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Analysis Global and Ultraviolet Radiation in Baghdad City, Iraq

Ali M. Alsalihi[1] Siaf H. Abdulatif [1,2]
1.Department of Atmospheric Sciences, College of science, Al-Mustansiriyah University, Baghdad, Iraq
2.Iraqi Meteorological Organization and Seismology, Ministry of Transport, Baghdad, Iraq

Abstract
In present study measurements of global solar radiation and ultraviolet (UVA and UVB) analyzed under different sky conditions. The global solar radiations of Baghdad city during study period highest in the summer are comparatively lower in the winter. The highest daily average solar radiation value of 897 W/m^2 was measured on June 8, whereas the daily minimum global radiation of 120 W/m^2 was recorded on December 30. The daily variation of UVA has maximum values in spring and summer days, while minimum values in autumn and winter days. The maximum value found in 13 June was 50.1 W/m^2, This value refers to a high level of harmful radiation, so it must warn against exposure to the sun at the afternoons during the summer days. The low levels of UVA were found in December, January, February and November. The moderate level of UVA was found in March, April, October and September. The high level of UVA was found in June, July, May and August. UV-B measurement is an indicator of the effect UV radiation on the human skin. The daily variation of UVB has maximum values in spring and summer days, while minimum values in autumn and winter days, where the maximum value found in 21 June was1.65 W/m^2. Furthermore empirical relationships between global and two component of UV radiation (UVA= 0.043G- 10.13) have correlation coefficients (0.96) and the percentage error (- 0.0179). It was found that there is a good agreement between measured and estimated values of global solar with UVA radiation respectively.
Keywords: Ultraviolet, solar radiation, Atmospheric science, Baghdad, Iraq

1. Introduction

The researches which investigated solar radiation within ultraviolet radiation bands has received a major attention in the last few years because of its biological, ecological effects produced by short-wave radiation received at the surface of the earth surface (Hedblom 1961) . Ultraviolet radiation is usually classified into three bands UV-C (100–280 nm) which is completely absorbed by stratospheric ozone; UV-B (280–315 nm) which is only partially absorbed or scattered in atmosphere and UV-A (315–400 nm) which represents most of the UV radiation received at the earth's surface (Diffey 2003; Fox 2000; Leavitt et al. 1997; Sliney 2001; van der Leun et al. 1998). In outer space, UV-B and UV-A band represent only 7.45% of the total solar radiation (Global Solar 2002; McKinlay and Diffey 1987; Standard 1998). The ozone layer forms a shield around the earth surface protecting the biosphere from the severe ultraviolet radiation coming from the sun. A weak reduction in the stratospheric ozone leads to an increase in the UV-B reaching the earth. UV radiation data are of particular interest because such radiation is energetic enough to break apart several biological molecules, including DNA [4]. The increase in UV radiation affects human health (Liou 2002). There are wide spatial and temporal variations in the UV irradiance at the surface of the earth depending on latitude, solar elevation, and atmospheric and local conditions. Atmospheric aerosols also affect the UV irradiance, but their influence is small relative to cloud cover (Carin and Bass 2001; Rohde 2007; Salby 1996). Among these factors influencing the UV irradiance, cloud cover present a high temporal and spatial variability. It is certain that clouds can cause large variability from year to other in UV radiation and therefore possibility play significant role in determining long term trends (Briggs and Smithson 1986; Pidwirny 2006). For the cloud effect, it is i to have important knowledge of clouds optical thickness. The main objective of this research paper is to evaluate and analyze solar radiation levels with hourly global and UVA and UVB bands conducted by measurements from Al-Mustansiriyah Solar station.

2. Ground measurements, Location of study and Statistical Criteria

The radiation measurements were measured every15minutes during the period of 1 January to 31 December 2015.Thesolar radiation station and automatic weather station (DAVIS VANTAGE PRO2) installed on the roof building of Atmospheric sciences department in Al-Mustansiriyah University (33º08'44"N;44º05'53"E; altitude 34m) as shown in figure (1). The sensor specifications which measure global solar radiation included within the automatic weather station (DAVIS VANTAGE PRO2) and Ultraviolet radiation within the UVA and UVB ranges measured by UV sensors (Kipp&Zonen, Delft, Netherland)(Kipp 2000) respectively are tabulated in Table (1) and Table (2).

