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ASSESSMENT OF ULTRAVIOLET (UV) RADIATION FROM TECHNICAL SOURCES

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Abstract. The paper presents the assessment of ultraviolet radiation from technical sources. It has been determined that the intensity of UVA radiation is about 10 times higher than the intensity of radiation of UVB. It has been investigated that the intensity of UV radiation during the welding process nonlinearly depends on the strength of the current, namely, if the strength of the current is reduced by 60%, the intensity of UV radiation is reduced by 20%, it also depends on the distance from the source, namely, if the distance is increased 10 times, the intensity of UV radiation is reduced about 25 times. The dose of UVA and UVB radiation from various resources is calculated. Comparison with the minimum erythema dose is submitted. It has been obtained that when the strength of the current is 315 A, the UV radiation dose exceeds 1 MED, namely, UVA ~ 3000, UVB ~300 times. After having carried out the experiment it has been found that the UV radiation emitted from a welder comprises about 80% of UVA, and about 20% of UVB. The results of investigation made in a solarium show that UV radiation from lamps comprises 98% of UVA radiation and 2% – of UVB radiation, while in the Sun rays reaching the Earth UV radiation comprises 96% of UVA and 4% of UVB.

Keywords: UVA radiation, UVB radiation, radiation intensity, technical sources, UV dose, minimal erythemal dose (MED).

1. Introduction

UV radiation originates a great number of biological and chemical processes which in the majority of cases are hazardous for animal and plant systems (Frederick and Lubin 1988; Diffey 1991).

The influence of UV radiation on the organism of a human being is mostly expressed by the influence on the eyes, skin and immune system. Long-lasting and prolonged stay in the Sun increases the relativity of aging of the skin and causes the appearance of dangerous skin diseases caused by the surplus of UV radiation (Diffey 1987; Madronich and de Gruijl 1993).

UV radiation is of 100 to 400 nm wave length. The waves of 200–300 nm length are absorbed by ozone (O_3) at a height of 50 km. The longest waves of UV radiation from 315 nm up to 400 are called UVA and are both very useful, relevant and necessary for the formation of vitamin D in the skin and plays a harmful role in that it causes sunburn on human skin and cataracts in our eyes. The radiation of shorter waves, namely, from 280 up to 315 nm, is called UVB; it damages the main nucleus of human life – desoxyribonucleic acid (DNA). UVB radiation being hazardous to living beings occupies the smallest part of the spectrum, from 280 up to 315 nm (ES 2006/25/EC, Chadyšienė and Girgždys 2008). UVC radiation is completely absorbed in the stratosphere.

The permeability of the hazardous effects of UV radiation has initiated a great number of researches during the recent 20 years (Van der Leun *et al.* 1998).

Arc welding produces a full spectrum of UV radiation, also ozone, aerosol particles (Valuntaitė and Girgždienė 2008). It is possible that welders are at greater risk of developing skin cancer than the general population. Studies have demonstrated that welding increases the risk of ocular melanoma. Just as we urge the public to protect themselves from UV radiation, we need to consider similar advice for arc welders (Dixon, A. and Dixon, B. 2004).

UVC radiation from electric arc welding (UVC 200–280 nm) will rapidly produce a bright cherry-red sunburn which is greatly different in appearance from the sunburn produced from over exposure to solar UV. Sunscreen preparations are not as effective against this type of radiation, which is extremely damaging to the skin, e.g. premature aging (Tenkate, Collins 1997).

To assess the current state of photokeratoconjunctivitis a lot of experiments have been made. Whereas 85.8% of the cases received exposures from welding, only 3.8% were professional welders, and most cases were of other occupations with occasional use of welding (Yuan-Lung *et al.* 2004).

Sunbeds are an important public health issue because of the size of the artificial tanning industry in terms of the number of commercial sunbeds and the number of people using them (Spencer and Amonette 1995). In Northern Europe, approximately 10% of the population use sunbeds on a regular basis for tanning purposes (The truth about tanning 1987). A study in Sweden schematically estimated that the population's UV radiation dose due to artificial tanning might be of the same order of magnitude as the potential increase in natural UV radiation dose resulting from 10% ozone depletion (Wester *et al.* 1999). Even in Australia, a country that has high UV radiation levels, 9%

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of people aged 14–29 have reported using a sunbed in the past 12 months (Dobbinson and Borland 1999).

