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Assessment of Daily and Annual Ultraviolet Radiation Doses Received by Outdoor Workers in Southwestern Nigeria

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ABSTRACT: A certain degree of solar light illuminance could prevent myopia in children. However, UV radiation (UVR) serves as mutagen and a non-specific damaging agent. Ultraviolet radiation can initiates and promote tumor growth, essentially under the skin. To this end, this study was designed to assess daily and annual UVR exposures of outdoor workers (OWs) in Southwestern Nigeria by using standard methods. Results obtained show that the mean daily and annual UV exposure were found to be 1.23 mW/cm^2 and 319.8 mW/cm^2 respectively. The mean predictive protection factor (PPF) for glass, trampoline and neem shade were found to be 43.84%, 98.69 % and 92.88 % respectively. This indicates that trampoline used to build tent has the greatest PPF followed by the shade of a neem tree. Results of this study also show that peak UVR exposures occur between 1400 and 1600 hours. Based on the findings of this study, outdoor workers could prevent UVR overexposure during the peak exposure period by working under the shade of a tree or wear effective UVR shields such as trampoline hat.

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The UV radiation is invisible to human perception, and most of human exposures from UV (>50%) is as a result of scattering and cloud reflection (Behar- Cohen *et al*., 2014, Sliney, 1997). The extent of scattering of UV is higher than the visible light. Observation has shown that the main proportion of UV-B incident at the face is as a result of diffuse sunlight. Artificial sources contribute to a lesser extent to exposure. However, with the advent of energy saving light sources exposures might increase. The use of welding machine, microscope, and sunbed could increase the exposure dose burden (WHO, 2013). Scattering of solar radiation (UV) is enhanced by clouds cover and haze. Ground reflection of UV depends on the surface. Grass reflects at low rates 2-5%, open water 3-13%, concrete about 10%, and snow 90% (Behar-Cohen *et al*., 2014). Solar angle determines UV intensity to the body, and higher altitude as well as lower latitude increase ambient UVR burden. Different groups of people are exposed to different doses of UV under different environmental conditions. Children are exposed to about 2-4 % of total available annual UV, and adults who work outdoor receive about 10%. The estimate of average annual UV dose vary from one location of the world to another. For Americans, it is 2.0 x 10^4-3.0 x 10^4 J/m^2, Europeans 1.0 x 10^4 – 2.0 x 10^4 J/m^2 and for Australians 2.0 x 10^4 – 5.0 x 10^4 J/m^2 (Godar *et al.*, 2011 and Godar *et al*., 2012). Studies indicate that incidence of myopia can be diminished by increasing outdoor time (Wu *et al*., 2013, Wu *et al*., 2018). The same study has shown that exposure to outdoor light led to less myopic shift, less axial elongation and a 54 % lower risk of rapid myopia among children in Asian countries. It is hypothesized that bright light decreases the risk of myopia development because of increase release of dopamine,