The study region is Baghdad city; it is the capital and the main administrative center of Iraq. Baghdad is located in the central part of Iraq on both sides of Tigris river .The climate of Baghdad city (which is part of the a plain area at the central of Iraq and has same climatic characteristics) may be defined as a semi-arid, subtropical and continental, dry, hot and long summer cool winters and short springs. Rainfall is very seasonal and occurs in the winter from October to may average annual rainfall is 120 mm. The maximum recorded temperature was 51 ˚C in summer while the minimum was - 0˚C. The average maximum temperature for the last 30 year is 30.8 ˚C and average minimum temperature is 15.5 ˚C for the same period. The daily average of sunshine duration is 9.6 hours and daily in coming radiation is 4.7 kwh.m^{-2}. The total average annual sunny hour during one complete year is about 3500 hours.

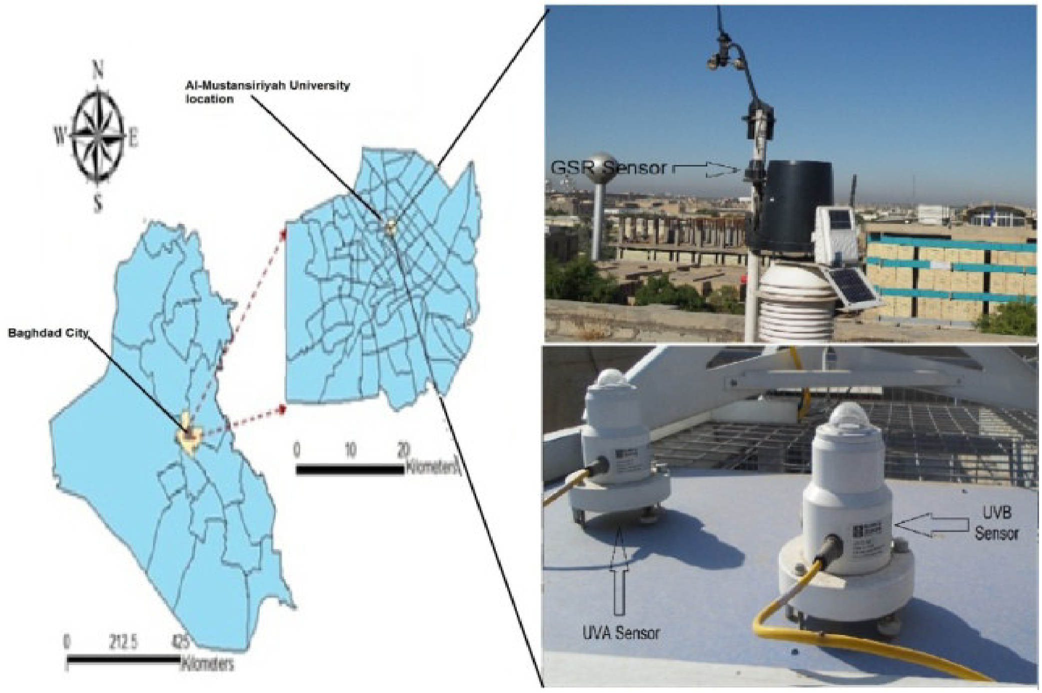


Fig 1: Ground-based multifunctional radiometric station at AlMustansiriyah location.

Table (1): Technical data for solar radiation sensor (Instruments 2014)

Resolution and Units	1 W/m^2
Range	0 to 1.800 W/m^2
Accuracy	5% of full scale (Reference :Epply psp at 1.000W/m^2)
Drift	Up to ±2 % per years
Cosine Response	± 3% far angle to incidence from 0o to 750
Temperature Coefficient	- 0.12 % per °C (-0.067% per °F) Reference temperature =25 °C (77 °F)
Update Interval	50 seconds to 1 minute (5 minutes when dark)
Current Graph Data	Instant Reading and Hourly Average :Daily , monthly High
Historical Graph Data	Hourly Average , Daily , Monthly Highs
Alarm	High Threshold from Instant Reading

Table (2): The specifications of the UVA and UVB sensors.

specifications	UVA	UVB
Spectral range (overall)	320 to 400 nm	285 to 320 nm
Sensitivity	5 to 15 μV/W/m²	7 to 14 μV/W/m²
Response time	< 18 s	< 5 s
Temperature dependence of sensitivity (-10 ºC to +50 ºC)	< 5 %	< 1 %
Operational temperature range	- 40 to +80 °C	- 40 °C to +80 °C
Field of view	150 °	180 °

3. Statistical Methods

In the literature, there are several statistical test methods used to statistically evaluate the performance of the models of solar radiation estimations. Among these, root mean square error (RMSE), mean absolute error (MAE), Agreement Index (AI) and the Determination Coefficient (R^2).

