hazardous parameters are fume concentration and UV radiation. The reason for this is that if the fume concentration reaches a critical point, it can interfere with the UV emission [32,33]. For the measurement of the UV radiation, the most accepted method is to use a fixed point from the welding process to be tested at a fixed position and measure the emission. If it is necessary to measure the emission in a larger space, then the measuring point can be moved to every important measuring point and a 3D scale of the radiation can be made [29,34,35]. The measuring

method for welding can be seen in Figure 2, which was made based on the experiment used in the tests of Takahashi, J. et al. [21], research about gas metal arc welding.

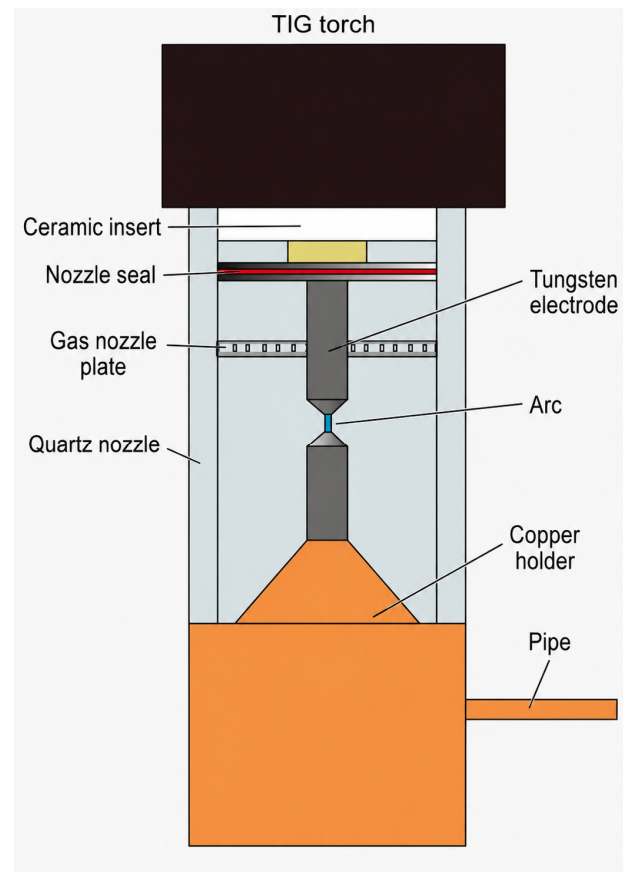


**Figure 2.** The setup layout for UV radiation measurement. (Figure made by the author based on Takahashi, J. et al. [21]).

It is important to mention the differences in the scale of emission depending on the welding process we are using and the shielding gas in the process [22,34,35]. If we look at arc welding with coated electrodes, we can say that the UV radiation is significantly lower compared to arc welding processes with shielding gas [35,36]. Even if we speak about the same welding process, if we choose a different option, like changing between AC and DC, the structure of the wavelength spectrum can change, so the measurement needs to be calculated with that as well [11]. The most critical aspect of such evaluations is selecting a measuring device with the appropriate spectral range. As demonstrated in the research by Nagi et al. [11], using equipment with a limited measurement range means that critical radiation wavelengths and rapid spectral shifts can be entirely left out and not considered in the final analysis. Furthermore, the base material heavily influences the spectrum output, as shown by Cressault et al. [37], who analysed the radiation emitted by isothermal arc plasmas in pure air compared to air–metal mixtures. Their findings revealed that introducing even a few per cent of metal vapour from the welded material into the plasma drastically changes the emission results, specifically by increasing the overall radiation intensity by several orders of magnitude and completely altering the dominant spectral peaks. The gas metal arc welding process establishes unwanted UV radiation. Measuring the radiation level is a complex task because of the sensitivity of the emission to environmental and welding parameters; even small changes can cause significant changes in UV radiation. The reason for the results is the following: either the composition of the arc changed or the stability, as well as the diameter of the arc. The reasons can lead to problems with the welded product quality. Consequently, these variations negatively impact the hazard zone surrounding the welding operation, significantly altering the critical exposure distances. These processes and connections are discussed at greater length in Sforza, P., & de Blasiis, D.'s [38] research and G. Alvarez Bestard and S. C. Absi Alfaro's research about the development of welding [28].

