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Estimation of ozone content employing ground- based UV measurements over Baghdad City, Iraq

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ABSTRACT

In terms of surface temperature control, ozone is a greenhouse gas that has a significant influence on weather and climate system regulation. O_3 absorbs the visible and ultraviolet region of the spectrum solar radiation, leading to a variation in the electronic energy of the molecule. The more powerful absorption occurs in UV rays, with lower absorption in the visible region. O_3 may absorb the infrared (IR rays) of the earth's atmospheric system. The methods used in the present study were based on ground-based UV measurements over Baghdad City- Iraq, where the considered UV radiation values were measured every 10 minutes during the period from October 2014 to December 2015. The sun radiation was measured by a station located at Mustansiriyah University in Iraq (33º08'44" N; 44º05'53" E; altitude 34 m). The results showed a positive direct relationship between the ultraviolet B (UV-B) and Global Solar Radiation (G) for hourly values in Baghdad, with a correlation coefficient of R = 0.885, and the UV levels rise with an increase in G. As a result, an empirical relationship association between them were established. In all areas of correlation relationship, the Determination Coefficient (R^2) of the two variables was greater than 0.98. With a good agreement between calculated values of hourly UV (UVe), and corresponding measured values (UVm), correlation coefficient R = 0.94. Calculated linear regression accounted for 90 % of the variance. So, the results of the UV-G relationship may be used to estimate UV-B values for measurements taken over a period of time at the Mustansiriyah site, for values that are difficult to measure, or for any place in Baghdad or the central area of Iraq, or sites with comparable climates.

Keywords: Ozone, UV Radiation, Atmosphere station, Baghdad, Iraq.
Article type: Research Article.

INTRODUCTION

The most crucial is ozone and following CO_2 and CH_4, is regarded as 3^{rd} greatest important significant anthropogenic trace gas (Gaur *et al.* 2014). It is produced when O_2 is photolyzed at wavelengths less than 242 nm to create oxygen atoms (Komala & Ambarsari 2018). Small fluctuations in O_2 photolysis are caused by variations in solar output, resulting in associated changes in ozone amounts. The variation in ozone concentration leads to profoundly influence the vertical thermal structure of the atmosphere (Lefohn *et al.* 2011). Natural and anthropogenic factors, like human activities could cause change in atmospheric ozone amount, through emission some of harmful substances, which can lead to destroy ozone layer (Alsalihi & Abdulatif 2016). Release of certain chemicals, can lead to the process of O_3 formation in the troposphere. The stratospheric incursion impacting surface O_3 has been one of two main sources for tropospheric O_3 (Sadanaga *et al.* 2008). It is important because, though accounting just for 10% of the higher sediment columns, it has the ability to impact climate since it is a greenhouse gas. By sunlight, the combination between generic nitrogen oxide (NOx) and volatile organic compounds (VOCs) and oxygen monoxide (CO) leads to produce ozone (AL-Salihi 2011; Reddy *et al.* 2012). Raising VOC concentrations while raising NOx levels causes an elevation or reduction in O_3 depending on the current VOC/NOx ratio (Reddy *et al.* 2012). Human activities, anthropogenic, and natural factors lead to emission