3.1 Root Mean Square Error (RMSE).

The root-mean-square error (RMSE) is a frequently used measure of the differences between values predicted by a model or an estimator and the values actually observed from the thing being modeled or estimated. RMSE is a good measure of precision. The value of RMSE is always positive, representing zero in the ideal case. The RMSE may be computed from the following equation

$$RMSE = \sqrt{\sum_{k=0}^{n} (y_k - x_k)^2 / n} \qquad (1)$$

3.2 Mean Absolute Error (MAE)

In statistics, the mean absolute error (MAE) is a quantity used to measure how close forecasts or predictions are to the eventual outcomes. The mean absolute error is given by:

$$MAE = \frac{1}{n}\sum_{i=1}^{n} |f_i - y_i| = \frac{1}{n}\sum_{i=1}^{n} |e_i| . \qquad (2)$$

As the name suggests, the mean absolute error is an average of the absolute errors $|e_i| = |f_i - y_i|$, where f_i is the prediction and y_i the true value. Note that alternative formulation may include relative frequencies as weight factors.

The mean absolute error is on same scale of data being measured.

3.3 Agreement Index (AI)

The index of agreement (IA or d) is given by:

$$IA = 1 - \frac{\langle (\chi_c - \chi_m)^2 \rangle}{\langle (|\chi_c - \langle \chi_c \rangle| + |\chi_m - \langle \chi_m \rangle|)^2 \rangle} \qquad (3)$$

The denominator in the above equation is referred to as the potential error. IA is a non-dimensional and bounded measure with values closer to 1 indicating better agreement.

3.4 Determination Coefficient

The correlation coefficient is a test of the linear relationship between the calculated and measured value which is defined by

$$r = \frac{\sum_{i=1}^{N} (y_i - \bar{y})(\chi_i - \bar{\chi})}{\left[\left\{\left[\sum_{i=1}^{N} (y_i - \bar{y})\right]\right\}\left\{\left[\sum_{i=1}^{N} (\chi_i - \bar{\chi}\right]\right\}\right]^{0.5}} \qquad (4)$$

Where y_i is the estimated value, x_i is the measured value $\bar{y}$, $\bar{x}$ are the meanvalue of the estimated and measured

values respectively and N is the number of the values.

4. Results and discussion

4.1 Global and UV solar radiation measurements in Baghdad.

The daily mean data of global and ultraviolet radiation (UVA and UVB at Baghdad for the period 1 January to 31 December 2015 are illustrated by Fig. (2, 3 and 4). From the Figures, the higher values of global solar radiation are in June and the lower values are in December. The UVA and UUB solar radiation has a maximum values also in June for 2015. The annual mean values for G and UVA and UVB are 615, 16.9 and 0.44 (W.m^{-2}) respectively.

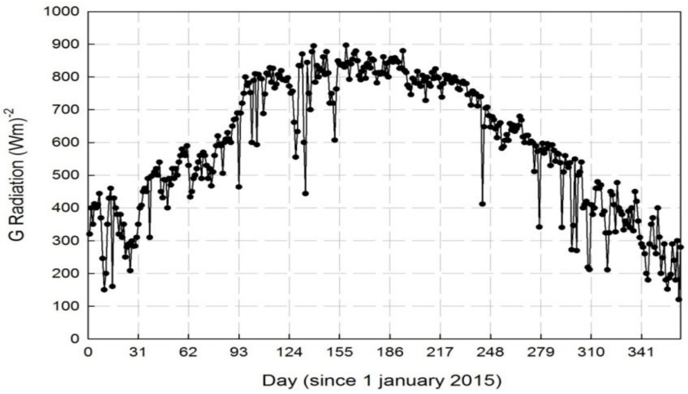


Fig 2: Daily G solar radiation variation through the year 2015.

