Asian Journal of Research and Reviews in Physics

Volume 8, Issue 3, Page 37-51, 2024; Article no.AJR2P.122084
ISSN: 2582-5992

Assessment and Modeling of Workplace Exposure to Solar Ultraviolet Radiation in Makurdi, Nigeria

Christopher Chiahemba Akoso [a], Samson Dauda Yusuf [a*] and Timothy Chidozie Akpa [b]

[a] Department of Physics, Faculty of Natural and Applied Sciences, Nasarawa State University, Keffi, PMB 1022, Nigeria.
[b] Department of Radiological Safety, Nigerian Nuclear Regulatory Authority, Abuja, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by authors SDY, CCA and TCA. The first draft of the manuscript was written by author CCA, reviewed and re-drafted by author SDY, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ajr2p/2024/v8i3169

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/122084

Original Research Article

Received: 26/06/2024
Accepted: 29/08/2024
Published: 02/09/2024

ABSTRACT

Solar radiation though beneficial to life but the harmful effects of over exposure especially in Nigeria has been neglected and its measurement/prediction has received negligible attention in the literature. This study measured and modeled workplace exposure to solar ultraviolet radiation

**Corresponding author: E-mail: samsonyusufu@yahoo.com;*

Cite as: *Akoso, Christopher Chiahemba, Samson Dauda Yusuf, and Timothy Chidozie Akpa. 2024. "Assessment and Modeling of Workplace Exposure to Solar Ultraviolet Radiation in Makurdi, Nigeria". Asian Journal of Research and Reviews in Physics 8 (3):37-51. https://doi.org/10.9734/ajr2p/2024/v8i3169.*

(SUVR) in Makurdi, Benue State, Nigeria. Digital broadband meter was used to measure solar power density in three site while polymer Polysolphone dosimeters were fitted on a human manikin and placed in the sun between 10:00 am- 4:00pm (6 hours) to quantify the amount of Solar UVR absorbed by three occupational workers (Traders, Fishermen and Staff/Students). Five dosimeters were deployed in each of the three sites for calibration to measure UV absorbance in J/m^2 while seven in each site were used for body parts. UV/VIS-spectrophotometer was handily used to measure both post and pre-absorbance and the UV exposures were calculated. The UV index was also calculated. Result shows that, head top had the highest exposure values 7.19kJ/m^2, 6.51kJ/m^2 and 7.00kJ/m^2, while the least values was under cloth cover 2.47kJ/m^2, 2.08kJ/m^2 and 2.20kJ/m^2 for traders, fishermen and staff/students respectively. Similarly, the calculated cumulative exposures were 3289.36kJ/m^2, 497.82kJ/m^2 and 1515.60kJ/m^2 at the market square, river bank and the campus respectively. These values were higher than international ICNIRP average value 30J/m^2. UV index at market square was 9 (media graphic colour purple), while at river bank and BSU campus was 8 (media graphic colour reddish). High mean irradiant values with high UV index indicates high risk of harm from unprotected sun exposure. Therefore, use of sun protective clothing is recommended and reduce time in the sun especially between 1:00pm and 2:00pm to prevent over exposure that will lead to serious harmful effects especially at the market place.

Keywords: Polysulphone dosimeter; UV radiation; occupation workers; outdoor exposure; UV index; UV/VIS-spectrophotometer.

1. INTRODUCTION

Human exposure to solar radiation has important public health implications as well as adverse effects. The ultraviolet radiation represents a small portion of the solar radiation spectrum (SRS) that spanned through the wavelength of 200 nm to approximately 400 nm [1]. According to International Agency for research on Cancer (IARC) [2], sufficient exposure to UV radiation is required to trigger the vitamin D production in humans necessary for mineral balance and skeletal maintenance and for regulation of cell proliferation and differentiation. In plants, it is needed for photosynthesis. However, over exposure to UV radiation can course serious health problems in humans like Photo-conjunctivitis, Skin cancers, Pterygiun, Cortical Cataract, Photo-ageing, Carcinoma of cornea, and immune depression. In plant, over exposure is a great threat to crops as it exposes them to diseases and other effects [3,4,5].

Any employee working outdoors (construction, agriculture, mining, landscapers, market places, fishermen, law enforcement officers, etc.) has the potential for over exposure to ultraviolet radiation (UVR) [6]. Market squares, opened playgrounds, tourist sites, farm lands, and construction sites in Nigeria are the places that present significant health risks to most people who expose their bodies to UV radiation without adequate protection. The risk is most significant in market sites, car parks and work sites located in the villages having little or no shade covers for UV protection [3]. The predominance of black and brown skin types in Africa which is very much resistant to instant sunburn or other acute effects of over exposure to solar UV radiation most often make people to neglect the necessity of UV protective measures resulting to increased risks associated with chronic effects of UV radiation exposure [3,6].

It is pertinent to note that; ultraviolet radiation is ubiquitous such that everyone has some levels of exposure to solar ultraviolet radiation on a daily basis. It is an exposure that cannot be entirely avoided as zero exposure would result to a huge burden of skeletal disease from vitamin D deficiency. However, evaluation of the burden of disease caused by excess exposure to UVR is very important since avoidance of excess exposure should easily be communicated as a simple public health message [7]. Despite the fact that Makurdi is located at low latitudes, characterized by high solar intensity and having high rates of outdoor workers, no much research is found in the literature on the assessment of UV exposure in this area [8]. Therefore, it is against this backdrop that the objective of this study is to carry out an assessment and model the impact of solar ultraviolet radiation of outdoor occupational workers especially in Makurdi Metropolis.

2. MATERIALS AND METHODS

2.1 Materials

The materials that were utilized for the purpose of this research includes TM-206 digital UV broadband meter used to measure UV irradiance, rubber human manikin used in place of humans for the research, UV/VIS spectrophotometer used to measure the UV absorbed dose from the dosimeters, polymer polysolphone dosimeters which acts in similitude of human skin was used to quantify UV absorbance, and Twelve-channel GPS used to measure the coordinates and elevation of the locations.

2.2 Methods

Study site: This study was carried out in Makurdi town which is the headquarters of Makurdi Local Government Area and the capital of Benue State. The town is located between latitude 7°38'N - 7°50'N, and longitude 8°24'E and 8°38'E. It is situated in the Benue valley in the North Central region of Nigeria. It is traversed by the second largest river in the country, the River Benue. The population of Makurdi is around 500,797 [9]. Makurdi town is made up largely of people who engage in civil service duties, commercial activities and agrarian peasantry.