The World Health Organization (WHO) has determined that more than 20% of cases of cataract might have developed due to the influence of UV radiation (WHO 1995).

Taken into consideration the mentioned above influence it is stated that most widely spread is erythema or burn caused by the spectrum of UV with the maximum at the 297 nm of the wave length (Diffey 1982; Berger and Urbach 1982). The studies of the influence of erythema on the human body are based on the studies of the minimum dose of UV erythema radiation which is the cause of the blush on the human skin possible to be noticed by an eye and of UV radiation without an advanced influence. The dose is known internationally as MED (minimum erythema dose – threshold dose that may produce sunburn, 1 MED ~ 56 mW/h) (Diffey 1990) and is always related to the type of skin.

UV radiation is disseminated not only by the Sun, but it is radiated during the process of welding, getting suntan at a solarium, by quartz lamps used in medicine.

The objective of the work is by carrying out the intensity measurements of UV radiation from technical sources to be able to calculate the receivable dose of UV radiation and to evaluate variations of the UV radiation intensity from the mentioned technical sources.

2. Methodology

In order to evaluate the variations of UV radiation emitted from the welding process five experiments were carried out. At each measuring point the intensity of UVA and UVB radiation was measured three times changing the distance from the source as well as the strength of the electric current. The following 45A, 130A, 315A were selected for the experiments. The work presents average data of measurements.

The measurements of UVA radiation intensity were carried out by a radiometer UVA–356 HA, the sensor of which registers UV radiation within spectral response 320–400 nm (Figs. 1, 2).

The measurements of UVB radiation intensity were carried out by a radiometer PMA 2200, the sensor of which registers UV radiation within spectral response 280–320 nm. The sensitivity of the sensor is 50 mW/cm^2 (Figs. 1, 3).

The determination error for UVA and UVB radiation intensity amounted to 10%.

Detectors give an accurate measurement of biologically weighted ultraviolet radiation from sunlight or artificial light sources, also called sunburning UV radiation. Its spectral response follows closely the erythema action spectrum. The detector has angular response very close to an ideal cosine function (Lambertian response) making it suitable for measurements of diffuse radiation or radiation generated by extended sources.

In the future research of UV radiation intensity from technical sources it is necessary to evaluate intensity of UVC radiation, while UVC radiation level is relatively high. Distance from the source is relatively small, and longer UVC radiation is partially absorbed.

