ISSN: 2141 – 3290
www.wojast.com

EVALUATION OF NET RADIATION IN UYO, CALABAR AND PORT HARCOURT, NIGERIA

EKANEM, I. E*., UMOH, A. A., AKPAN, U. E. AND ATAT, J. G.
Department of Physics, University of Uyo, Uyo.
***Correspondence**: *ekaneminiodu@yahoo.com*

ABSTRACT

Knowledge of net radiation is essential in any location that requires a solar energy technology application. This work evaluates net radiation in three cities of close boundaries (Uyo, Calabar, and Port Harcourt) in southern Nigeria. The atmospheric data for the period of 20 years (2000-2020) were obtained from the Nigerian Meteorological Agency (NIMET). The mean values of the surface albedo, net shortwave and longwave radiation were computed using Mathematical tools and SPSS packages. The result obtained showed that the highest value (0.694, 0.687, and 0.685 for Uyo, Calabar and Port Harcourt respectively) of the albedo was in the rainy season with its peak in August while its lowest values of 0.489, 0.577 and 0.594 for Uyo, Calabar and Port Harcourt respectively were in the dry season within November to March. The net radiation R_n was observed to vary directly with the net shortwave and longwave radiation but indirectly with albedo. The highest net radiation values obtained were 6.512 $MJm^{-2}day^{-1}$, 4.52 $MJm^{-2}day^{-1}$ and 4.313 $MJm^{-2}day^{-1}$ for Uyo, Calabar and Port Harcourt correspondingly. The lowest were 2.717 $MJm^{-2}day^{-1}$, 2.144 $MJm^{-2}day^{-1}$ and 2.308 $MJm^{-2}day^{-1}$ for Uyo, Calabar and Port Harcourt respectively. Solar energy applications are encouraged in these cities since the albedo results are higher than the minimum standard of 0.3.

KEYWORDS: Solar Energy, Meteorological Data, Reflectivity index, Albedo

INTRODUCTION

Over the years, solar radiation getting to the earth's surface is naturally a fundamental renewable energy source. It is one of the thermal energy components of the atmosphere. Solar radiation is the only form of energy that can travel through the vacuum of outer space. The solar energy which drives nearly all the components of the earth is characterized by short wavelength (Abdulazeez *et al*., 2005). Surface net-radiation is a critical component of the global water and energy cycle. It couples the land surface to the lower atmosphere and exerts a dominant control on the terrestrial hydrological cycle. Net radiation is an important factor in studies of land–atmosphere processes, water resource management, and global climate change. Nigeria is blessed with an abundant amount of sunshine. It has been observed by Burari and Sambo (2001) that, there is an estimated 3000 hours of annual sunshine. The sun warms the earth and makes life possible. Among the other renewable energy sources, only solar energy has the greatest potentiality to be consistently available and it is free from environmental hazard (Ugwu and Ugwuanyi, 2011). Solar energy is the world's most abundant source of energy. The amount of insolation received by the surface of the earth per minute is greater than the energy utilization by the entire population in one year (Burari and Sambo, 2001).

The sun is the major source of radiation within the earth's surface. Solar interactions on the atmosphere leads to changes in weather as well as climate change (Ibeh *et al*., 2011). Solar radiation while passing through the earth's atmosphere is subject to mechanism of atmospheric scattering and absorption. The scattering depends on the incoming radiation and the size of the scattering particles or gas molecules. Solar energy generates clouds, cleanses our water, produces plants, keeps animals and humans warm, and drives ocean currents and thunderstorm (Hostmeyer, 2006).

In power sector, solar panels have been developed to trap solar radiation to generate electricity with full optimization. This has replaced power generation for both conventional and non-conventional means since it is abundant, cheap and available. Solar energy system design and assessment depends largely on adequate information of the solar radiation characteristics of a region such as sunshine duration, temperature, rainfall, relative humidity, cloud and others (Umoh *et al*., 2013). The best radiation information is obtained from experimental measurement of the global and diffuse components of solar radiation at any location but due to the high cost of establishing and maintaining solar radiation equipment, effort has to be made on the use of reliable estimating methodologies (Burari *et al*., 2006).