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neurotransmitter found in retina which is responsible for retinal signaling that can influence refractive development (Zhou *et al*., 2017). Exposure to a level of sunlight can assist in vitamin E synthesis in the skin. Although exposures to outdoor sunlight are protective against myopia in children, excessive UV radiation may predisposes children to certain diseases: cataract, pterygium, and macular toxicity later in adult life (Behar- Cohen *et al*., 2014). Efforts have been made to create awareness about the hazard involved in the exposure of population to UV, and campaign is ongoing on its prevention (Beckes *et al*., 2018) especially among the light skinned individuals. The nature of UV (wavelength) affects the depth of penetration into the biological tissue (epidermis, dermis and subcutaneous layer). Interaction of UV with epidermis can lead to formation of reactive products such as free oxygen radicals. In situation of acute irradiation, several cytokines are released, activated or synthesized keratinocytes. This is in turn is responsible for local or systematic inflammatory reactions such as vasodilation, edema, and possibly hypogeraxia (Coroneo, 2011; Pearse *et al*., 1987; Fisher *et al*., 1997).The main skin reaction to UV exposure include neo-melanogenesis and skin thickening. These are adaptive mechanism and are responsible for tanning. Exposure to UV over a long period could lead to complex phenomena of photo ageing and chronic damage (Mean and Juzenine, 2010; Pearse *et al*., 1987). Certain factors influence UV exposures. Such factors include; the nature of occupation, individual factors and environmental factors. Environmental factors includes atmospheric composition, sun angle, altitude, cloud cover and reflectance. (Modenese *et al*., 2018). Since UV affects the skin and eyes, it is important to protect the two organs from the solar and UV exposures through the use of effective materials and gears with high predictive protection factors (PPFs). In a study carried out in Nigeria, Achigbu and Ezepue (2014) found that a strong relationship exists between the outdoor exposure of commercial cyclists to sunlight during the day and the development of pterygium. Against this backdrop, it is essential to ascertain the daily and annual dose of outdoor workers in Nigeria. Therefore, the objective of this study is to assess the daily and annual ultraviolet radiation doses received by outdoor workers and determine the protection effectiveness of three materials in a community in Southwest, Nigeria.

MATERIALS AND METHODS

The study was carried out in September, 2021 in an open field and a parking lot (neem tree shade). Two wooden stool-like frame of different heights were constructed to represent an adult (160 cm) and a youth (141 cm) subjects. Three different UV shielding materials were examined. They are trampoline (usually water proof leather used for tent making), glass (used for window construction) and tree foliage (neem tree-serves as parking lot). Measurements of UV exposures and sunlight illuminance were carried out under three UVR shields and an open sky condition. The glass material was constructed like a prototype building with dimension of: height is 7 cm, length, 70 cm, thickness, 0.4 cm and breadth of 60 cm. A trampoline was designed to cover the prototype building and the measurement was done within the confine of the covered prototype building framework. The neem tree is about 10 m high, and the leaves covered a perimeter of about 20 m. Different dosimeters were used to measure UV exposures (irradiance) and sunlight intensity (illuminance) respectively. Calibrated TENMARS UV-AB (TIM 213) meter was used to measure UV exposures in the range of 290 nm and 390 nm (wavelength range).The UV meter has a range of 3999µW/cm^2 and 39.99 mW/cm^2. The dimension of the dosimeter is 133 x 48 x 27 mm and it is 90 g in weight. The second dosimeter used for the measurement is a calibrated MENTECH Digital Lux Meter: LX-101A (130 g in weight). The dimension of the lux meter is 162 x 60 x 32 mm. Infra-red thermometer was used to measure the temperature under different conditions. The relative humidity was measured with the aid of Weather Daily APP on Android. Equipment used were obtained from the Health Physics Unit of Department of Physics, University of Medical Sciences, Ondo. Open sky exposures were measured at a height of 160 and 141 cm as representative of the height of adult and youth respectively. The ten hour period (daily) of sunlight was divided into five groups consisting of two hours each (8-10 am, 10-12 pm, 12-2 pm, 2-4 pm and 4-6 pm). Measurement of both irradiance (mW/cm^2) and illuminance (lux) were repeated five times within each subgroup of two hours and the mean values were found and recorded. Data on UV irradiance (mW/cm^2) and solar illuminance (lux) were manually input in Excel 2013 software. Descriptive statistics was used to analyze the data obtained. An attempt was made to calculate the predictive protection factors (PPFs) of different materials examined: trampoline, glass and neem tree foliage. Sun protection effectiveness of the three different materials were obtained by comparing the total solar UV radiation (UVR) exposure with and without each of the protective material for the same exposure duration. The sun protection effectiveness is expressed as a predictive protection factor (P [%]) representing the relative reduction in predicted UVR dose for any skin zone (Beckes *et al*., 2018). This is shown in equation 1

$$P(\%) = \frac{\alpha_{uv-\beta_{uv}}}{\alpha_{uv}} \text{ x } 100 \qquad (1)$$

Where $P(\%)$ is the predictive protection factor, $\alpha_{uv,}$ measured UV exposure without protection and β_{uv}, measured UV with protection.