Sample points/ locations: The simple random sampling technique was used to select three locations where the area monitoring survey was carried out and the GPS readings for the study locations where data was taken for this study is presented in Table 1, while the map of Makurdi showing the sample location is shown in Fig. 1.

Table 1. GPS locations at various study sites

S/N	Location	Location Code	Longitude	Latitude	Angle of elevation
1	River Bank	RB	07^{0}44.8056'	008^{0}30.7782'	65m
2	Benue State University	BSU	07^{0}43.6893'	008^{0}33.3250'	103m
3	Wurukum Market	WM	07^{0}43.5840'	008^{0}32.9831'	81m

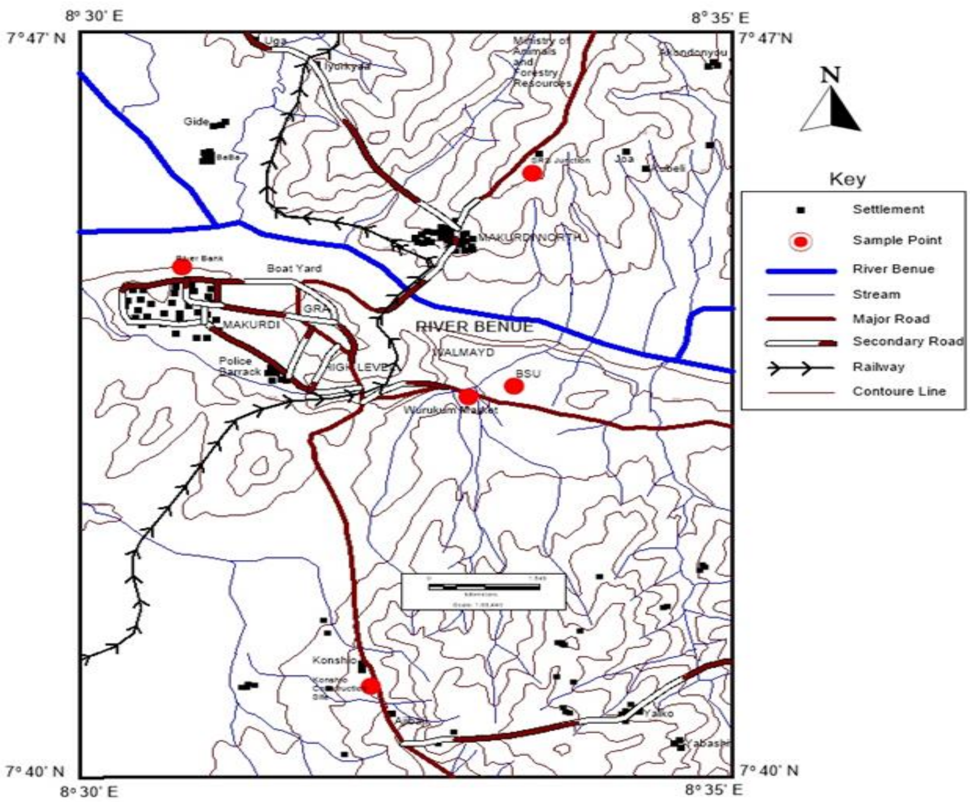

Fig. 1. Map of the study area showing sampling location points

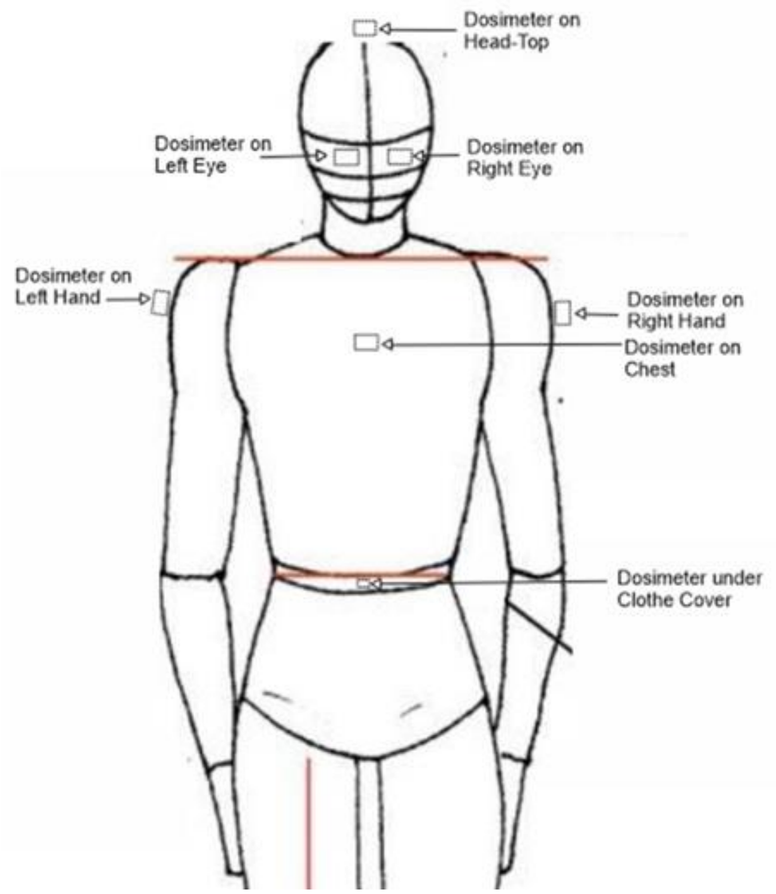

Fig. 2. Dosimetric experiment

***In situ* data collection method:** Calibration and human exposure of three occupations (traders, fishermen, and students/staff) was done, each occupation per day at the same site and on the same day. This was to avoid mismatch errors. Dosimeters of size 2cm by 2cm were attached on different parts of human manikin for the number of working hours per day. The dosimeters were then placed on the spectrophotometer machine to measure the rate of radiation absorbance from the dosimeters. First the pre-exposure optical absorbance was measured when the dosimeters have not been exposed. Then the same dosimeters were placed on the different parts of the human manikin i.e. head top, left and right hand, left and right eye, chest, and under cloth cover. They were then exposed for about 8 hours, removed and placed on the spectrophotometer machine to measure the post-exposure optical absorbance. Finally, the change in optical absorbance was calculated for each exposed dosimeter, this was achieved as the pre-absorbance results were subtracted from post-absorbance to get the actual absorbed dose for each dosimeters. At the same time the UV meter was used for measuring the irradiance in each of the sites. We exposed the UV meter facing the direction of the sun rays and place it at an angle of 90 degrees. When the UV meter is switched 'ON', it measures the sun irradiance. The mean of three (3) readings from each site was used to validate or ascertain the presence of radiation in each site by comparing the values to those gotten from the dosimeters. The GPS meter was also used to measure the latitude and longitude of each location. Fig. 2 shows an example of how the dosimeters were placed on the manikin.

