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## Analysis of Experimental Solar Radiation Data for Osogbo, Nigeria

\*Yusuf, A., Bolarinwa, H.S., Animasahun, L.O. and Babatunde, Y.O.

*Department of Physics Electronics and Earth Sciences, Fountain University, Osogbo, Nigeria*

### Abstract

An analysis of measured global solar radiation (GR) in Osogbo (7.77°N, 4.57°E, 288m) is presented in the form of hourly average, monthly average and percentage frequency distribution. The experimental data corresponds to a year data of 2017. The results reveal that the monthly average values of daily total radiation exhibit seasonal variation with maximum value in dry season month of March (16.59MJ/m<sup>2</sup>) and minimum value in wet season month of August (8.98 MJ/m<sup>2</sup>). The annual average GR value is 14.20 MJ/m<sup>2</sup> while the annual cumulative GR is 5122 MJ/m<sup>2</sup>. The solar radiation climate of Osogbo has also been compared to those reported for a number of locations. The percentage frequency of days possessing irradiation rate greater than 15 MJ/m<sup>2</sup> is 14 percent whereas that possessing less than 10 MJ/m<sup>2</sup> is 61 percent. We conclude, based upon the above analysis that Osogbo is characterized by relatively low global solar radiation.

**Keywords:** Global solar radiation, Cumulative frequency, Measured, Seasons

### Introduction

The knowledge of global solar radiation is vital in the design of a solar energy conversion system. Global solar radiation received at any site should be useful not only to the location where the radiation data is collected but for the world (Okundamiya, Emagbetere, & Ogujor, 2016; Nwokolo & Ogbulezie, 2018; Neelamegama & Amirtham, 2016). Because the global study of the world distribution of global solar radiation requires data for various countries and for the purpose of worldwide marketing, the designers of solar equipment will need to know the average global radiation available in different locations (Akapbio & Etuk, 2002; Ajayi, Ohijeagbon, Nwadialo, & Olasoje, 2014). However, it is the nature of these data to be spotty, poorly distributed, so can not be

directly used in solar applications. Therefore, these data have to be organized, analyzed and examined to identify missing records, outliers and erroneous values (Masseti, 203; Feng, Hu, & Qian, 2004). Researchers around the world, have used statistical analyses such as cumulative frequency distribution and frequency table, in order to reform the raw data into practical information. For instance, Joseph and Danny (Joseph & Danny, 1996) analyzed the solar radiation in Hong Kong and discovered that over 80% of solar radiation measured in the region occurs between 9:00 to 17:00 (local time). However, Topcu et al (Topcu, Dilmac, & Aslan, 1995) studied the total radiation received in turkey

\*Corresponding author: +2348063667704

Email address: [yabdulhamid10@yahoo.com](mailto:yabdulhamid10@yahoo.com)

based on seasons. The authors used the annual average of hourly total radiation of  $300\text{w/m}^2$  for that region as a benchmark for classification. It is worth noting that over 40% of data obtained in spring and autumn exceed the annual total radiation of  $300\text{w/m}^2$ , while 60% and 20% data for summer and winter exceed the annual total respectively. Using a frequency distribution table, Kudish et al (Kudish, Wolf, & Machlav, 1983) correlated the global irradiation incident on a horizontal surface in Israel. They observed that 46% of days possessed irradiation greater than  $20\text{MJ/m}^2$  while 11% possessed less than  $10\text{MJ/m}^2$  of irradiation. Kuye and Jagtap (Kuye & Jagtap, 1992) analyzed 13-year data of global irradiation incident on a horizontal surface in Port Harcourt, Nigeria. They discovered that the rate of variation in solar radiation occurs mostly in the wet season. Cavalcanti (Evandro, 1991) presented the solar radiation data for Rio De Janeiro, Brazil. The author observed that 64.1% of days of the year possessed solar radiation greater than  $14\text{MJ/m}^2$  while 12 percent of days possessed solar radiation less than  $7.2\text{MJ/m}^2$ . Recently, Gairaa and Benkacali (Gairaa & Benkacalia, 2011) studied the seasonal variation in solar radiation field in southern Algeria Peninsula. The recorded the monthly average daily higher value of radiation in summer ( $7762\text{Wh/m}^2$ ) and lower ones in winter ( $3915\text{Wh/m}^2$ ). Despite the amount of work on the study of solar radiation around the world, none of these types of investigation have been related to Osogbo, southwest region of Nigeria. Therefore, the aim of this study is to analyze the measured global solar radiation, so as to provide designers and engineers of solar technology with solar radiation data for Osogbo.