Measurements were carried out in a tertiary institution (University of Medical Sciences, Ondo) open field and under a neem tree which serves as a parking space as seen in Figures 1 and 2. The trampoline examined is an opaque water proof thick leather material, while the glass is a sodalime glass. It is also known as sodalime silica glass with refractive index of 1.46 and density of 2.5 g cm^{-3} (Kerazi and Benysuns, 2017).

Fig 1: Open Field

Fig 2: Neem Foliage (Shade)

The mean daily dose, $\boldsymbol{M_{uv}}$ was calculated by using equation (2)

$$\boldsymbol{M_{uv}} = \sum_{i=1}^{n=5} \frac{\boldsymbol{X_i}}{\boldsymbol{n}} \qquad (2)$$

Where $\boldsymbol{X_i}$ is daily **UV** dose (mW/cm^2) and $\boldsymbol{n}$ is the number of days selected out of 30 days of this investigation.

Equation (3) gives the annual exposure (D_{Auv}) obtained from extrapolation of mean daily exposure, and it is assumed that each outdoor workers spends five days per week (260 days per year) in the open without protective material and ten hour exposures per day with mean daily exposure of $\boldsymbol{M_{i,uv}}$ (mW/cm^2)

$$D_{Auv} = \sum_{i=1}^{n=260} \boldsymbol{M_{i,uv}} \qquad (3)$$

Where $i = 1, 2, 3 \ldots \ldots \ldots \ldots \ldots \ldots n$

RESULTS AND DISCUSSION

Table 1 is the report of UV measured between the hours of 8 am and 6 pm (10 hrs). Other physical parameters measured and recorded are mean temperature and relative humidity. The bihourly means range between 0.52 mW/cm^2 (8 to 10 am) and 2.41 mW/cm^2 (2-4 pm), and the daily means (for the sample selected from a monthly record) range between 0.83 mW/cm^2 (Day 5-26/9/2021) and 1.75 mW/cm^2 (Day 2-23/9/2021) with a mean of 1.22 mW/cm^2. Data considered in this study consists of those selected from the measurement done in the month of September, 2021.Temperature and relative humidity range between 28.36^{o}C and 35.28^{o}C and 77.40 % and 89.20 % respectively. Measurements were carried out in an open field and under a neem tree. The mean UV exposures increased steadily from 8-10 am and reached the peak between 2 and 4 pm daily. The mean peak values observed throughout the five days selected from the data for the whole month of September occurred between 2 and 4 pm, and it is an indication that the incidence of UV exposures is more pronounce between those two hours if all the physical parameters are kept constant. Similarly Table 2 indicates that the bihourly means of illuminance (light intensity) ranged between 30,140 lx (8-10 pm) and 92,620 lx (2-4 pm), and the daily mean values ranged between 39,220 lx (Day 5) and 90,600 lx (Day 2).

The mean solar light illuminance recorded in this study is 59,524 lx at temperature of 32.38^{o}C and relative humidity of 80.96 %. The mean peak value of illuminance occurred between 2-4 pm.

