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Investigation and Estimation of the Daily UVI Behavior Based on Global Radiation over Selected Cities in Iraq

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The ultraviolet Index (UVI) is a measure of the level of ultraviolet (UV) radiation and the potential danger of sun exposure. It is a linear scale that measures the intensity of UV radiation concerning sunburn, ranging from 0 to 11 or more. A higher UVI indicates a greater potential for damage to the skin and eyes and a shorter time for harm to occur. Objective: The current study aims to investigate the (UVI) in several Iraqi cities and assess its relationship with global radiation to determine potential health risks for the population Radiation and Plant Health: Although the focus of the paper is on human health, you could argue that understanding the impact of UV radiation on plants is relevant to agriculture. High levels of UV radiation can damage some crops, reducing yield. The paper establishes a link between global radiation and UVI, and since global radiation affects plant growth, there's a very indirect connection. Materials and Methods: The UVI data were collected using an autonomous DAVIS weather station (Vantage Pro2) equipped with a Solar UV Radiation Sensor DS6490. Results: The maximum daily value in late spring and early autumn with very high levels during summer days ranged from 12.43 to 10.16, while minimum levels were found in fall and winter at 2.1 and 2.4 and it was uncovered throughout the months of December and January. In March, October, and November, UVI levels were primarily moderate. The high level of UVI which exceeds 7 UVI over shown 7 months per year, particularly during the three summer months with very high UVI values (12.43 to 9.47). The necessary measures must be taken to protect against exposure to UV rays on days when the values are high, as well as to preserve crops on these days. Conclusions: UVI levels tend to increase or decrease on a monthly period, the greatest rate of variation was 5.1 % in March and the lowest was 1.7 % in June and July respectively. The shows a correlation coefficient of-0.91 for daily values and-0.93 for monthly values. We note that UVC has been filtered into the atmosphere and does not reach the surface of the earth, and it is considered one of the most dangerous types.

Keywords: Solar radiation, ultraviolet (UV) radiation, ozone, ultraviolet index (UVI), Baghdad.

INTRODUCTION

UV radiation is a type of electromagnetic radiation with a shorter wavelength than visible light but a longer wavelength than X-rays. UV rays constitute roughly 10% of the total electromagnetic radiation emitted by the sun, the term "UV" is given the name 'ultraviolet' because its wavelength is shorter than the violet color visible to the human eye. The wavelength of the phenomenon under consideration spans a range of 10 to 400 nanometers (Hockberger, 2002).
According to the ISO 21348 standard, the electromagnetic spectrum of UV radiation has been divided into several bands, as shown in Table 1. (Li *et al.*, 2021).

Table 1. The bands of UV radiation.

Name	Abbreviation	Wavelength(nm)
Ultraviolet A	UV-A	315–400
Ultraviolet B	UV-B	280–315
Ultraviolet C	UV-C	100–280
Near ultraviolet	N-UV	300–400
Middle ultraviolet	M-UV	200–300
Far ultraviolet	F-UV	122–200
Hydrogen Lyman	H Lyman-α	121–122
Extreme ultraviolet	E-UV	10–121
Vacuum ultraviolet	V-UV	100–200

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Sunlight reaching the uppermost region of the Earth's atmosphere contains around 50% infrared light, 40% visible light, and 10% UV light (Liu *et al.*, 2020). When the sun is at its greatest point in the sky (its zenith), the atmosphere blocks roughly 77% of the sun's UV rays, whereas, on the surface of the earth, sunlight consists of approximately 44% of the light that is within the visible spectrum, 3% UV, and the remaining infrared (IR) radiation (Sengupta *et al.*, 2018; Maka and O'Donovan, 2019). Over 95% of the UV radiation that reaches the Earth's surface consists of UVA, which is characterized by longer wavelengths, while the remaining portion is comprised of the shorter wavelength UVB rays. The Earth's surface receives a small amount of UVC radiation (Syed *et al.*, 2012). Cloud cover and atmospheric conditions have a significant impact on the amount of UVB that is still present in the UV after passing through the atmosphere. Patches of blue sky that emerge between clouds on "partly cloudy" days are sources of UVA and UVB scattering because of Rayleigh scattering, which is the same thing that causes visible light scattering to cause the sky to seem blue. The quantity of absorption produced by clouds during complete cloudiness is strongly influenced by cloud thickness and latitude (Xia *et al.*, 2021). All UV rays are blocked by diatomic oxygen (100-200nm) or ozone (triatomic oxygen) (200-280nm) in the atmosphere. The ozone layer then blocks the majority of the UV light. Meanwhile, UVA rays are not affected by ozone, and most of them reach the earth. UVA rays make up nearly all of the UV light that penetrates Earth's atmosphere (Emery *et al.*, 2002).UVB is considered biologically active, as for UVA it constitutes 95% of the UV rays that reach the surface of the earth. One of the benefits of UV rays especially UVB is that it causes to produce vitamin Din the human body which is necessary for life, as humans need some UV radiation to maintain adequate levels of it (Wacker and Holick, 2013), according to World Health Organization, exposure of the face, hands and arms for (5-15) minute per week during the summer months is sufficient to maintain healthy levels of vitamin D (Radiation, 2003).UV rays also treat some skin diseases such as psoriasis, eczema, jaundice, and vitiligo (Juzeniene and Moan, 2012). Another benefit is increasing UVI works to strengthen the radio waves of the mobile phone, which leads to an increase in the signal value, as it doubles by increasing the UVI value from 0 to 5 (Nemah *et al.*, 2021). Excessive exposure to UV rays affects the skin, causes burns and skin cancer, and affects the immune system of the human body (Radiation, 2003), retina the dioptric system of the eye might be subject to both acute and chronic detrimental effects (Meyer-Rochow, 2000).UVB rays are also harmful to living organisms, damaging DNA, proteins, lipids, and membranes, Plants that use sunlight for photosynthesis and are unable to avoid exposure to high levels of UVB radiation will put them at risk (Hollósy, 2002).UVB radiation significantly influences plant development by exerting a notable impact on many plant hormones (Vanhaelewyn *et al.*, 2016). Studies have shown that the number of days of high UVIwas 127 days equal to about 34% of the days of the year between March and September (Basheer *et al*., 2021), The dangerous time for sun exposure is between 11 am and 2 pm (Lamy *et al.*, 2021).

