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# PRELIMINARY INVESTIGATION OF THE ATTENUATION OF SOLAR RADIATION IN THE ATMOSPHERE OVER MAKURDI, NIGERIA

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## ABSTRACT

The attenuation of solar radiation in the atmosphere over Makurdi (Latitude 7° 7' N and longitude 8° 6' E) was investigated by measurements of direct solar radiation (I) carried out using a digital sun photometer that measured in $Wm^{-2}$. The measurements were made at 9:00hrs, 12:00 hrs and 15: 00hrs daily for six months. Global solar radiation, ($I_G$) was calculated for the six months using Gun Bellani measurements from Air Force Base, Makurdi. The diffuse component of solar radiation ($I_D$) was evaluated and the extraterrestrial solar radiation ($I_o$) was obtained by calculation using the equation of Duffie and Beckman (1983) and Liou (1980). The variation of attenuation with clearness index $K_i$ was found. The attenuation in the atmosphere over Makurdi was found to be highest in the month of August with a value of 0.975 and lowest in December with a value of 0.427. There was good agreement in the pattern of variation of attenuation in Makurdi when compared with that of Ilorin that lies in the same geographic latitude.

## Key words:

attenuation of solar radiation, direct solar radiation, Global solar radiation, diffuse solar radiation, clearness index

## Academic Discipline And Sub-Disciplines

Physics

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## TYPE (METHOD/APPROACH)

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## INTRODUCTION

As solar radiation passes down through the atmosphere, dissipation and conversion takes place [1]. Through this process, the intensity of solar radiation reduces to values less than the one from the Sun. This dissipation or depletion of solar radiation due to scattering by molecules and aerosols, and absorption and reflection by clouds is called attenuation. This attenuation of the solar radiation causes modification in the radiation balance of the Earth. It is responsible for visibility reduction, and is believed to influence climate; and therefore crop production, through its effects of Photosynthetically Active Radiation (PAR) ([2]; [3] and [4]. Therefore, the effective design and utilization of solar energy systems depend largely on adequate information of the solar radiation characteristic of the region or location of the systems.

This work investigates the attenuation of global solar radiation in the atmosphere over Makurdi, Nigeria. Makurdi having an area of about 33.16 km$^2$ is located at latitude 7$^o$.41' N and longitude 8$^o$.37'E. This work will contribute to the awareness of the prospects of solar energy utilization in Makurdi, and the time and month of the year that the energy utilization could be maximized. It will also help the people, majority of who are farmers, to have an idea of the period the photo-synthetically active radiation is attenuated. Hence, it will enhance adequate planning in farming and solar energy technology in the area and its environs.

Some research works have been carried out on the estimation of global solar radiation in Nigeria and Makurdi in particular using some empirical and theoretical relations ([5-9]). Similarly, some studies have been carried out on the estimation of the diffuse fraction of solar radiation for Makurdi ([10 – 11]). However, none has been recorded on the attenuation of the global solar radiation in the area. Hence, this work is a part of the on - going research work on the attenuation of the global solar radiation in, Makurdi, Nigeria.

## METHODS

The direct solar radiation, I was measured using a digital sun photometer at the engineering complex of the University of Agriculture Makurdi between the periods 9:00 hrs, 12:00 hrs and 15:00 hrs each day, and the monthly mean daily values were obtained and recorded for a period of six months, (August 2011 – January, 2012). Secondly, some global solar radiation, $I_G$ data were obtained from the Gunn - Bellani radiation integrator at the Air force Base Makurdi, at 106.4 m altitude. The data were analyzed from daily values to monthly mean values and converted to energy unit, MJm$^{-2}$day $^{-1}$, using a factor of 1.264 ([12]).

The monthly extraterrestrial radiation, the diffuse solar radiation, the air mass values, and the attenuation coefficients and were computed using some empirical relations. Hence, the mean monthly daily extraterrestrial radiation $I_o$ on a horizontal surface was computed using the expression given by [13] as:

$$I_o = \frac{24}{\pi} I_{sc} E_o \left( \frac{\pi}{180} w_s \sin\emptyset \sin\delta + \cos\emptyset \cos\delta \cos w_s \right) \qquad (1)$$

where $I_{sc}$ is the solar constant in MJm$^{-2}$day$^{-1}$. The value of $I_{sc}$ to be used in this work is 4.921 MJm$^{-2}$day$^{-1}$. $E_o$ is the eccentricity correlation factor of the Earth's orbit. The value of $E_o$ was obtained using the expression given by [14] as :

$$E_o = 1 + 0.0033 \left( \frac{360J}{365} \right) \qquad (2)$$

$w_s$ is the sunrise sunset hour angle given by [15] as:

$$w_s = \cos^{-1}(-\tan\emptyset \tan\delta) \qquad (3)$$

where $\emptyset$ and δ are the latitude and declination angles respectively. The value of declination was computed using the equation of [16]:

$$\delta = 23.45\, sin \left[ 360 \left( \frac{J+284}{365} \right) \right] \qquad (4)$$

J is the day number of the year.