Table 1: Measured UV (mW/cm^2) exposure of an Adult between the hours of 8:00 am and 6:00 pm

Time	8-10 am	10-12noon	12-2pm	2-4pm	4-6 pm	Daily mean (mW/cm^2)	Mean Temp (^{o}C)	Mean um. (%)
Day	UV Exposure (mW/cm^2)							
1	0.56	0.80	1.00	1.31	0.83	0.90	28.36	89.20
2	0.59	2.46	2.46	3.32	0.94	1.75	35.28	80.20
3	0.53	0.42	1.95	3.14	0.75	1.36	33.86	78.60
4	0.35	1.59	1.27	3.28	1.86	1.27	34.88	77.40
5	0.58	1.27	0.76	0.98	0.56	0.83	29.50	79.40
Hourly mean	0.52	1.31	1.49	2.41	0.99	1.22	32.38	80.96

Table 2: Sunlight illuminance (lux) received by an Adult between the hours of 8:00 am and 6:00 pm

Time	8-10 am	10-12noon	12-2pm	2-4pm	4-6 pm	Daily Mean (lux)	Mean Temp (°C)	Mean Hum (%)
Day	Light illuminance (lux)							
1	25500	32100	41400	59900	50200	41820	28.36	89.20
2	50200	88000	108400	127000	79400	90600	35.28	80.20
3	22300	16700	73000	125200	32300	53900	33.86	78.60
4	15000	75800	51600	110400	107600	72080	34.88	77.40
5	37700	64000	33100	40600	20700	39220	29.50	79.40
Hourly Mean	30140	55320	61500	92620	58040	**59524**	32.38	80.96

Figure 3 is the distribution of UV radiation (8-10 am, 10 am-12 pm, 12-2 pm, 2-4 pm, 4-6 pm) during the period of 22nd to 26th September, 2021. The last part of Figure 3 (6) is the mean value. The result shows that the highest exposure is found between 2 and 4 pm. The mean value of UV exposure which occurs between 2-4 pm is 2.41 mW/cm^2 and the minimum mean value is found to be 0.52 mW/cm^2. This occurred between 8-10 am. Figure 4 shows the relationship between solar light illuminance and irradiance (UV exposure). The plot shows that there is a linear relationship between the two parameters (Illuminance, L_x and UV exposure, U_v) This relationship is shown in equation 4.

$$L_x = kU_v \pm D \qquad (4)$$

Where k is the slope of the graph and D the intercept. The value of k and D are functions of the day, cloud cover and relative humidity.

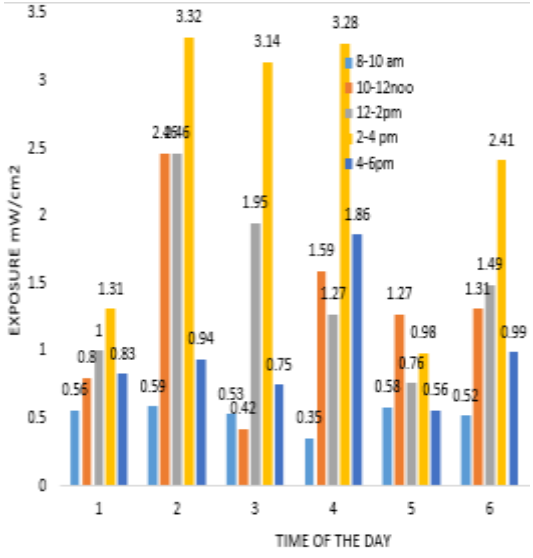

Fig 3: Plot of Distribution of UV exposure during the day

Table 3 shows the daily and bihourly UV exposure through a plane glass. The mean daily exposures ranged between 0.38 and 1.16 mW/cm^2 with a mean of 0.67 mW/cm^2. The bihourly measurement ranged between 0.324 and 1.018 mW/cm^2 with a mean of 0.674 mW/cm^2. Table 4 is also UV exposure measured under trampoline. The range of daily exposure lies between 0.00 and 0.03 mW/cm^2 with a mean value of 0.012 mW/cm^2.

