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DETERMINATION OF THE OCULAR DOSE AND THE ENERGY BUDGET OF THE EYE IN RELATION TO SOLAR ULTRAVIOLET RADIATION

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ABSTRACT: *Measurements of global ultraviolet irradiance were carried out with Kipp and Zonen CUV5 radiometer. The measurement was done from 17th September 2015, through to 30th December 2015, within University of Ghana campus, located in Accra, Ghana. The measured ultraviolet irradiances were used to estimate the ocular dose for 27 different days. The result showed that the maximum dose obtained was 1.361 J/cm2 which is 36.1 % higher than the threshold limit value of 1.000 J/cm2. The study also indicated that 44.5 % of the days for which the ocular dose was calculated exceeded the threshold limit and this gain could lead to occurrence ocular diseases.*

KEYWORDS: Ocular dose, **Ultraviolet irradiance; Radiometer; Threshold limit; maximum dose; ocular diseases.**

INTRODUCTION

Ocular disorder relating to UVR insolation is called Ophthalmohelioses. It has also been established that different environmental and biological conditions can lead to formation and progression of Pterygium, Photo keratoconjunctivitis, pingueculae, and cataracts (Jaros and Deluise, 1988). Some of the environmental factors include; heat, dust, humidity, and UVR. Biological factors also include genetics, pre-existing pathologies, and infection (Threlfall, 1993). Each ocular tissue selectively transmits radiation and in doing so filters radiation reaching subsequent tissues (Roberts, 2002). Due to the selective absorption, the lens receives a far lesser percentage of the incident solar UVB on the earth surface than the exposed cornea (Gies and Roy, 1988). From the radiant energy striking the surface of the cornea, approximately 0 % below 280 nm is transmitted and its transmittance is 8 % at 300 nm, 55 % at 320 nm, 63 % at 340nm, 66% at 360nm. It is known that damage to the lens through UVA absorption requires prolonged and chronic exposure (Zigman, 1995). There has not been enough information in the scientific literature on ocular dose, especially in relationship to ultraviolet irradiance. This investigation was carried out in order to verify the estimated ocular dose to the threshold limit proposed by ACGIH and ICNIRP. The main purposes of the study are to estimate the ocular dose and calculate the net energy budget of the eye.

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Data Collection

Global Solar ultraviolet radiation data were observed using Kipp and Zonen CUV5 UV radiometer. This type of radiometer has a calibration factor or sensitivity of $300\mu V/Wm^{-2}$ and a response time of 5 s. It has a field view of 180 degree and maximum UV irradiance of $400\,Wm^{-2}$. The radiometer is coupled to a voltmeter. In order to obtain the values of solar irradiance, the radiometer was placed on a stand at a height of about 1.7 meters. Using a stopwatch, the recordings of the total solar ultraviolet irradiance was done in a time interval of 10 minutes. Data was observed between 17th September 2015 and 30th December 2015.

Daily Ocular Solar Radiation Dose

The Ocular dose is the energy striking or delivered to the eye in a given time (Jagger, 1985). The daily ocular solar ultraviolet radiation dose was calculated from time spent outdoors not under shade or the use of hats and spectacles. The daily ocular solar radiation dose (OSD) was calculated as

$$OSD = \frac{O.E \times UV}{12} \qquad (1)$$

Equation (1) was used by (Timothy J.T., and English D.R., 1999)
where UV is the daily ultraviolet radiation solar energy in W/m^2 per day, the factor 12 is the global average day length and O.E is the ocular sun exposure.
The daily ocular sun exposure was calculated based on the duration of the sun exposure, the frequency of wearing a hat, spectacles or both. The ocular sun exposure can be expressed as:

$$\mathrm{O.E} = \mathrm{hr} \times \mathrm{place} \times \mathrm{surface} \times \mathrm{spec} \times \mathrm{Hat} \times \mathrm{cl} \qquad (2)$$

Equation (2) was used by McCarty et al., in 1996
Where *hr* is hours spent outdoor, place is the weighting factor for type of surface over which outdoor job was performed, *spec* is the weighting factor for frequency of spectacles worn, *Ha*t is frequency of hat worn on the day, *cl* is weighting factor for frequency of contact lens worn on the day and *OSD* is daily ocular ultraviolet radiation dose in $W\,h/m^{-2}$.