This work is aimed at using some atmospheric parameters in determining the albedo, net shortwave and longwave radiation which is used to evaluate the net radiation. Net radiation is the difference between short-wave radiation and long-wave radiation. It is the balance between incoming and outgoing energy at the top of the atmosphere. It is the critical component of the surface energy budget. It can be determined by either direct measurement or by calculation. The direct measurement uses net radiometer; calculation method involves the use of standard meteorological method which summarises into two: the air temperature and the soil surface temperature.

Description of Study Area

The areas selected for this study are Uyo, Calabar, Port Harcourt. These cities were chosen because of their climatic and industrial features. They are located in the south-south geopolitical zone of Nigeria. These cities are situated in the Niger Delta region of Nigeria. The oil fields are present in economical quantity. Longitudes 5°E and 8°E (Balogun and Obebe, 2013) and latitudes 3°N and 6°N defined the location of the Niger Delta (Akpabio *et al.*, 2023a; Reijers *et al.*, 1996). The dry and the wet seasons are experienced (Atat *et al.*, 2023; Ejoh *et al.*, 2023), with mean monthly rainfall of 0.135 m as at wet season, to around 0.065 m in dry season (Atat *et al.*, 2020a; George *et al.*, 2017; Akpabio *et al.*, 2023b). Appreciable sediment of nearly 5.0 x 10^5km^3 is suspected (Atat *et al.*, 2020b; Umoren *et al*., 2020; Atat *et al.*, 2020c). It is the youngest Sedimentary basin in the Benue Trough system as stated by Atat and Umoren (2016). According to George *et al*. (2017), groundwater is found at the top of the stratigraphic arrangement. It generates significant income for the country (Hunt, 1996).

Calabar lies on the latitude 4.97° North and longitude 8.01° East with an elevation of 16m above sea level. Its climate feature is monsoon with a lengthy wet season and a short dry sea. It is located at the rainforest belt of Nigeria. The harmattan is noticeably less pronounced in the city. Uyo lies on the latitude 5.05° North and the longitude 7.93° East with an elevation of 45m above the sea level. It is located on the rainforest zone of Nigeria. Its level of industrialization is advancing. Port Harcourt is an industrial area in the tropical rainforest zone. It lies on latitude 4.79° and at an altitude 19.5m above sea level. Its longitude is 7.00° East.

MATERIALS AND METHOD

Materials Data Collection

The monthly mean meteorological data (maximum and minimum temperature, dew point temperature, relative humidity, and global solar radiation) were collected from the archives of the Nigerian Meteorological Agency (NIMET). The data obtained from three Cities (Calabar, Uyo, and Port Harcourt) covered a period of twenty years (2000-2020). Microsoft Excel and SPSS packages were adequate for the workflow.

Method

The monthly average global solar radiation, maximum temperature, minimum temperature, mean temperature, relative humidity and vapour pressure were obtained using Equations 1 to 10. The solar radiation value H_m, which were measured using Gunn-Bellani radiation integrators in millimetres by NIMET were converted to MJ/m^{2}day using a factor of 1.216 (Ododo, 1994). Values for monthly average extraterrestrial global radiation H_o were computed for the fifteenth day of each month (Klein, 1998). According to Duffie and Beckman (1991), the mean extraterrestrial solar radiation, H_o may be obtained using Equation 1.

$$H_0 = \frac{24}{\pi} I_{sc} E_o \left(\frac{\pi}{180} W_s \sin\phi \sin\partial + \cos\phi\cos\partial \sin W_s\right) \quad (1)$$

Where I_{sc} is the solar constant in (MJm^{-2} day^{-1}), expressed mathematically in Equation 2.

$$I_{sc} = \frac{1367\times 3600}{1000000} \; MJm^{-2}day^{-1} \quad (2)$$

E_o is the eccentricity correlation factor defined in Equation 3.

$$E_0 = 1 + 0.033 \cos\left(\frac{360d}{365}\right) \quad (3)$$

Equation 4 is adequate for determining the hour angle (W_s).

$$w_S = \cos^{-1}(-\tan\phi \tan\partial) \quad (4)$$

Where ɸ and ∂ are the latitude and declination angles respectively.

$$\partial = 23.45 \sin 360\left(\frac{d+284}{365}\right) \quad (5)$$

where d is the characteristic day number for each month. For instance, d = 1 on 1st January to 365 on 31st December. d from January to December is given as, Jan = 15; Feb = 46; Mar = 74; April = 105; May = 135, June = 166; July, 196; August = 227; Sept. = 258; Oct. = 288; Nov. 319; Dec. = 349. The values of ɸ in the study areas are ɸ (Uyo) = lat 5.05°, ɸ (Cal) = lat 4.97°; ɸ (P.H) = lat 4.76°.