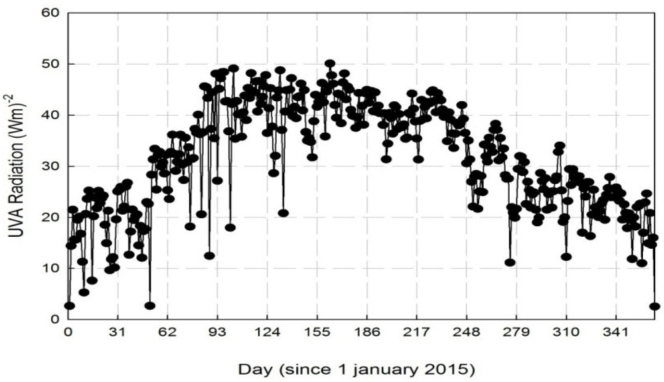


Fig 3: Daily UVA radiation variation through the year 2015.

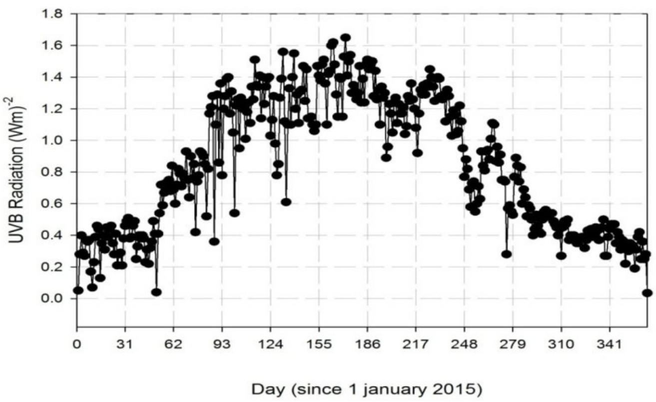


Fig 4: Daily UVB radiation variation through the year 2015.

In Figure 5, is shown that the global solar radiation flux for each hour of the day and each month during the year 2015. This figure is a good illustration of the type of variation which can take place through a year. The maximum global irradiance hourly values occur at solar noon and the minimum in the extreme hours (the beginning and the end of the day). In 2015, the highest maximum takes place in June with a value of 877 W/m^2 and the lowest in December with a value of 495 W/m^2 (at solar noon) in 2015.

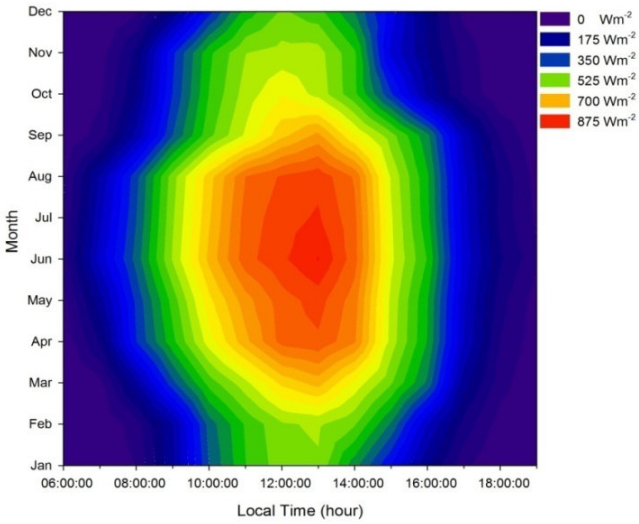


Fig 5: measured hourly global solar radiation15th day of each month in 2015.

In Figure 6, is shown that the global solar radiation flux for each hour of the day and each month during the year 2015. This figure is a good illustration of the type of variation which can take place through a year. The maximum global irradiance hourly values occur at solar noon and the minimum in the extreme hours (the beginning and the end of the day). In 2015, the highest maximum takes place in June with a value of 47 W/m^2 and the lowest in December with a value of 18 W/m^2 (at solar noon) in 2015.