Dosimeter calibration method: The calibration of the dosimeters was done at the measurement site. This was achieved by subjecting 5 dosimeters each at Wurukum Market (traders), River Benue Wadata axis (Fishermen) and Benue State University campus (student/staff) to series of solar UV radiation on a plane surface, while measuring the solar UV exposures with the UV meter. This was done to enable measurement of UV exposures in J/m^2.

UV meter exposure quantity calculation method: The desired exposure quantities were also calculated following the works of Park et al. [10], Parisi and Turnbull [11], and Parisi et al. [12] as follows:

$$Exposure\ Quantity\ \left(\frac{J}{m^2}\right) = Calibrationfactor\ (Constant) \times Absorbance \quad (1)$$

The calibration factor is often taken as the gradient of a line and this is sufficiently approximated for a UV polysulphone dosimeter.

Dosimeter UV exposure calculation method: The UV exposure (E) of each individual dosimeter was calculated following the works of Igbawua et al. [3] as follows:

$$E = \sum_{t_1}^{t_2} I \times \Delta t \quad (2)$$

Where E is the exposure in (J/m^2), I is the measured irradiance or heat flux density (W/m^2) and Δt is the exposure time interval from t_1 to t_2.

UV Index Calculation Method: The UV Index for the three sites were calculated following the relationship given by Downs et al. [13] as follows:

$$I_{uv} = \frac{E_{ery}}{25} \quad (3)$$

Where E_{ery} is erythemally effective UV irradiance.

3. RESULTS

3.1 Calibration Result

The dosimeter calibration at the three sites was carried out between 11-13 March, 2021 and the result of the pre-absorbance and the post-absorbance were recorded and presented in Table 2.

From Table 2, Optical absorbance of individual dosimeters used for calibration was tabulated which depicts the actual values those dosimeters absorbed within the exposure period for calibration. Three distinct calibration timeline were deployed. This is also illustrated in Table 2 as the dosimeters deployed at Wurukum market were calibrated at 60mins intervals. Those at River bank were calibrated at 10mins interval, while those at Benue State University, at 30mins interval each were used for the calibration. The highest absorbance was observed in Wurukum marker (0.605) at 300mins while the lowest was observed in the river bank (0.120) at 10mins.

The result shows that increased calibration time of the dosimeters results in have higher absorbance. Which implies that the rate of optical absorbance of the dosimeters is directly proportional to the calibration time.

3.2 Cumulative UV Exposure

Table 3 shows the results for cumulative exposure of the dosimeters during 60mins interval calibration on 11th March, 2021. To calculate the UV exposure of each dosimeter at an interval of one (1) hour, we use Equation (2) as:

$$En = \sum_{t_1}^{t_2} I \times \Delta t$$

For n = 1

$E_1 = 105.5 * 3600 = 379800 J/m^2$

$E_1 = 379.80 kJ/m^2$

The same procedures were followed to calculate for the 5 dosimeters used for calibration. The total exposure for each dosimeter was the cumulative sum of the exposure calculated for the current exposure interval (60 minutes) and the sum of previous exposures of the dosimeters taken in that order. The UV exposure of each dosimeter was estimated from a single measurement made at the end of an interval of 60 minutes. The UV irradiance was therefore approximated to be constant for the 60-minute exposure intervals.

Table 2. Optical absorbance at various study sites (Calibration)

Location Code	Tag No.	Duration (mins)	Mean Post Abs	Mean Pre-Abs	Optical Abs
WM5	1	60	0.401	0.113	0.288
	2	120	0.500	0.128	0.372
	3	180	0.532	0.113	0.419
	4	240	0.662	0.101	0.561
	5	300	0.720	0.115	0.605
RB5	6	10	0.228	0.108	0.120
	7	20	0.310	0.114	0.198
	8	30	0.350	0.112	0.238

Location Code	Tag No.	Duration (mins)	Mean Post Abs	Mean Pre-Abs	Optical Abs
	9	40	0.398	0.103	0.295
	10	50	0.449	0.103	0.346
BSU5	11	30	0.311	0.102	0.209
	12	60	0.341	0.103	0.238
	13	90	0.499	0.115	0.384
	14	120	0.561	0.101	0.460
	15	150	0.593	0.116	0.477

Key: Post Abs = Post absorbance, Pre-Abs = Pre absorbance, WM = Wurukum Market, RB = River Bank, and BSU = Benue State University

Table 3. Cumulative UV exposure at Wurukum market

S/No	Dosimeter Exposure Time (Mins)	Change in Optical Absorbance (ΔA_{330})	UV Irradiance for Exposure Interval (W/m^2)	Approx. UV Exposure for each Interval (kJ/m^2)	Cumulative UV Exposure (J/m^2)
1	60	0.288	105.5	379.80	379.80
2	120	0.372	177.3	638.28	1018.08
3	180	0.419	189.6	682.56	1700.64
4	240	0.561	227.3	818.28	2519.44
5	300	0.605	214.0	770.40	3289.36