EVALUATION OF CLEAR SKY RADIATION AND CLEAR SKY INDEX

Monthly mean clear sky radiation (R_{so}) was obtained by inserting the value of station elevation (Z) and the corresponding extraterrestrial radiation (H_o) into Equation 6.

$$R_{so} = (0.75 + 2\times 10^{-5} Z)\, H_o \quad (6)$$

ESTIMATION OF ALBEDO

The values of the reflected radiation (H_r) were obtained by inserting the corresponding values of clear sky index and extraterrestrial radiation using appropriate part of Equation 7. The albedo (α) according to Ahren *et al*. (2005) may be determined using Equation 7

$$\alpha = \frac{H_r}{H_o} \text{ for } H_r = \left[1 - \left(\frac{H_m}{H_o}\right)\right] H_o \quad (7)$$

where H_o is extraterrestrial radiation; $\frac{H_m}{H_o}$ is the clear sky index (k).

The values of the net shortwave radiation R_{ns} were obtained by inserting the values of the albedo and the corresponding values of the solar radiation into Equation 8 (Ahren, 2005).

$$R_{ns} = (1-\alpha)H_m \quad (8)$$

where α is the surface albedo, H_m is the incoming solar radiation

The values of the net longwave radiations were obtained by inserting the values of stefans Boltzmann constant (4.903×110^{-9}MJK^{-4}m^{-2}day^{-1}), vapour pressure, mean monthly minimum and maximum temperature, solar radiation and clear sky solar radiation into Equation 9 (Tasumi *et al.*, 2008).

$$R_{nl} = \sigma\left\{\frac{T_{max}^4 + T_{min}^4}{2}\right.\left(0.34 - 0{,}14\sqrt{e_a}\right)\left.\left(1.35\frac{H_m}{R_{so}} - 0.35\right)\right\} \quad (9)$$

where σ is the Stefans Boltzmann constant, e_a is the vapour pressure. Parameter $\left(0.34 - 0{,}14\sqrt{e_a}\right)$ expresses correction for air humidity and $\left(1.35\frac{H_m}{R_{so}} - 0.35\right)$ shows the effect of cloudiness.

ESTIMATION OF NET RADIATION

The net radiation values for the study were obtained by Equation 10.

$$R_n = R_{ns} - R_{nl} \qquad (10)$$

R_{nl} is the net longwave radiations, R_{ns} is the net shortwave radiation

RESULTS AND DISCUSSION

This study has been conducted to compute the net radiation in three cities of close boundaries: Uyo, Calabar, and Port Harcourt in southern Nigeria. The mean values of the surface albedo, net shortwave and longwave radiation have been obtained. The results from Uyo, Calabar and Port Harcourt data are present in Tables 1 to 3 respectively. The mean variation of net radiation with months in Uyo, Calabar and Port Harcourt correspond to Figures 1, 3 and 5. Figures 2. 4 and 6 are the outcomes of the mean variation of global solar radiation and net radiation noted from Uyo, Calabar and Port Harcourt respectively.

Table 1: Monthly mean Albedo, Net shortwave radiation, Net longwave radiation and net radiation parameters in Uyo

Months	Albedo	H_m ($MJm^{-2}day^{-1}$)	R_{ns} ($MJm^{-2}day^{-1}$)	R_{nl} ($MJm^{-2}day^{-1}$)	R_n ($MJm^{-2}day^{-1}$)
JAN	0.554	15.194	6.771	1.709	5.061
FEB	0.516	17.399	8.389	1.927	6.462
MAR	0.589	15.389	6.305	1.387	4.917
APR	0.566	16.146	6.964	1.482	5.481
MAY	0.564	15.741	6.846	1.481	5.365
JUN	0.681	14.318	5.809	1.303	4.505
JULY	0.656	12.191	4.174	0.918	3.251
AUG	0.685	11.177	3.399	0.679	2.717
SEPT	0.592	15.665	6.091	1.354	4.737
OCT	0.567	15.645	6.749	1.593	5.155
NOV	0.489	17.551	8.943	2.229	6.513
DEC	0.512	16.267	7.931	2.122	5.807