The energy budget of the eye

The energy budget of the eye is calculated from the rate of absorption of solar radiation and the rate of loss of energy by the eye.
The rate of loss of energy from the eye occurs through the processes of convection, radiation and tears evaporation. The rate of energy loss can be expressed as

$$-\frac{dQ}{dt} = h(T - T_a) + \sigma\varepsilon(T^4 - T_a{}^4) + E \qquad (3)$$

Equation (3) was used by Ang et al., 2006
where *h* is heat transfer coefficient between the eye and the ambient environment, *T* temperature of the surface of the eye, *E* is eye surface evaporation, σ is the Stefan- Boltzmann constant and T_a is the ambient temperature

The rate of absorption of solar radiation by the eye can be described by

$$Q_{abs} = \varepsilon I_o \qquad (4)$$

where ε is the emissivity of the eye and *Io* is incident ultraviolet irradiance.
Combining equation (3) and (4), the energy budget of the eye can be determined as:

$$E_b = Q_{abs} - \frac{dQ}{dt} \qquad (5)$$

3.0 RESULT AND DISSCUSSION

The ocular dose was calculated based on an exposure time of 8 hour period and no protecting gear worn on the eye. The estimates were done for the following 27 calendar days in 2015, as shown in the Table 1 below:

The maximum value was observed on 322 [calendar day] with a value of 1.361 J/cm^2, which is 36.1 % higher than the exposure limit or threshold limit value. The threshold limit proposed by American conference of Governmental Industrial Hygienists (ACGIH) and International Commission on non -Ionizing Radiation Protection (ICNIRP) is 1.0 J/cm^2. The minimum value was showed on the calendar day 261 with an ocular dose of 0.57 J/cm^2 which is 57 % of the proposed exposure limit (1.0 J/cm^2). On calendar days 259, 261, 268, 276, 281, 284, 288 and 290, the solar ultraviolet radiation (UVR) dose estimated did not exceed the threshold limit value. The ocular dose estimated for the above calendar days were 60%, 57%, 84 %, 78 %, 84 %, 81 %, 69 % and 78 % of the exposure limit or threshold limit respectively. On calendar day 297, the ocular dose was a little higher than the exposure limit i.e. 0.4 %. Also around calendar day 315, the ocular dose estimated was 16.6 % higher than the exposure limit. On calendar day 323 and 328, the ocular dose calculated was both 23.1 % higher than the known exposure limit of 1.0 J/cm^2. It was observed that 44.5% of the days observed was above the dose threshold limit. The percentage gained in the ocular dose estimation could be due to high intensity of the solar ultraviolet radiation (UVR) measured. This gain could cumulatively lead to cataracts, photo keratoconjunctivitis, and retinal injury.

Also, the energy budget was also determined for the same period of time and these are shown in the Table 2 below. The energy budget recorded on calendar day 259 was 0.033 W/cm^2 and then decreases to 0.030 W/cm^2 on day 261. It then started increasing to 0.051 W/cm^2 on day 268. The maximum peak was recorded on calendar day 322 with a value of 0.0917 W/cm^2. The minimum net energy balance value observed on calendar day 261 with a value of 0.030 W/cm^2. The net energy begins to decrease after the calendar day 322 and then further falls to calendar day 337 with a value of 0.041 W/cm^2. It then begins to rise again through calendar day 348 and then attain a second maximum on day 350 with energy budget of 0.085 W/cm^2. The energy budget then decreased suddenly until it reaches 0.062 W/cm^2 on the day 355. The sudden decrease is as a result of a reduction in intensity of the solar ultraviolet radiation and this may be caused by the presence of clouds cover. The difference between the maximum and the minimum net energy balance recorded was 0.061 W/cm^2, which is 67.0 % of the maximum energy budget value.

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Furthermore, it was observed that the rate of absorption of solar irradiance on the eye surface was greater than the rate of loss of energy by the eye and this indicating that energy is continuously accumulated in the eye.

CONCLUSION

The UV ocular dose was estimated for outdoor workers with no protection worn on the eye. The study revealed that 44.5 % of the days for which the ocular dose was calculated exceeded the threshold limit which is 1 J/cm^2. This gained could cumulatively lead to eye diseases such as cataracts and photokeratitis. The maximum energy budget of the eye estimated was recorded on calendar day 322 with a value of 0.0917 W/cm^2 and decreased to 0.0301 W/cm^2 at calendar day 261. The decrease could be due to a reduction in intensity of solar Ultraviolet radiation. It could be noticed that the rate of absorption of solar irradiance on the eye surface was more than the rate of loss of energy by the eye.

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APENDICES

Table 1: Estimated ocular dose for a period of 8 hours in each day.

Calendar day	Ocular dose (J/cm^2)
259	0.603
261	0.570
268	0.778
276	0.784
281	0.842
284	0.810
288	0.693
290	0.780
297	1.004
309	0.875
313	0.725
315	1.296
317	1.186
322	1.361
323	1.231
328	1.231
335	0.972
336	1.102
337	0.713
348	1.037
349	1.166
350	1.231
355	0.972
356	0.972
357	1.102
363	0.972
364	1.102

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Table 2: Estimated net energy balance of the eye

Calendar day	Radiant energy budget of the eye (W/cm^2)
259	0.0328
261	0.0301
268	0.0462
276	0.0444
281	0.0575
284	0.0537
288	0.0405
290	0.0487
297	0.0643
309	0.0534
313	0.0431
315	0.0877
317	0.0799
322	0.0917
323	0.0833
328	0.0842
335	0.0633
336	0.0743
337	0.0412
348	0.0695
349	0.0802
350	0.0852
355	0.0622
356	0.0643
357	0.0755
363	0.0643
364	0.0729

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