### 2.3. The Used Test Method

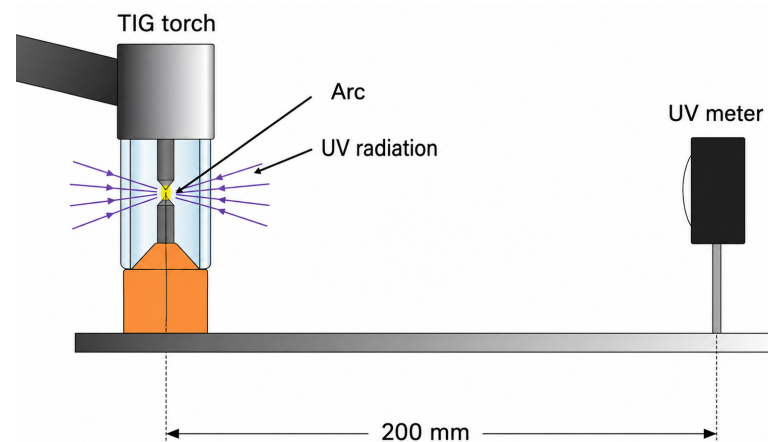
The three main gases we researched were nitrogen, argon, and helium, as well as a mixture of argon and helium. We used a fixed setup where the parts per million (ppm) value of the shielding gas in the chamber could be measured, and the amperage could be freely adjusted during the process. The purity of the shielding gas was maintained at 12 L/min, and the ppm at the start of the test was less than 1000 ppm. The gases were helium 4.6, argon 4.6, and argon 70–helium30 (4.6 purity designation equal to 99.996% purity of the gas in accordance with the EN ISO 14175 standards), and the distance between the two electrodes was 1 mm. The schematic of the experimental setup is shown in Figure 3.



**Figure 3.** The experimental setup of the arc chamber and its main parts (figure made by the authors).

The sensor was placed at a fixed distance from the measuring device, which measured UV radiation in the range of 290–390 nm. The device used for the measurements was a PCE-UV34 UV(PCE Deutschland GmbH, Meschede, Germany) meter, and for generating the desired current, we used a Panelectrode ZEUS 200 LCD type welding machine, made by Panweld ER 23 Ltd., Budapest, Hungary. According to the manufacturer's specification of the PCE-UV34 UV meter, the instrument is intended for UV-A/UV-B measurements and provides direct irradiance values in  $\text{mW}/\text{cm}^2$ . Therefore, it is suitable for industrial field measurements aimed at comparing UV radiation levels under different welding conditions and supporting preventive occupational safety decisions. The parameters that we used in every measurement were direct current with a starting current of 20% less than the main current in every test, and the shielding gas flow rate was constant at 12 L/min. The setup can be seen in Figure 4. As shown in the figures, the arc was generated between two tungsten electrodes. This material was chosen for its remarkably high melting point, which creates an ideal environment for forming the arc. The arc was formed between two tungsten electrodes. The material of the electrodes was tungsten lanthanum WLa15, and

the diameter was 2.4 mm, with the electrode in a copper socket to ensure the best possible heat conduction. To ensure that the shielding gas flowed within a closed space, a quartz bulb was used. Based on preliminary measurements, it did not affect the UV radiation results, but it provided a controlled environment for the experiments.



**Figure 4.** The schematic picture of the measurement (figure made by the authors).

We also conducted tests using a porcelain gas deflector, but the results showed occasional oxidation of the electrode, and it was difficult to control the purity of the shielding gas due to atmospheric contamination. As discussed in the previous part of the research, the composition of the shielding gas and, consequently, the plasma can significantly influence the level of UV radiation.