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of compounds that deplete the ozone, resulting in alterations in O_3. Furthermore, it has resulted in a lengthy O_3 depletion in a larger portion of the atmosphere (McKenzie *et al.* 2011). The generation of hydroxyl radicals (OH) due to UV photooxidation in the existence of water vapour, is primarily fuelled by ozone. Hydroxyl radicals by playing a role in climate, are vital for the stratospheric ozone layer, and are responsible for the oxidation of a number of trace gases. Reddy *et al.* (2012). The catalytic ozone loss occurs as a result of a variety of gas-phase chemical cycles, the most significant of which are recently assumed to occur in the low stratosphere around mid-latitudes. The main electromagnetic wavelength emitted from the sun is between 200 and 400 nm. In contrast, the mean energy input density released at the photosphere is 6.2107 W m^{-2} (Hester *et al.* 2000). The energy of radiation is split according to the emission wavelength spectrum, which includes infrared IR wavelengths greater than 720 nm, visible (VIS) wavelengths from 400 to 720 nm, and UV spectral ranges greater than 720 nm (Frederick *et al.* 2000). UV-A refers to wavelengths ranging from 315 to lower limit of visible wavelength, i.e., 400 nm. UV-B corresponds to spectral ranges of 280 to 315 nm, while UV-C to wavelengths of 190 to 280 nm (Organization and Organization 2010). The link between UV light and stratospheric ozone is best explained using this categorization. One of the most significant events impacting it is the absorption of UV photons through photochemical processes. This is a common occurrence in the ozone creation and destruction cycle, which happens mostly in the stratosphere (Preez *et al.* 2019). Many researchers and research centres have estimated ozone, using different methods and devices to investigate the variability of total ozone column. For instance, Pancholi *et al.* (2018) illustrated in meteorological conditions, daily and seasonal alterations of environmental contaminants in the surrounding environment of a sub metropolitan area in western India. The highest/lowest O_3 levels were reported pending the pre-monsoon/monsoon seasons, correspondingly. The O_3 production during the day demonstrated an antithesis connection, with a maximum in the middle of the day and reduced at night (Al-Salihi *et al.* 2015). From 1979 through 2004, the negative trend for O_3 was apparently observed for all months, however the positive trend for O_3 was definitely evident during 2005-2007. The findings may be used to offer detailed descriptions of TOC alterations in Iraq, as well as to inform the climate change studies in the country (Xu *et al.* 2011). Seasonal alterations in O_3 and its precursors have been found in metropolitan areas, with the highest mixing proportions of O_3 occurring late in the spring and early summer, while the lowest in winter (Karavana-Papadimou *et al*. 2013). The applicability of van Heuklon's O_3-estimation formula levels were evaluated against satellite data for a variety of European towns in this study. By encouraging findings, The van Heuklon formula was used to create a new model (Demirhan *et al.* 2005). By investigating the temporal and geographic fluctuation of TOC, while discussing fluctuation of O_3 in overall across Eastern Mediterranean and South-eastern Europe, they discovered that lower stratospheric temperature has a significant impact on stratospheric ozone at mid-latitude (AL-Salihi 2011). Once analysing the link between total organic carbon and solar activity utilizing spectroscopy and energy density for Baghdad throughout the period (1997-2005), it was discovered that solar activity exhibited a little impact on total ozone generation (AL-Salihi 2009). In recent years, growing anthropogenic processes related to human activity have resulted in a significant ozone reduction in the spring season over Antarctica. Numerous investigations based on ground and satellite measurements have found them to be accurate (Hassan *et al.* 2013). The researchers discovered that ozone concentrations are related to wind speed and nitrogen oxides are significantly depended on the daily cycle. After performing continuous observations for a full year from December 2011 to December 2012, O_3, nitrogen oxide, and carbon monoxide were gathered during the summer from three places: residential, industrial, and rural. The rural site displayed the greatest O_3 levels, while the industrial site the lowest (Nozawa *et al.* 2007). Differences in the intensity ratio of UV-B to UV-A radiation for solar ultraviolet radiations were studied in Tokyo, Japan, Sao Martinho da Serra, Brazil, Punta Arenas, Chile were discovered in both hemispheres. Additionally, the results show a clear negative relationship with the quantity of O_3 along the line of sight. However, many studies have provided positive reports regarding estimation and calculation of the total O_3 column (AL-Salihi 2011; Preez *et al.* 2019). The main goal of this research is to develop a mathematical formula for estimating total ozone using ground-based UV-B measurements.

MATERIALS AND MTHODS

Experimental site and measurement

The UV values used in this study were obtained every ten minutes in the solar radiation station on the top of Department of Atmospheric Sciences Building, Mustansiriyah University (33o08'44" N; 44o05'53" E; altitude 34 m), as illustrated in Fig. 1 during the period between October 2014 and December 2015. Tables 1 and 2 include the sensor parameters for measuring (UV-A) and (UV-B) respectively, as well as global solar radiation by the autonomous weather station (Kipp & Zonen 2000b).

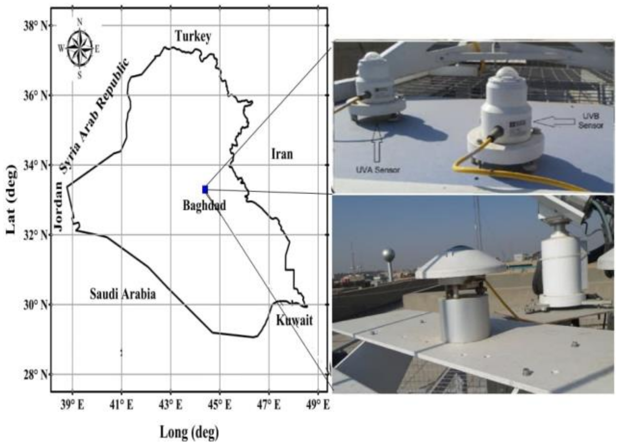

Fig. 1. Solar Radiation Station in Mustansiriyah University is placed on the top roof of the Department of Atmospheric Sciences.