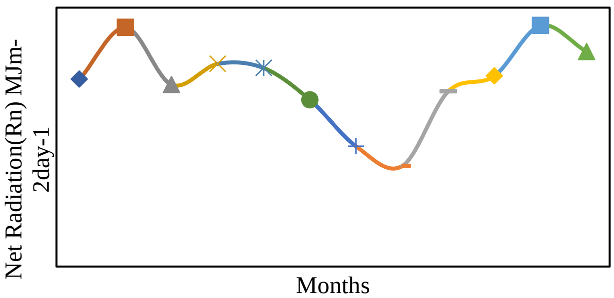

Figure 1: Mean Variation of Net Radiation Over Uyo

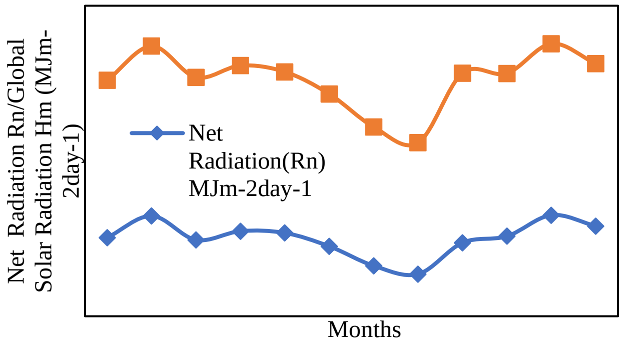

Figure 2: Mean Variation of Global Solar Radiation and Net Radiation Over Uyo

Table 2: Monthly mean Albedo, Net shortwave radiation, Net longwave radiation and net radiation parameters for Calabar

Months	Albedo	H_m ($MJm^{-2}day^{-1}$)	R_{ns} ($MJm^{-2}day^{-1}$)	R_{nl} ($MJm^{-2}day^{-1}$)	R_n ($MJm^{-2}day^{-1}$)
JAN	0.618	12.635	4.825	1.248	3.57
FEB	0.601	14.032	5.577	1.297	4.282
MAR	0.653	12.885	4.457	0.932	3.524
APR	0.668	12.508	4.144	0.812	3.332
MAY	0.664	12.384	4.142	0.801	3.341
JUN	0.713	11.472	3.615	0.694	2.921
JULY	0.687	10.011	2.725	0.449	2.272
AUG	0.679	9.712	2.508	0.333	2.144
SEPT	0.669	11.961	3.807	0.756	3.049
OCT	0.643	12.828	4.573	1.036	3.537
NOV	0.577	14.247	6.022	1.5	4.521
DEC	0.593	13.159	5.347	1.435	3.912

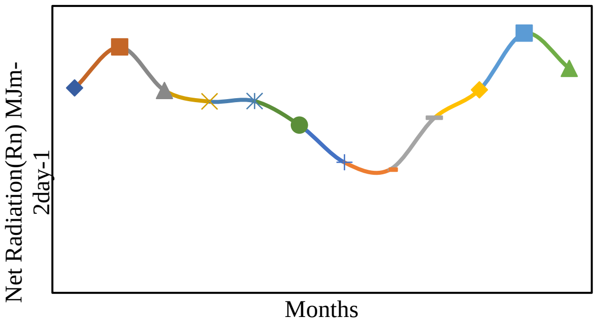

Figure 3: Mean Variation of Net Radiation Over Calabar

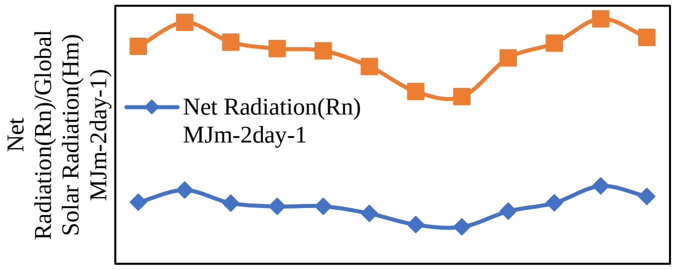

Figure 4: Mean Variation of Global Solar Radiation and Net Radiation Over Calabar

