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Evaluation of Clearness Index and Diffuse Ratio of Some Locations In South Western, Nigeriausing Solar Radiation Data.

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Abstract: *In this study, evaluation of clearness index ($K_T = H/H_0$) and diffuse ratio (H_D/H) were carried out so as to assess the feasibility of solar energy utilization in the six selected tropical stations in South Western, Nigeria. Accumulated data of global solar radiation, minimum and maximum temperature were obtained from the Satellite –derived data from the National Aeronautic and Space Administration (NASA) through National Space Research and development Agency, Abuja. The data obtained covered a period of eleven years (January, 1985 – December, 2005). The clearness index and diffuse ratio were compared, while the transparency of each locations sky was investigated and the monthly variation of clearness index and diffuse ratio were evaluated. The results revealed that the clearness index varies with the geographical location and period of the year. The months of January and December have the highest clearness index values range between 0.57 and 0.62 while the month of August has the least values ranging from 0.35 to 0.39. The results revealed that the values of global solar radiation computed vary from 12.248 – 20.844 $MJm^{-2}day^{-1}$ in Abeokuta, 12.880 – 21.744 $MJm^{-2}day^{-1}$ in Ado Ekiti , 12.064 - 21.888 $MJm^{-2}day^{-1}$ in Akure, 12.600 – 19.224 $MJm^{-2}day^{-1}$ in Ikeja , 12.960 – 22.916 $MJm^{-2}day^{-1}$ in Ogbomoso and 12.420 – 21.276 $MJm^{-2}day^{-1}$ in Osogbo. The implications of these results on the effective utilization of solar energy are discussed. The results in this study serve as very useful information for engineers and other renewable energy technologists in the process of designing and estimation of performance of solar application systems.*
Key words: Global Solar radiation, Diffuse solar radiation, Clearness index, Diffuse ratio, Nigeria

I. Introduction

Solar energy is a sustainable, clean and abundant energy re-source, this implies that its harvesting, conversion and use would occur in a sustainable manner and avoid any negative impacts on the people and natural environment (Sanusi and Abisoye, 2011). Evaluation and performance of solar technologies require information related to meteorology and solar radiation. Solar radiation at the earth's surface is essential for the development and utilization of solar energy. It is needed for designing collectors for the solar heater and other photovoltaic equipment that depend on solar energy. Knowledge of the global solar radiation is of fundamental importance for all solar energy conversion systems. The transparency of the atmosphere is indicated by fraction of Extraterrestrial radiation that reaches the earth's surface as global radiation. It is measure of the degree of clearness of the sky (Akhlaque et al. 2009.). Clearness index reflects the meteorological variations in the troposphere depending on the location, couple with astronomic and meteorological calculation. Its evaluation requires astronomical calculations at the top of the troposphere by considering time of the year and geographical consideration as well as surface measurement of global solar irradiation variations. Clearness index is a measure of solar radiation extinction in the atmosphere, which includes effects due to clouds but also effects due to radiation interaction with other atmospheric constituents. In terms of sky conditions classification, the clearness index is a widely used index since it depends on global solar radiation irradiance (Muneer, 1995: Li et al.; 2004). Low clearness means low global radiation which usually attributes to a cloudy sky with high portion of diffuse components. Large values of clearness index means high global radiation, which is dominated by the direct component (Li et al.; 2004). Clearness index (K_T) is expressed as the ratio of the monthly mean daily global solar radiation on horizontal surface (H) to monthly mean daily extraterrestrial horizontal radiation (H_0).
Notable researchers have been carried out studies in the estimation of clearness index and related parameters such as diffuse ratio and diffuse co-efficient for the purpose of modeling and study sky conditions in the various location in Nigeria:Falayi and Rabiu, (2011); Oyedepo (2011); Okogbue et al (2002, 2009); Ojosu (1989; Augustine and Nnabuchi (2009); Ezekwe(1981) and Dike et al (2011). In this present study, Clearness index, diffuse ratio and diffuse co efficient are calculated from the acquired solar radiation data which are considered as an essential requirement to conduct feasibility studies for solar energy systems.. However, the prime objectives of this study are to determine the clearness index, K_T , diffuse ratio and diffuse co-efficient which depict the effectiveness of the sky in scattering the incoming radiation. Also, characterization of solar radiation

for evaluation of clearness index (K_T) and diffuse ratio (K_D) were carried out so as to assess the feasibility of solar energy utilization in the selected tropical stations.

