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TYPICAL SOLAR RADIATION DATA FOR OSOGBO, NIGERIA

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Abstract

The measured values of the hourly global solar radiation, GR, on a horizontal surface for a year period (January 1st–December 31st,2017) have been collected and used to examine the solar radiation characteristics in Osogbo, Nigeria. The daily total values and their monthly and seasonal means, as well as their frequency distributions, have been calculated and investigated. The preliminary data set show the annual trend of GR to be symmetry around August, with peak value of about 23.38 MJ m^{-2} in June and a minimum value of 3.26 MJ m^{-2} in August, which is the peak of the monsoon season. It was also noticed that 5MJm^{-2}, 10 MJm^{-2}, 15MJm^{-2} and 20 MJm^{-2} of GR are received for 362, 311, 170 and 9 days over the year respectively. A comparative study has also been done to investigate the quantity of global radiation values received in Osogbo. It was found that GR values received during the period is low when compared to other region around the world.

KEYWORDS: Global solar radiation, Osogbo, distribution, seasonal, frequency.

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INTRODUCTION

The knowledge of global irradiation for a given region is essential for the utilization of solar energy. Adequate information on the intensity of global irradiance at a given location is used as a guide for the design of solar energy conversion equipment and can also be utilized in cost analysis of the solar system. The financial analysis of any investment in solar system is heavily dependent on accurate inputs of highly organized data. But readily available insolation data, from weather stations all over the world are poorly distributed and spotty and such cannot be used in solar application. Therefore, it become necessary for these data to be processed, examined and organized for the design of solar systems [1]. For instance, when designing an efficient solar system, the number of consecutive days with insolation above or below certain threshold hold the bases of the size of the solar components that will be required for the design. Researchers in the past have used statistical tools to analyze solar radiation data in a format for practical applicability. Raja and Twidell [2] constructed cumulative frequency distribution for daily global insolation over five locations (Karachi, Quetta, Multan, Lahore and Peshawar) in Pakistan. The study revealed that the locations have at least 85% probability of receiving daily insolation greater than 10 $MJm^{-2}d^{-1}$, while Quetta and Karachi have 85% probability of receiving daily insolation greater than 15 $MJm^{-2}d^{-1}$. In a later year Raja and Twidell [1] presented a quantitative variability of global insolation over Pakistan. The cumulative frequency distribution shown that an average of 10 $MJm^{-2}d^{-1}$ of insolation were expected to be received in 324, 261, 338, 351, 331 and 349 days per year in Islamabad, Karachi, Lahore, Multan, Peshawar and Quetta. Al-Hinai and Al-Alawi [3] constructed a cumulative frequency distribution of insolation over six locations (Buraimi, seeb, fahud, sur, marmul and salalah) in Oman. They found that, in Salalah, 12 $MJm^{-2}d^{-1}$ of global insolation are expected for 5 days in August and 324 days over the year, while in Seeb the global insolation of 12 $MJm^{-2}d^{-1}$ is expected for 31 days in August and 354 days over the year. The main objective of this study is to use statistical tools to describe the characteristics and behavior of global solar radiation, and to contribute significantly to the measurement and analysis of global solar radiation in this part of the

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world, because there are no previous studies or publications on Osogbo's solar radiation climate.
77.3% days at Kigali. Therefore,

Methodology

Site description

Osogbo, the city in which this research project is located, is the Osun state capital in Nigeria, with coordinates of latitude7.77°N; Longitude 4.57°E; altitude 288m. Osogbo is located in the forest zone of southern Nigeria. The mean yearly temperature is about 27°C while the mean yearly rainfall is between 1200 mm and 1450 mm. The country, and of course Osogbo experience two distinctive seasons. The wet season (May to October) and the dry season (November to April). These seasons are influenced by the Northeasterly dry Harmattan wind from the Sahara Desert which gives rise to the dry seasons and the Southwesterly humid Monsoon wind from the Atlantic Ocean give rise to the rainy season [4]. The project site is on a flat platform at the top of Department of Physics Electronics & Earth Sciences building located within the campus of Fountain University, Osogbo, far from any obstructing structures.