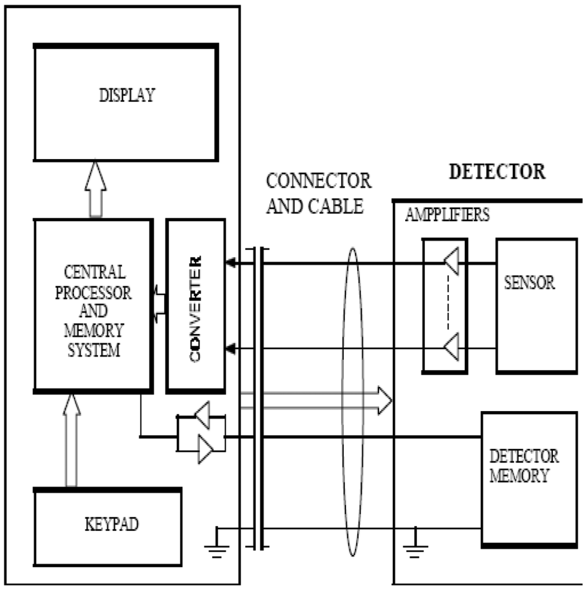

Fig. 1. Principal scheme of UV radiometers

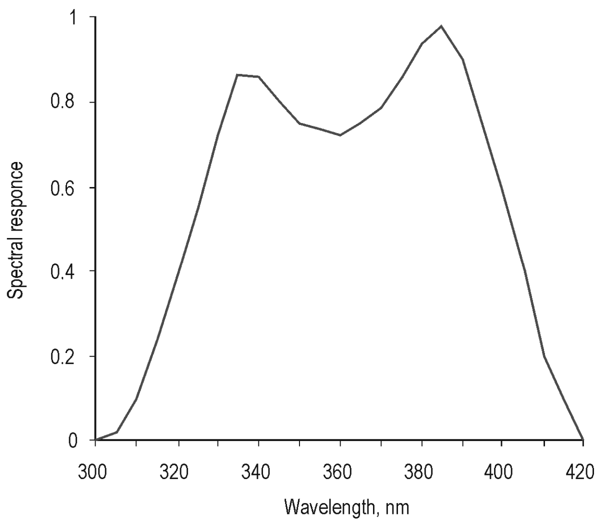

Fig. 2. Spectral characteristic of UVA detector 365 HA

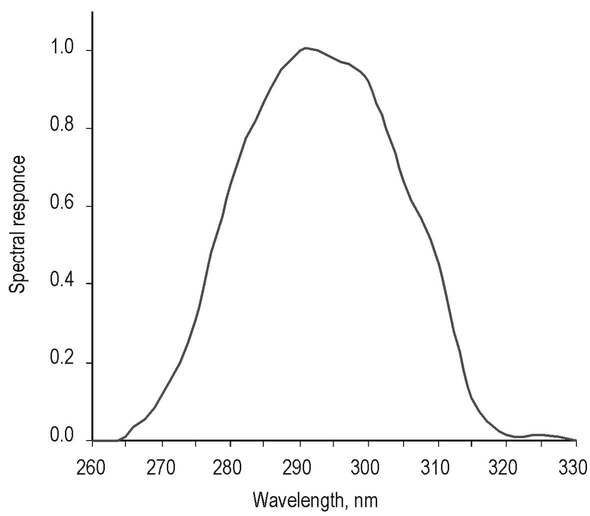

Fig. 3. Spectral characteristic of UVB detector PMA 2201

3. Results

During the investigation the intensity of UVA and UVB radiation was measured as close as possible to the source of radiation by changing the distance from the source. The way of reducing the intensity of UV radiation from the welder by applying various glasses was also investigated. The work presents the results of the tests carried out by welding 3 mm thickness electrodes under the different source intensity.

During metal arc welding produced UV radiation intensity depends on the arc temperature in welding point. The arc temperature depends on electric current strength. In our investigation UV radiation dependence on the electric current strength have been analysed.

The results were also compared with the intensity values of UVA and UVB radiation intensity emitted from the Sun.

Trendlines are used to display graphically trends in data. There are some types of trendlines: linear, logarithmic, polynomial, power, exponential, moving average. A trendline is the most reliable when its R-squared value is at or near 1. Later the values of trendlines are called empirical values.

In Fig. 4 the averaged experimental results of UVA and UVB radiation intensity under different electric current strength of a welding machine are presented. A linear trendline clearly shows the increase of UVA and UVB radiation intensity when electric current strength is increased. Notice that the R-squared value for UVA radiation is 0.94, and for UVB radiation it is 1 which is a good fit of the line to the experimental data.

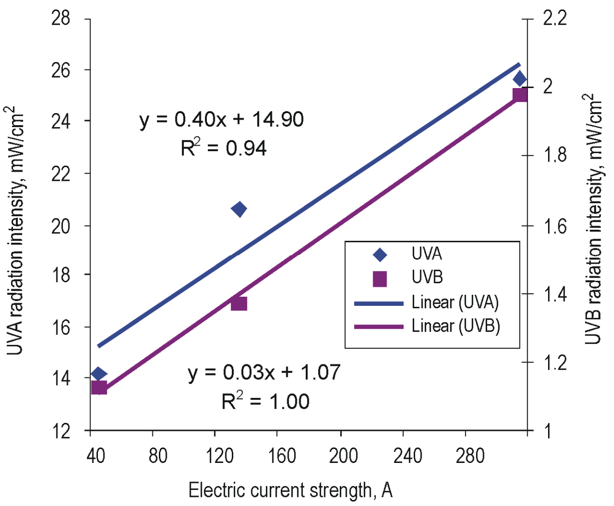

Fig. 4. UVA and UVB radiation intensity under different electric current strength

Fig. 5 gives the intensity of UVA radiation during the welding process under different source intensity and distance. It is determined that during the welding process the intensity of UVA radiation emitted depends on the intensity of the source, namely, by reducing the intensity by 59%, the intensity of UVA radiation is reduced by 17% as well as reducing the distance from the source, namely, after having increased the distance 10 times the intensity of UVA radiation is reduced 25 times.