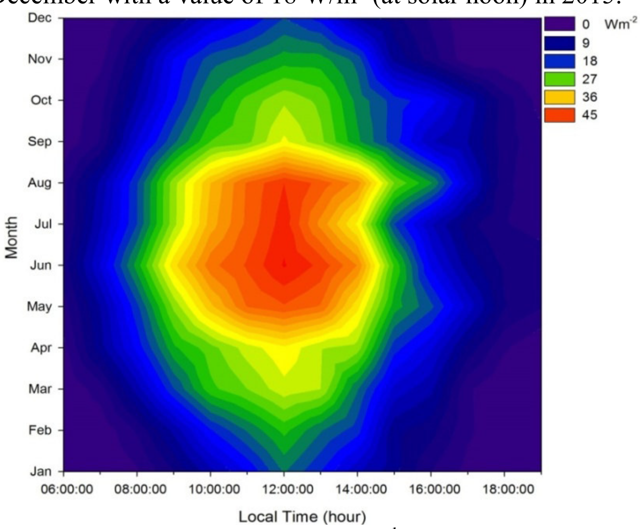


Fig 6: measured hourly UVA radiation 15th day of each month in 2015.

4.2 Empirical relation Between G and UVA

Several correlation types were investigated to propose the best fit between G and UVA data. It was found that the data is going towards the best linear fit in the form:

$$UVA = aG + b \qquad (5)$$

Where: a and b are regression coefficients which depend on the weather parameters of the location. The data have been processed by a statistical software and the obtained values for **a** and **b** were found to be 0.043 and – 10.13 respectively as shown in Fig 7. The obtained values for the correlation coefficient were R= 0.96 and the percentage error of estimation were - 0.017.

Accordingly; the empirical relationship investigated equation (5) becomes:

$$UVA = 0.043G - 10.13 \qquad (6)$$

The measured data of global solar G in Equation (6) to calculate the corresponding values of UVA radiation. The estimated data of UVA solar radiation were compared with the corresponding measured data during the Study period. The results were illustrated by Fig. (8), it can be seen that the calculated values of UVA solar radiation are in a good agreement with the measured values for most months of the year. The assurance factor which represent the percentage error between the estimated and the measured values of UVA solar radiation was in the range form – 0.108 to 0.068 for the year 2015, The annual mean values of the assurance factor are - 0.017 for the studied period.