II. Materials And Methods

The materials required for this study are the Satellite-derived data on solar radiation, relative humidity, minimum and maximum temperature which are adopted from the Atmospheric center data of National Aeronautic and Space Administration and National Space and Development Agency, Abuja. The data obtained covered a period of eleven (11) years, from January 1995 to December, 2005 for six locations in South western Nigeria which lie on the latitudes and longitudes (Lat. 07˚ 03′N , Long. 03˚ 19′ E) for Abeokuta, (Lat.07˚ 38′N, Long. 05˚ 12′ E) for Ado Ekiti, (Lat. 07˚ 15′ N Long. 05˚ 05′ E) for Akure, (Lat., 06˚ 25′ N Long. 03˚ 27′ E) for Ikeja, (Lat., 08˚ 01′ N Long. 04˚ 11′ E) for Ogbomoso and (Lat., 07˚ 48′ N Long. 04˚ 42′ E) for Osogbo. Acquired data were used to calculate values of the clearness index K_T , diffuse ratio $K_D$and diffuse co efficient K_c for each location, these depict the effectiveness of the sky in scattering incoming radiation. In the process of data treatment, the global solar radiation data measured in $KWm^{-2}day^{-1}$ was converted to $MJm^{-2}day^{-1}$ using a factor of 3.6 (according to Igbal 1983.).

Solar radiation data were presented in dimensionless form as the ratio of global irradiance (H) to extraterrestrial radiation (H_0) . Then the clearness index could be expressed as;

$$K_T = \frac{H}{H_0} \qquad 1$$

Where K_T is the clearness index, which is a measure of the availability of solar radiation or the transmissivity of the atmosphere.

$$KD = \frac{H_d}{H} \text{and} K_c = \frac{H_d}{H_0} \qquad 2$$

(Okogbue et al, 2002, 2009);

Where KDand K_c represent the diffuse ratio and diffuse co-efficient respectively, which are transmission characteristics of diffuse radiation and hence mirror the effectiveness of the sky in transmitting diffuse solar radiation.

In this study, simple model of the Supit and Van Kappel (1998) was adopted to estimate the monthly mean of daily total terrestrial solar radiation falling on horizontal surface at a particular location. According to Supit and Van Kappel (1998),

$$H = H_0\left[\sqrt[a]{(T_{max} - T_{min})} + \sqrt[b]{(1 - C_w/8)}\right] + c3$$

Where C_w is the mean of the total cloud cover of the daytime observation in percents, tenths, or in eight of the sky covered by cloud, T_{max} and Tmin are maximum and minimum temperature. H_0 is the monthly mean of daily total extraterrestrial solar radiation on horizontal surface in the absence of atmosphere while a, b and c are empirical constants.

$$H_0 = \frac{24 \times 3600}{\pi} G_{sc}\left(1 + 0.033Cos\frac{360n}{365}\right)\left(Cos\emptyset Cos\delta Sin\omega_s + \frac{2\pi\omega_s}{360} Sin\emptyset Sin\delta\right)4$$

Where H_0 is the monthly mean daily extraterrestrial radiation in MJm^{-2} , $G_{sc}$is the solar constant with a value $1367W/m^2$ while w_s is the sunset hour angle for the typical day n for each month in degrees, then

$$\omega_s = Cos^{-1}(-tan\theta tan\delta) \qquad 5$$

θ is the Latitude angle for the location in degrees

$\delta$is the declination angle for the month in degree and n is the mean day of each month and

$$\delta = 23.45\, Sin\left[360\left(\frac{284+n}{365}\right)\right] \qquad 6$$

III. Results And Discussion.

Results

Table 1 : **Monthly average clearness index K_T, the diffuse ratio and the diffuse co-efficient for Abeokuta.**

Month	H_0	H	H_D	$KD=H_D/H$	$Kc=H_D/Ho$	$K_T = \frac{H}{H_0}$
JAN	33.09779	19.64291	20.02582	1.019494	0.60505	0.593481
FEB	35.25611	20.31709	20.87673	1.027545	0.592145	0.576272
MAR	37.17388	20.21891	22.22836	1.099385	0.597956	0.543901
APR	37.6868	18.76582	23.34436	1.243983	0.619431	0.497941
MAY	36.93472	17.92473	22.56873	1.259083	0.611044	0.485308