Table 1. UVA and UVB sensors specifications. (Kipp & Zonen 2000a).

Specifications	UVA	UVB
Spectral extent (Inclusive)	320 to 400 nm	280 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 °C to +40 °C)	< 5 %	< 1 %
Operational temperature range	-40 to +80 °C	-40 °C to +80 °C
Field of view	150 °	180 °

Table 2. Solar radiation sensor to technical data.

Resolution and Units	W/m2
Range	0 to 1.800 W/m2
Accuracy	5% of full scale (Reference: Epply psp at 1.000W/m2)
Drift	Up to ±2 % per years
Cosine Response	± 3% far angle to incidence from 0o to 750
Temperature Coefficient	- 0.12 % per oC (-0.067% per oF) Reference temperature =25 oC (77 oF)
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

Study area

Baghdad is situated on a large plain with a total size of 204 km^2 and is located at 33° 36′ N; 44° 40′ E, 34 m. Baghdad is the Iraqi capital, which is separated into Karkh and Rusafa by the Tigris, It is Iraq's commercial and economic hub, with numerous companies, refineries, electric power producing plants, and other industrial operations. By a population of 20% of Iraq's total population, Baghdad is one of the country's most populous cities (Rabee 2015). As a result, behind Tehran, Iran's capital, it is the second largest city in our region. Baghdad's climate is similar to that of Iraq. Summers are hot, dry, and long, with subtropical, continental, and semi-arid areas receiving the most rainfall. Temperatures can reach 51ºC, while winters may be cold, with lows as low as 0 ºC Springtime is brief. Average maximum and minimum temperatures during the previous 30 years, have reached between 30.8-15.5 ºC, respectively. Duration medium daily sunshine reached 9.6 hours. The received daily radiation is 4.7 kwh m^{-2} and during one complete year, total average annual sunny hour is about 3500 hours (Atlas 2018).

RESULTS AND DISCUSSION

Relationship of ultraviolet radiation with effective ozone

The experimental relationship of the UV-B / UV-A ratio and efficient O_3 is shown in Fig. 2. In order to obtain an empirical equation to estimate the effective ozone. Once the UV-B to UV-A flux ratio is compared to effective ozone, the relation of ultraviolet radiation from the sun and O_3, resulting from climax ozone and air mass becomes obvious. The measured UV-B to UV-A proportion, by the Spectro-Radiometers in Mustansiriyah Solar Station, demonstrates a link correlation to effective ozone. By coefficients of -0.84, there is a definite dis-correlation. The findings revealed a substantial negative association between ultra violet ratio and efficient O_3, by ozone serving as a strong predictor of UV data estimates. These findings also imply that the quantity of efficient O_3, may be determined using the observed UV ratio (Equation 1; Fig. 2).

$$O_3 = 591.8 - 320.8\left[\frac{UVB}{UVA}\right] - 107.2\left[\frac{UVB}{UVA}\right]^2 12.84\left[\frac{UVB}{UVA}\right]^3 \qquad \textbf{(1)}$$

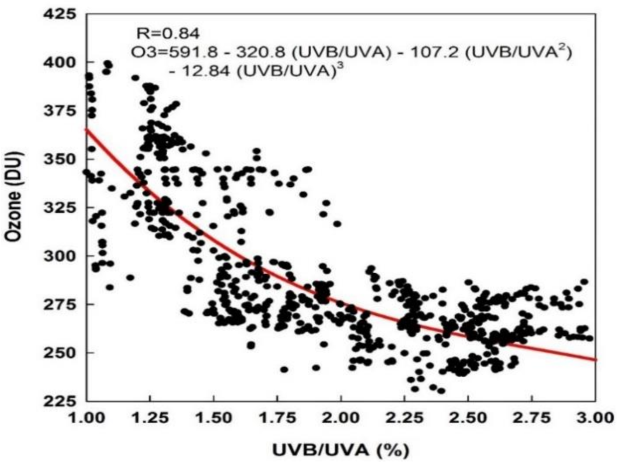

Fig. 2. Relationship of UV-B/UV-A ratio versus effective O_3.