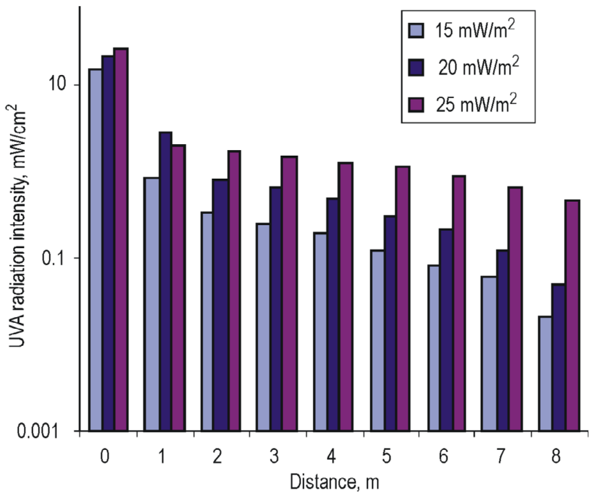

Fig. 5. Intensity of UVA radiation under different source intensity (15.0; 20.0; 25.0 mW/m^2) emitted during the welding process

Fig. 6 presents the intensity of UVB radiation emitted during the welding process under different intensity of the source and distance from the source. From the data of the experiments, it is exhibited that the intensity of UVB radiation emitted during the welding process is 10 times less than the intensity of UVA radiation.

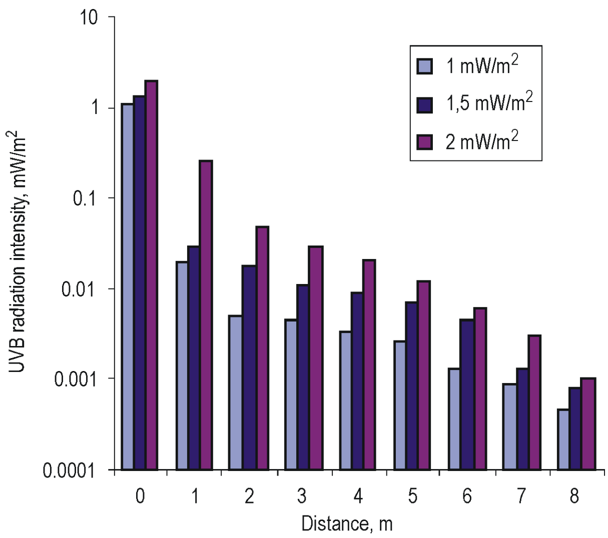

Fig. 6. Intensity of UVB radiation under different source intensity (1.0; 1.5; 2.5 mW/m^2) emitted during the welding process

The UV radiation emitted from the Sun comprises 96% of UVA and 4% of UVB radiation. After the test it has been determined that the UV radiation emitted from the welder is about 80% of UVA, and about 20% of UVB radiation.

It is known that the intensity of the flow of light is directly proportional to the force of electric current strength and conversely proportional to the square of the distance from the source. Figs. 7, 8 present the reduction of the intensity of UV radiation by increasing the distance from the source (welding device) that has been measured experimentally. It has been registered during the experiment that the intensity of UV radiation measured is reduced similarly to the power trendline, i.e. after having reduced the distance by a square value from the source, the intensity of UV radiation is reduced by an approximate square value. Notice that the R-squared value for UVA radiation of 25 mW/m^2 the source intensity is 0.87, and for UVA radiation of 15 mW/m^2 – 0.95 which is a good fit of the line to the experimental data.

During the experiments the values of UVA and UVB radiation intensity were measured, which are presented in Figs. 7 and 8. The results exhibit the values of experimental UV radiation that mostly coincide with power trendline values.

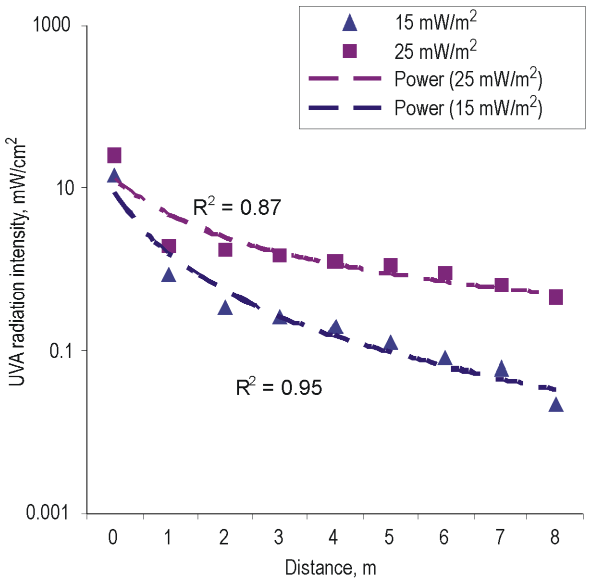

Fig. 7. Intensity of UVA radiation under 15 mW/m^2 and 25 mW/m^2 source intensity