JUN	36.21632	15.75491	21.82255	1.385127	0.602561	0.435022
JUL	36.41965	13.84691	22.68982	1.63862	0.62301	0.380204
AUG	37.14437	13.34945	23.87782	1.788674	0.642838	0.359394
SEPT	37.10783	14.148	24.012	1.697201	0.647087	0.381267
OCT	35.60009	16.416	22.572	1.375	0.634043	0.461122
NOV	33.42343	18.09818	19.38436	1.071067	0.579963	0.541482
DEC	32.25023	19.14545	19.33855	1.010085	0.59964	0.593653

***Table 2* : Monthly average clearness index K $_T$, the diffuse ratio and the diffuse co-efficient for Ado -Ekiti**

Month	H_0	H	H_D	KD=H_D/H	Kc=H_D/H_0	$K_T = \frac{H}{H_0}$
JAN	33.09779	20.25818	20.54945	1.014378	0.620871	0.612071
FEB	35.25611	20.44145	20.92582	1.023695	0.593537	0.579799
MAR	37.17388	20.22218	21.96655	1.08626	0.590913	0.543989
APR	37.6868	18.78545	23.57345	1.254878	0.62551	0.498462
MAY	36.93472	17.93127	22.86655	1.275233	0.619107	0.485486
JUN	36.21632	15.80073	21.99927	1.392295	0.607441	0.436287
JUL	36.41965	13.91891	22.54582	1.619798	0.619056	0.382181
AUG	37.14437	13.24473	23.84509	1.800346	0.641957	0.356574
SEPT	37.10783	14.184	24.21818	1.70743	0.652643	0.382237
OCT	35.60009	16.05273	22.67345	1.412436	0.636893	0.450918
NOV	33.42343	18.81164	19.91127	1.058455	0.595728	0.562828
DEC	32.25023	19.77709	19.83927	1.003144	0.615167	0.613239

***Table 3.:* Monthly average clearness index K $_T$, the diffuse ratio and the diffuse co-efficient for Akure.**

Month	H_0	H	H_D	KD=H_D/H	Kc=H_D/Ho	$K_T = \frac{H}{H_0}$
JAN	33.25308	20.39564	20.54945	1.007542	0.617972	0.613346
FEB	35.36763	20.55927	20.92582	1.017829	0.591666	0.581302
MAR	37.21805	20.11745	21.96655	1.091915	0.590212	0.540529
APR	37.656	18.78545	23.57345	1.254878	0.626021	0.49887
MAY	36.84606	17.94436	22.86655	1.274302	0.620597	0.487009
JUN	36.10218	15.81055	21.99927	1.39143	0.609361	0.437939
JUL	36.31811	13.85673	22.54582	1.627067	0.620787	0.381538
AUG	37.09127	13.22509	23.84509	1.803019	0.642876	0.356555
SEPT	37.12546	14.22	24.21818	1.703107	0.652334	0.383026
OCT	35.69071	16.09527	22.67345	1.408703	0.635276	0.450965
NOV	33.56826	18.90982	19.91127	1.05296	0.593158	0.563324
DEC	32.41789	19.74109	19.83927	1.004973	0.611985	0.608957

***Table 4*: Monthly average clearness index K $_T$, the diffuse ratio and the diffuse co-efficient for Ikeja.**

	H_0	H	H_D	KD=H_D/H	Kc=H_D/Ho	$K_T = \frac{H}{H_0}$
JAN	33.61716	18.88364	20.04873	1.061698	0.596384	0.561726
EB	35.62715	19.76727	21.21382	1.073179	0.59544	0.554837
MAR	37.31728	19.82945	22.5	1.134676	0.602938	0.531375
APR	37.57753	18.45818	23.42291	1.268972	0.623322	0.491203
MAY	36.63096	16.86764	23.07273	1.36787	0.62987	0.460475
JUN	35.82706	13.77164	22.33309	1.621673	0.623358	0.384392
JUL	36.07269	14.19709	22.76836	1.603734	0.63118	0.393569
AUG	36.96014	14.67818	23.26255	1.584838	0.629396	0.397135
SEPT	37.16175	14.80255	24.12655	1.629892	0.649231	0.398327
OCT	35.90048	16.13782	23.82873	1.476577	0.663744	0.449515
NOV	33.90736	18.14073	21.52145	1.186361	0.634713	0.535009