Noting that global solar radiation is the sum of direct short wave radiation from the Sun and diffuse sky radiation from all upward angles, the diffuse solar radiation, $I_D$, values were then obtained using the expression:

$$I_D = I_G - I \qquad (5)$$

The most important parameter that determines solar irradiance under clear sky conditions is the distance, H that the Sunlight has to travel through the atmosphere. H is shortest when the Sun is at the zenith. The ratio of an actual path length p of the sunlight to this minimal (shortest) distance H is known as optical air mass. When the Sun is at its zenith, the optical air mass is unity and the radiation is described as air mass one ($AM_1$) radiation. When the Sun is at an angle $\theta_z$ to the zenith, the air mass m is given as by [1] as:

$$Air\ mass, m = (\cos\theta_z)^{-1} \qquad (6)$$

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The Zenith angle was obtained from [17] as

$$\theta_z = \cos^{-1}(sin\delta sin\emptyset + cos\delta cos\emptyset cos\omega) \qquad (7)$$

where, δ is the declination of the Earth; ∅ is the latitude of the location and ω is the Sunrise hour angle . Thus, solar zenith angle is a function of time, day number and latitude

Finally, the attenuation coefficient, $\tau_{mkd}$, was evaluated using an extract from [1] as:

$$\tau = \frac{(InI_o - InI)}{\text{m}} \qquad (8)$$

## RESULTS AND DISCUSSION

Table 1 presents different types of solar radiation (Direct, global and diffuse solar radiation) received on the surface over Makurdi, Nigeria between August, 2011 and January 2012, while, Figure 1 a – c give the relationship between attenuation coefficients and clearness indices over Makurdi at different time regimes: 9:00, 12:00 and 15:00 hrs respectively. Finally, the Monthly mean of the relationship between attenuation coefficients and clearness index over Makurdi is as shown in Figure 1d.

**Table 1: Solar radiation parameters received on the surface over Makurdi, Nigeria between August, 2011 and January 2012**

| Months | Solar radiation ($MJm^{-2}day^{-1}$) | | |
|---|---|---|---|
| | Direct | Global | Diffuse |
| August | 10.810 | 13.807 | 2.998 |
| September | 11.712 | 15.885 | 4.174 |
| October | 16.533 | 18.074 | 1.541 |
| November | 18.094 | 18.983 | 0.889 |
| December | 18.533 | 18.561 | 0.027 |
| January | 16.268 | 17.090 | 0.822 |

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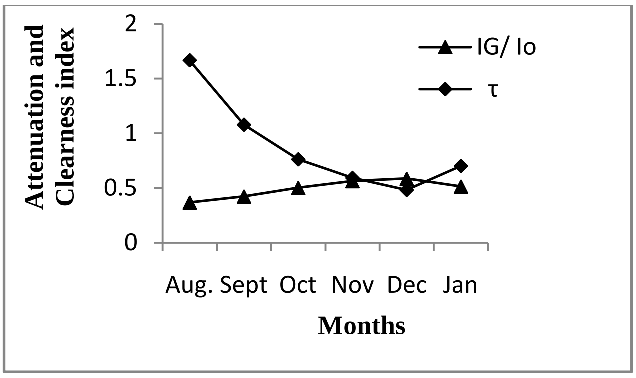
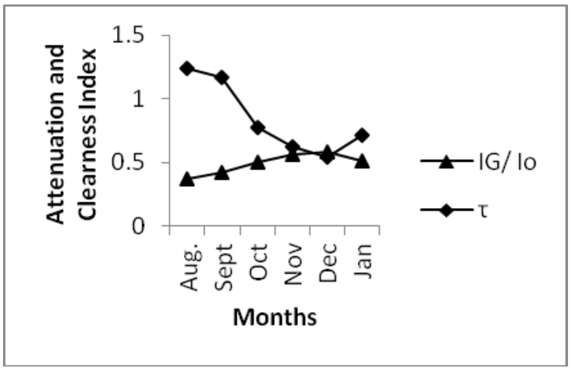
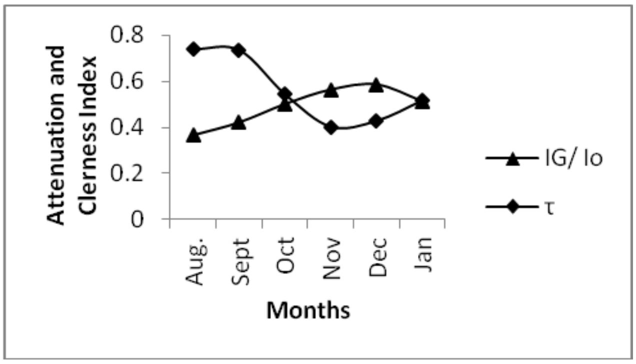