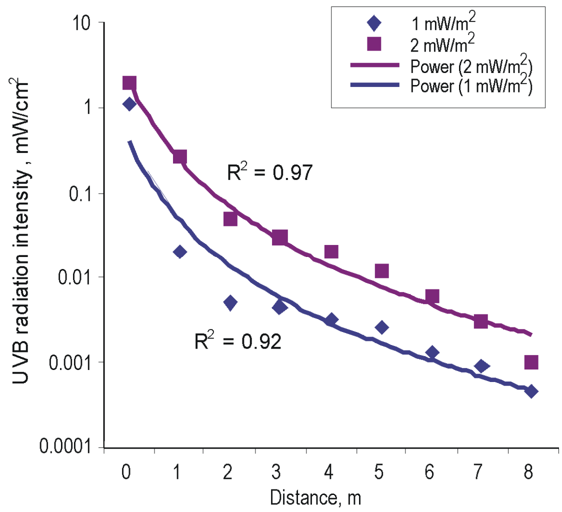

Fig. 8. Intensity of UVB radiation under 1.0 mW/m^2 and 2.0 mW/m^2 source intensity

The intensity of experimental UVA radiation (Fig. 7), under the 15 mW/m^2 source intensity, differs least from the empirical (about twice) one, and under the source intensity of 25 mW/m^2 and distance from the source of up to 4 meters, the experimental values of UVA are averagely about 2 times higher. When the distance is 8 meters, the experimental values of UVA radiation under the source intensity of 25 mW/m^2 agreed with the empirical ones.

The ratio of values of experimental intensity of UVB radiation (Fig. 8) differs from UVA. Under the intensity of the source of 1.0 mW/m^2 and distance from the source to the detector of a radiometer of 4 meters, the values of experimental UVA radiation are by about 25% lower than the empirically calculated ones. When the distance is 5 meters, from the source, the experimental values increase twice, within 8 meter distance they agreed with the empirically calculated ones.

When the source intensity is of 2.0 mW/m^2 and distance from the source is from 4 to 6 meters, the values of experimental UVB radiation are averagely 3 times higher than the empirical values. Only when the distance from the source is 8 meters, the experimental values are reduced so much that they are lower about 4 times than the empirical ones.

Figs. 7, 8 and 9 show that in the majority of cases the intensity of UVA radiation measured during the experiment is 10–100 times higher than the empirically calculated one. The measured average intensity of UVB radiation just negligibly differs from the empirically calculated one. The observed difference of values at the moment of the experiment in the intensity of measured UVA and UVB radiation and its empirical values may be determined by the additional albedo of UV radiation.

That is why it is so important to select building materials with the lowest albedo for finishing of premises in which welding operations are performed. Selection of proper building materials would allow to protect welding operations as well as the other employees working in the same premises from the hazardous influence of UV radiation.

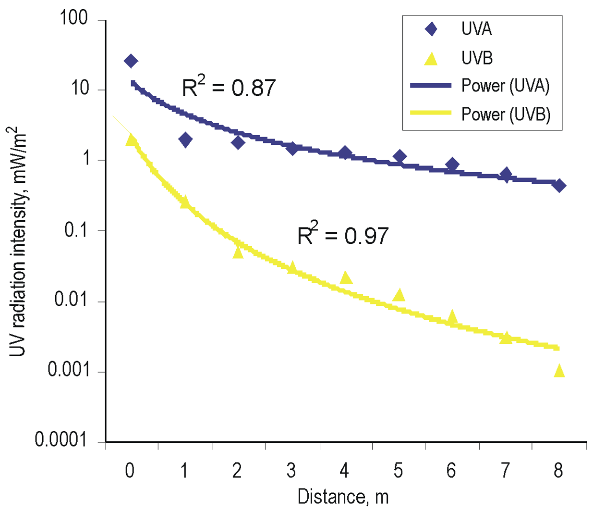

Fig. 9. Intensity of UVA radiation at 25 mW/m^2 source intensity and intensity of UVB radiation at 2.0 mW/m^2 source intensity