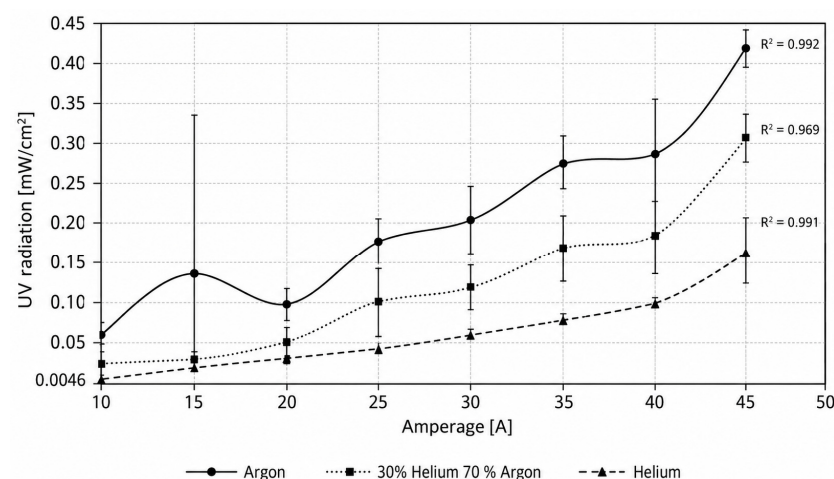
In this research, we aim to draw attention to the hazards of ultraviolet (UV) radiation and to emphasise the importance of appropriate protective measures during TIG (Tungsten Inert Gas) welding, not only for welders but also for personnel supervising or assisting the process. The study focuses specifically on UV radiation emitted by the TIG welding arc. For this purpose, an experimental setup was selected that minimises contamination and enables the investigation of UV radiation generated primarily by the shielding gases themselves. This controlled arrangement makes it possible to compare the effect of different shielding gas compositions on UV emission under consistent welding conditions.

### 3. Results

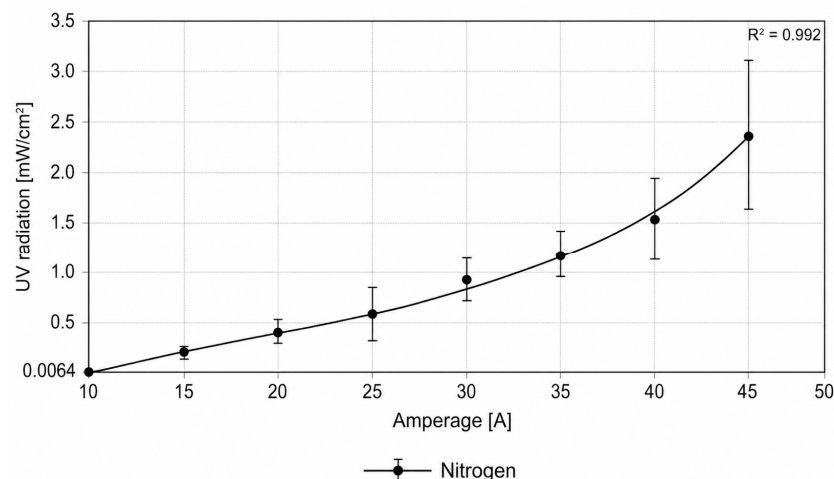
In our tests, we aimed to check the characteristic changes in UV radiation in the case of different shielding gases.

The results of the argon, helium, and their mixture tests can be seen in Figure 5. As shown in the diagram, the emission at 10 A ranges from a minimum of 0 mW/cm<sup>2</sup> to a maximum of approximately 0.06 mW/cm<sup>2</sup>. The zero minimum occurs because the 10 A measurements were so close to the lower detection limit of the equipment that we could not obtain a reading in every instance; consequently, the lowest values were rounded to 0. Below 10 A, starting the arc becomes increasingly difficult, so we only measured down to 10 A. In the tests, we adjusted the welding current in 5-ampere intervals and monitored the corresponding changes in the emission from the gas mixtures. As observed, argon, which has a higher radiation wavelength in the measurement range than helium, shows approximately three times higher UV radiation intensity compared to helium. This can be traced back to the ionising energy of the gases [7]. Interestingly, when only 30% helium was added to the shielding gas mixture, the radiation level decreased by about 30% as well. In this case, the difference was only around twice that of pure helium radiation at the same current. This means that if we add a gas with different parameters, it can change the radiation with a huge impact on the results. So, as of now, we can say that if we use