DEC	32.81161	18.86727	20.04218	1.062272	0.610826	0.575018

***Table 5* : Monthly average clearness index K $_T$, the diffuse ratio and the diffuse co-efficient for Ogbomoso.**

Month	H_0	H	H_D	KD=H_D/H	Kc=H_D/Ho	$K_T = \frac{H}{H_0}$
JAN	33.34135	20.40545	20.52982	1.006095	0.615747	0.612017
FEB	35.43081	20.93891	21.03709	1.004689	0.593751	0.59098
MAR	37.24267	21.57709	22.67345	1.050811	0.608803	0.579365
APR	37.63779	20.28109	23.75673	1.171373	0.631193	0.538849
MAY	36.79485	19.14545	23.24945	1.214359	0.631867	0.52033
JUN	36.03646	16.85455	21.84545	1.296117	0.606204	0.467708
JUL	36.25957	14.48182	22.94509	1.584407	0.632801	0.399393
AUG	37.06034	13.67673	24.00218	1.754965	0.647651	0.369039
SEPT	37.13491	14.85818	23.55055	1.585022	0.634189	0.400114
OCT	35.74192	17.028	21.91745	1.287142	0.613214	0.476415
NOV	33.65053	19.59382	20.74582	1.058794	0.616508	0.582274
DEC	32.51326	20.07818	20.36945	1.014507	0.626497	0.617538

***Table 6* : Monthly average clearness index K $_T$, the diffuse ratio and the diffuse co-efficient for Osogbo.**

Month	H_0	H	H_D	KD=H_D/H	Kc=H_D/Ho	$K_T = \frac{H}{H_0}$
JAN	33.00859	19.93091	20.11745	1.00936	0.609461	0.60381
FEB	35.19183	20.42836	20.89309	1.022749	0.593692	0.580486
MAR	37.14802	20.31709	22.08436	1.086985	0.594496	0.546923
APR	37.70379	18.74291	23.48509	1.253012	0.622884	0.497109
MAY	36.98483	17.77091	22.73236	1.27919	0.61464	0.480492
JUN	36.28104	15.59127	21.71782	1.392947	0.5986	0.429736
JUL	36.47714	13.428	22.95491	1.709481	0.629296	0.368121
AUG	37.17413	12.996	24.264	1.867036	0.652712	0.349598
SEPT	37.09714	14.02364	24.20182	1.725788	0.65239	0.378025
OCT	35.54773	15.98073	23.06291	1.44317	0.648787	0.449557
NOV	33.34019	18.42545	19.59709	1.063588	0.587792	0.55265
DEC	32.154	19.16836	19.24364	1.003927	0.598483	0.596142

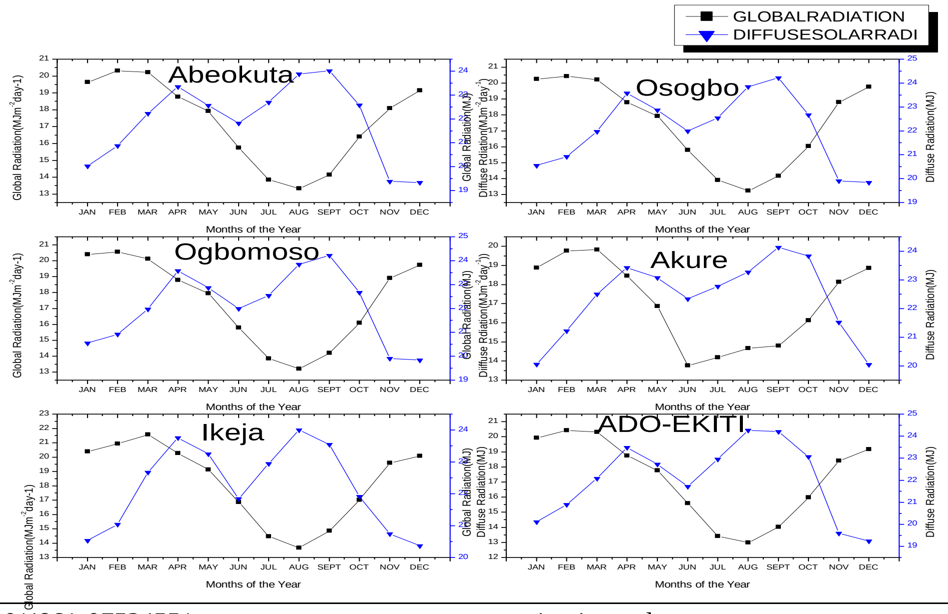

Figure 1: Plots of monthly average global and Diffuse radiation for the selected cities for the year 199-2005.