## Material and Method

### Climatic Characteristics

Nigeria lies between latitudes  $4^\circ$  and  $14^\circ$  North of the equator and between longitude  $3^\circ$  and  $15^\circ$  east of the Greenwich Meridian. Its average yearly solar radiation on a horizontal surface varies between  $3.7\text{KWhm}^{-2}\text{day}^{-1}$  along the coastal area and  $7.0\text{KWhm}^{-2}\text{day}^{-1}$  along the semi-arid area to the north (Ojosu, 1990). The country experiences a tropical climate with 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 (Ezekwe, 1998). Osogbo ( $7.77^\circ\text{N}$ ,  $4.57^\circ\text{E}$ , 288m), the southwest region of Nigeria under study lies along the path of this front and receives both weather conditions. This area is characterized by high humidity and rainfall. The mean yearly temperature is about  $27^\circ\text{C}$  and its relative humidity is between 92% and 99% (Ola & Adewale, 2014). The mean yearly rainfall is between 1200 mm and 1450 mm (Nigerian Environmental Study/Action Team (NEST). Nigeria's Threatened Environment: A National Profile, 2019)

### Experimental Setup and Procedure

The result showed in this work were obtained for a complete year in 2017, using a Davis Wireless Vantage Pro2 weather station. The weather station contains sensors for global solar radiation, relative humidity, temperature, rainfall, wind speed and wind direction, which are packaged and termed Integrated Sensor Suite (ISS). The GR on a horizontal surface has been measured using the Davis pyranometer. A console which integrates a weather link software and USB data logger that connects directly to a computer continuously saved data record. The instrument is installed at the top of Department of Physics Electronics & Earth Sciences building located within the campus of Fountain University, Osogbo, far from any obstructing structure. From the global solar radiation data collected every minute, the average hourly values were calculated. From the hourly data set, the daily and monthly statistics were calculated.

## Results and Discussions

### Monthly and Annual Global Solar Radiation

The monthly and annual values of GR on the horizontal surface are shown in Table 1. From the table, it can be seen that the yearly cumulative GR is  $5122.53\text{MJ/m}^2$ . The dry season months (November to April), contribute 53.9 percent of the annual total, while the wet season months (May to October) contribute about 46.1 percent. The GR recorded in the dry season is not as high as expected

when compared with that of the wet season. This is because the dry Harmattan wind that blows over the country within the dry season months decreases the high solar radiation that would to have been received under the clear sky conditions (Ezekwe , 1998). The month of August contributes the least, bring responsible for only about 5.4 percent. This is due to the prevailing raining cloud situation in Nigeria in the month of August (Fagbenle , 1992).

**Monthly Average Hourly Global Radiation**

The annual monthly averages of hourly global radiation and monthly averages of daily total radiation values are presented in Table 2. At the time of maximum incoming solar radiation, the average hourly GR values are 2.37 MJ/m<sup>2</sup> (12-13h) and 1.73 MJ/m<sup>2</sup> (12-13h local time) in dry and wet seasons respectively. The annual average GR value is 14.20 MJ/m<sup>2</sup>. The monthly average values of daily total radiation vary with seasons with a maximum value of 16.59MJ/m<sup>2</sup> occurs in the dry season month of March and minimum value of 8.98 MJ/m<sup>2</sup> occurs in the wet season month of August. This seasonal variation is typical of the tropical rain climate of the southwest region of Nigeria and is

mainly due to the moderate degree of cloudiness & Suleman , 1989; Griffiths, 1981).

**Frequency Distribution of Daily Global Radiation**

The percentage frequency distribution of daily total GR for each month is given in Table 3. In November 80.6 percent of all days receive less than 15 MJ/m<sup>2</sup> and in March the corresponding figure is 86.8 percent. During the dry season (November - April) 84.9 percent of all days receive less than 15 MJ/m<sup>2</sup> and only 1 percent exceed 20 MJ/m<sup>2</sup>and none above 25 MJ/m<sup>2</sup>. In the wet season (May - October) 12.6 percent of all days receive between 15 MJ/m<sup>2</sup>and 25 MJ/m<sup>2</sup> but only 0.1 percent exceed 30MJ/m<sup>2</sup>.

**Comparison of Osogbo’s Solar Radiation Climate to those Reported for Other Sites in the Region**

The results of our analysis of the solar radiation climate for Osogbo was compared with similar analysis earlier conducted for Port Harcourt climate by Kuye and Jagtap (Kuye & Jagtap, 1992)The parameters describing the two solar radiation climates are presented in table 4.