Comparison of measured and calculated ozone

Fig. 3 compares the ozone calculated using the locally established equation to the ozone observed. The scatter plot between the estimated and observed ozone is shown by the linear regression with a gradient value of 0.84. Method of linear regression has been employed, to verify the correlation between the calculated and measured ozone (Fig. 3) exhibiting the scatter plot between the measured and calculated ozone values which is estimated by equation 2 (Fig. 3).

$$\text{Calculated } (O_3) = 0.709 \text{ x measurement } (O_3) + 82.5 \qquad \textbf{(2)}$$

In smaller and larger effective ozone, the agreement between data and fitting findings is a little less good. Moreover, Fig. 3 includes the tendency as one of the reasons of the favourable outcomes for the data of larger effective O_3. This is owing to the fixed exposure modes requirement for a short exposure period in SSO. Due to the fall of the Automatic Exposure (AE) mode, the disparity in signal noise ratio grows more severe, as the sun zenith angle data grows higher. It is also certain when examining the correlation coefficients in Figs. 2 and 3. To improve data quality, the exposure time should be increased and the Spectroradiometer be replaced.

Comparisons between monthly mean calculated and measured ozone

Fig. 4 shows the ozone calculated using the calculation and actual readings. The calculated ozone levels behave differently than observed ones. Moreover, it can be observed that the ozone calculated from Equation 1, is extremely consistent with the measured ozone (Fig. 4) indicating that they are an excellent match.

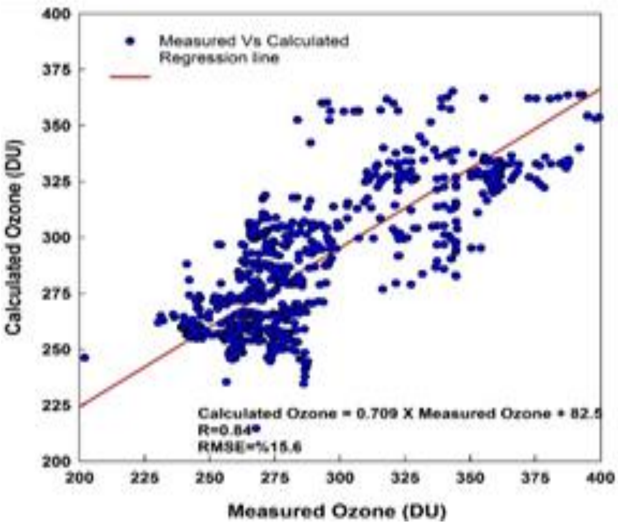

Fig. 3. Relationship between effective ozone from ultraviolet ratio radiation and effective ozone measured, in Mustansiriyah Site in Baghdad City.

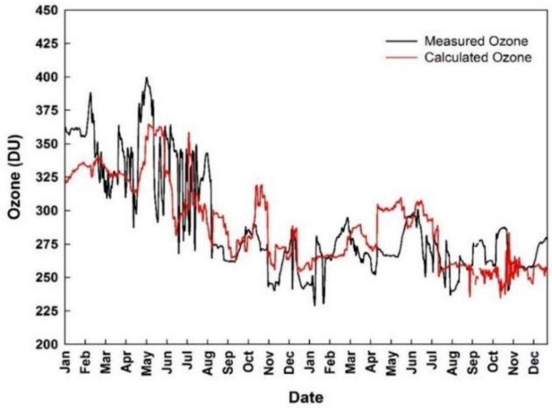

Fig. 4. The comparisons between monthly mean calculated and measured ozone.

The hourly mean ultraviolet solar radiation UV-A (W m^{-2}) and global solar radiation, G (W m^{-2})

Changes in atmospheric conditions play a crucial effect in limiting ozone concentrations (Fig. 5). On hot, bright days with calm air, ozone is easily produced. When it is cloudy, chilly, wet, or stormy, though, ozone production is severely inhibited. Climate and ozone exchange the influence on each other. The production of ozone is affected by temperature, humidity, wind, and the existence of numerous substances in the atmosphere. All these factors influence the environment, while the existence of ozone in the atmosphere influences the elements of the atmosphere. Cooler temperatures lead to more stratospheric polar clouds and lower ozone levels, whereas warmer temperatures lead to more stratospheric polar clouds and higher ozone levels. So, warmer temperatures lead to more stratospheric polar clouds and higher ozone levels. The year-to-year alterations in temperature are caused by atmospheric movements. We may expect more ozone by hotter temperatures. There is a definite correlation between rising ozone levels and overall warmer days. We can anticipate alterations in ozone air quality when the troposphere warms on a worldwide scale. The likelihood that higher summer temperatures will result in the increased demand for air conditioning and energy. The majority of our electric generating plants produce NOx. As a result, the increased amounts of ozone pollution can be predicted as NOx emissions rise. The potential for a bigger layer of ozone to develop is increased by water vapour transported by a warmer atmosphere. Increased clouds, typically early in the morning, can reduce reaction rates and, as a result, ozone production rates. The stratosphere has cooled due to the increased amounts of trace gases in the atmosphere. This cold exhibits an impact on the rate of chemical processes that control the ozone layer's content in the stratosphere. Fig. 4 illustrates the high concentration from March through May as well as in summer months of May-July. The association of UVA & G hourly readings was measured in Baghdad (Fig. 5), with a correlation value of R, demonstrating a rise in UV-A with an elevation in G. (0.92).