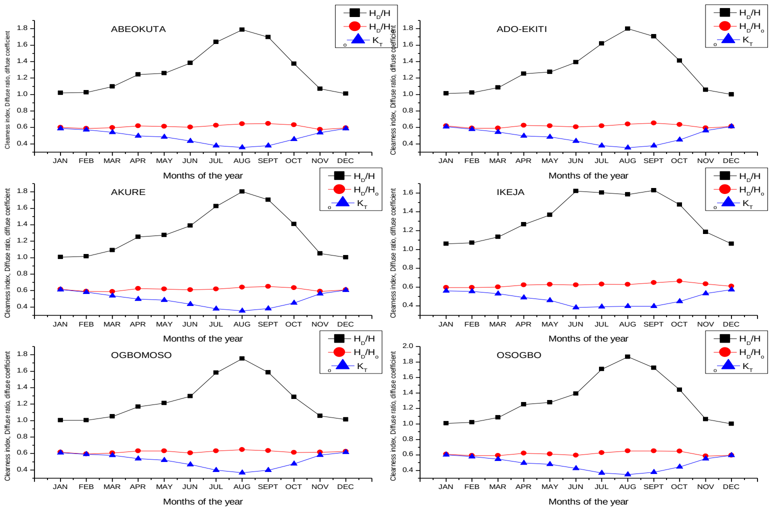

Figure 2*:*Plots of monthly averages of clearness index (K_T), diffuse ratio (H_D/H) and diffuse co-efficient (H_D/H_0) over the selected cities for the period 1995 – 2005.

IV. Discussion

The table 1-6 shown that the contributions of diffuse solar radiation is very low throughout the year in all the cities with the exception of months July - September, mainly due to presence of cloud , rainfall, suspension of water particles that lead to scattering, absorption and reflection of incoming solar radiation to the earth's surface. Figure 1 shows the plots of monthly average global and diffuse radiation for the locations for the year 1995 -2005.

From the figure 1, it was observed and obvious for Abeokuta that the global radiation is very low during the raining period (between June - October) with values ranging between 13.00 – 15.50MJm^{-2}day^{-1} while the diffuse solar radiation has rather very high value of 24.53 MJm^{-2}day^{-1} during such period (July and August). During the dry period between the months of November to March, the global solar radiation values range between 19.50 – 20.5 MJm^{-2}day^{-1}. Also, diffuse radiation showed bi-modal pattern throughout the years under consideration. It was shown that the global and diffuse solar radiation for Ado – Ekiti portray similar patterns. For the month of July and August which are typical of wet season, the global radiation value is very low (13.20 MJm^{-2}day^{-1}) while the diffuse solar radiation value is 24.40 MJm^{-2}day^{-1}. Generally, the figures displayed similar patterns except Ogbomoso which has close values for both global and diffuse radiation with a value of 16.45 MJm^{-2}day^{-1}. Also, global solar radiation for Ikeja is very low in the month of August. This slight difference in the patterns may be attributed to the latitudinal difference that existing between the locations. Hence, the global solar radiation in the locations vary from 12.248 – 20.844 MJm^{-2}day^{-1} in Abeokuta, 12.880 – 21.744 MJm^{-2}day^{-1} in Ado Ekiti ,12.064 - 21.888 MJm^{-2}day^{-1} in Akure , 12.600 – 19.224 MJm^{-2}day^{-1} in Ikeja , 12.960 – 22.916 MJm^{-2}day^{-1} in Ogbomoso , 12.420 – 21.276 MJm^{-2}day^{-1} in Osogbo . The results are in good agreement with that of Augustine and Nnabuchi (2010); Chukwuemeka and Nnabuchi (2009) and Oyedepo (2010).