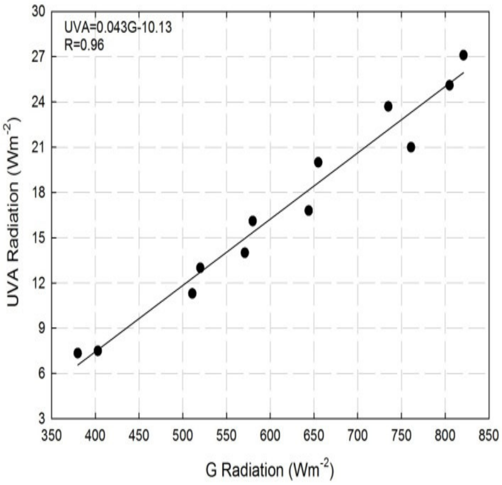
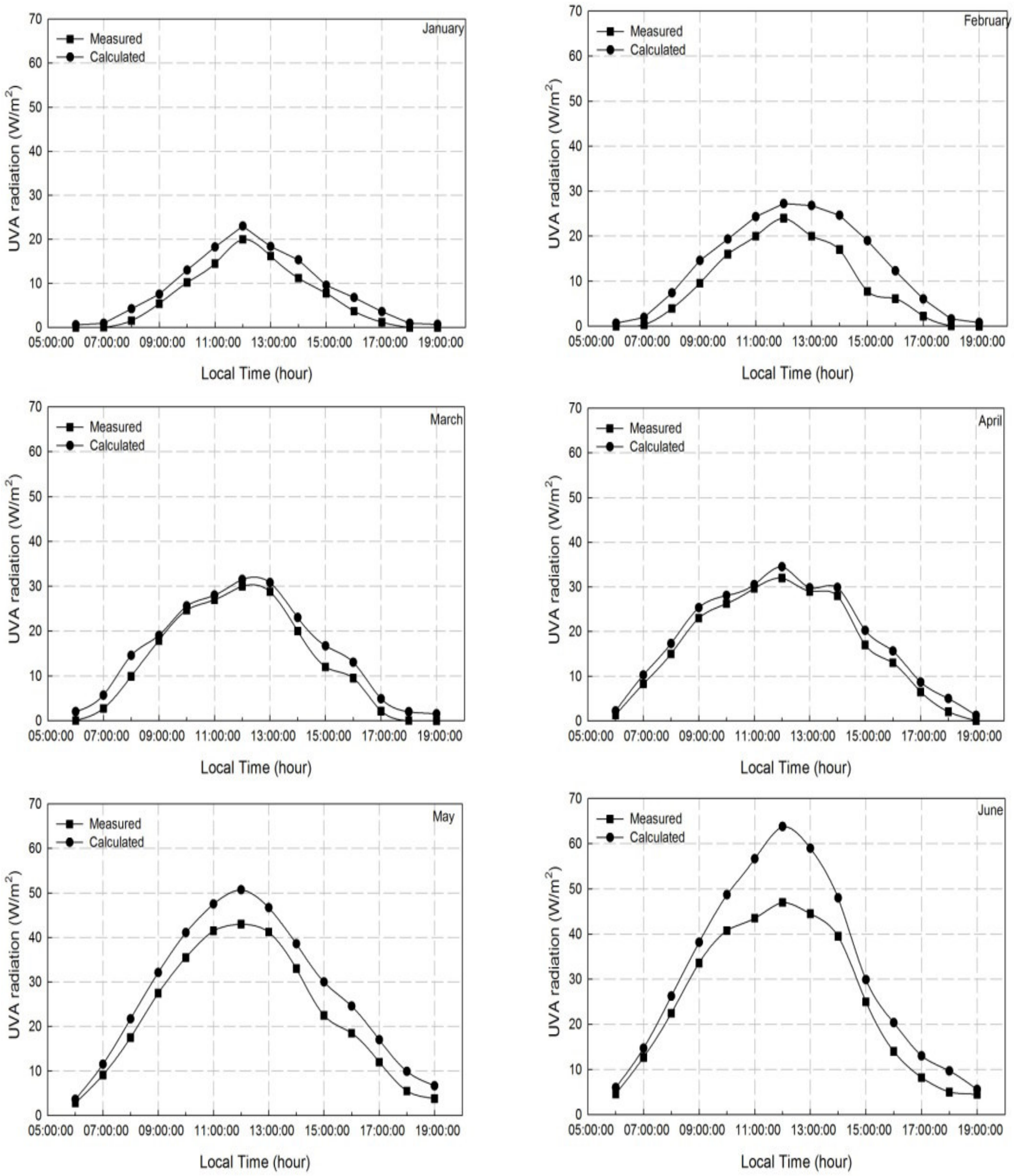


Fig 7: Correlation between G and UVA radiation for Baghdad city during (Jan – December) 2015.