Table 3: Monthly mean Albedo, Net shortwave radiation, Net longwave radiation and net radiation parameters for Port Harcourt

Months	Albedo	H_m ($MJm^{-2}day^{-1}$)	R_{ns} ($MJm^{-2}day^{-1}$)	R_{nl} ($MJm^{-2}day^{-1}$)	R_n ($MJm^{-2}day^{-1}$)
JAN	0.637	12.422	4.509	1.15	3.357
FEB	0.624	13.571	5.091	1.203	3.885
MAR	0.661	12.696	4.288	0.928	3.367
APR	0.669	12.365	4.089	0.88	3.208
MAY	0.663	12.143	4.083	0.971	3.112
JUN	0.714	11.453	3.728	0.869	2.316
JULY	0.703	10.399	3.042	0.625	2.413
AUG	0.698	10.285	2.882	0.566	2.308
SEPT	0.661	11.817	3.747	0.831	2.913
OCT	0.649	12.719	4.453	1.096	3.353
NOV	0.594	13.966	5.644	1.507	4.13
DEC	0.607	13.162	5.172	1.415	3.75

Equation 1 was adequate for the determination of global radiation. Surface albedo was obtained using Equation 7. Equations 8 and 9 satisfied the assessment of the net shortwave and the net longwave. Net radiation outcome was achieved with Equation 10. The results are displayed in Tables 1 to 3 and Figures 1 to 6.

From Table 3, the net radiation noted from Port Harcourt data has the maximum net radiation of about 4.133 $MJm^{-2}day^{-1}$ which corresponds to the minimum albedo of 0.594 in the month of November with high net longwave radiation of about 1.507$MJm^{-2}day^{-1}$. The minimum net radiation noted is about 2.306$MJm^{-2}day^{-1}$ corresponding to maximum albedo of about 0.714 in June with low net longwave radiation of about 0.566$MJm^{-2}day^{-1}$ and low net shortwave radiation of about 2.882$MJm^{-2}day^{-1}$.

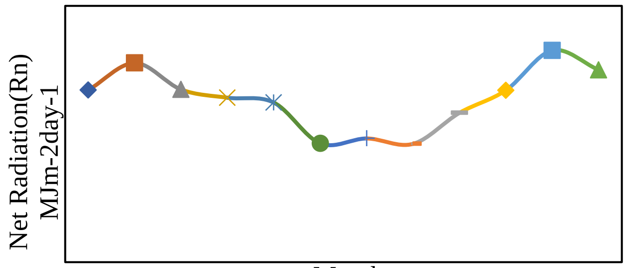

Figure 5: Mean Variation of Net Radiation Over Port Harcourt

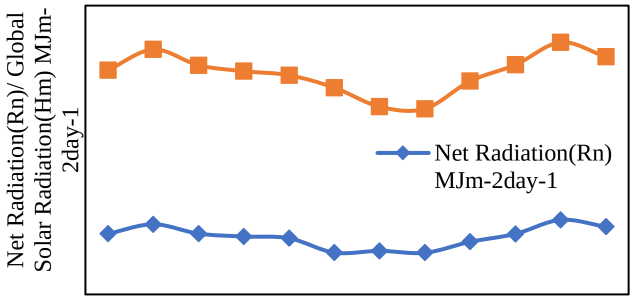

Figure 6: Mean Variation of Global Solar Radiation and Net Radiation Over Port Harcourt

Table 1, the maximum R_n of about 6.713$MJm^{-2}day^{-1}$ corresponds to a low albedo of about 0.489$MJm^{-2}day^{-1}$; the minimum R_n of about 2.717$MJm^{-2}day^{-1}$ corresponds to the maximum albedo of about 0.694 in August with a low R_{nl} of about 0.679$MJm^{-2}day^{-1}$ and R_{ns} of about 3.399$MJm^{-2}day^{-1}$. This relationship existing among albedo, R_{nl} and R_{ns} in Uyo and Port Harcourt could also be observed in Calabar location using Table 2. This is in agreement with Audu and Isikwue (2014), who obtained a positive value of 0.7 in Makurdi, higher than that of the Earth value of 0.3 in August, Babatunde *et al*. (2005) 0.64 for Ilorin, and Wiliams (2016) who inferred that R_n varies directly with R_{nl} and R_{ns}, but indirectly with albedo with the highest albedo value of 0.69 and lowest value of 0.48 for Enugu location.