The result of this study shows that there is great availability of solar radiation in all the locations but the values in Abeokuta and Ikeja are relatively low. In application point of view, solar energy devices will function successfully throughout the year in Akure, Ogbomoso, Ado Ekiti and Osogbo compared to Ikeja and Abeokuta that are very close to the sea with cold air flow over them. The air steam flow is characterized by thick stratocumulus cloud cover which attenuates solar radiation from reaching the earth's surface in the locations. Also, evidence of high values of diffuse solar radiation during the wet period especially August implies that the solar radiation received at the surface during the periods consists mainly of the diffuse components. This is consistent with the dependence of the diffuse solar radiation reaching the surface on solar elevation and atmospheric turbidity, air mass, atmospheric water vapour content and layer, and distribution of cloud cover in the areas during the period (Okogbue et al, 2009).

It is also deduced from figure 1 that a seasonal variation of global solar radiation with the highest values corresponding to dry season (November to March) while the least values are observed at the peak of the raining season between (May to October) of the years considered. The high values is due to sky that clear off cloud and some aerosol particles that attenuate the incident of solar radiation to the earth's surface. The low values are due mainly to presence of cloud, rainfall, suspension of water particles that lead to scattering, absorption and reflection of incoming solar radiation to the earth's surface.

Figure 2 presents the plots of the monthly variations of the clearness index (K_T) , diffuse ratio (H_D/H), and diffuse coefficient (H_D/H_0) for all the locations which serve as useful hints in the course of discussion of the sky conditions in the process of transmitting and scattering of incoming solar radiation. Low clearness means low global radiation which usually attributes to a cloudy sky with high portion of diffuse components. Large values of clearness index means high global radiation, which is dominated by the direct component**.** It is also seen from the figure 2 that a pronounced dip was observed in the patterns of the clearness index and rise in diffuse radiation in the months of August throughout the periods considered except in Ikeja (Lagos), that has dip in clearness index and rise in diffuse ratio in the months of June and September of the years. The dip in the values of K_T is in accordance with high values H_D/H for the same months.

For all the locations under study, clearness index (K_T) value ranges between 0.35 – 0.59 (Abeokuta), 0.36 – 0.61 (Ado Ekiti), 0.34 – 0.61 (Akure), 0.32 – 0.48 (Ikeja), 0.39 – 0.61 (Ogbomoso) and 0.34 -0.53 (Osogbo). In Abeokuta, the highest K_T (0.595) observed in January and December while the lowest K_T (0.351) occurred in August. In Ado Ekiti, the highest value of K_T (0.613) observed in January and December and lowest value K_T (0.382) observed in July. Highest value K_T(0.612) observed in Akure in January while the lowest K_T (0.353) occurred in August. In Ikeja, highest value K_T (0.575) observed in December and lowest value K_T(0.381) in July. In Ogbomoso, the highest value of K_T (0.617) observed in January and December and lowest value K_T (0.369) observed in August. In Osogbo, the highest value of K_T (0.603) occurred in January while the lowest value of K_T (0.342) observed in August. This indicates that the sky is very clear over Akure, Ado Ekiti, Ogbomoso and Osogbo throughout the year except in June to September.

V. Conclusion.

In this study, solar radiation data was used toevaluation the clearness index ($K_T = H/H_0$) and diffuse ratio (H_D/H) so as to assess the feasibility of solar energy utilization in selected tropical stations Abeokuta, Ado Ekiti, Akure, Ikeja, Ogbomso and Osogbo, all in South western, Nigeria. The results showed a seasonal variation of global solar radiation with the highest values corresponding to dry season (November to March) while the least values are observed at the peak of the raining season between (May to October) of the years considered. The global solar radiation in the locations vary from 12.248 – 20.844 $MJm^{-2}day^{-1}$ in Abeokuta, 12.880 – 21.744 $MJm^{-2}day^{-1}$ in Ado Ekiti , 12.064 - 21.888 $MJm^{-2}day^{-1}$ in Akure , 12.600 – 19.224$MJm^{2}day^{-1}$ in Ikeja ,12.960 – 22.916 $MJm^{-2}day^{-1}$ in Ogbomoso ,12.420 – 21.276 $MJm^{-2}day^{-1}$ in Osogbo .