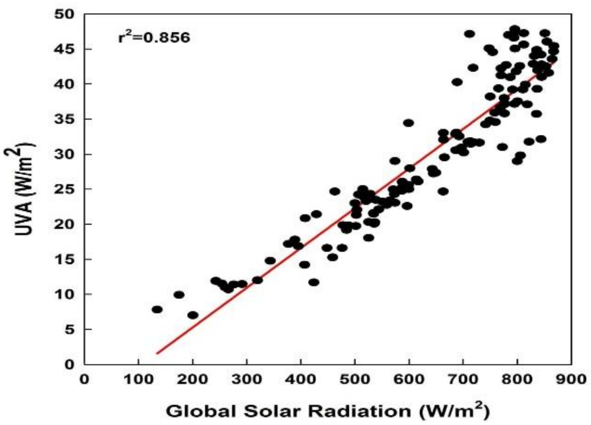

Fig. 5. Hourly mean ultraviolet solar radiation UV-A (W m^{-2}) and global solar radiation, G (W m^{-2}).

Hourly mean ultraviolet solar radiation UV-B (W m^{-2}) and hourly global solar radiation, G (W m^{-2})

Fig. 6 illustrated the UV-B and G relations for hourly mean over Baghdad City. It shows a positive direct relationship between them, with a correlation coefficient R = 0.885.

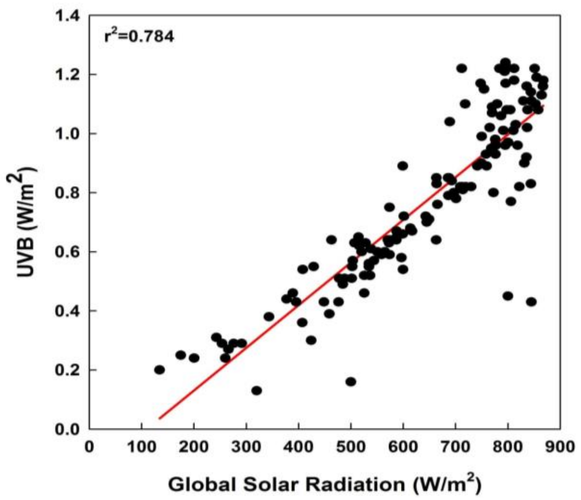

Fig. 6. Hourly mean ultraviolet solar radiation UV-B (W m^{-2}) versus Global Solar Radiation, G (W m^{-2})

Hourly mean ultraviolet solar radiation UV radiation (W m^{-2}) and Global Solar Radiation, G (W m^{-2})

The connection of UV and G readings at hourly intervals in Fig. 7 demonstrates that G elevates by UV upraise. This lead to examine empirical relationship between the two parameters. To detect the best fit of UV and G data, there were many kinds of correlation (Linear, second order polynomial, and power). During the study period the results shows that the determination coefficient (R^2), for all types of correlation, between the two parameters about 0.98, so it looks, a linear relation between them. Many prior studies (Cañada *et al.* 2003; Robaa, 2004; El-Noubi, 2006; Escobedo *et al.* 2009; Santos *et al.* 2011; Ali 2015) exhibit the connection of UV and G appearing a linear equation, which are consistent with the findings of this study. The functional relationship between the two parameters was obtained from the following Fig. 7.

The relation between UV estimated and UV measured

As shown in Fig. 8, the estimated ultraviolet (UVe) hourly values and the corresponding measured values (UVm) exhibit a good agreement with the correlation coefficient (R= 0.94). This implies that the estimated and observed UV levels in the Mustansiriyah zone were in good agreement with each other. The estimated regression line explained around 90% of the variation. The results obtained from the relation of UV with G can be used to assessment of UV values for measurements available in a limited time at Mustansiriyah Site or for values hard to measure, or any location in Baghdad, the central region of Iraq, or locations with a comparably climate. Table 3 compares the results of current study with previous ones.