**Table 1: Monthly and Annual Totals of Global Solar Radiation (Gr) on A Horizontal Surface (Mj/M<sup>2</sup>)**

JAN	FEB	MAR	APR	MAY	JUNE	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
451.34	428.30	497.19	422.88	510.08	423.82	358.43	278.17	343.43	450.09	471.81	486.99	5122.53

**Table 2: Monthly average hourly global radiation (MJ/m<sup>2</sup>)**

	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	DAILY TOTAL
JAN		0.12	0.53	1.05	1.60	2.12	2.29	2.24	2.01	1.47	0.83	0.29	0.01		14.56
FEB		0.15	0.56	1.18	1.74	2.00	2.30	2.30	1.99	1.68	1.02	0.36	0.03		15.31
MAR	0.02	0.25	0.72	1.31	1.99	2.35	2.58	2.31	2.13	1.62	0.94	0.35	0.02		16.59
APR		0.03	0.27	0.76	1.28	1.86	2.03	1.68	2.02	1.99	1.70	1.04	0.41	0.05	15.12
MAY		0.05	0.34	0.86	1.42	1.99	2.29	1.69	2.42	2.22	1.66	1.05	0.44	0.04	16.47
JUN		0.04	0.31	0.75	1.17	1.60	2.13	1.64	1.91	1.73	1.52	0.94	0.35	0.04	14.13
JUL		0.02	0.25	0.55	0.99	1.30	1.48	1.28	1.50	1.47	1.40	0.85	0.43	0.06	11.58
AUG		0.01	0.17	0.45	0.59	0.81	1.13	1.24	1.24	1.17	1.17	0.65	0.31	0.04	8.98
SEP		0.02	0.21	0.44	0.72	1.23	1.45	1.81	1.90	1.64	1.03	0.71	0.29	0.01	11.46
OCT	0.01	0.10	0.44	0.94	1.33	1.60	1.92	2.11	2.11	1.96	1.21	0.65	0.15		14.53
NOV	0.02	0.26	0.70	1.16	1.89	2.34	2.50	2.42	2.07	1.46	0.75	0.16			15.73
DEC	0.01	0.21	0.63	1.15	1.96	2.44	2.54	2.37	2.02	1.44	0.75	0.18			15.70
Yearly	0.02	0.11	0.43	0.88	1.39	1.80	2.05	1.92	1.94	1.65	1.17	0.60	0.20	0.04	14.20

**Table 3: Percentage frequency distribution of daily totals of global solar radiation**

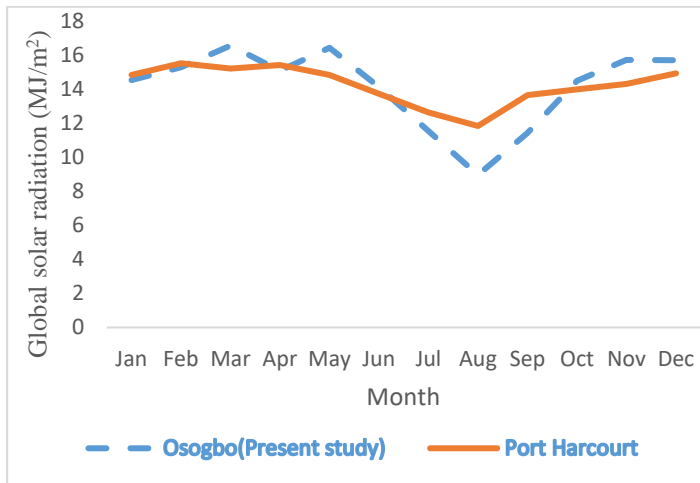
	0-5	5-10	10-15	15-20	20-25	25-30	30-35
JAN	33.6	21.2	29.0	15.9	0.3	0	0
FEB	34.5	22.3	29.2	13.4	0.5	0	0
MAR	36.5	23.3	27.0	12.4	0.8	0	0
APR	37.1	25.5	26.6	9.9	0.8	0	0
MAY	39.5	23.6	25.3	10.7	0.7	0.2	0
JUN	40.0	21.5	27.2	8.5	2.0	0.7	0
JUL	38.7	23.8	25.6	10.9	0.7	0.2	0
AUG	38.0	27.0	23.8	8.4	2.7	0	0
SEP	43.3	23.8	16.2	10.5	5.1	0.7	0.3
OCT	34.7	24.6	25.7	12.7	2.3	0	0
NOV	36.7	21.7	22.2	16.9	2.5	0	0
DEC	42.2	18.6	21.8	16.9	0.5	0	0
dry	36.8	22.1	26	14.3	0.9	0	0
wet	39	24.1	24	10.3	2.3	0.3	0.1
year	37.9	23.1	25	12.3	1.6	0.2	0.0