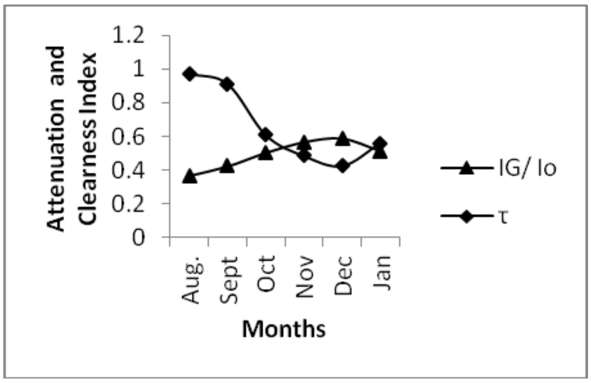

(a) Attenuation and clearness index over Makurdi at 9:00hrs




(b) Attenuation and clearness index over Makurdi at 12:00hrs




(c) Attenuation and clearness index over Makurdi at 15:00hrs




(d) Monthly mean attenuation of solar radiation and clearness index over Makurdi

Fig. 1: The relationship between solar radiation attenuation and clearness index over Makurdi , Nigeria

From Table 1, the least direct solar radiation was observed in the month of August with a value of 10.810MJ/m2day. The amount or intensity increased steadily through until it reached a maximum, (of 18.533$MJm^{-2}$ $day^{-1}$), in the month of December. The low value of direct solar radiation observed in August could be due to the presence of rain clouds which were predominant during that time. Hence, as the rainy season began to give way, the rain clouds started diminishing, leading to an increase in intensity of direct solar radiation received on the surface. Consequently, in December, the thick clouds had almost disappeared and then highest direct solar radiation intensity was received on the surface. However, between December and January, a slight decrease in the direct solar radiation intensity was observed, although still in dry season. This decrease could be attributed to the attenuation by the presence of some dust particles in the atmosphere during that period, which has always been known to be a harmattan period in the North central part of the country. By the same reason, the global solar radiation followed the same trend as the direct solar radiation, having the maximum and minimum intensities of *18.983*and*13.807* $MJm^{-2}$ $day^{-1}$ in November and August, respectively (Table 1).

The diffuse solar radiation, on the other hand, decreased from September through and reached a minimum in December after which it began to increase. This variation is due to the dense cloud cover during the rainy season which disappeared as the rainy season receded. At 9:00 hrs (Fig. 1a), the best clear sky condition of ≈ 59% was obtained in the month of December, with a corresponding attenuation coefficient of about 0.4808. But the least clearness index, $K_i$ at this time regime obtained in the month of August with a value of 0.368 when the attenuation is a maximum with the value of 1.6661. However, at this time of the day, the result showed that the station experienced clear sky conditions in all the months under review except August and September where the clearness index, $K_i$ < 0.5 (50%).

On the other hand, at 12:00 hrs (Fig1b), the best clear sky condition of ≈ 59% occurred in December when the attenuation was a minimum with a value of 0.5446. In August and September $K_i$ < 0.5 (50%) the attenuation is high. At 15:00 hrs

(Fig1c), the station experienced clear sky conditions (i.e $K_i$ > 0.5 (50%) in all the months under review except August and September where $K_i$ < 0.5 (50%) due to high attenuation of solar radiation.

However, the monthly mean attenuation coefficient and clearness index curves (Fig. 1d) shows that the highest amount of attenuation (0.975) occurred in August while the least attenuation (0.427) of the solar radiation occurred in December, probably due to reason earlier on asserted. Correspondingly, the clearness index was highest with the value of 0.580 in the month of December and lowest in August with the value of 0.288. Consequently, within the months of October to January solar energy utilization is highly encouraged in the city of Makurdi, following the low value of attenuation and high clear sky condition.