Considering seasonal variation in R_n, the net radiation was observed from Figures .1-.6, to be high during the dry season (October – March). This could be attributed to low albedo which allows much solar radiation to reach the earth surface during the season. During the dry season, Port Harcourt was observed to have a mean net radiation of about 3.639$MJm^{-2}day^{-1}$, Calabar has about 3.892$MJm^{-2}day^{-1}$, and Uyo has a mean of about 5.685$MJm^{-2}day^{-1}$. Also, a low value of 2.72 $MJm^{-2}day^{-1}$, 2.14 $MJm^{-2}day^{-1}$, and 2.31n $MJm^{-2}day^{-1}$, respectively for Uyo, Calabar and Port Harcourt. $MJm^{-2}day^{-1}$, Low net radiation was observed during the rainy season mostly from June to August. This could be due to high cloudiness of the sky during the season. During the rainy season, Port Harcourt was observed to have a mean net radiation of about 2.799$MJm^{-2}day^{-1}$, Calabar had about 2.843$MJm^{-2}day^{-1}$, Uyo had a mean of about 4.343$MJm^{-2}day^{-1}$, and Uyo had the highest value. This could be due to its location at a higher altitude than the other cities. This implies that the highest net radiation could enhance solar energy technology services in Uyo. On the other hand, Port Harcourt and Calabar experienced the least net radiation, and the location considered all have similar net positive radiation. In all, the locations considered have low net radiation as a result of its proximity to water bodies.

CONCLUSION

The net radiation obtained in the study varies directly with global solar radiation and inversely with albedo. The area showed a positive net radiation in each of the location with its peak value during November and February and least value in June, July and August where rainfall is dominant and the reflectivity index is high due to much water vapour and cloud in the area, and its values are closely similar. The cities are therefore suitable for solar energy applications.

REFERENCES

Abdulazeez, M. A., Burari F. W. and Ahmed A. (2005). Estimation of Monthly Average Global Solar Radiation in Yola. *Journal of Renewable Energy* 6(2): 88-90.

Ahren, C. D. (2005). *Essentials of Meteorology*. California: Published by Thomson Brook/Cole, U.S.A.56-58.

Akpabio, I. O., Atat, J. G. and Akankpo, A. O. (2023a). Local Fit Parameter Satisfying Shear Modulus Porosity Relation for Southern Z Basin Analysis. *Neuroquantology*, 21(5): 1385-1391.

Akpabio, I. O., Atat, J. G., Umoren, E. B. and Ekemini, J. D. (2023b). The reservoir rock volumetric concentration and tortuosity description of pore space of Xa field, Niger Delta Basin. *World Journal of Advanced Science and Technology*, 03(01): 001–013.

Atat, J. G. and Umoren, E. B. (2016). Assessment of Mechanical and Elastic Properties of Soils in the South Eastern Part of Niger Delta, Nigeria. *World Journal of Applied Science and Technology*, 8(2): 188-193.

Atat, J. G., Akankpo, A. O., Umoren, E. B., Horsfall, O. I. and Ekpo, S. S. (2020c). The Effect of Density-velocity Relation Parameters on Density Curves in Tau (τ) Field, Niger Delta Basin. *Malaysian Journal of Geosciences (MJG)*, 4(2): 54-58.

Atat, J. G., Essiett, A. A., Ekpo, S. S. and Umar, S. (2023). Modelling of Bulk Modulus from Sand [API <75]-shale [API >75] Lithology for X_A Field in the Niger Delta Basin. *World Journal of Advanced Research and Reviews*, 18(03): 635–644.

Atat, J. G., Uko, E. D., Tamunobereton-ari, I. and Eze, C. L. (2020a). Site-Dependent Geological Model for Density Estimation in the Niger Delta Basin, Nigeria. *Malaysian Journal of Geoscience*, 4(1): 1-6.

Atat, J. G., Uko, E. D., Tamunobereton-ari, I. and Eze, C. L. (2020b). The Constants of Density-Velocity Relation for Density Estimation in Tau Field, Niger Delta Basin. *IOSR Journal of Applied Physics*, 12(1): 19-26.