Data collection and rehabilitation

Solar radiation data from Davis Wireless Vantage Pro2 weather station in Osogbo were obtained for a complete year in 2017. The solar radiation measured is the global i.e the sum of direct and diffuse radiation as recorded by Davis pyranometer. Following the rehabilitation techniques adopted by [5], the collected data were examined for missing data. Missing data were replaced and erroneous values were removed. From the global solar radiation data collected every minute, the daily and monthly mean were obtained from the recorded GR values.

Results and discussion

Characteristics of global solar radiation, GR, on a horizontal surface

The mean values of the hourly GR received on a horizontal surface through a day in different months for the period January 1st to December 31st, 2017 are plotted and presented in Figures 1 and 2. In addition, the daily totals and the monthly and seasonal mean values GR through the same period have been computed and illustrated in Figures 4–6 respectively

Hourly variation of GR

It is noticed from (Fig 1 and 2) that the GR is symmetry around August with respect to the months. An increase in GR values around noon from January to March (0.29 MJ m−2) is noticed with a decrease from March to August (1.45 MJ m−2), while a step wise increase from August to December (1.41 MJ m−2) was also noticed. The rise and fall of the hourly values of GR throughout the day is generally symmetrical with respect to the solar noon for all days of the year.

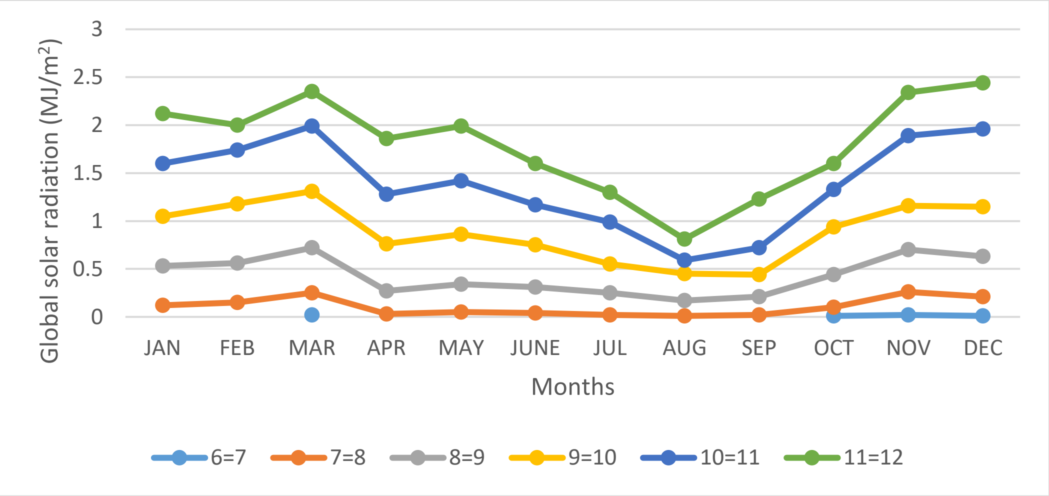

Fig. 1. Monthly mean average hourly global radiation for 6-12 hour (GMT)

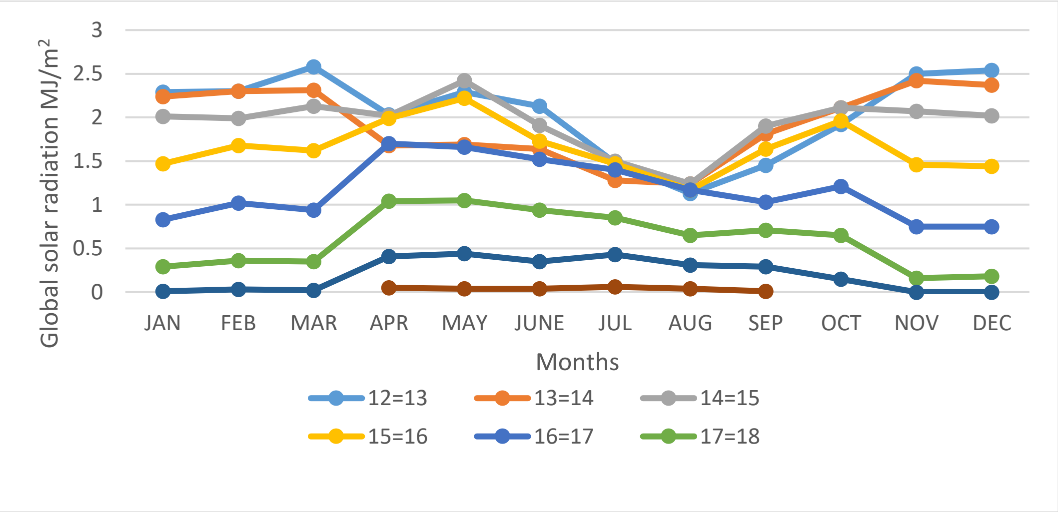

Fig. 2. Monthly mean average hourly global radiation for 12-20 hour (GMT)