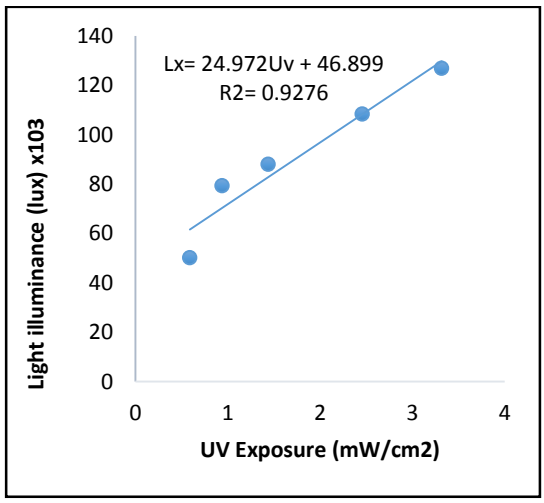

Fig 4: Relationship between light illuminance and UV exposure (23rd September, 2021)

Table 5 is a report of distribution of mean UV exposure measured under a tree. The range of daily exposure is found to be 0.05-0.08 mW/cm^2 with a mean of 0.067 mW/cm^2. The bihourly range is 0.056 - 0.68 mW/cm^2 with a mean of 0.19 mW/cm^2. The bihourly mean is higher than the daily mean by a factor of 2.88 units. The daily means of UV exposures recorded under different materials show that, the value recorded under a plane glass is higher than that of trampoline and neem tree by a factor of 56 and 10.2 unit respectively. This indicates that UV exposures recorded under a plane glass per day is higher than that of trampoline by a factor of 56 units and neem tree by a factor of 10.2 units. This is an indication that trampoline and neem tree are effective shielding materials. Table 6 is the report of calculated Predictive Protection Factor (PPF-[P]) for different materials. The PPFs-(P) measured when glass is used as shielding material range between 11.22 and 57.68% with a mean of 43.84 %. For trampoline used as protective material, the range of PPFs calculated lie between 97.79% and 99.84 % with a mean of 98.69%.

Table 3: Daily and bihourly UV exposure through plain glass (soda lime)

Time	1st Day	2nd Day	3rd Day	4th Day	5th Day	Mean
8-10 am	0.24	0.25	0.57	0.23	0.33	0.324
10-12 pm	0.35	0.45	0.22	1.43	0.78	0.646
12-2 pm	0.46	1.60	1.38	1.31	0.34	1.018
2-4 pm	0.53	1.34	0.46	1.42	0.46	0.842
4-6 pm	0.32	0.43	0.29	1.40	0.25	0.538
Daily Mean	0.38	0.81	0.58	1.16	0.43	**0.674**

Table 4: Daily and bihourly UV exposure through trampoline

Time	1st Day	2nd Day	3rd Day	4th Day	5th Day	Mean
8-10 am	0.00	0.01	0.01	0.00	0.000	0.01
10-12 pm	0.02	0.03	0.01	0.02	0.01	0.018
12-2 pm	0.01	0.05	0.04	0.00	0.00	0.02
2-4 pm	0.03	0.05	0.03	0.01	0.00	0.024
4-6 pm	0.02	0.03	0.01	0.03	0.00	0.018
Daily Mean	0.02	0.03	0.02	0.01	0.00	**0.018**

Table 5: Daily and bihourly UV exposure (mW/cm^2) through a tree shade (neem)

Time	1st Day	2nd Day	3rd Day	4th Day	5th Day	Mean
8-10 am	0.03	0.11	0.02	0.01	0.11	0.056
10-12noon	0.03	0.07	0.01	0.11	0.11	0.066
12-2 pm	0.06	0.09	0.10	0.05	0.04	0.68
2-4 pm	0.07	0.08	0.14	0.05	0.06	0.08
4-6 pm	0.05	0.04	0.05	0.15	0.03	0.064
Daily Mean	0.05	0.08	0.06	0.07	0.07	**0.067**

Table 6: Mean and range of calculated Predictive Protection Factor for different material