pure helium, we can get around a 55% decrease in radiation compared to argon. And we can get a 30% decrease in the case of a 30% helium 70% argon mixture. With this result, we performed one more test at only 45 amperes with a 70% helium–argon mixture. The results gave us an extra 20% decrease in the UV radiation. With this, we can say that if we use a more highly concentrated mixture, it will not be necessary to use much less UV radiation within exact ranges. The fitting curves shown in Figures 5 and 6 were generated from the measured average UV irradiance values using Microsoft Excel’s built-in least-squares trendline function. A polynomial trendline was applied only to visualise the tendency of the measured data within the investigated current range. The fitting was performed without additional weighting, and the coefficient of determination ( $R^2$ ) was calculated in Excel from the measured mean values and the fitted curve. The curves are therefore intended only as descriptive visual aids and not as physical models of arc radiation. No extrapolation outside the measured current range should be made from these curves. In particular, the fitted curves should not be interpreted as indicating UV emission at 0 A, because no welding arc exists without current. Values close to zero at 10 A were treated as measurement values close to the lower detection limit of the instrument and were included only for the measured current point. The fitted curves (Figure 5) are shown only to visualise the measured trend within the 10–45 A current range and should not be extrapolated to 0 A or beyond the measured interval.



**Figure 5.** Diagram of UV emission in the case of amperage of argon, helium and a mixture containing 30% helium.



**Figure 6.** Diagram of UV emission as a function of amperage and of nitrogen.

For more precise findings, more gas mixtures need to be tested.

The average data with its deviation from these tests is presented in Table 2. The standard deviation values presented in Table 2 indicate the repeatability of the measurements at each current level and gas composition. Where appropriate, these values should be considered together with the plotted trends when interpreting the variability of the UV emission. When using nitrogen, arc ignition at 10 A proved highly difficult and unstable. Nevertheless, a measurable UV radiation value was detected at this current level and is reported in Table 2. This value should be interpreted as a near-threshold measurement rather than as a stable operating point. The fitted curves shown in Figure 5 are valid only within the experimentally investigated current range of 10–45 A. They must not be extrapolated to 0 A or to any current value outside the measured interval. At 0 A, no welding arc is generated; therefore, there is no arc-related UV emission from the shielding gas plasma. The fitted curves are used only to visualise the trend of the measured data within the tested current range and should not be interpreted as physical emission models at very low or zero current. As part of the research, we conducted tests with nitrogen. In these tests, we observed that it has a way higher radiation intensity than we expected. The results of the test can be seen in Figure 6. During the test, the arc was much more unstable than with argon or helium, which is why the radiation jumped by an order of magnitude. This is also supported by the fact that at the beginning of the measurement, we only measure 2–3 times the radiation, and then it suddenly increases when the arc loses its stability. As the arc expands, the increase in the radiating surface is directly proportional to the rise in radiation. As a result, we can conclude that the stability of the arc is a very important factor in terms of UV radiation. In welding, a stable arc is preferable first and foremost if you want to produce a good weld, but this result gives us an additional reason to choose the correct gas mixture for every application [15]. This also supports the statement that in most cases, it was only nitrogen that was used in welding root protection.

**Table 2.** The UV levels as a function of the used gases and amperage, and the standard deviation of the measured data as a function of the amperage.

| Amperage                                | Chemical Composition of the Used Gases (%) |          |               |          |
|-----------------------------------------|--------------------------------------------|----------|---------------|----------|
|                                         | 100% He                                    | 100% Ar  | 30% He 70% Ar | 100% N2  |
| Measured UV Level (mW/cm <sup>2</sup> ) |                                            |          |               |          |
| 10 A                                    | 0.0046                                     | 0.0629   | 0.0255        | 0.0064   |
| 15 A                                    | 0.0206                                     | 0.1390   | 0.0324        | 0.1575   |
| 20 A                                    | 0.0344                                     | 0.0993   | 0.0510        | 0.3870   |
| 25 A                                    | 0.0430                                     | 0.1763   | 0.1015        | 0.5340   |
| 30 A                                    | 0.0624                                     | 0.2041   | 0.1198        | 0.9190   |
| 35 A                                    | 0.0802                                     | 0.2760   | 0.1705        | 1.1625   |
| 40 A                                    | 0.0990                                     | 0.2824   | 0.1830        | 1.5200   |
| 45 A                                    | 0.1628                                     | 0.4227   | 0.3090        | 2.3800   |
| Amperage                                | Standard deviation (mW/cm <sup>2</sup> )   |          |               |          |
|                                         | 100% He                                    | 100% Ar  | 30% He 70% Ar | 100% N2  |
| 10 A                                    | 0.003441                                   | 0.013642 | 0.005442      | 0.002221 |
| 15 A                                    | 0.005043                                   | 0.198047 | 0.012580      | 0.019092 |
| 20 A                                    | 0.009023                                   | 0.018968 | 0.024369      | 0.069130 |
| 25 A                                    | 0.005083                                   | 0.025355 | 0.068180      | 0.194548 |
| 30 A                                    | 0.006140                                   | 0.056562 | 0.033236      | 0.192033 |
| 35 A                                    | 0.005563                                   | 0.037384 | 0.046275      | 0.208310 |
| 40 A                                    | 0.002973                                   | 0.089789 | 0.068158      | 0.358391 |
| 45 A                                    | 0.034568                                   | 0.053392 | 0.053009      | 0.723878 |