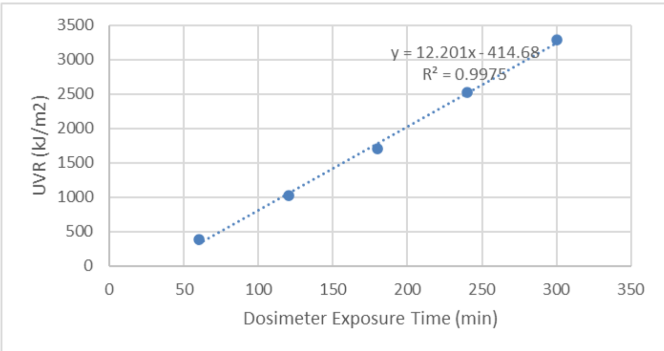

Fig. 3. Dosimeter calibration curve at Wurukum Market

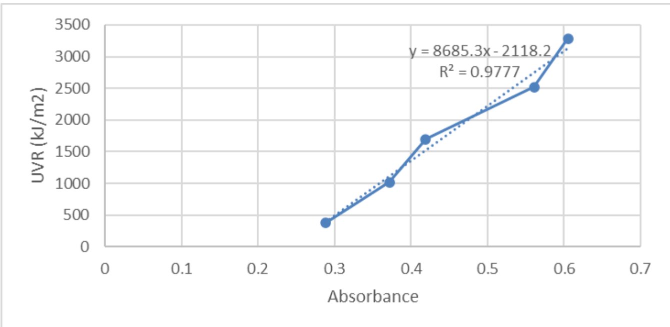

Fig. 4. Dosimeter response curve at Wurukum Market

From Table 3, it was observed that at higher intensity of the sun, the approximate UV exposure within the interval was very high as well. This is evidently noticed when the irradiance of 227.3 W/m^2 irradiance, the higher approximate exposure of 818.28 kJ/m^2 within the interval was recorded. Likewise, at low irradiance of 105.5 W/m^2, 379.80 kJ/m^2 was recorded indicating the lowest approximate UV exposure for the entire period of measurement within the study site. The graph of Cumulative UV exposure was plotted against the time of exposure to get a calibration curve as shown in Fig. 3. Furthermore, cumulative UV exposure was plotted against absorbance (Fig. 4) to show the response curve of the dosimeters.

Fig. 3 shows the calibration curve for cumulative UV exposure with dosimeter exposure time. The straight line graph plotted indicates that the higher the time of exposure, the higher the amount of UV absorbed. Also, Fig. 4 indicates a strong relationship between increasing exposure to UV radiation and the absorbance in the measured exposure intervals of 60 minutes (between 10.00 am and 4.00 pm). A straight line graph was therefore plotted to get the calibration equation which is y = 12.201x - 414.68 with R^2= 0.9975.

Table 4 presents the result of cumulative exposure of the dosimeters during 10mins interval calibration on 12th March, 2021. Once again we used Equation (2) to calculate the UV exposure of each dosimeter at an interval of ten (10) minutes at River bank.

$$En = \sum_{t_1}^{t_2} I \times \Delta t$$

For n = 1

$E_1 = 129.3 * 600 = 77.58 J/m^2$

$E_1 = 77.58 kJ/m^2$

The total exposure for each dosimeter was the cumulative sum of the exposure calculated for the current exposure interval (10 minutes) and the sum of previous exposures of the dosimeters taken in that order. The UV exposure of each dosimeter was estimated from a single measurement made at the end of an interval of 10 minutes.

From Table 4 we can still observe once again that at higher intensity of the sun, the approximate UV exposure within the interval was higher compare to lower intensities. This is evidently noticed when high irradiance of 194.5 W/m^2 was recorded, corresponding to high approximate exposure of 116.70 kJ/m^2 within the interval. Likewise, at low irradiance of 129.3W/m^2, 77.58 kJ/m^2 was recorded indicating the lowest approximate UV exposure for the entire period of measurement within this study site. The graph of Cumulative UV exposure was plotted against the time of exposure to get a calibration curve as shown in Fig. 5. Furthermore, cumulative UV exposure was plotted against absorbance (Fig. 6) to show the response curve of the dosimeters.

Table 4. Cumulative UV at river bank, Wadata axis

S/No	Dosimeter Exposure Time (Mins)	Change in Optical Absorbance (ΔA_{330})	UV Irradiance for Exposure Interval (W/m^2)	Approx. UV Exposure for each Interval (kJ/m^2)	Cumulative UV Exposure (kJ/m^2)
1	10	0.120	129.3	77.58	77.58
2	20	0.198	145.2	87.12	164.70
3	30	0.238	172.9	103.74	268.44
4	40	0.295	187.8	112.68	381.12
5	50	0.346	194.5	116.70	497.82

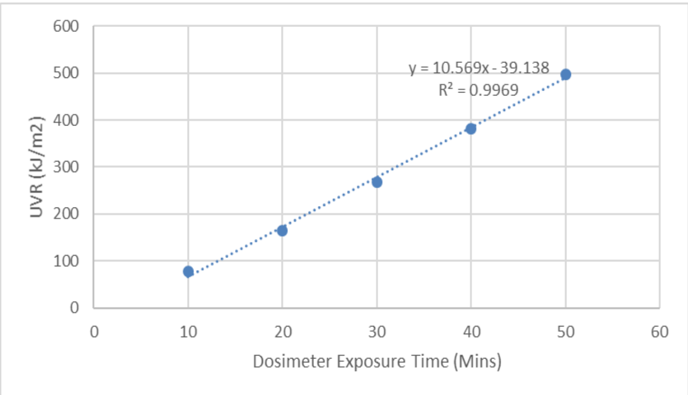

Fig. 5. Dosimeter calibration curve at river bank (Wadata Axis)

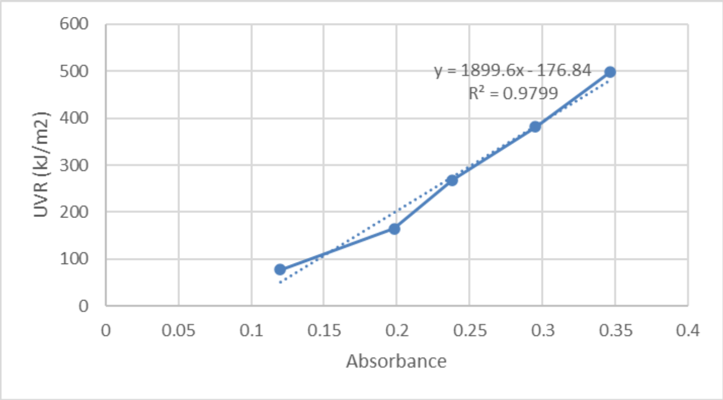

Fig. 6. Dosimeter response curve at river bank (Wadata Axis)