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The maximum values are recorded around local noon, with average values ranging from 2.58 MJ m^{-2} in March to 1.13 MJ m^{-2} in August in a rather symmetrical way, while the minimum values are observed at early morning and late afternoon. This pattern is mainly due to the solar height as well as the outcome of the longer path traversed by the solar radiation in the early morning and late afternoon than in the solar noon. This longer path navigation comes with greater amount of absorption and scattering leading to reduction of the global solar radiation in the early morning and late afternoon hours compared to the noon time.

In addition, it is also noticed that the GR values in the forenoon are much lower than in the afternoon during the months of the year with the exception of month of December. The mean difference between GR values for 2 h before and after noon for the wet season months (May to October) equals 0.70, 0.78, 0.49, 1.08, 1.76 and 1.29 MJ m^{-2} for May, June, July, August, September and October respectively. However, the mean difference between GR values for 2 h before and afternoon for the dry season months of November, January, February, March and April equals 0.26, 0.53, 0.7, 0.1 and 0.56 MJ m^{-2} respectively, with no significant differences between 2 h before and after noon for the month of December. This may be attributed to the fact that the concentration of atmospheric pollutants in the forenoon is higher than in the afternoon because of the existence of frequent surface inversions, also the vast amount of water vapor and high air mass, in turn increases the depletion of radiation during the wet season (May to October).

Variation of daily total of GR.

Figure 3 shows the variation of the daily total values of GR for the study period. It was found that the daily values of GR vary from the minimum value of 3.26 MJ m^{-2} on day 241st (29 August), which is the peak of the monsoon season to the maximum value of 23.38 MJ m^{-2} on day 153rd (2 June), which is within the beginning of the wet season month. Also noticeable from the figure are the remarkable variation in the daily averages, especially during the wet months (May to October). This variation is due to the fluctuation of the atmospheric conditions such as dust, atmospheric water vapor content and type of clouds, which consequently affect the radiation balance over the area [6].

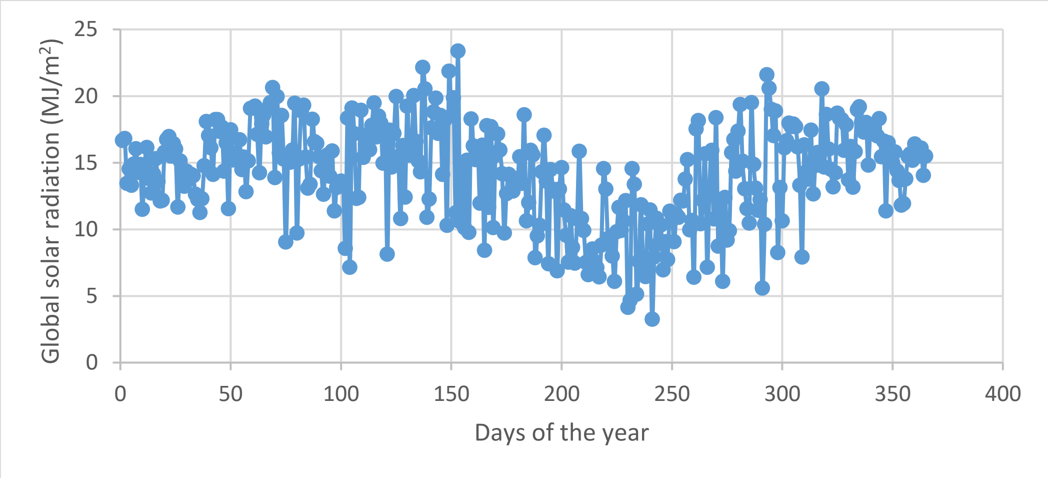

Fig. 3. Daily average and daily peaks of global solar radiations throughout the year

Variation of monthly and seasonal means of GR

Figure 4 shows the variation of the monthly mean of GR during the study period. It is seen that the monthly mean values of GR vary between a minimum value of 8.98 MJ m^{-2} during August and a maximum value of 16.59 MJ m^{-2} during March, i.e. by a factor of 1.8. The results of the monthly mean of GR show that the standard deviation has relatively high values in May (±3.48) and October (±3.92) compared with the small values of January (±1.54) and December (±1.87). This may be attributed to the strong fluctuation in the density of atmospheric dust particles.