#### 4. Discussion

Our results show that the composition of the shielding gases drastically influences the intensity of the emitted UV radiation. Under identical parameters, pure argon generates around three times more UV radiation than pure helium. This difference can be attributed to the different ionisation energies and plasma characteristics of the gases, similar to what is mentioned in the literature regarding ionisation energies (based on the work of Diffey [7]). On the base of the examination of different gas mixtures, it should be noted that adding just 30% helium to the shielding gas mixture resulted in a reduction in radiation levels of approximately 30% compared to pure argon. But in the case of 70% helium, the changes are not this radical, only a 20% reduction in radiation. This shows that by consciously modifying the gas composition, the UV exposure can be effectively reduced, while the favourable arc properties of argon are largely retained, but the effect is not linear with the change in the gas percentages.

The highest UV radiation values were observed during the measurements with pure nitrogen, reaching 2.38 mW/cm<sup>2</sup> at 45 A. Based on the analysis of the arc we saw in the tests, this order of magnitude jump is directly related to the severe instability of the arc. The loss of arc stability and expansion proportionally increases the radiating plasma surface, resulting in extremely dangerous UV levels. This instability and the resulting emission change highlight that even small changes in technological parameters and arc geometry have a significant impact on the danger zone, as detailed in previous research on welding processes by Sforza and de Blasiis [37] and Alvarez Bestard and Absi Alfaro [38].

In future research, it is worth extending the measurements to higher currents and wider spectra, including the biologically extremely destructive UVC range. We also aim to investigate the relationship between the stability of UV emission and the quality of the weld, and to determine precise safety distances (occupational exposure limits) for specific gas mixtures. In further research, it is absolutely justified to examine the effect of welded materials and metal vapours, since the results of Cressault et al. [11] highlighted that even a few per cent of metal vapour entering the plasma can increase the radiation intensity by orders of magnitude and completely change the dominant spectral peaks.

It should be noted that the present results refer to a controlled electrode-shielding gas configuration and not to a complete welding operation involving a molten base material. In real welding, changes in the welded material may affect the UV radiation intensity and spectral distribution because metal vapours, alloying elements, surface oxides, coatings, and contamination can modify the arc-plasma composition, self-absorption, and arc stability. Consequently, the absolute UV emission values may differ for different base materials, although the present setup remains suitable for comparing the relative effect of shielding gas composition under controlled conditions. Future research will therefore include material-specific measurements with commonly welded alloys.

#### 5. Conclusions

In gas shielded metal arc welding, selecting the appropriate gas mixture is crucial not only for producing high-quality, defect-free welds but also for significantly mitigating occupational health risks. In this study, we systematically measured the UV radiation emission (in the 290–390 nm range) of pure argon, pure helium, a 70% argon/30% helium mixture, and pure nitrogen across varying low current intervals (10 A to 45 A). Our empirical results demonstrated that the composition of the shielding gas drastically affects the intensity of the emitted UV radiation. We found that under identical parameters, pure argon generates approximately three to four times higher UV radiation intensity than pure helium. This significant variance can be directly attributed to the differing ionisation energies and plasma characteristics of the respective gases. Crucially, our measurements