Table 1 presents the doses of intensity of UVA and UVB radiation, the doses emitted due to the radiation and minimum erythema doses, disseminated by the welding

Table 1. Intensity of UVA radiation emitted from different sources and the dose of UV radiation received within an hour

Source	UVA, mW/cm^2	UVB, mW/cm^2	How many times 1 MED is exceeded	
			UVA	UVB
Electric welding (45A) 20 cm	2.0 ± 0.2	1.1 ± 0.1	329	183
Electric welding (130A) 20 cm	17.9 ± 2	1.4 ±0.1	2932	224
Cutting (315A) 20 cm	18.7 ± 2	1.9 ± 0.2	3055	314
Electric welding (130A) 20 cm through reading-glasses	1.9 ± 0.2	0.4 ± 0.04	317	69
Electric welding (130A) 20 cm through photochromatic glasses	1.4 ± 0.1	0.3 ± 0.03	235	50
Gas welding 50 cm	0.03 ± 0.003	0.007 ± 0.0007	5	1
Semiauthomatic welding 50 cm	0.2 ± 0.02	0.03 ± 0.003	40	6
Medical quartz lamp 20 cm	1.9 ± 0.2	–	308	
Tubular quartz device 20 cm	1.3 ± 0.2	–	210	
Solarium	1.0 ± 0.1	0.02 ± 0.002	175	4
Sun at summer noon	2.5 ± 0.3	0.01 ± 0.001	400	2

process, using different materials at the welding process and under different intensity of the source. The table also presents the results of measurements of medical devices emitting UV radiation, and comparison of the values of UV radiation used in the lightning of solariums, of day-time lamps and radiation emitted from the Sun.

Table 1 presents the results of the experiments and data on the UVA and UVB radiation intensity emitted from various sources as well as data on the dose received, and the received dose is compared with the minimum erythema dose (MED) (dose causing skin blush). The UVA and UVB doses were calculated for the duration of an hour. The minimum erythema dose was accepted on the basis of the fact that in Lithuania people mostly have I and II skin types (22 mJ/cm^2).

It is determined that the highest intensity of UVA and UVB radiation appears during the operation of cutting metals – correspondingly, 18.7 mW/cm^2 and 1.9 mW/cm^2, when the strength of the current is 315 A. The maximum dose is received when during the metal-cutting operation it is, correspondingly, about 67 and 7 J/m^2. It is determined that during cutting, when the intensity of the source of UVA radiation is 1500 mW/m^2 and that of UVB radiation is about 1.0 mW/m^2, the received UV radiation dose per hour exceeds the minimum erythema dose, namely, UVA is about 3 000, UVB about 300 times higher. Although the determined doses of UV radiation significantly exceed the recommended minimum erythema dose, the protective safety measures applied during the welding operation completely protect a human being from hazardous effects of UV radiation.

The maximum dose is received during the metal-cutting operation, and it is about 100 times higher than UV radiation dose emitted by the Sun. The calculated dose of the UVB maximum intensity radiation emitted by the Sun is about 2 times lower than UV radiation dose emitted by soliarium lamps. The calculated dose of the UV maximum intensity radiation emitted by the Sun also exceeds the minimum erythema dose, so it is not recommended to stay very long in the open Sun at noon in summer.

As at present the attendance of solariums is popular, measurements of the intensity of UVA and UVB radiation in a solarium were carried out.

Based on the conclusions of the research more than 90% cases of non-melanoma skin cancer is stated for people possessing the I and II type skin, and the majority of the population of Lithuania have the exact type of skin. That is why it is so especially important to inform the public on the hazardous effect of UV radiation. Trying to assess the influence of UV radiation on the public, Table 1 gives the intensity of UVA and UVB radiation as well as the dose of UV radiation in the solarium. In the solarium it has been determined that the UV radiation emitted from the lamp is comprised of 97.6% of UVA and 2.4% of UVB, but on the website of the solarium it is stated that the UV radiation from the lamps of solarium is comprised of UVA of 97.7–98.5%, and of UVB of 1.5–2.3%. Judging from the results received during the experiment it is found that the part of doses of UVB radiation from the lamps of the solarium is slightly higher, and UVA radiation is correspondingly lower. Since the effect of UVB radiation is especially hazardous to public health it is necessary to inform customers.