Audu, M.O. and Isikwue B.C., (2014): Estimation of Albedo of the Earth’s Atmosphere at Makurdi –Nigeria. *International Journals of Scientific and Technology Research*, 3(4): 375-380.

Babatunde E.B., Falaiye O.A. and Uhuegbu, C.C. (2005). Simulated reflection SW radiation and its characteristic variation at Ilorin, Nigeria. *Nigeria Journal of Physics*,17:193-201

Balogun, J. O. and Obebe, K. A. (2013). Application of Rock Physics Modelling in Hydrocarbon Prospectivity Evaluation of Turonian Reservoir Units in the Niger Delta of Nigeria. *Journal of Petroleum and Geothermal Energy*, 2(1): 34-49.

Burari, F. W., Abdulazeez, M. A. and Sulaiman, M. N.(2006). Mathematical models for prediction of Global Solar Radiation for Maiduguri, Nigeria. *Nigerian Journal for tropical Engineerig*, 6(1): 32-37

Burari, F. W. and Sambo, A. S. (2001). Models for the prediction of Global solar radiation for Bauchi using Meteorological data Analysis. *Nigerian Journal of Renewable Energy*, 9(2):30-33.

Duffie, J.A. and Beckman, W.A. (1991): *Solar Engineering of Thermal Processes, 2nd (Edition).* New York. John Wiley and Sons, 1(2):44-47

Ejoh, E. F., Essiett, A. A., Atat, J. G., Inam, E. J., Essien, I. E., Bede, M. C. and Benjamin, E. U. (2023). Assessment of Soil to Cassava Transfer Factor of Radionuclides in Ughelli North Local Government Area, Delta State, Nigeria. *Journal of University of Babylon for Pure and Applied Sciences (JUBPAS)*, 31(3): 247 – 260.

George, N. J., Atat, J. G., Udoinyang, I. E., Akpan, A. E. and George, A. M. (2017). Geophysical Assessment of Vulnerability of Surficial Aquifer in the Oil Producing Localities and Riverine Areas in the Coastal Region of Akwa Ibom State, Southern Nigeria. *Current Science*, 113(3): 430-438.

Hostmeyer, S. (2006). “Relative Humidity, Frost point and Dew Point Temperature,. *Ohio Harby Journal*. 2(7):32-40.

Hunt, J. M. (1996). *Petroleum Geochemistry and Geology*. W. H. Freeman and Company, California.

Ibeh, G. F., Anyigor, I. S, Umahi, A.E. and Etaba, M. A. (2011). Statistical Analysis of estimation of global solar radiation with two Models at Uyo. *Journal of National Science Research*, 2(5): 2224-2234

Klein, S. A. (1998). Calculation of monthly average insolation on filted surface. *Solar Energy Journal* 20: 209-242.

Ododo, J.C. (1994). New Models for the Prediction of Solar Radiation in Nigeria.Paper presented at second OAU/STRC Conference on New Renewable and Solar Energy at Bamako, Mali.

Reijers, T. J. A., Petter, S. W. and Nwajide, C. S. (1996). The Niger Delta basin: Reijers, T.J.A., ed., Selected Chapter on Geology: SPDC Wa.: LP1O3-118.

Tasumi, M., Allen, R. G., and Trezza, R. (2008). At-surface reflectance and albedo from satellite for operational calculation of land surface energy balance. *Journals of Hydrological Engineering*, 13: 51–63.

Ugwu, A. I. and Ugwuanyi, J. U. (2011). Performance assessment of Haggreaves model in estimating solar and radiation in Abuja using minimum climatological data. *International Journal of Physics*, 1(1):1-5.

Umoh, M. D., Udo, S.O. and Udokah, Y. N. (2013). Solar radiation on Horizontal surface base on sunshine hours over Oweri, Nigeria. *Asian Journal of Science and Technology*, 4(10): 116-119.

Umoren, E. B., Akankpo, A. O., Udo, K. I., Horsfall, O. I., Atat, J. G. and Asedegbega, J. (2020). Velocity-Induced Pitfalls in Pore Pressure Prediction: Example from Niger Delta Basin, Nigeria. *IOSR Journal of Applied Geology and Geophysics*, 8(1): 52 – 58.

Williams, E.P. (2016). Evaluation of net radiation in some cities in southern Nigeria. *Unpublished M.Sc work*