revealed that substituting just 30% of argon with helium in the gas mixture resulted in a disproportionately large reduction in UV emission, decreasing the radiation level by approximately 30% compared to pure argon. This highlights that strategically modifying the shielding gas composition is a highly effective, practical method for reducing UV exposure in the workplace without entirely losing the beneficial arc characteristics of argon. Furthermore, tests conducted with pure nitrogen exhibited the highest UV radiation values by a significant margin, reaching up to  $2.38 \text{ mW/cm}^2$  at 45 A. When the arc loses stability and expands, the radiating plasma surface increases proportionally, emitting extremely hazardous levels of UV radiation. While nitrogen is typically used in welding only as a backing gas (root protection) rather than a primary shielding gas, these findings strongly caution against its use in any application where the arc might be directly exposed to the environment or the operator. Since the current study was limited to the 290–390 nm spectrum and low current applications, it provides a foundational understanding but necessitates further investigation. In the continuation of our research, comprehensive verification and control measurements will be conducted at much higher amperages and across broader spectral ranges (including the highly destructive UVC). Based on these future tests, our goal is to correlate UV emission stability with weld seam quality and to establish exact safety distance charts (occupational exposure limits) based on specific gas mixtures, further enhancing safety protocols in the welding industry. It should be emphasised that the PCE-UV34 is not a spectroradiometer and does not provide wavelength-resolved irradiance data. Accordingly, the reported values represent broadband, unweighted UV irradiance in the 290–390 nm range and should not be interpreted as final spectrally weighted occupational exposure limit values. Nevertheless, the instrument is well suited for practical industrial safety screening, comparative workplace measurements, and the preliminary identification of high-UV-exposure conditions around welding operations. Future work will include calibrated spectroradiometric measurements and appropriate biological weighting functions to support a complete regulatory exposure assessment.

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## Abbreviations

The following abbreviations are used in this manuscript:

|     |                                |
|-----|--------------------------------|
| AC  | Alternating Current            |
| DC  | Direct Current                 |
| DIN | Deutsches Institut für Normung |

|        |                                                |
|--------|------------------------------------------------|
| DNA    | Deoxyribonucleic Acid                          |
| DT     | Delayed Tanning                                |
| EM     | Electromagnetic                                |
| EUV    | Extreme Ultraviolet                            |
| Far-UV | Far Ultraviolet                                |
| IPD    | Immediate Pigment Darkening                    |
| IR     | Infrared                                       |
| ISO    | International Organisation for Standardisation |
| PLE    | Polymorphous Light Eruption                    |
| PPE    | Personal Protective Equipment                  |
| SLE    | Systemic Lupus Erythematosus                   |
| TIG    | Tungsten Inert Gas                             |
| UV     | Ultraviolet                                    |
| UV-A   | Ultraviolet type A                             |
| UV-B   | Ultraviolet type B                             |
| UV-C   | Ultraviolet type C                             |
| VIS    | Visible (Spectrum/Light)                       |
| WHO    | World Health Organisation                      |

