İZMİR İLİNDE AL_2O_3: C DOZİMETRELER KULLANILARAK SOLAR UVB RADYASYONUNUN ÖLÇÜLMESİ

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ÖZET

Solar UV radyasyonunun ekolojik sistem üzerine önemli etkileri olduğu bilinmektedir. Stratosferdeki ozon tabakasının incelmesi nedeniyle yeryüzüne ulaşan ultraviyole (UV) radyasyonundaki artışların oluşturabileceği riskler birçok araştırmacı tarafından çalışılmaktadır. UVB radyasyonu, küresel solar UV radyasyonunun sadece küçük bir kısmını oluştursa da, insan ve hayvanlar ile bitkiler üzerinde zararlı etkilere neden olmaktadır. Ayrıca, UVB radyasyonun karasal ve deniz ekosistemindeki canlı organizmalar üzerinde olumsuz etkileri de bulunmaktadır.

Bu çalışmanın amacı, solar UVB radyasyonunun ölçülmesinde termolüminesans dozimetrelerinin (TLD) kullanılabilirliğini araştırmaktır. TLD'ler, ucuz olmaları kolay bulunabilmeleri ve basit kullanımları gibi bazı üstün özelliklere sahiptir. Araştırmamızda, UVB radyasyonunu ölçmek için Al_2O_3: C termolüminesans dozimetreleri kullanılmış olup bunlar, düşük iyonlaştırıcı radyasyon dozlarına ve UVB radyasyonuna çok duyarlıdır. Yeryüzüne ulaşan UVB radyasyonunun günlük miktarı çalışma yapılan günlerde 09:00 ile 16:00 saatleri arasında periyodik olarak alüminyum oksit dozimetrelerle ölçülmüştür. Elde edilen sonuçların Ege Üniversitesi Güneş Enerjisi Enstitüsü' nden alınan UV radyasyon verileri ile uyumlu olduğu görülmüştür.

Anahtar Kelimeler: Solar UVB radyasyon, TLD, Al_2O_3:C dozimetre, Radyasyon ölçme

MEASUREMENT OF SOLAR UVB RADIATION USING AL_2O_3:C DOSIMETERS IN CITY OF IZMIR

ABSTRACT

It is well known that UV radiation has a significant effect on our ecologic system. The risks that may be caused by the increases in ultraviolet (UV) radiation reaching the earth’s surface due to the depletion of stratospheric ozone have been studied by many researchers. Although UVB radiation consists only a small fraction of the global solar UV radiation, it causes harmful effects on human, animal and plant. Furthermore, UVB may have several adverse effects on living organism in terrestrial and sea ecosystem.

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The aim of this work is to investigate the usability of thermoluminescence dosimeters (TLDs) in measuring the solar UVB radiation. TLDs have some superior characteristics such as their availability, being cheap and easy to use. In this study, we used Al_2O_3:C thermoluminescence dosimeters for measuring the UVB radiation, they are very sensitive to low ionizing radiation doses and UVB radiation. The daily exposures of the ground surface UVB radiation were periodically measured using aluminium oxide dosimeters. The measurements were taken from 09:00 to 16:00 in each study day. Obtained results were observed to be consistent with the UV data received from Ege University, Solar Energy Institute.

Key words: Solar UVB radiation, TLD, Al_2O_3:C dosimeter, Radiation measurement

1. INTRODUCTION

Solar UV radiation is part of the electromagnetic spectrum. The UV spectrum is further subdivided into three regions according to wavelength: UVA (400-315 nm), UVB (315-280 nm) and UVC (280-100 nm) (Sliney, 2007). When sunlight passes through the atmosphere, all UVC and about 90% of UVB radiation is absorbed by ozone, water vapour, oxygen and carbon dioxide. UVA radiation is less affected by the atmosphere but the energy of this radiation is not so high. Therefore, it is less harmful comparing to other part of UV radiation. The biological effects of solar UV radiation vary extremely depending on the wavelength. Diffey stated in his article that on summer day most of the terrestrial radiation is UVA (95%) and the remaining small part is UVB (4%) radiation. However, UVB is much more effective than UVA at causing biological damage (Diffey, 2002 and 2002).