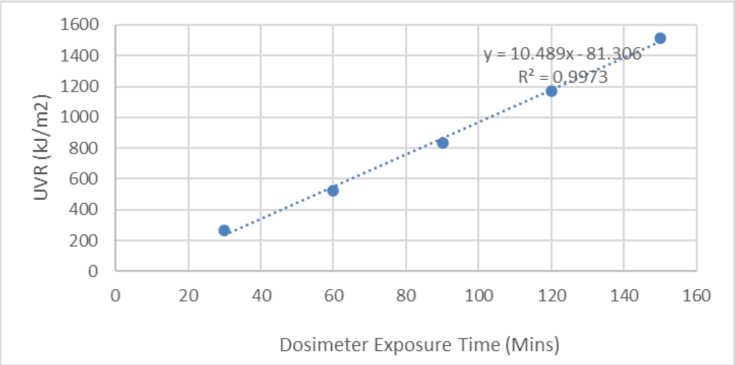

Fig. 7. Dosimeter calibration curve at Benue State University

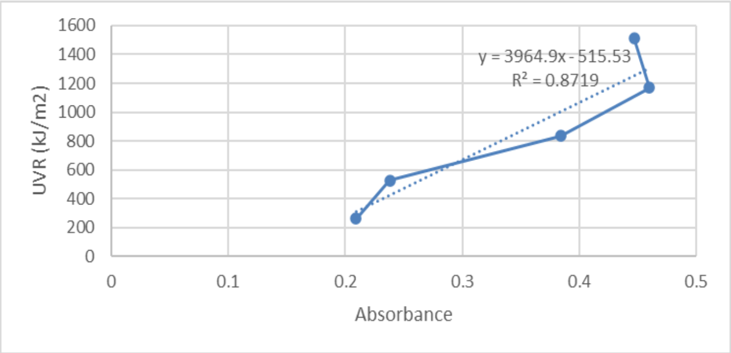

Fig. 8. Dosimeter response curve at Benue State University

Table 5. Cumulative UV exposure at Benue State University

S/No	Dosimeter Exposure Time (Mins)	Change in Optical Absorbance (ΔA_{330})	UV Irradiance for Exposure Interval (W/m²)	Approx. UV Exposure for Each Interval (kJ/m²)	Cumulative UV Exposure (kJ/m²)
1	30	0.209	146.8	264.24	264.24
2	60	0.238	145.8	262.44	526.68
3	90	0.384	172.0	309.60	836.28
4	120	0.460	185.7	334.26	1170.54
5	150	0.477	191.7	345.06	1515.60

Fig. 5 shows the calibration curve for cumulative UV exposure with dosimeter exposure time. The straight line graph was plotted which indicates that, as the exposure time increase, the rate of UV absorbance increase as well. Also, Fig. 6 indicates a strong relationship between increasing exposure to UV radiation and the absorbance in the measured exposure intervals of 10 minutes (between 12.00 noon and 1.00 pm). Periods of cloud cover were avoided during the measurement so as to obtain better results. A straight line graph was therefore plotted to get the calibration equation which is y = 10.569x - 39.138 with R^2= 0.9969. The calibration period was chosen around this period because of high intensities of UV exposures usually experienced around this interval.

Table 5 showed the result for cumulative exposure of the dosimeters during 30mins calibration interval on 13th March, 2021. Equation (2) was once again used in calculating UV exposure of each dosimeter at an interval of thirty (30) minutes.

$$En = \sum_{t_1}^{t_2} I \times \Delta t$$

For n = 1

$$E_1 = 146.8 * 1800 = 264.24 J/m^2$$
$$E_1 = 264.24 J/m^2$$

The total exposure for each dosimeter was the cumulative sum of the exposure calculated for the current exposure interval (30 minutes) and the sum of previous exposures of the dosimeters taken in that order.

From Table 5, it was also observed that at higher intensity of the sun, the approximate UV exposure within the interval was higher compare to lower intensities. This is noticed when the high irradiance of 191.7W/m^2 was recorded, with a corresponding high approximate exposure of 345.06kJ/m^2 within the interval. Likewise, at low irradiance of 145.8W/m^2, 262.44kJ/m^2 was recorded indicating the lowest approximate UV exposure for the entire intervals of measurement within this study site.

The graph of Cumulative UV exposure was plotted against the time of exposure to get a calibration curve as shown in Fig. 7. Furthermore, cumulative UV exposure was plotted against absorbance (Fig. 8) to show the response curve of the dosimeters.

Fig. 7 shows the calibration curve for cumulative UV exposure with dosimeter exposure time. The straight line graph was plotted which indicates that, as the exposure time increase, the rate of UV absorbance increase as well. Once again the almost linear line graph in Fig. 8 indicates a strong relationship between increasing exposure to UV radiation and the absorbance in the measured exposure intervals of 30 minutes (between 11.30 am and 2.30 pm). A straight line graph was therefore plotted to get the calibration equation which is y = 10.489x - 81.306 with R^2 = 0.9973.

Table 6 present the result of the cumulative exposure of dosimeters placed on various body parts at the three (3) sites. The desired quantity of UV exposure of each dosimeter placed on the body parts were calculated using equation (1) as:

$$Exposure\ Quantity\ \left(\frac{J}{m^2}\right) = calibration\ factor\ (constant)\ * absorbance$$

For the Wurukum Market, the constant (calibration factor) was gotten to be 12.201kJ/m^2 from the calibration curve of Fig. 3. Similarly, the calibration constant of the River Bank and Benue State University were 10.569kJ/m^2 and 10.489kJ/m^2 respectively as obtained from Figs. 5 and 7. The desired exposure quantity of various body parts for Wurukum were calculated and presented in Table 6. Thus, that of the head top can be calculated as follows:

$$EQH = 12.201 * 0.589 = 7.186 kJ/m^2$$

Where EQH is desired exposure quantity for the dosimeter placed on the head top (HT). The same formula was used to calculate for the right eye (RE), left eye (LE), right hand (RH), left hand (LH), chest (CH), and under clothe cover (CL) for all the three (3) sites between 11 - 13th March, 2021. The result is presented in Table 6.