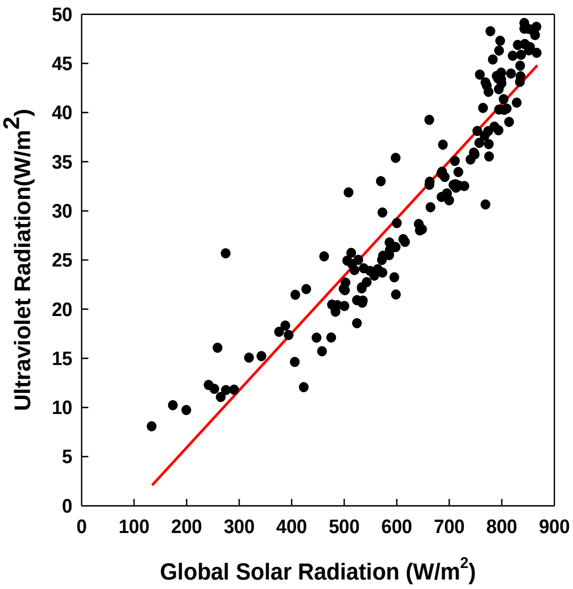

Fig. 7. The hourly mean ultraviolet solar radiation UV radiation (W m^{-2}) and global solar radiation, G (W m^{-2}).

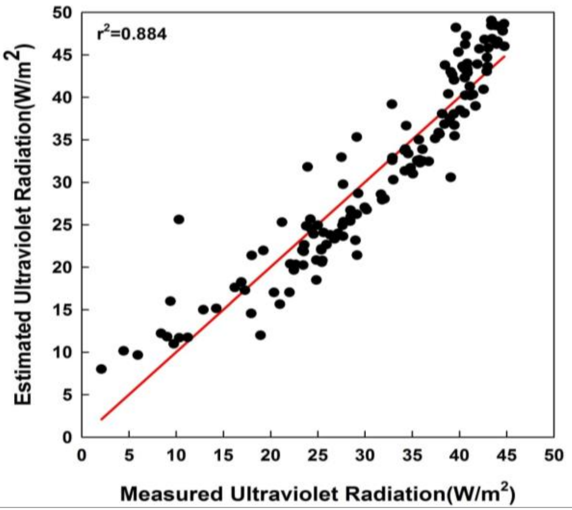

Fig. 8. The relation between ultraviolet global solar radiation UV estimated and UV measured.

Table 3. Comparison between present study and previous ones for UV/G ratio (%).

Study area Lat., long.	UV/G %	Land use	Authors
Córdoba (37.89° N ,4.76° W)	4.2	Urban	Cañada *et al.* (2003)
Cairo (30. 08° N, 31.28° E)	3.5	Urban	Robaa (2004)
Qena (26.17° N, 32.72° E)	3.3	Urban	El-Noubi (2006)
Botucatu 22.88° S ,48.43° W	4.2	Rural	Escobedo et al. (2009)
Qena (26.17° N, 32.72° E)	3.3	Urban	Ali (2015)
Baghdad (33° 36′ N; 44°40′ E)	4.2	Urban	The present study

CONCLUSIONS

When comparing UV-B to UV-A ratio radiation with effective O_3, the relationship between them will be evident due to the climax ozone and air mass. There is a clear anti-correlation between effective ozone and the UV-B to UV-A ratio of UV rays, as measured by Spectro-radiometers in Mustansiriyah Solar Station, with correlation coefficient of -0.84. The association between UVA and G hourly values over Baghdad was calculated. It shows an increase in UVA by the elevated G (correlation coefficient of R = 0.92). The findings revealed a significant negative correlation coefficient between UV ratio and effective ozone, with ozone serving as a perfect indicator for UV data estimations. These results also imply that the quantity of effective ozone may be determined using the observed UV ratio. Calculated ozone from equation 1, exceedingly correspond with the ozone of measured.

Ozone concentrations are significantly affected by alterations in meteorological conditions. On hot, bright days with stagnant air, ozone is more easily generated. When it is gloomy, chilly, wet, or windy, though, ozone generation is reduced. Cooler temperatures lead to more stratospheric polar clouds and lower ozone levels, whereas warmer temperatures lead to higher ozone levels. Atmospheric movements lead to alterations in temperature from year to year. Because the majority of electric power plants release NOx, increasing levels of ozone pollution may be predicted as NOx emissions rise.

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