http://dx.doi.org/10.4314/gjpas.v19i1.18

GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL. 19, 2013: 145-149

 ISSN 1118-0579
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AN ASSESSMENT OF ULTRAVIOLET RADIATION COMPONENTS OF LIGHT EMITTED FROM ELECTRIC ARC AND THEIR POSSIBLE EXPOSURE RISKS

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(Received 13 May 2013; Revision Accepted 19 June 2013)

ABSTRACT

The study of Ultraviolet Radiation has of recent become interesting because of the health hazards it poses to human. Apart from its intensity reaching the earth from the sun, other man-made sources have been identified. We have undertaken the measurement of UV radiation from electric arc welding light generated by 240 TURBO Clarke weld arc operated at a voltage of 120 V using the National Institute of Standard and Technology UVX radiometer and sensors of UVP Company, Upland, USA. Three sensors UVX-25, UVX-31 and UVX-36 were used to measure the three components of UV radiation namely UV-C, UV-B and UV-A respectively. Each of these sensors or probes was set at the same varying distances in turn from the emitted arc light. The result showed that the UVX-25 probe (for UV-C) recorded the highest intensities going from 3.4 to 0.2 mW/cm^2; the UVX-31 probe (for UV-B) recorded intensities ranging from 3.2 to 0.8 mW/cm^2 while UVX-36 probe (for UV-A) recorded intensities from 1.60 to 0.96 mW/cm^2, all measured at distances from 25.0 cm to 350.0 cm respectively from the UV light. Converting mW/cm^2 to mJ/cm^2, our recorded values clearly showed that for 1.0 second the UVX-25 recorded UV radiation 3.4 to 0.2 mJ/cm^2, UVX-31 recorded 3.2 to 0.8 mJ/cm^2 and UVX-36 recorded 1.60 to 0.96 mJ/cm^2 from a distance of 25 to 350 cm respectively. According to American Conference of Governmental Hygienist (ACGH), the Threshold Limit Value (TVL) of exposure for UV-C and UV-B radiations ranges from 3.0 mJ/cm^2 to 1000 mJ/cm^2, for exposure to the eye not exceeding 8 hours period, while for UV-A, the TLV should not exceed1.0 mW/cm^2 for period greater than 16 seconds. These values are therefore high for exposure limits of 8 hours for UV-B and UV-C and the 16 minutes for UV-A. The investigation showed that UV-radiation emitted from arc welding machine of the type used in this work could indeed pose harmful health risk to the occupational electric arc worker if no serious precaution is undertaken in the course of performing his work.

KEYWORDS: Ultra-violet radiation, Intensity, Exposure, Health, Distance.

1. INTRODUCTION.

Radiation is a form of energy, which may or may not be visible to the human eye. Ultraviolet (UV) radiation is a type of electromagnetic energy with wavelength shorter than visible light. It is therefore is invisible to the naked eye. Excessive exposures to UV light poses certain risks to human and this, of recent, has become particularly interesting as the ozone layer that screens its intensity in the earth atmosphere is being depleted (Newman, 1991; Corbitt, 1990).

Sunlight is not the only source of UV radiation as assumed by many. Other anthropogenic sources of UV radiation arising from day to day human activities are available in literature (CCOHS, 2005). Tanning booth, vapour lamp, some halogen, fluorescence (Driscoll and Pearson, 1998), incandescent and arc welding lights are known sources of UV radiation. Other human practices that give rise to increased exposure to UV are therapeutic and preservative practices using UV radiation even though carefully monitored doses are allowed at regular scheduled intervals (Ware *et al*., 2003).

The human eye is particularly sensitive to UV radiations; even a short exposure for a few seconds can result in painful, but temporary condition known as photokeratitis (WHO, 2004), caused by inflammation of the cornea of the eye thereby making it to discharge water and consequently blurring the vision. Excessive exposure to UV radiation also causes conjunctivitis which is the inflammation of the conjuctivia, a membrane that covers the inside eye lid and the sclera, the white part of the eye. The eye as a result becomes swollen and produces watery discharge (CCOHS, 2005). Certain components of the UV radiation have been known to cause damage to the skin.