The result of the dosimeters on the various body parts showed some variations and has revealed some useful information that are worthy of interpretation. However, in each of the three (3) sampled sites, the readings appeared to follow the same pattern with the dosimeters placed on HT having the highest exposure quantity as compared with other body parts 7.19kJ/m^2, 6.51kJ/m^2 and 7.00kJ/m^2 for Wurukum Market, River Bank and Benue State University respectively, followed by the dosimeter placed on

Table 6. Cumulative exposure (kJ/m²) of dosimeters placed on various body parts at the sampling sites

S/No.	Body parts	Occupational Cumulative Exposure (kJ/m²)		
		Traders	Fishermen	Staff/Students
1	HT	7.19	6.51	7.00
2	RE	3.67	3.48	3.63
3	LE	3.53	3.28	3.13
4	RH	6.04	5.35	5.13
5	LH	5.27	3.30	4.15
6	CH	6.67	5.62	5.24
7	CL	2.47	2.08	2.20
	Mean	4.98	4.23	4.35

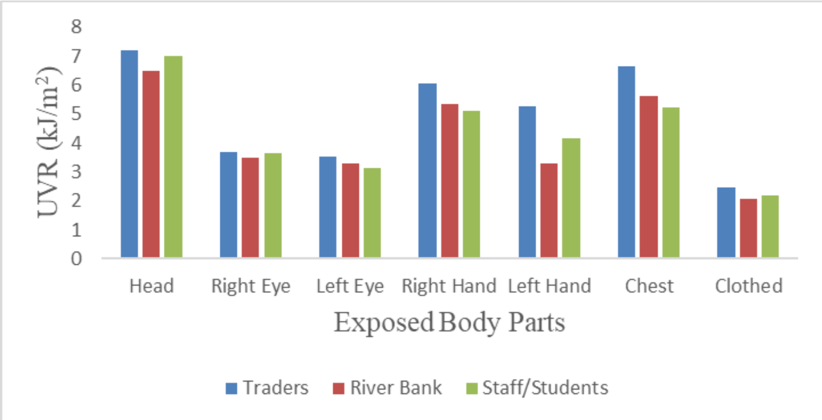

Fig. 9. Cumulative Exposure of Dosimeters placed on various body

CH 6.67kJ/m² at Wurukum Market, 5.62kJ/m² at River Bank and 5.24kJ/m² at the Benue State University. While the dosimeters placed at CL recorded the lowest across the three sites 2.47kJ/m² at Wurukum Market, 2.08kJ/m² at river bank and 2.20kJ/m² at Benue State University. This implies that CH is capable of shielding some UV radiation from reaching the skin. In general, the dosimeter at Wurukum Market (traders) recorded the highest readings in all the body parts as compared to river bank (fishermen) and Benue State University (staff/students). In terms of the mean cumulative UV radiation from the various body parts in each of the sampled sites, Wurukum Market recorded the highest 4.98kJ/m², followed by Benue State University 4.35kJ/m² and the least was at River Bank 4.23kJ/m². The variation of the cumulative UV radiation from the various body parts in each of the sampled sites is shown in Fig. 9.

3.3 Calculated UV Index for the Sampling Sites

The UVI for the study locations at the peak hours of this research duration were calculated from the values of UV Irradiance in Tables 3, 4 and 5. This was achieved using equation (3). The values of UV Index obtained are tabulated in the Table 7. However, from equation 3 the UV index for WM, BSU, RB, can be calculated as follows:

$$I_{uv} = \frac{E_{ery}}{25}$$

For WM,

$$I_{uv} = \frac{E_{ery}}{25} = \frac{227.3}{25} = 9$$

For BSU

$$I_{uv} = \frac{E_{ery}}{25} = \frac{191.7}{25} = 8$$

For RB

$$I_{uv} = \frac{E_{ery}}{25} = \frac{194.5}{25} = 8$$

The result from the calculated UV Index showed that WM have the highest UV Index value of 9 which indicates high risk of harm from unprotected sun exposure. This is represented by the media graphics colour purple. Similarly,

Table 7. Calculated UV Index, description and recommendations for protection

S/N	Location	Calculated UV Index	Description	Media Graphics Colour	Recommendations for Protection
1	WM	9	Very high risk of harm from unprotected sun exposure	Purple	Wear sunglasses and use sunscreen having SPF 15 or higher, cover the body with sun protective clothing and a wide-brim hat, and reduce time in the sun from two hours before to three hours after solar noon (roughly 11:00 am to 4 PM during dry season that observe daylight saving time. Extra care should be taken as skin can burn easily.
2	BSU	8	Very high risk of harm from unprotected sun exposure	Reddish	Wear sunglasses and use sunscreen having SPF 15 or higher, cover the body with sun protective clothing and a wide-brim hat, and reduce time in the sun from two hours before to three hours after solar noon (roughly 11:00 am to 4 PM during dry season that observe daylight saving time.
3	RB	8	Very high risk of harm from unprotected sun exposure	Reddish	Wear sunglasses and use sunscreen having SPF 15 or higher, cover the body with sun protective clothing and a wide-brim hat, and reduce time in the sun from two hours before to three hours after solar noon (roughly 11:00 am to 4 PM during dry season that observe daylight saving time.

Key: WM = Wurukum Market, BSU = Benue State University, and RB = River Bank

BSU and RB were found to have UV Index of 8 which also depict high risk of harm from unprotected sun exposure. The media graphics colour from these two sites is however, reddish. It is therefore recommended that people working outdoors in these sites; WM, BSU and RB should Wear sunglasses and use sunscreen having SPF 15 or higher, cover the body with sun protective clothing and a wide-brim hat, and reduce time in the sun within solar peak hours during dry season that observe daylight saving time.

4. DISCUSSION

The result of workplace exposure to solar ultraviolet radiation in Makurdi, Nigeria shows variation from site to site within the study area. Polymer polysulphone dosimeters deployed for calibration at three different locations representing three occupations enabled the dosimeter to effectively measure cumulative UV radiation in J/m^2. The calibration equation which is the graph of the cumulative UV exposure against the exposure time for the various study sites were y = 12.201x – 414.68 (R^2 = 0.9975), y = 10.569x – 39.138 (R^2 = 0.9969) and y = 10.489x – 81.306 (R^2 = 0.9973) for Market Square, River Bank and Benue State University respectively. The equation enables us to deduce the calibration factor which is equivalent to the gradient of a curves. However, Findings from this study have revealed that the calibration factors were found to be 12.201 for Market Square, 10.569 for River Bank and 10.489 for Benue State University. This is significant as it is used in the quantification of the dosimeters placed at various body region among the different study sites. The different body parts exposed to UV radiation were measured with the dosimeter and findings from this study have revealed that the dosimeter placed on the head recorded the highest cumulative UV radiation exposure across all the sites with 7.19kJ/m^2 for traders, 6.51kJ/m^2 for fishermen and 7.00kJ/m^2 for staff/students. The dosimeter placed under cloth cover recorded the least cumulative UV radiation exposure across all the locations 2.47kJ/m^2, 2.08kJ/m^2 and

2.20kJ/m^2 for traders at WM, fishermen at the RB and staff/student at BSU campus respectively. These results reveals that the clothing put on assisted in attenuating the solar UV radiation penetrating the skin thereby reducing the harm it would have caused on our bodies. Other parts of the body measured also showed high values, and all these values were quite high compared to standard value of 30J/m^2 as recommended by ICNIRP for occupational exposure as stated in Vecchia et al. [14]. This intensity radiation may be because according to Agada et al. [15], Makurdi exist within the sedimentary geology, it has stone soils that are fine-grained, moderately sorted and micaceous and in some parts, they are calcareous and shelly (which helps in absorbing intense heat) and are loosely packed. The variation in values may be attributed to the movement of the sun along the equator, body geometry as well as varying intensities of the sun for the different days of measurement.