Material	1st Day	2nd Day	3rd Day	4th Day	5th Day	Mean (range) (%)
			UV dose (mW/cm^2)			
Glass	57.68 (54.00-61.45)	55.03 (34.95-68.75)	46.22 (75.5-85.35)	11.22 (3.15-34.29)	49.07 (38.58-55.36)	43.84 (11.22-57.68)
Trampoline	98.36 (97.50-100.00)	97.79 (97.70-98.50)	98.18 97.45-9904	99.27 (98.39-100)	99.84 99.21 -100	98.69 (97.79-99.84)
Tree Shade	94.74 (93.97-96.25)	93.27 (81.35-97.59)	95.52 (93.33-97.62)	89.72 (71.43-96.09)	91.13 (81.03-94.74)	92.88 (89.72-95.52)

The mean PPFs (P) for neem tree (shade) range between 89.72% and 95.52% with a mean of 92.88%. This result is an indication that trampoline is the most effective material for shielding UV among three materials examined in this study. This implies that trampoline can serve as effective material for hat and UV umbrella. It shields away almost all the UV exposures. Its protective ability is higher than that of glass by a factor of 2.23 units. In addition, the shielding ability of neem tree is greater than that of glass by a factor of 2.12 units. The results in Table 6 report the percentage by which the UV exposure is reduced under a given condition (glass, trampoline and neem). The discomfort resulting from heat is the problem that might be encountered in an attempt to use trampoline to produce UV shield, however, this might be reduced by placing a bright colored insulating material inside the hat or umbrella. This type of umbrella would shield the eyes and skin from about 99% of UV exposures while the neem foliage can be effective in shielding up to 93%.

Table 7 is the result of means and ranges of solar light illuminance measured under various materials examined in this study. The means and ranges of illuminance measured when the detector was shielded with glass, trampoline and vegetation (neem tree foliage) are: 431.80 x 10^2 (257.20 - 641.60) x 10^2 lx, 29.16 x10^2 (20.20 - 46.00) x 10^2 lx and 71.40 x 10^2 (56.60-92.40) x10^2 lx respectively. The trend of illuminance here lend credence to the fact that UV exposure is a function of solar light exposure. The range (257, 200– 641, 600 lx) of illuminance obtained through a glass in this study is higher than the range (1,792-6,800 lx) of values measured in Singapore (Lanca *et al*., 2018) by factors which range between 9.44 and 14.4 unit. The mean (2916 lx) value of illuminance measured in this study shows that trampoline is more effective in shielding light than baseball hat material used in Singapore (Lanca *et al*., 2018). Figures 5 and 6 show the plot of UV doses recorded in this study for adult and youth subjects respectively. The two graphs show that the UV exposures increase steadily in Day 2 and Day 3 and the peak for both days are seen between 2 and 4 pm. This decreases steadily to low values which range between 0.5 mW/cm^2 and 1 mW/cm^2 at about 6 pm. Day 4 has a small peak between 4 and 6 pm and another peak between 10-12 pm. The peak of Day1 lies between 10 and 12 pm.

Table 7: Mean and range of illuminance (lux) measured for different materials

Day	1st Day	2nd Day	3rd Day	4th Day	5th Day	Mean (range)
Material	Illuminance (lx) x10^2					
Glass	257.20 (173-351)	641.60 (194-1058)	348.80 (134-823)	541.20 (128-833)	370.20 (158-587)	431.80 (257.20-641.60)
Trampoline	31.40 (16-42)	46.00 (23-51)	26.00 (13-47)	20.20 (5-34)	22.20 (14-35)	29.16 (20.20-46.00)
Tree Shade	56.60 (43-79)	82.40 (47-103)	62.00 (22-100)	63.60 (35-94)	92.40 (34-199)	71.40 (56.60-92.40)

Patterns shown in Figures 5 and 6 indicate that the occurrence of UV exposures sets in at about 10 am, and attains its peak between 2 and 4 pm. Further extensive study is required to prove this observation. The plots for both adult (Figure 5) and youth (Figure 6) indicate that the occurrence of UV exposures peaked between 10-12 pm and 2- 4pm.