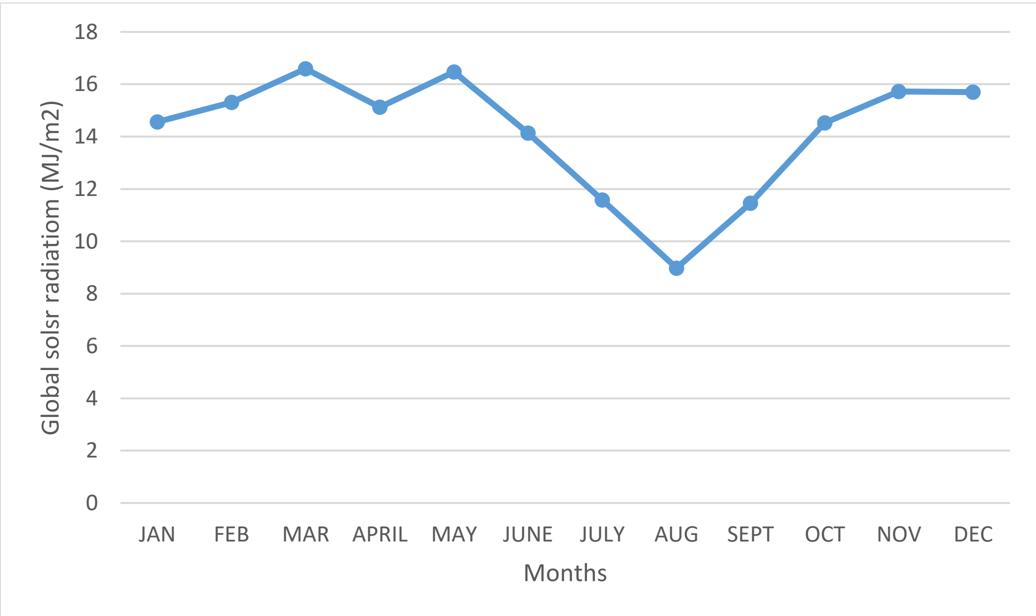

Fig 4. Variation of the monthly mean of GR

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Frequency distribution of GR.

The cumulative frequency distribution of GR in different months and the whole period are given in Table 1. From this table, the first column gives a threshold class interval of 1 MJm^{-2} of GR, while the next 12 columns contain the mean number of days for each month for which the values of GR are greater than or equal to the given class interval. The last column contains the highest number of consecutive days per month occurring over the year. It is noticed that 5MJm^{-2}, 10 MJm^{-2}, 15MJm^{-2} and 20 MJm^{-2} of GR are received for 362, 311, 170 and 9 days over the year respectively. It must be noted that there is no day in the year that has a value of GR greater than 25 MJm^{-2}. The number of days with GR value between 5 MJm^{-2}-10 MJm^{-2}, 10 MJm^{-2} – 15 MJm^{-2} and 15 MJm^{-2} - 20 MJm^{-2} are 51, 141 and161 days over the year respectively. However, 10 MJm^{-2} and above of GR was received through out in the months of January, February and December and for about 20 days or more for the rest of the months with exception of August where 10 MJm^{-2} was received for just 11 days