4. Conclusions

1. The UV radiation emitted from technical sources has been assessed. It has been determined that the intensity of UVA radiation is 10 times higher than the intensity of UVB radiation.
2. It has been determined that during welding processes the intensity of UV radiation depends on the intensity of the source, namely, after having reduced the intensity of the source by about 60%, UV radiation intensity is reduced by 20%. It also depends on the distance from the source, namely, after having increased the distance 10 times the UV radiation intensity is reduced 25 times.
3. During cutting the received UV radiation dose per hour exceeds 1 MED, namely, UVA is about 3 000, UVB about 300 times higher.
4. UV radiation from welders comprises about 80% of UVA and about 20% of UVB, and UV radiation from the solarium lamps comprises 98% of UVA and 2% of UVB.

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DIRBTINIŲ ŠALTINIŲ SKLEIDŽIAMOS UVA IR UVB SPINDULIUOTĖS ĮVERTINIMAS

R. Chadyšienė, A. Girgždys

S a n t r a u k a

Darbe radiometriniais metodais nustatyti ir įvertinti dirbtinių šaltinių skleidžiamos ultravioletinės alfa ir beta spinduliuotės (UVA ir UVB) intensyvumo pokyčiai ir apskaičiuota įvairių šaltinių sukuriama UVA ir UVB spinduliuotės dozė. Nustatyta, kad suvirinimo proceso metu skleidžiamos UV spinduliuotės intensyvumas priklauso nuo šaltinio intensyvumo (sumažinus šaltinio intensyvumą apie 60 %, UV spinduliuotės intensyvumas sumažėja apie 20 %) bei nuo atstumo nuo šaltinio (padidinus atstumą 10 kartų UV spinduliuotės intensyvumas sumažėja apie 25 kartus). Įvairių šaltinių sukuriama UVA ir UVB spinduliuotės dozė palyginama su minimalia eritemine doze. Gauta, kad suvirinimo metu, esant 315 A elektros srovės stipriui, UVA spinduliuotės dozė 1 MED viršija apie 3000, UVB ~ 300 kartų. Nustatyta, kad apie 80 % iš suvirinimo aparato skleidžiamos UV spinduliuotės yra UVA, o apie 20 % – UVB. 98 % soliariumo lempų skleidžiamos UV spinduliuotės yra UVA ir 2 % – UVB, gi iš Žemę pasiekiančios Saulės UV spinduliuotės 96 % yra UVA ir 4 % UVB.

Reikšminiai žodžiai: UVA spinduliuotė, UVB spinduliuotė, spinduliuotės intensyvumas, technogeniniai šaltiniai, UV dozė, minimali eriteminė dozė (MED).

ОПРЕДЕЛЕНИЕ УФА- И УФБ-ИЗЛУЧЕНИЙ ОТ ТЕХНОГЕННЫХ ИСТОЧНИКОВ

Р. Хадишене, А. Гиргждис

Р е з ю м е

Радиометрическими методами определены изменения УФА- и УФБ-излучений некоторых техногенных источников, а также рассчитана доза УФА- и УФБ-излучений этих источников. Установлено, что в среднем интенсивность УФА-излучения в 10 раз сильнее интенсивности УФБ-излучения. Установлено также, что в процессе сварки интенсивность испускаемого УФ-излучения зависит от интенсивности источника: при снижении интенсивности источника на 60% интенсивность УФ-излучения снижается приблизительно на 20%; при увеличении расстояния от места сварки в 10 раз интенсивность УФ-излучения снижается приблизительно в 25 раз. Рассчитана доза УФА- и УФБ-излучений, создаваемая различными техногенными источниками. Представлено ее сравнение с минимальной эритемной дозой. Получено, что во время сварки при силе электрического тока 315 А доза УФА-излучения превышает 1 МЭД в 3000 раз, а УФБ-излучения – в 300 раз. Экспериментальными исследованиями получено, что испускаемое при сварке УФ излучение на 80% состоит из УФА-излучения и на 20% – из УФБ-излучения. В солярийуме, где был проведен эксперимент, УФ-излучение ламп состоит на 98% из УФА лучей и на 2% из УФБ лучей. Для сравнения: околоземное УФ-излучение Солнца в Литве состоит в среднем на 96% из УФА лучей и на 4% из УФБ лучей.

Ключевые слова: УФА-излучение, УФБ-излучение, интенсивность излучения, техногенные источники, УФ доза, минимальная эритемная доза.

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