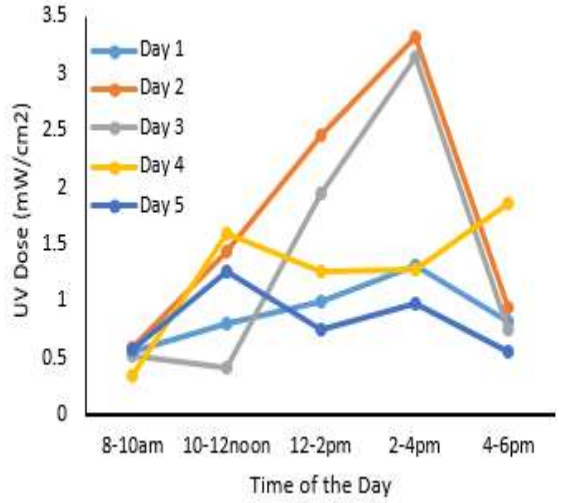

Fig. 5: UV doses received by adult subject versus time of the day

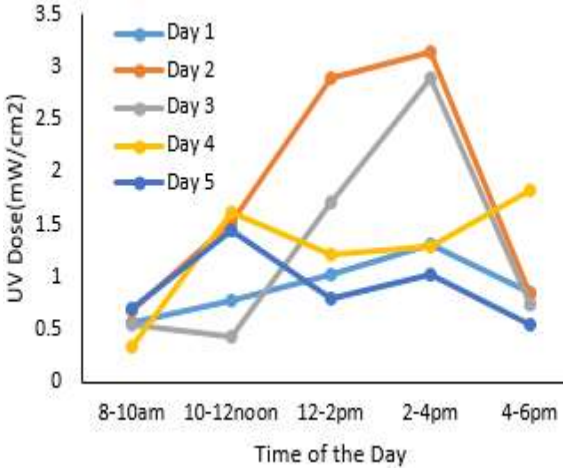

Fig.6: UV doses received by youth subject versus time of the day

Therefore, it is essential, for outdoor workers, and albino subjects to avoid exposures during the peak hours when UV exposure is more pronounced or wear effective UV shields. This is to prevent detrimental effects resulting from long unprotected exposures. Earlier background investigations and literature have shown that some outdoor workers (fishermen, Commercial Motorcycle Riders, Street Hawkers) spend more than ten hours in the sun daily (Achigbu and Ezepue, 2014). The mean daily dose (1.23 mW/cm^2) and annual dose (319.8 mW/cm^2) calculated in this study are shown in Table 8. These values depend on the intensity of sunlight (D'Orazio *et al*., 2013) as shown in equation 4.

Table 8: Mean Daily UV and Annual Doses of an outdoor worker

Dose	Mean UV daily Dose (mW/cm^2)	Annual UV Dose (mW/cm^2)
Adult	1.23	319.8

Since UV radiation affects the eyes (leads to pterygium) of an outdoor workers who spend a length of time in the sun essentially in equatorial region of the world, it is important that protective head dress, umbrellas and UV glasses be used during the hours of intense sunlight (between 2 pm and 4 pm). This could prevent excessive irradiance from the sun especially in cloudless days of the year.

Conclusion: In this preliminary study, UV irradiance and solar illuminance were measured under four conditions (open field, neem foliage, plane glass and trampoline material). Results show that the peak UV exposures and illuminance occurred between 2 pm and 4 pm. The predictive protection factors (PPFs) calculated show that trampoline, neem foliage are more effective UV shields than plane glass. The mean daily UV dose received by an outdoor worker is 1.23 mW/cm^2 and the estimated equivalent annual dose is 319.8 mW/cm^2 in southwestern Nigeria. Since length of exposure predisposes pterygium and other eyes and skin problems, it is essential for outdoor workers to use UV shields and protective materials during the day time.

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