Table 1. Cumulative frequency of daily global radiation

MJm-2d-1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1	31	28	31	30	31	30	31	31	30	31	30	31	365
2	31	28	31	30	31	30	31	31	30	31	30	31	365
3	31	28	31	30	31	30	31	31	30	31	30	31	365
4	31	28	31	30	31	30	31	30	30	31	30	31	364
5	**31**	**28**	**31**	**30**	**31**	**30**	**31**	**28**	**30**	**31**	**30**	**31**	**362**
6	31	28	31	30	31	30	31	27	30	30	30	31	360
7	31	28	31	30	31	30	29	23	27	30	30	31	351
8	31	28	31	29	31	30	24	17	25	30	29	31	336
9	31	28	31	28	30	29	23	14	23	29	29	31	326
10	**31**	**28**	**29**	**28**	**30**	**27**	**20**	**11**	**20**	**27**	**29**	**31**	**311**
11	31	28	29	28	27	24	16	8	15	24	29	31	290
12	29	26	29	27	27	21	14	5	12	22	29	28	269
13	26	22	29	24	25	19	12	4	8	20	28	28	245
14	20	22	26	19	25	16	8	2	6	17	23	26	210

15	**12**	**16**	**25**	**16**	**22**	**13**	**5**	**0**	**6**	**15**	**17**	**23**	**170**
16	8	11	17	12	19	8	2		3	13	14	13	120
17	0	8	14	9	16	5	2		3	10	10	9	86
18		4	12	5	12	2	1		2	6	6	4	54
19		1	8	2	8	1	0		0	5	1	1	27
20		**0**	**1**	**0**	**4**	**1**				**2**	**1**	**0**	**9**
21			0		2	1				1	0		4
22					1	1				0			2
23					0	1							1
24						0							0

Comparison of Osogbo's solar radiation climate to those reported around the world

The results of the analysis of the solar radiation climate for Osogbo is compared with similar analysis earlier conducted for Oman [3] and some cities in Pakistan [2]. The percentage distribution of numbers of days with insolation for these regions are presented in table 2.

Table 2. Percentage distribution of numbers of days with insolation

	Percentage distribution of numbers of days with insolation							
$G(MJ/m^2)$	Osogbo[P/S]	Salalah[3]	Seeb[3]	Peshawar[1]	Lahore[1]	Multan[1]	Quetta[1]	Karachi[1]
5	362(99.1%)	363(99.4%)	365(100%)	355.2(97.5%)	357.5(97.9%)	359.9(98.6%)	362.9(99.4%)	361.9(99.1%)
10	**311(85.2%)**	**337(92.3%)**	**359(98.3%)**	**331.2(90.7%)**	**314.3(86.1%)**	**335.4(91.9%)**	**349.9(95.9%)**	**350.8(96.1%)**
15	170(46.5%)	296(81.1%)	318(87.1%)	247.8(67.9%)	210.6(57.7%)	250.7(68.7%)	305.3(83.7%)	300.7(82.4%)
20	**9(2.5%)**	**110(30.1%)**	**227(62.1%)**	**166.6(45.6%)**	**116.1(31.8%)**	**150.9(41.3%)**	**218.4(59.8%)**	**160.5(44.0%)**
25	-	-	80(21.9%)	75.6(20.7%)	42.1(11.5%)	49.6(13.6%)	129.4(35.4%)	36.3(10.0%)
30	**-**	**-**	**-**	**10.0(2.8%)**	**-**	**-**	**36.3(5.7%)**	**-**

From table 2, it is clearly noticed that Seeb has the greatest percentage for all levels of GR values throughout the year, but with a GR value not greater than 25 MJm^{-2}. Osogbo has the lowest percentage for all levels of GR values throughout the year, and also with a GR value not greater than 25 MJm^{-2}. Peshawar and Quetta are the only stations that receive GR greater than 30 MJm^{-2} for 2.8% and 5.7% of days over the year respectively.

Conclusion

The present study is an attempt to study the characteristics and behavior of global, *GR*, measured values in Osogbo. Also, the solar radiation climate of Osogbo has been compared with those reported for other sites in the world. The results are summarized in the following:

(1) The GR is symmetrical with respect to the solar noon for all days of the year.
(2) The maximum values of GR are recorded around noon with average values ranging from 2.58 MJm^{-2} in March to 1.13 MJm^{-2} in August.
(3) The minimum values of GR are observed at early mornings and late afternoons.
(4) The monthly mean GR varies between 8.98 MJm^{-2} in August and 16.59 MJm^{-2} in March.
(5) The cumulative frequency distribution reveals that Osogbo has the lowest percentage for all levels of GR values throughout the year, and also with a GR value not greater than 25 MJm^{-2}.

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