It is well known that UV radiation has a significance effect on our lives, living organism, terrestrial and sea ecosystem (United Nations EP, 2006; Medhaug et al., 2009; McKenzie et al., 2011). Adequate levels of solar UV radiation are beneficial not only for the synthesis of vitamin D but also may help to prevent some type of cancers and also support human mental health (Norval et al., 2007; Humble, 2010; Gimenez et al., 2015). However, long periods of solar UV radiation exposure can cause harmful effects on eyes, immune system, and skin (Medhaug et al., 2009; Diepgen et al., 2012; United Nations EP, 2006). There are also harmful effects of UVB radiation on terrestrial ecosystem such as deceleration of photosynthesis of plants and infertility of soils because of loss of microorganisms in soils (Ekici and Aksoy, 2001). In addition, increases in solar UV level for animal and plant can cause change in breeding and altered species (Caldwell and Flint, 1994). Increases in skin cancer and cataracts; detrimental effects on terrestrial and sea ecosystems; chemical changes in the lower atmosphere (troposphere) depend on the intensity and exposure time to ambient solar radiation. (Diffey, 2002; Medhaug et al., 2009; Siani et al., 2009; Madronich, 1998; NEHC-TM92-5, 1992).

It has seen rapid growth in the number and quality of solar UV measurements last decade. In this period, many new commercial and scientific-based UV detectors have been developed for solar UV measurements. Also, various research and studies have been carried out to calibrate and intercomparisons of these detector systems. Detector systems used in solar UV radiation measurements have some advantages and disadvantages as compared with each other. There are some difficulties of consistently measuring solar UV-B radiation at ground level.

Researchers are trying different techniques and methods to overcome these difficulties. In order to achieve good and acceptable measurements, application of strict protocols both at the time of calibration and measurement are needed. The main problem here is that UVB radiation consists only a small fraction of the global solar UV radiation at ground level. Due to their high cost and expensive maintenance and calibration procedures, researchers are trying to develop more economical measurement systems using by different techniques and methods.

In this context, one of the methods used to measure UV radiation is the thermoluminescence (TL). When a material is exposed to ionizing radiation, part of the absorbed energy is stored in metastable energy levels of its electronic energy levels. Adding some impurities or causing defects in the lattice structure or in some other way may form local energy levels or traps in a material. Part of the stored energy may later be released as visible light by heating the material. This phenomenon is called TL (Escobar et al., 2003).

In recent years, considerable interest has been given to the investigation of the TL response of phosphors to the UV radiation (Vij, 1993). Examples of particular studies include work on pure CaF_2, a useful dosimeter of terrestrial solar UV radiation (Edwin et al., 1972), and CaF_2:Dy, the latter displaying high TL response to UV radiation following sensitization by means of high temperature treatment (Bassi et al., 1975). Other works have been focused on the UV response of Al_2O_3, investigating its sensitivity against UV radiation (Oster et al., 1994; Pradhan et al., 1996; Duggan et al., 2000; Sawakuchi et al., 2008). Furthermore, LiF:Mg,Cu,P (TLD-100H), CaF2:Dy (TLD-200), CaF_2:Mn (TLD-400), α-Al_2O_3:C (TLD-500), 7LiF:Mg,Cu,P (TLD-700H) and $CaSO_4$:Dy (TLD-900) thermoluminescence dosimeters were investigated for their response to UV radiation. However, there are few studies in literature regarding the UVB measurement using the TL technique (Sono and McKeever, 2002; Abdullah et al., 2001; Vergana and Romero, 1996).

The aim of the current study is to investigate the usability of thermoluminescence dosimeters (TLD) for measuring the solar UVB radiation, due to having some superior characteristics such as their availability, being cheap and easy to use.

2. MATERIALS AND METHODS

In order to measure the UVB radiation, Al_2O_3:C pellets of 5 mm diameter and 1 mm thick provided by Landauer were used. The samples were pre-annealed in air at 900 ºC for 15 minutes and quenched to room temperature to remove any existing charge from traps. Since the dosimeters are sensitive to daylight, they were protected from direct light during handling, irradiation and readout process. The glow curves were recorded by heating the samples at a uniform rate of 2 ºC s^{-1} ranged from 30 ºC to a final temperature of 300 ºC using a temperature controller. The luminescence emission was detected by a photo-multiplier tube (EMI 9635QB) with a heat absorbent filter (Schott KG-1) in order to prevent the black body radiation reaching the PM tube. The signal from PM tube was amplified and interfaced to a personal computer.