**Table 4: A comparison of the solar radiation climates of Osogbo, Nigeria and Port Harcourt, Nigeria**

	Osogbo	Port Harcourt
Latitude	7.77°N	4.44°N
Longitude	4.57°E	7.1°E
Elevation	288 m	20 m
Annual average daily global solar radiation (MJ/m <sup>2</sup> )	14.20	14.24
Annual total global solar radiation (MJ/m <sup>2</sup> )	5122.5	5763.4
Range of monthly-average daily global solar radiation (MJ/m <sup>2</sup> )	16.59 (Mar) - 8.98 (Aug)	15.54 (Feb) – 11.85 (Aug)
Range of percentage frequency distribution of daily total of global solar radiation (MJ/m <sup>2</sup> )		
0-5	37.9	2.9
5-10	23.1	16.2
10-15	25	30.5
15-20	12.3	42.7
20-25	1.6	7.5
25-30	0.2	0.3
30-35	0.1	0

These data appear to be in agreement but the slight differences between them are the distribution of radiation intensity. The modal radiation group for Port Harcourt is 15-20MJ/m<sup>2</sup>, which amount to 42.7 percent

of total daily radiation, while Osogbo has a modal group of 0-5MJ/m<sup>2</sup> corresponding to 37.9 percent of total daily radiation. The monthly-average daily global solar radiation of the two sites are plotted in Figure 1.

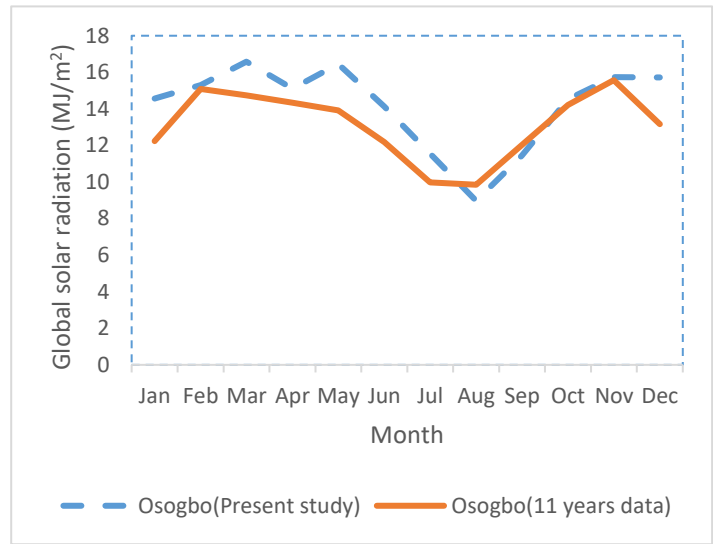


**Figure 1: Monthly-average daily global solar radiation for Osogbo and Port Harcourt**

The radiation value for Port Harcourt is somewhat greater than those corresponding to Osogbo in the wet months, most prominent during the peak of the wet season but appears to be in agreement during the dry season. The general variation in trend noticed between the two data sets may be caused by the sun's elevation, variations in cloud cover, angle of inclination on which the intensity of solar radiation depends (Akinnubi, Akinwale, Ojo, Ijila, & Alabi, 2007; Udo, 2002). The global solar radiation from these two cities in Nigeria was compared with other radiation data reported, for Rio De Janeiro, Brazil (Evandro, 1991), Istanbul (Topcu, Dilmac, & Aslan, 1995), Beer Sheva, Israel (Kudish, Wolf, & Machlav, 1983), Hong Kong (Joseph & Danny, 1996) and Oman (Al-Hinai & Al-Alawi, 1995). It is apparent from these data that the southern part of Nigeria experiences low solar radiation. The low solar radiation in Nigeria has been attributed to the high moisture content of the air and the cloud cover during the wet season, and the dust and smoke from grass fires during the dry season (Griffiths, 1981).

It is also of importance to compare the average monthly values of GR measured in Osogbo (present study) with the 11 years (1997-2007) GR data obtained for this site (Osogbo) by Ohunakin et al (Ohunakin, Adaramola, Oyewola, & Fagbenle, 2013) from Nigeria Meteorological Agency (NIMET), Oshodi, Lagos. Fig 2 shows the measured global solar radiation for the present

study and 11 years of data obtained for this site (Osogbo) from NIMET, Oshodi, Lagos.



**Figure 2: Monthly-average daily global solar radiation for Osogbo**

These data appear to be in agreement during the latter part of the wet season months but with slight differences for the rest of the year. This variance may be attributed to the fact that the data studied by Ohunakin et al (Ohunakin, Adaramola, Oyewola, & Fagbenle, 2013) was not directly measured at the location under study.

### Conclusion

The GR data of 2017 have been analyzed and presented in the form of tables. The monthly daily GR is  $14.20 \text{ MJ/m}^2$  and varies between  $8.98 \text{ MJ/m}^2$  and  $16.59 \text{ MJ/m}^2$ . The study reveals that there is an evident variation in solar radiation activity between the two main seasons. Therefore designers are advised to track their solar system based on these changes.

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