For all the locations, K_T ranges between 0.35 – 0.59 (Abeokuta), 0.36 – 0.61 (Ado Ekiti), 0.34 – 0.61 (Akure), 0.32 – 0.48 (Ikeja), 0.39 – 0.61 (Ogbomoso) and 0.34 -0.53 (Osogbo). The clearness index values indicate that the sky is very clear over Akure, Ado Ekiti, Ogbomoso and Osogbo throughout the year except June to September. Clearness index maps showed latitudinal variations in clearness index with high values in Ogbomoso, Ado – Ekiti , Akure and Osogbo. Clearness index maps revealed that global solar radiation dependent on latitude, the higher latitudes received more radiation.There is great availability of solar radiation in Akure, Ado Ekiti, Ogbomoso and Osogbo, so solar energy devices will function successfully throughout the year. The results provide a useful source of information in the design and estimation of performance of solar application systems.

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References

[1]. Akhlaque A.M; Firoz A and Wasim, M.A (2009), 'Estimation of Global and Diffuse Solar Radiation for

[2]. Hyderabad, Sindh, Pakistan'**, Journal of Basic and Applied Science**, Vol. 5, No2, pp 73-77

[3]. Augustine C. and NnabuchiM.N (2009): ' Relationship between Global Solar Radiation and Sunshine hours for Calabar, Port Harcourt and Enugu, Nigeria,' **International Journal of Physical Sciences**Vol,. 4 (4) pp 182 -- 188.

[4]. Beyer, H. G; Czeplak G; Terzenbach U and Wald, L (1997): 'Assessment of the method used to construct Clearness Index Maps for the New European solar Radiation Atlas (ESRA)**' SolarEnergy**, vol. 61 (6), pp 389 – 397.

[5]. Chukwuemeka A and Nnabuchi, M.N (2009), 'Solar Radiation in Port Harcourt: Correlation with Sunshine Duration', **The Pacific Journal of Science and Technology**, Vol.10 (1): 681–685.

[6]. Ezekwe, C.I and Ezeilo, C.C.O. (1981): 'Measured Solar Radiation in a Nigerian Environment compared with predicted data'. **Solar Energy**, 26 pp. 181 -186.

[7]. Falayi, E.O and Rabiu, A.B (2011): 'Estimation of Global Solar radiation using cloud cover and surface temperature in some selected cities in Nigeria.' **Scholar Research Library** vol. 2 (3) pp 99 – 109.

[8]. Igbal, M (1983), **An Introduction to Solar Radiation**, Academy Press, New YorkLi DHW, Lam JC. 2001. An analysis of climatic parameters and sky condition classification. **Building and Environment 36:** 435–445.
[9]. Li DHW, Lau CCS, Lam JC. 2004. Overcast sky conditions and luminance distribution in Hong Kong. **Building and Environment 39** 101–108.
[10]. Muneer T. 1995. Solar irradiance and illuminance models for Japan II: luminous efficacies. **Lighting Research and Technology 27:** 223–230.
[11]. Muneer T. 1998. Evaluation of the CIE overcast sky model against Japanese data. **Energy and Buildings**: Elsevier, Netherlands; **27**: 175–177.
[12]. Oji, J. O; Idusuyi,N; Aliu, T. O ; Petinrin, M. O; Odejobi, O.A and Adetunji, A. R (2012); "Utilization of Solar Energy for power generation in Nigeria**" International Journal of Energy Engineering. 2**
[13]. **(2)**pp 54 -59.
[14]. Ojosu, J.O (1984); 'Solar radiation Maps of Nigeria. **Nigeria Journal of Solar Energy**. Vol 8 pp 370 –384.
[15]. Okogbue EC, Adedokun JA. 2002. Characterization of sky conditions over Ile-Ife, Nigeria based on 1992–1998 Solar Radiation Observations. **MeteorogischeZeitschrift,** Germany **11**(6): 419–423.
[16]. Okugbue, E.C; Adedokun, J.A and Holmgren, B (2009): Hourly and daily clearness index and diffuse fraction at a tropical station, ile Ife, Nigeria, **International Journal of Climatology 29**, 1035 -1047.
[17]. Sanusi, Y.K and Abisoye, S.G. (2011): ' Estimation of Solar Radiation at Ibadan, **Nigeria' Journal ofEmerging Trends in Engineering and Applied Sciences (JETEAS)** 2 (4) pp 701 -705.
[18]. Sunday OlayinkaOyedepo (2011): 'Estimation of Global and Diffuse Solar radiations for selected Cities in Nigeria'**International Journal of Energy and Environmental Engineering,** 2 (3) Pp13 – 33.