The cumulative mean of UV radiation exposure in this study for the traders, fishermen and staff/students were 4.977kJ/m^2, 4.231kJ/m^2, 4.354kJ/m^2 respectively within a 6 working hour-exposure. The mean UV radiation exposures were higher than the recommended value of 30J/m^2 by ICNIRP international standard for occupational exposure as stated in Vecchia et al. [14], for a 6-hours exposure period for both the eyes and skin. This, therefore has the potential of causing cell damage as well as various UV related diseases like skin cancer, DNA damage etc. [14]. Majority of the damage due to solar UV radiation is as a result of this little but intermittent and cumulative absorbed doses which over a period of time, affects the body in later stages of life. The chronic exposure gives rise to accelerated skin aging process, increases the risk of developing skin cancer; both melanoma and non-melanoma, eye cataracts, and pterygium which are prominent in North Central Nigeria especially within the age bracket of 50 years and above. This finding is not in line with the findings of Igbawua et al. [3] who worked on average solar UV radiation dosimetry in central Nigeria using UVR meter and Polymer Polysulphone dosimeters at Gboko, central market, Benue State and obtained a mean UV radiation exposure of 432 ± 47J/m^2, the values in the present study exceeded their own by more than a factor of 10.

The daily cumulative exposure of workers to UV radiation were calculated to be 3289.36kJ/m^2, 497.82kJ/m^2, and 1515.60kJ/m^2, at Wurukum Market, River bank and BSU campus respectively. The results from this study clearly depicts that, people who allow direct penetration of UV radiation exposure on their skin have high risk of developing chronic effects of UVR exposure even without the acute effects especially at the Wurukum market. Although there maybe variations with different individual exposure due to the position while carrying out daily activities. Apart from women who use artificial hairs on their heads and few covering their heads with head-ties and hats, greater population normally leave their heads unprotected. Therefore, it is necessary for constantly using protective covers such as hats and shade, sun glasses and protective clothing among others as a means of protection against high UVR exposures which could lead to harmful effects like photo aging, skin cancer, etc. This finding is in line with the findings of Sabburg et al. [16] who carried out a research to determine the effect of cloud coverage on UVA exposures to humans in Toowoomba, Australia using broad-band visible-infrared and UVA sensors together with a sun tracking, wide-angle video camera and recorded a daily cumulative UVA exposure of 688.8kJm^{-2} for 48% overall sky cloud coverage with the sun covered 60% and daily cumulative UVA exposures of 652.5kJm^{-2} and 568.1kJm^{-2} for 27% overall sky cloud coverage with the sun covered 40% and 100% respectively. Also, this finding is in line with that of Sombo et al. [6] who measured and modeled ultraviolet radiation exposure of outdoor workers (Traders, Drivers/Commuters and Construction workers) within Makurdi Metropolis using digital broad band meter and Polymer Polysolphone dosimeters and obtained the highest values from the dosimeters placed on head top 8.73kJ/m^2, 6.67kJ/m^2 and 7.40kJ/m^2 for drivers/commuters, construction workers and traders respectively. They also obtained the least values with the dosimeters worn under clothe cover 2.06kJ/m^2, 2.56kJ/m^2 and 3.07kJ/m^2 at the market square, car park and construction site respectively. Their cumulative exposure was 610.98kJ/m^2, 1923.84kJ/m^2 and 3526.92kJ/m^2. Also in line with the current research is the findings of Sombo et al. [5], who carried out an assessment of indoor and outdoor solar ultra-violet (UV) radiation at commercial centers in Makurdi metropolis using a portable digital solar power meter (TM-206) and obtained the outdoor mean UV irradiance of 697.24± 8.74W/m^2 with corresponding cumulative exposure of 2510.18 ± 0.61kJ/m^2 and indoor UV mean irradiance of 77.87 ± 6.50W/m^2

with corresponding cumulative exposure of 280.34 ± 0.48kJ/m^2 for traders and the general public in the market places.

However, these findings are not in line with that of Herlihy et al. [17] who measured solar UV for recreational activities such as tennis, sailing, swimming, walking, golf, and gardening in Hobart, Tasmania using polysulphone badges on parts of the body such as the cheek, hand, shoulder, back, chest, thigh, and calf. They found that collectively, those who sailed received the highest cumulative UV exposures (1712J/m^2 ± 435), in addition, taking all of the activities into consideration, the shoulder received the highest exposure of 0.43J/m^2. The difference in result is could be due to the fact that they made use of individuals who were moving from one place to another while carrying out gaming activities which means they would have spent most of the day in sheds. Furthermore, regional variation could be the reason for the difference in result. Also, the findings are not in line with those of Wright and Coetzee [18] who worked on ambient solar UV radiation and seasonal trends in potential sunburn risk among school children in South Africa, using UV Biometers (model 501) comprising a Robertson-Berger pattern UV radiation detector, digital recorder and control unit. They obtained the highest seasonal averaged ambient solar UV-B radiation of 1.36kJ/m^2 in De Aar during summer and the lowest record of 0.27kJ/m^2 at Cape Point during winter. The seasonal variation in the amount of ambient solar UV-B radiation was very small, ranging between 0.14kJ/m^2 and 0.5kJ/m^2. The disagreement in the findings of the current study is due to the fact that different methods were deployed for both research. More so, Wright and Coetzee [18] focuses on the ambient solar irradiance, whereas the current research focused on the occupational exposure to UV radiation. This finding is also not in line with those of Gies et al. [19] who quantified UVR exposure of building and construction workers involved in typical outdoor work by using UVR-sensitive polysulphone film badges. The doses received ranged from a median SED of 0.29 (29J/m^2) for cabinet makers to 9.98 (998J/m^2) for pavers and tillers. When taking all 19 occupations and nearly 500 workers into account, the median SED was 4.53 (453J/m^2). The difference could also be as result of region and climatic variations. Furthermore, the constant depletion of ozone layer by the increased emission of greenhouse gases could be the reason for disparity in both findings.