## References

- Gallagher, R.P.; Lee, T.K.; Bajdik, C.D.; Borugian, M. Ultraviolet radiation. *Chronic Dis. Can.* **2010**, *29*, 51–68. [\[CrossRef\]](#)
- Hamouda, S.A.; Alshawish, N.K.; Abdalla, Y.K.; Ibrahim, M.K. Ultraviolet Radiation: Health Risks and Benefits. *Saudi J. Eng. Technol.* **2022**, *7*, 533–541. [\[CrossRef\]](#)
- Sklar, L.R.; Almutawa, F.; Lim, H.W.; Hamzavi, I. Effects of ultraviolet radiation, visible light, and infrared radiation on erythema and pigmentation: A review. *Photochem. Photobiol. Sci.* **2013**, *12*, 54–64. [\[CrossRef\]](#) [\[PubMed\]](#)
- Tiesinga, E.; Mohr, P.J.; Newell, D.B.; Taylor, B.N. CODATA recommended values of the fundamental physical constants: 2018. *Rev. Mod. Phys.* **2021**, *93*, 025010. [\[CrossRef\]](#) [\[PubMed\]](#)
- ISO 21348:2007; International Organization for Standardization. Space Environment (Natural and Artificial)—Process for Determining Solar Irradiances. ISO: Geneva, Switzerland, 2007.
- Knuschke, P. UV Exposure. In *Kanerva's Occupational Dermatology*; John, S., Johansen, J., Rustemeyer, T., Elsner, P., Maibach, H., Eds.; Springer: Cham, Switzerland, 2020. [\[CrossRef\]](#)
- Diffey, B.L. Sources and measurement of ultraviolet radiation. *Methods* **2002**, *28*, 4–13. [\[CrossRef\]](#) [\[PubMed\]](#)
- International Commission on Non-Ionizing Radiation Protection (ICNIRP). Guidelines on Limits of Exposure to Ultraviolet Radiation of wavelengths between 180 nm and 400 nm (Incoherent Optical Radiation). *Health Phys.* **2004**, *87*, 171–186. [\[CrossRef\]](#) [\[PubMed\]](#)
- Chinnasamy, S.; Ramachandran, M.; Sivaji, C. A Study on Ultraviolet Radiation and Its Effects. *J. Adv. Mech. Eng.* **2022**, *1*, 1–9. [\[CrossRef\]](#)
- Hessling, M.; Haag, R.; Sieber, N.; Vatter, P. The impact of far-UVC radiation (200–230 nm) on pathogens, cells, skin, and eyes—A collection and analysis of a hundred years of data. *GMS Hyg. Infect. Control* **2021**, *16*, Doc07. [\[CrossRef\]](#) [\[PubMed\]](#)
- Cressault, Y.; Gleizes, A.; Riquel, G. Calculation of the radiation emitted by isothermal arc plasmas in air and air-metal mixtures. In Proceedings of the 20th International Symposium on Plasma Chemistry (ISPC-20), Philadelphia, PA, USA, 24–29 July 2011; p. 115.
- Vishnyakov, V.I.; Kiro, S.A.; Ennan, A.A. Reducing of UV Radiation Intensity, Ozone Concentration and Fume Formation in Gas Metal Arc Welding. *Aerosol Sci. Eng.* **2020**, *4*, 192–199. [\[CrossRef\]](#)
- Norval, M.; Halliday, G.M. The consequences of UV-induced immunosuppression for human health. *Photochem. Photobiol.* **2011**, *87*, 965–977. [\[CrossRef\]](#) [\[PubMed\]](#)
- Dixon, A.J.; Dixon, B.F. Ultraviolet radiation from welding and possible risk of skin and ocular malignancy. *Med. J. Aust.* **2004**, *181*, 155–157. [\[CrossRef\]](#) [\[PubMed\]](#)
- Lopes, F.C.P.S.; Sleiman, M.G.; Sebastian, K.; Bogucka, R.; Jacobs, E.A.; Adamson, A.S. UV Exposure and the Risk of Cutaneous Melanoma in Skin of Color: A Systematic Review. *JAMA Dermatol.* **2021**, *157*, 213–219. [\[CrossRef\]](#) [\[PubMed\]](#)
- Fitzpatrick, T.B. The validity and practicality of sun-reactive skin types I through VI. *Arch. Dermatol.* **1988**, *124*, 869–871. [\[CrossRef\]](#)
- Devi, Q.A.; Silaban, G.; Salmah, U. The Effect of Ultraviolet Radiation Intensity on Eye Disorders Among Welders in Medan Maimun District, Medan City in 2024. *Int. J. Health Educ. Soc.* **2025**, *8*, 109–118. Available online: <https://share.google/TAP17S7ZbhlJBWz1B> (accessed on 15 January 2026). [\[CrossRef\]](#)