After the pre-annealing, to determine the UVB dose-response of Al_2O_3:C, each sample packed in a 340 nm cut-off filter (Schott UG-11), was illuminated with a high-pressure mercury lamp (Philips 93136E) used as UV light source. This illumination was performed from 1 to 60 minutes and then TL signals were recorded Fig. 1 shows the experimental setup used to determination of UVB dose reponse of Al_2O_3:C.

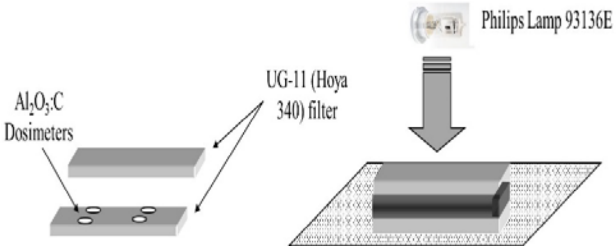


Figure 1. Experimental setup for UVB dose response of Al_2O_3:C.

After determining the UVB dose response by mercury lamp, the dosimeters exposed to sun light from 9 am to 6 pm in 10 minutes periods (Fig. 2). The signals only arising from the sample were obtained after subtraction of the background, which were taken with a blank sample. The luminescence signals of dosimeters were integrated between 100^o and 250^{o}C, which provides the total UVB radiation dose response of the dosimeter. For the calibration of the Al_2O_3:C dosimeter, A UV sensor (Vantage Pro Weather Station) was used in the same period and found the exposing UV radiation dose as UV index unit (1 UV index=25 mW m^{-2}).

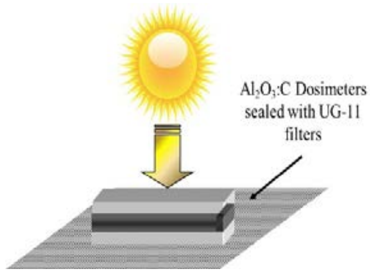
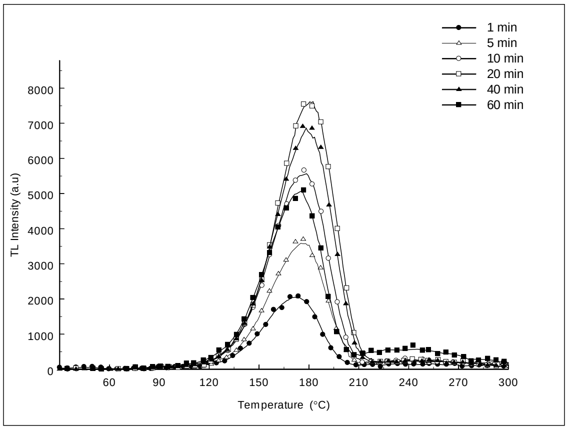


Figure 2. Experimental setup for solar UVB measurement

3. RESULTS

To determine the optimum UV exposure period to the solar UV radiation, the dose response curve of Al_2O_3:C dosimeters should be derived. For this purpose, the dosimeter exposed to Hg lamb with UG-11 filter in different periods varied from 1 min to 60 min. After that TL measurements were conducted and the background signals were subtracted from the TL signal. Some of TL glow curves used plotting the UVB dose response curve of Al_2O_3 dosimeter are presented in Fig 3. It was observed that the glow curves peaked at 180^{o}C. This result is in good agreement with the literature (McKeever et al., 1999).



(a) (b)

Figure 3. TL glow curves of Al2O3 dosimeters recorded after UVB exposure by Hg lamp.

The dose response curve was plotted by integrating the underlying area between 100 and 250 ºC of these TL glow curves (Fig 4). These integrations were associated with the exposed UVB radiation dose of the dosimeter. It was observed that the dose response curve increased linearly up to 20 minutes and followed by a gradual decrease for longer exposure times which can be attributed to the saturation of the TL detectors. Therefore, the duration of exposing the dosimeters to the solar UVB was chosen as 10 min.