The result from the calculated UV Index showed that WM have the highest UV Index value of 9 which indicates high risk of harm from unprotected sun exposure. While that of BSU and RB were found to have UV Index of 8 which also depict high risk of harm from unprotected sun exposure as categorized by WHO [20]. Such effects include photo-conjunctivitis, skin cancers, cortical cataract, carcinoma of cornea, plant susceptibility to diseases and great threat to crops and ecological system. It is therefore advice that people within this region should wear protective clothing, sunglasses as well as avoid outdoor activities for long period especially in dry season in other to avoid adverse effects of over exposure.

5. CONCLUSION

This research work made use of a polymer polysulphone dosimeter which were fitted on a human like figure to measure UV radiation on different parts of the body for traders at market square, fishermen at the river bank and Staff/Student at the Benue State University campus respectively. The UV radiation exposure on different human body parts varies with difference in body parts. From the result, the head top had the highest values, while the dosimeters worn under clothe cover had the least values. Similarly, UV Irradiances at various intervals were measured and the cumulative exposures were calculated. The UV Index were calculated at the peak hours of the research and were found to be quite high, which implies that if proper precautionary measures are not taking before engaging in outdoor activities, it may lead to over exposure to UV radiation that can cause both acute and chronic effects.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Diffey BL. Solar ultraviolet radiation effects on biological systems. Physics of Medical Biology. 1991;36(3):299–328.

2. IARC Publications. Vitamin D and Cancer. International Agency for Research on Cancer working group reports Volume 5. Lyon Cedex, France; 2008.
3. Igbawua T, Ikyo B, Agba E. Average solar UV radiation dosimetry in Central Nigeria. International Journal of Environmental Monitoring and Analysis. 2013;1(6):323-327.
4. Wolska A. Occupational explosive to solar ultraviolet radiation of polish outdoor workers: Risk estimation method and criterion. International Journal of Occupational Safety and Ergonomic. 2013;19(1):107-116.
5. Sombo T, Ellah MS, Awuhe AA, Geoffrey FT, Shivil TJ. Assessment of solar ultra-violet radiation exposure at major commercial centers in Makurdi Metropolis, North Central-Nigeria. IOSR Journal of Applied Physics (IOSR-JAP). 2018;10(3): 12-14.
6. Sombo T, Shivil TJ, Igbawua T. Measurement and assessment of occupational exposure to solar ultraviolet radiation in Makurdi Metropolis, Benue State, Central Nigeria. Radiation Science and Technology. 2021;7(2):32-40.
7. WHO. Health and Environmental Effects of Ultraviolet Radiation. A scientific summary of environmental health criteria 200, Ultraviolet Radiation (WHO/EHG/99.37); 2006.
8. Shivil TJ. Measurement and modelling of occupational exposure to solar ultraviolet radiation in Makurdi Metropolis, Benue State. An MSc Thesis Submitted to the School of Postgraduate Studies, University of Agriculture Makurdi, Nigeria (Unpublished); 2019.
9. Inter Press Service. Nigeria: Census Stirs Up Emotions in States, Africa News. 2007;2:12.
10. Park SS, Lee YG, Kim M, Kim J, Koo J, Kim CK, Um J, Yoon J. Simulation of threshold in UV exposure time for vitamin D synthesis in South Korea. Advances in Meteorology; 2019.
    Available:https://doi.org/10.1155/2019/4328151.
11. Parisi A, Turnbull DJ. Solar UV dosimetry. In: UV Radiation and its Effects: An Update 2006, 19-21 Apr 2006, Dunedin, New Zealand; 2006.
    Available:https://eprints.usq.edu.au/1476/.
12. Parisi AV, Turnbull DJ, Schouten P, Downs N, Turner J. Techniques for solar dosimetry in different environments. In UV radiation in global climate change. Springer, Berlin, Heidelberg; 2010.
13. Downs N, Parisi AV, Galligan L, Turner J, Amar A, King R, Ultra F, Butler H. Solar radiation and the UV index: An application of numerical integration, trigonometric functions, online education and the modelling process. International Journal of Research in Education and Science (IJRES). 2016;2(1):179-189.
14. Vecchia P, Hietanen M, Stuck BE, Van Deventer E, Niu S. Protecting workers from ultraviolet radiation. Oberschleißheim Germany: International Commission on Non-Ionizing Radiation Protection. 2007; 14.
15. Agada I, Ibuot JC, Ekpa M, Obiora DN. Investigation of subsurface for construction purposes in Makurdi, Benue State, Nigeria using electrical resistivity method. Journal of Geology and Mining Research. 2017;9(2):9-17.
    Available:https://doi.org/10.5897/JGMR2017.0275.
16. Sabburg J, Rives JE, Meltzer RS, Taylor T, Schmalzle G, Zheng S, Huang N, Wilson A, Udelhofen PM. Comparisons of corrected daily-integrated erythema UVR data from the U.S. EPA/UGA network of Brewer spectroradiometers with model and TOMS-inferred data. Journal of Geophysical Research: Atmospheres. 2001;107(D23):4676.
    DOI:10.1029/2001JD001565.
17. Herlihy E, Gies PH, Roy CR, Jones M. Personal dosimetry of solar UV radiation for different outdoor activities. Photochemistry and Photobiology. 1994; 60(3):288-294.
18. Wright CY, Coetzee G. Ambient solar UV radiation and seasonal trends in potential sunburn risk among schoolchildren in South Africa. South Africa Journal of Child Health. 2011;5(2):33-38.
19. Gies DR, Bolton CT, Thomson JR, Huang W, McSwain MV. (2003). Wind accretion and State Transitions in Cygnus X-11. The Astrophysical Journal. 2003;583(1):424-436.
20. WHO. Global solar UV index: A practical guide. A joint recommendation of the World Health Organization, World

Meteorological Organization, United Nations Environmental Programme, and the International Commission on Non-Ionizing Radiation Protection. World Health Organization, Geneva; 2002. ISBN 92 4 159007 6.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/122084