Three major components of UV radiation can be identified namely UV-A, UV-B and UV-C. The sun emits UV-C but it is absorbed as mentioned earlier by the ozone layer of the atmosphere before reaching the earth. Man-made sources also emit UV-C which must be shielded from reaching the body because of its very

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harmful nature. UV-B causes skin burns, erythema and darkening of the skin. UV-A is relatively harmless but could cause darkening of the skin. It is also known that certain chemical and medication act as photosynthesizing agents capable of enhancing effects of UV from sunlight and other sources. The maximum absorption of UV-A in the lens is a possible factor for the clouding of the eye lens known as cataract. Sunburn is a sign of short term over-exposure to UV radiation while pre-mature aging and skin cancer are effects of prolonged UV radiation exposure (Hanson *et al*., 2006, Charles, 1987). It has been reported that certain oral preparation and drugs such as birth control pills, benzyl and peroxide products as well as some cosmetics may increase skin (in all types of skin) and eye sensitivity to UV radiation (FDA, 2000).

The basic needs of man obviously makes it clear that no human can escape from being exposed to ultra violet radiation whether natural, anthropogenic or both. Although a means of UV exposure, phototherapy has been suggested and used under supervision of dermatologist to treat ailments including psoriasis, eczema, lupus (CCOHS, 2005). The availability of this therapy notwithstanding, the present increasing cases of skin cancer and different eye diseases prevalent in our communities today call for caution in uncontrolled exposure to UV radiation.

The depletion of the ozone layer leading to increased solar activities on earth has prompted many into the study of UV radiation. However, not many studies have actually attempted to quantify the amount of UV radiation received in daily occupational practices. Professional activities using arc welding have made many to be ignorantly exposed to UV radiation especially unskilled users of this UV source. This fact calls for proper understanding of the nature of the UV light emitted from arc light. This study is set up to quantify within certain working voltages and distances from the arc light the intensities of the components of UV radiation emitted during welding with a view to understanding the risk the worker could be exposed to in his professional practice.

2. THEORY

Ultraviolet (UV) light is an electromagnetic radiation with a wavelength shorter than that of visible light but longer than x-rays, in the range of 100 nm to 400 nm and energies from about 3 eV to 12 eV. As an electromagnetic radiation, UV radiation is classified by relating the photon energy, E to the wavelength, λ:

$$E = \frac{hc}{\lambda} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where c is the velocity of photon. The wavelength is related to the frequency, υ as

$$\lambda = \frac{c}{\upsilon} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Using Equations and (1) and (2), ultraviolet radiation has been group into UV-C, UV-B and UV-A corresponding to wavelengths of 10 - 280 nm, 280 - 315 nm and 315 - 400 nm respectively (ISO 21348).

3. MATERIALS AND METHOD

An ultraviolet radiometer, UVX radiometer, was used to measure UV intensities from an electric arc (240TURBO Clarke weld) at various distances of the arc from the radiometer. The radiometer has a digital read out in radiometric units with a broad dynamic range from 0.1 μW/cm^2 to 20 mW/cm^2 and calibration traceable to the National Institute of Standard and Technology (NIST), UVP Company, Upland, USA. It has three sensors designated as UVX-25, UVX-31 and UVX-36. The sensor head UVX-25 captures UV radiation in the area of 250 nm – 300 nm and calibrated at a wavelength of 254 nm. The sensor head UVX-31 captures UV radiation of area 260 - 365 nm and calibrated at a wavelength of 310 nm, while the sensor head UVX-36 captures UV radiation of area 305 nm – 400 nm and calibrated at a wavelength of 365 nm. The sensors were calibrated such that each one could easily be interchanged with another sensor without affecting the overall system accuracy.

The arc welding machine was set at a voltage of 120 V for the UV measurement. This voltage was selected considering the welding electrode used by the occupation welder. The thickness of the electrode, the type of metal used as electrode and the type of metal to be welded determine the choice of the voltage. With the machine turned on, the welding was carried out and using the UVX-25 probe placed at 25 cm from the welding point and about 1 m from the ground, the intensity of the UV light was recorded. The distance between the welding point (light point) and the sensor was then varied in steps of 25 cm up to 150 cm and then at 50 cm interval for the latter to give significant differences up to 350 cm. All the measurements were performed at a continuous welding process to sustain the same intensity level. The procedure was repeated separately for the UVX-31 and the UVX-36 probes. The ambient value of UV intensity was carefully noted to avoid interference with our measurement.