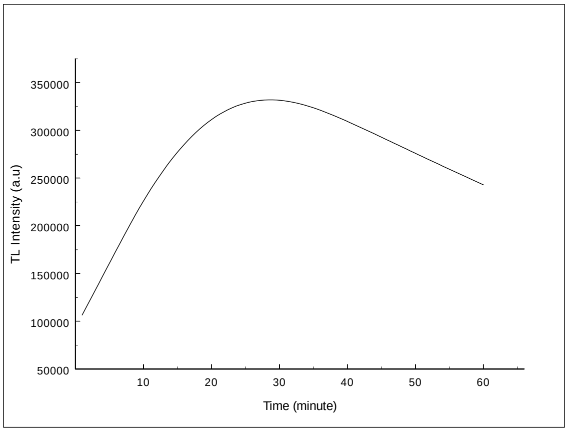


Figure 4. Test Dose response curve of Al2O3 dosimeters for UVB radiation.

After recording the TL signals of the dosimeters, underlying area between 100 and 250 ºC of obtained TL glow curves were integrated so daily solar UVB radiation dose were determined. To convert integrating area values to mW m^{-2} unit, which is a measure of UV index, solar UV measurements were made in Solar Energy Institute of Ege University, Turkey by using UV sensor that gives the results in UV index (1 UV index = 25 mW m^{-2}). Figure 5 and Figure 6 present the daily solar UV radiation dose distribution measured by UV sensor and the daily solar UVB radiation dose distribution obtained by Al_2O_3:C TL detectors.

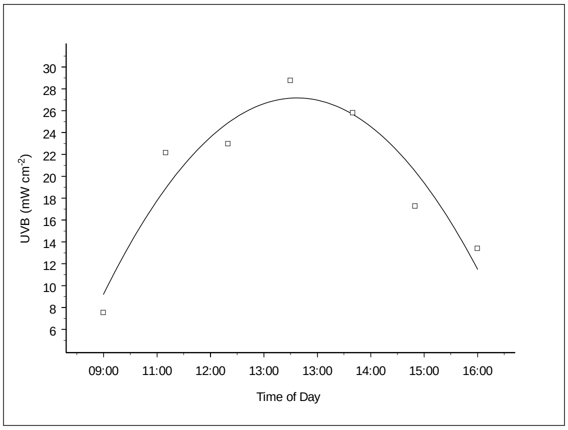


Figure 5. UV radiation dose distribution measured by UV sensor for 10 min.

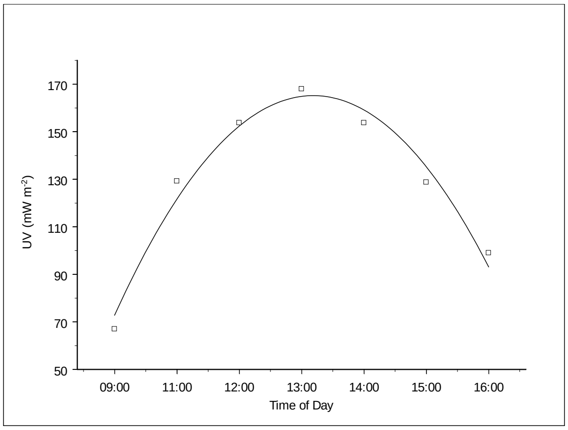


Figure 6. Distribution of UVB radiation dose obtained by Al2O3:C dosimeters after exposing 10 min. to the solar UVB.

The slight differences between the results obtained by UV sensor and TLDs may be speculated as follows; the obtained dose using UV sensor was the daily UV radiation dose, however, the obtained dose by using TL detectors was the daily UVB radiation dose since detectors was exposed to the solar UV using UG-11 cut-off filters. When Al_2O_3:C dosimeter exposed to direct solar UV radiation without packing with UG-11, accurate dose may not be determined because of the influence of Phototransfered Thermoluminescence (PTTL). These inaccuracies may arise because of some direct or indirect interactions of solar UV radiation.

4. CONCLUSION

The obtained results from the TLD measurements showed that the highest UVB radiation doses are between 12 and 14 o'clock. It is observed that the results are consistent with the results from meteorological UV radiation measurement system. For their superior characteristics such as availability, cheapness and ease of use, it can be suggested that Al_2O_3:C dosimeter can be used as sensors in UVB radiation measurements with the TL method.

Due to the harmful effects of UVB radiation on humans, animals and plants, measurements of daily exposures of the solar UV radiation are very important for the future of our planet. From this point of view, data from this work will provide valuable insights for studies on monitoring daily exposure of the solar UVB reaching earth's surface.

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