18. Fritschi, L.; Driscoll, T.; Nguyen, H.; Carey, R.N. Occupational Exposure to Artificial Ultraviolet Radiation from Welding in Australia. *Int. J. Prev. Med.* **2024**, *15*, 43. [\[CrossRef\]](#) [\[PubMed\]](#)
19. Akegbejo, D.A. Health Effects of Welding Fumes and Ultraviolet Radiation, Use of Personal Protective Equipment (PPE) among Production Welders. *Glob. Sci. Acad. Res. J. Educ. Lit.* **2024**, *2*, 43–48.
20. Simon, J.C.; Cruz, P.D.; Bergstresser, P.R.; Tigelaar, R.E. Low dose ultraviolet B-irradiated Langerhans cells preferentially activate CD4+ cells of the T helper 2 subset. *J. Immunol.* **1990**, *145*, 2087–2091. [\[CrossRef\]](#)
21. Takahashi, J.; Nakashima, H.; Fujii, N.; Okuno, T. Comprehensive analysis of hazard of ultraviolet radiation emitted during arc welding of cast iron. *J. Occup. Health* **2020**, *62*, e12091. [\[CrossRef\]](#) [\[PubMed\]](#)
22. Tenkate, T.D. Optical radiation hazards of welding arcs. *Rev. Environ. Health* **1998**, *13*, 131–146. [\[CrossRef\]](#) [\[PubMed\]](#)
23. The Japan Welding Engineering Society. *A Research Report on the Performance of Eye Protectors Against Optical Radiation*; The Japan Welding Engineering Society: Tokyo, Japan, 1980. (In Japanese)
24. Emmett, E.A.; Buncher, C.R.; Suskind, R.B.; Rowe, K.W., Jr. Skin and Eye Diseases Among Arc Welders and Those Exposed to Welding Operations. *J. Occup. Med.* **1981**, *23*, 85–90. [\[CrossRef\]](#) [\[PubMed\]](#)
25. Okuno, T. Measurement of ultraviolet radiation from welding arcs. *Ind. Health* **1987**, *25*, 147–156. [\[CrossRef\]](#) [\[PubMed\]](#)
26. EN 379:2003; ICS 13 340 20 Personal eye-protection—Automatic Welding Filters. European Standard: Pilsen, Czech Republic, 2003.
27. Nakashima, H.; Utsunomiya, A.; Takahashi, J.; Fujii, N.; Okuno, T. Hazard of ultraviolet radiation emitted in gas metal arc welding of mild steel. *J. Occup. Health* **2016**, *58*, 452–459. [\[CrossRef\]](#) [\[PubMed\]](#)
28. Pires, I.M.; Quintino, L.; Miranda, R.M. Analysis of the influence of shielding gas mixtures on the gas metal arc welding metal transfer modes and fume formation rate. *Mater. Des.* **2007**, *28*, 1623–1631. [\[CrossRef\]](#)
29. Kafi, A.; Nyikes, Z.; Schramkó, M.; Kovács, T.A. Arc welding safety zones determination as a function of the UV radiation. In *Journal of Physics: Conference Series*; IOP Publishing: Bristol, UK, 2022; Volume 2315, p. 012029. [\[CrossRef\]](#)
30. Masili, M.; Duarte, F.O.; Ventura, L. Evaluation of solar ultraviolet blocking by sunglasses and their compliance with recommended safety limits. *Res. Biomed. Eng.* **2025**, *41*, 5. [\[CrossRef\]](#)
31. Rossi, M.L.; Vilarinho, L.O. Measurement of visible ultraviolet radiation during arc welding for issues of health and safety at work. *Weld. Int.* **2009**, *23*, 432–438. [\[CrossRef\]](#)
32. Peng, C.Y.; Liu, H.H.; Chang, C.P.; Shieh, J.Y.; Lan, C.H. Evaluation and monitoring of UVR in shield metal arc welding processing. *Health Phys.* **2007**, *93*, 101–108. [\[CrossRef\]](#) [\[PubMed\]](#)
33. Schramkó, M.; Kafi, A.; Kovács, T.A. Analysis of the Harmful Effects of UV Radiation Generated During Welding. *Acta Mater. Transylvanica* **2022**, *5*, 89–92. [\[CrossRef\]](#)
34. Rybczyński, A.; Wolska, A. Selected measurement problems during the evaluation of occupational exposure to UV radiation emitted by the welding arc. In *Proceedings of the 2016 IEEE Lighting Conference of the Visegrad Countries (Lumen V4)*, Karpacz, Poland, 13–16 September 2016; IEEE: Piscataway, NJ, USA, 2016. [\[CrossRef\]](#)
35. Pontes, L.F.F.; Martins, W.d.P.; Meneses, V.A.d.; Ferreira, R.P.; Leal, V.S. Effect of MIG/MAG welding energy on the generation of ultraviolet radiation (UV-A) in sheet metal, according to occupational hygiene standards. *Obs. Econ. Latinoam.* **2025**, *23*, e9679. [\[CrossRef\]](#)
36. Murugan, S.S.; Sathiy, P. Analysis of welding hazards from an occupational safety perspective. *Vietnam J. Sci. Technol. Eng.* **2024**, *66*, 63–74. [\[CrossRef\]](#)
37. Sforza, P.; de Blasiis, D. On-line optical monitoring system for arc welding. *NDT E Int.* **2002**, *35*, 37–43. [\[CrossRef\]](#)
38. Alvarez Bestard, G.; Absi Alfaro, S.C. Measurement and estimation of the weld bead geometry in arc welding processes: The last 50 years of development. *J. Braz. Soc. Mech. Sci. Eng.* **2018**, *40*, 444. [\[CrossRef\]](#)

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