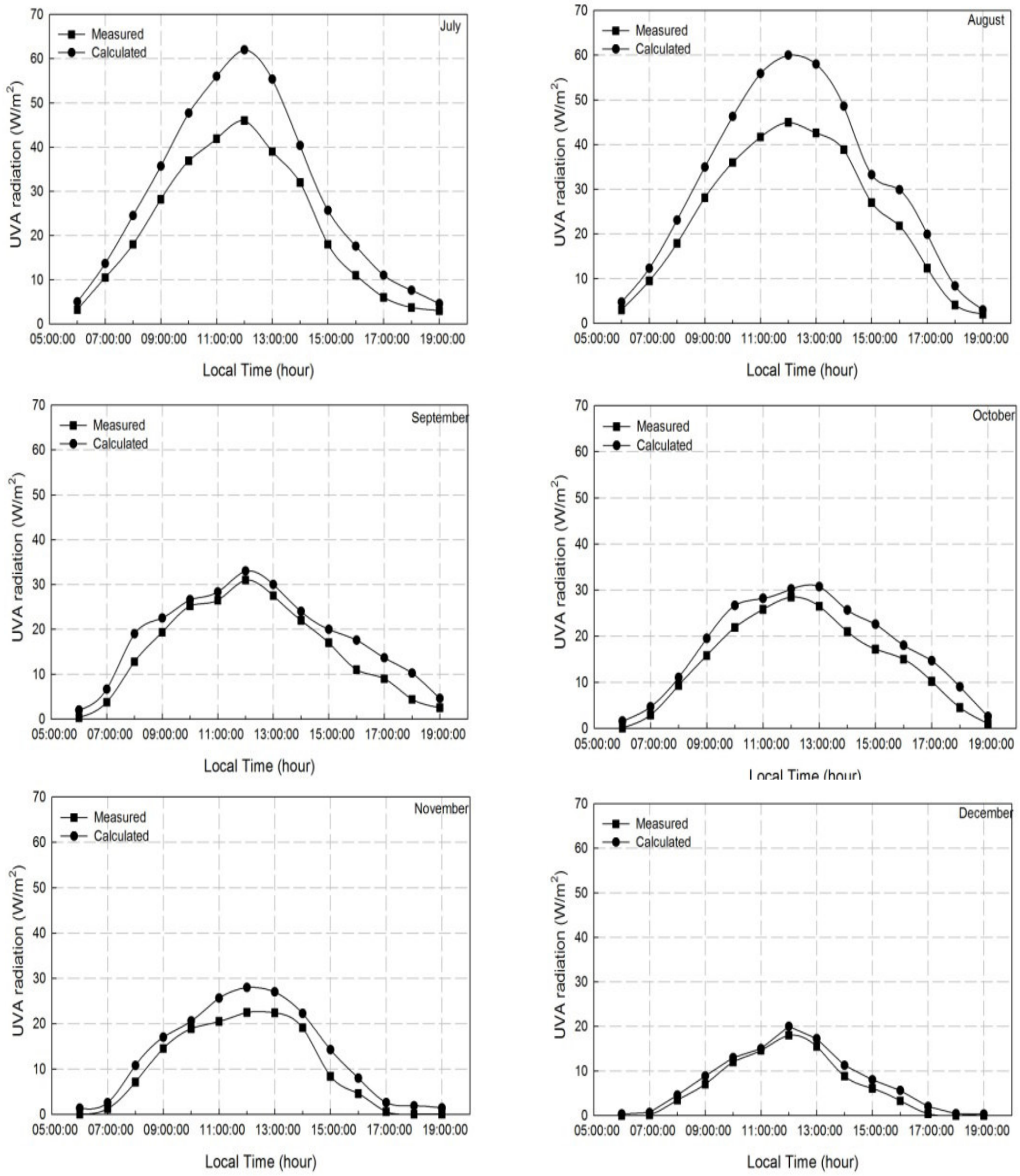


Fig 8: Comparison between calculated and measured hourly UVA radiation at the 15th day of each month in 2015.

5. Conclusions

The following are the main concluding remarks of this research:

The global solar radiation of Baghdad city during the year 2015 indicates a strong potential for utilizing solar energy in Baghdad. Daily average solar radiation data show that average values are higher in the summer from April to August and are comparatively lower in the winter. The highest daily average solar radiation value of 897W/m^2 was measured on June8, whereas the daily maximum global radiation of 120W/m^2 was recorded on December 30.

The daily variation of UVA has maximum values in spring and summer days, while minimum values in autumn and winter days. The maximum value found in 13 June, This value refers to a high level of harmful radiation, so it must warn against exposure to the sun at the afternoons during the summer days. The low levels of UVA were found in December, January, November and February. The moderate level of UVA was found in March, October, April and September. The high level of UVA was found in June, July, May and August.

UV-B measurement is an indicator of the effect UV radiation on the human skin.The daily variation of

UVB has maximum values in spring and summer days, while minimum values in autumn and winter days. The maximum value found in 21 June, This value refers to a high level of harmful radiation, so it must warn against exposure to the sun at the afternoons during the summer days. The low levels of UVB were found in December, January, November and February. The moderate level of UVB was found in March, October, April and September. The high level of UVB was found in June, July, May and August.

The investigated empirical relationships between global and two component of UV radiation (UVA= 0.043G - 10.13) correlation coefficient (0.96) and percentage error (- 0.0179). From the results obtained and discussions, it was found that there is a good agreement between measured and estimated values of global solar and UVA radiation, which favor the use of the investigated empirical formula with confidence to calculate the ultraviolet component of solar radiation at different sites in Iraq.

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