4. RESULT AND DISCUSSION

The results of the measurements using the three probes are given in Tables 1 - 3. The results in these tables indicate the presence of the three components of UV radiation measured by the sensors. The UVX-25 probe that measured UV intensity of the wavelength at 250 nm, representing UV-C (100 nm - 280 nm), recorded intensity values of 3.4 to 0.2 mW/cm^2 at distances of 25 to 350 cm respectively from the arc light. The UVX-31 probe which measured intensity at 310 nm wavelength, representing UV-B, gave the intensities ranging from about 3.2 to 0.8 mW/cm^2, while the UVX-36 probe that measured the intensity at 360 nm wavelength, representing UV-C, recorded intensity values ranging from 1.60 to 0.96 mW/cm^2 at the same distance of 25 to 350 cm respectively from the light. The plot of the intensity against the distance of the probes from the arc (UV light) for each of UV components is given in Figure 1.

Table 1: UV Intensity measured using UVX – 25 Probe

S/No	DISTANCE (cm)	INTENSITY (mW/cm^2)
1	25	3.40
2	50	3.00
3	75	2.60
4	100	2.00
5	125	1.6
6	150	1.4
7	200	1.2
8	250	0.4
9	300	0.2
10	350	0.2

Table 2: UV Intensity measured using UVX – 31 Probe

S/No	DISTANCE (cm)	INTENSITY (mW/cm^2)
1	25	3.2
2	50	2.0
3	75	2.4
4	100	1.8
5	125	1.4
6	150	1.0
7	200	1.0
8	250	0.8
9	300	0.8
10	350	0.8

Table 3: UV Intensity measured using UVX – 36 Probe

S/No	DISTANCE (cm)	INTENSITY (mW/cm^2)
1	25	1.60
2	50	1.58
3	75	1.50
4	100	1.46
5	125	1.40
6	150	1.20
7	200	1.04
8	250	0.96
9	300	0.96
10	350	0.96

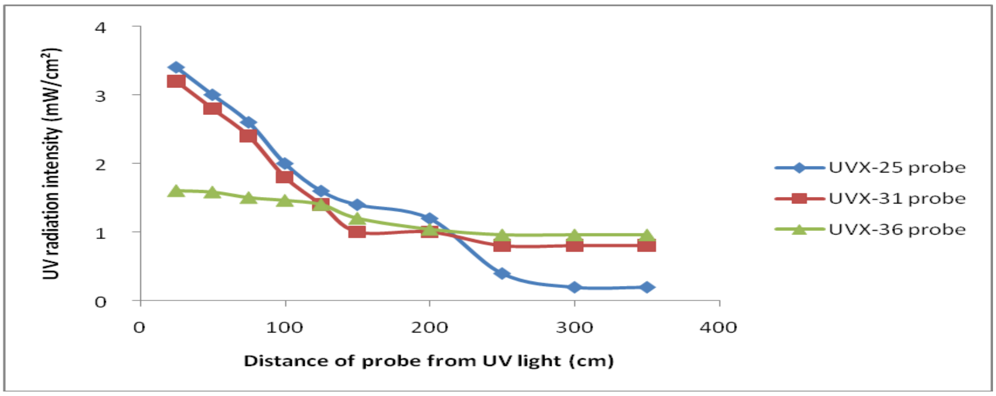

Figure 1: The variation of UV radiation components intensities with distance from electric arc source

The measurements indicated that the low wavelength parts of the UV light dominate the emission from the arc light. Specifically, the UVX-25 probe recorded the highest intensities at closer range of the detector than the other probes. The intensity value recorded by the UVX-31probe at 25 cm was less than that recorded by the UVX-25 by about 6 % while intensities from 200 cm were greater for the former probe than the later. However, the intensities recorded by the UVX-36 probe were lower than those of UVX-25 and UVX-31 by about 40% to 50% within the first 100 cm of the detector to the UV light. It was observed that the intensity decreases less rapidly for the UVX-31 and UVX-36 probes than that of UVX-25.