## CONCLUSION

The following inferences are drawn from this work:

- The month of December experienced the highest direct solar radiation in Makurdi with the value of 18.533MJm MJ $m^{-2}$ $day^{-1}$ while the month of August recorded the least value of 10.810 MJ $m^{-2}$ $day^{-1}$.
- The Diffuse solar radiation in Makurdi was highest in the month of September with a value of 4.174 MJ $m^{-2}$ $day^{-1}$ and lowest with the value of 0.027 MJ $m^{-2}$ $day^{-1}$ in the month of December.
- The monthly mean attenuation of solar radiation in the atmosphere over Makurdi was highest in the month of August and lowest in the month of December highest with values of 0.975 and 0.427 respectively.
- Considering time regimes, clear sky conditions are better (i.e $\mathbf{K_i}$ > 0.5 (50%) in relatively all the months.
- This work is ongoing so that a complete assessment could be made of the attenuation of solar radiation over a longer period in the atmosphere over Makurdi , Nigeria.

## REFERENCES

[1] Campbell, I.M. (1979). Energy and the atmosphere. A physical – Chemical Approach. Unwin Brothers Ltd., Britain

[2] Dicherson, R.R.; Kondragunta, S.; Stenchikoo, G.; Liveroro, K.L.; Doddrige, B.G. and Holben. B.N (1997): The impact of aerosols on solar ultraviolet radiation and photochemical smog, *Science* 278: 827 – 830.

[3] Schwartz, S.E (1996): The white house effect-shortwave radiation forcing of climate by anthropogenic aerosols: an overview, *J. Aerosol sci.,* 3, 359-382.

[4] Chameides, W.I.H.; Yu, S.C.; Liu. M.; Bergin. X.; Zhon. I.; Mearness G.; Wang, C.S.; Kiang, R.D.; Saylor, C.; Luo, Y.; Huang, A.; Steiner, F. and Georgi (1999): Case study of the effects of atmospheric aerosols and regional haze on agriculture: An opportunity to enhance crops yields – China through emission control, *proc. Nat. Acad. Sci.* 96:13626 – 13633.

[5] Akpabio, L .E. and Etuk, S. E. (2003). Relationship between Global Solar Radiation and Sunshine Duration for Onne, Nigeria, Turkish Journal of Physics, 27,161 - 167,

[6] Falayi, E.O; Adepitan , J.O. and Rabiu, A.B. (2008) Empirical Models for the Correlation of Global Solar Radiation with Meteorological Data for Iseyin, Nigeria, International Journal of Physical Sciences 3(9):210 - 216.

[7] Isikwue, B. C.; Amah, A. N. and Agada, P. O.(2012a). Empirical Model for the Estimation of Global Solar Radiation in Makurdi, Nigeria, Global Journal of Science frontier Research Physics Space Science (USA), 12 (1):58 – 61

[8] Okogbue E.C. and Adedokun, J.A. (2002). On the Estimation of Solar Radiation at Ondo, Nigeria, Journal of Physics, 14: 97 - 99,

[9] Sambo, A. S, (1986): Empirical Model for the Correlation of Global Solar Radiation Meteorological Data for Northern Nigeria, Solar and Wind Technology vol. 3(2): 89 - 93.

[10] bIsikwue, B. C., Odiaka, C. H. and Utah, E. U. (2012b). Estimation of the diffuse fraction of Solar Radiation for Makurdi, Nigeria. International Journal of Science and Advanced Technology 2(2): 1- 4.

[11] Isikwue, B. C., Audu, M. O. and Utah, E. U. (2012c)Empirical Models for Estimating Diffuse fraction of Solar Radiation over Makurdi, Nigeria. International Journal of Science and dvanced Technology 2(2): 5- 10

[12] Ododo, J. C: Sulaiman, A. T: Aidan, J: Yuguda, M. M. and Ogbu, F. A. (1995).The Importance of Maximum Air Temperature in the Parameterization of Solar Radiation in Nigeria.Renewable energy 6(7): 751-763.

[13 ] Duffie J.A and Beckman W.A. (1991): *Solar Energy Thermal Processes.* John Wiley and Sons Inc. New York

[14] Liou, K.N. (1980): *Introduction to Atmospheric Radiation.* Academy Press, New York

[15] Faydh, M.A.A and Ghazi. A. (2010): Estimation of global solar radiation in horizontal surfaces over Haditha, Samara and Beji, Iraq. *Pacific J. of Sci. and* Tech. 11(1):73-82

[16] Cooper, P.I. (1969): The absorption of solar radiation in solar stills. *Solar Energy*,12 (3): 313

[17] Sukhatme, S P. (1985) Solar Energy: Principles of Thermal Collection and Storage. Tata- Mc Graw Hill, India