Based on the results and from the relationship between energy and power, an intensity of 3.4 mW/cm^2 recorded by the UVX-25, for one second, will be equivalent to 3.4 mJ/cm^2. This means that for the 1-hour period of exposure stated above the maximum intensity of 3.4 mW/cm^2 recorded by the UVX-25 probe at the 25 cm position from the source would correspond to exposure value of 12,240 mJ/cm^2 so that the individual would have been exposed to 97,920 mJ/cm^2 of the UV radiation within the 8 hours. This value, if received over a long time by the unprotected worker, would certainly amount to significant risk at this low wavelength portion of UV radiation (CCOHS, 2005). At 3 m away from the source, the probe (UVX-25) recorded 0.2 mJ/cm^2 which will result in 12 mJ/cm^2 in one hour. This indicates an approximate total exposure of 5,760 mJ/cm^2 for the 8-hour period at a distance of 3 m from the source. Similarly, the UVX-31 sensor which recorded 3.2 mW/cm^2 and 0.8 mW/cm^2 at 25 cm and 300 cm respectively would mean cumulative 8-hour exposures of 92,160 mJ/cm^2 at 25 cm and 23,040 mJ/cm^2 at 3 m respectively away from the source.

According to American Conference of Governmental Industrial Hygienists (ACGIH), the actinic ultraviolet spectrum region (200-315 nm; about half of the UV-C and most of the UV-B range), the exposure of the unprotected skin or eye should not exceed 3.0 to 1000 mJ/cm^2 within 8-hour period; the lower the value (usually referred to as the Threshold Limit Value – TLV) for a particular frequency, the higher the risk. Consequently, UV-C at a wavelength of 270 nm poses the highest risk with TLV of 3.0 mJ/cm^2 than would the same UV-C at 200 nm corresponding to TLV of 100 mJ/cm^2. Similarly, a UV-B wavelength 290 nm poses higher risk with TLV of 10 mJ/cm^2 than that at 310 nm with TLV of 200 mJ/cm^2. For UV-C, a wavelength of 240 nm correspond to TLV of 10 mJ/cm^2 while and UV-B at 300 nm has also a TLV of 10 mJ/cm^2. This means UV-C wavelength of 240 nm would produce the same risk effect as UV-B at wavelength of 300 nm.

Using the same standard (ACGIH), for UV-A or near ultraviolet spectral region (315 - 400 nm), exposure to the eye should not exceed 1.0 mW/cm^2 for period greater than 1000 s (approximately 16 minutes). For exposure times less than1000 s, the dose should not exceed 1.0 J/cm^2. Considering our measured value of 1.6 mW/cm^2 at a distance of 25 cm from the light, the exposure for 1000 s would be 1600 mJ/cm^2 (1.6 J/cm^2) and at 3 m away would be 960 mJ/cm^2 (0.9 J/cm^2 ≈ 1.0 J/cm^2).

The fact that a welder using the electric arc is exposed to UV light could further be seen in his working position from the arc light. The welding electrode was about 33 cm in length which was held by an electrode holder of about 15 cm long at about 10 cm of its length. The electrode itself was held at about 30 cm of its length. This means that, on the average, the welder's hand would be located at a distance of about 40 cm away from the UV source at full electrode length. As welding progresses, the electrode length could reduce up to 3 cm before replacing it with a new one. This means the welder's hand could be as close as about 15 cm from the light source. Furthermore, the average position of the arc welding personnel from the UV source was seen to be about 50 cm when welding on standing position but his trunk was closer to the source while on a squatting position. It is therefore seen, going by the results obtained from the measurements at 25 cm and at 50 cm sensor positions from the source, that the electric arc welder would be exposed to all the types of UV radiation at significant intensity levels.

This clearly indicates that serious exposure risk can result in the unprotected personnel using this instrument (the electric arc), especially when exposed for over long period of time. The persistence of the intensity of this UV wavelength with distance also signifies higher exposure of careless and ignorant nearby individual involved in regular activity near the occupational electric arc work as seen in many factories.

5. CONCLUSION AND RECOMMENDATION

The investigation here has shown that all the three components of UV radiation were present in the electric arc light used in this study and of course light that could be generated from other types of arc welding equipment. The intensities of the various components of the UV spectrum were significant to cause damages not only to visual system but with potential of dermatological effect such as skin cancer, erythema and fast skin ageing given what is known in literature.

Although the intensities of the different categories of the UV light decreased with varying distances from the light source as expected, the intensities up to 3 m away could still be regarded as significant to pose some exposure and visual defects to individuals who stay long within such radius where arc welding activities are taking place, especially those who would not discriminate against such emission.

Following the aforementioned, the use of protective coverings all over the body and good dark protective eye goggles must always be embraced by the career welder. Professional or career electric arc workers that already have established cases of hypertension and other ailments predisposing them to use of blood pressure suppressant drugs and certain antibiotic respectively should embrace additional protective measures from the risks of exposure arising from the electric arc light.

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