MATERIALS AND METHODS

The measurements of UV radiation, represented by the UVI, were collected throughout the entire duration of the study, from January 1, 2019, to December 31, 2021. These UVI data were obtained from a solar radiation station and an automatic weather station (DAVIS VANTAGE PRO2) installed on the rooftop of the Atmospheric Sciences Department building at Al-Mustansiriyah University (latitude 33º08'44"N, longitude 44º05'53"E, altitude 34m).

Baghdad is located in central Iraq, on both banks of the Tigris River. Baghdad's climate (which is part of a plain in central Iraq and has similar climatic features) may be described as semi-arid, subtropical, and continental, with dry, hot, and lengthy summers, cold winters, and brief springs. Rainfall events appear in the winter from October to May, with an average yearly rainfall of (120mm) (Al-Salihi *et al.*, 2013). In the summer, the highest recorded temperature was 51 degrees Celsius, while the lowest was 0 degrees Celsius. The average daily period of sunlight is 9.6 hours, and the daily incoming radiation is (4.7 $kwhm^{-2}$). The entire average yearly sunshine hour throughout a full year is around 3500 hours.

RESULT AND DISCUSSION

***Daily time series of UVI*:** The data employed in the present study were collected at noon daytime. According to the UVI time series over Baghdad which is illustrated in Fig 3, the daily variation of UVI has the greatest values observed during spring and summer days whereas minimum values recorded in autumn and winter days, as shown in the Figure 1.

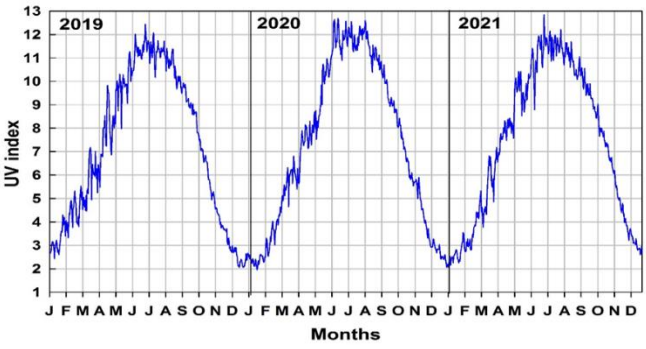


Figure 1. Daily UVI over Baghdad for the 1 January 2019 – 31 December 2021.

In general, the highest records of (12, 12.1, and 12,1) were found on 4 June 2019, 13 June 2020 and 22 June 2021

respectively. This level signifies a notable extent of hazardous radiation, hence necessitating a recommendation to refrain from sun exposure in the afternoon hours during summer days, especially in the month of June, contrast. The lowest radiation values recorded on December 9, 24, and 25 in the years 2019, 2020, and 2021 were 2, 2.15, and 1.9, respectively. These levels of radiation do not pose any discernible risk, therefore rendering precautionary measures unnecessary. The overall mean value was 7.1, This signifies a reasonably high level and should be maintained in the shade during midday to avoid browning the skin.

***Monthly UVI*:** The rate of fluctuation indicates how frequently UVI levels increase or decrease every month. In general, the highest rate of variance was 5.1 % in March and the lowest was 1.7 % in June and July respectively. The growing rates were discovered in August, September, and October, with the highest increasing rate in March being 5.1 % and the lowest increasing rate in February and May being 3.1 %. June, July, August, September, October, November and December tend to decline with the largest decline shown in October at 10.2%. The results are presented in Table 2 and Figure 2, where the negative sign indicates a reduction in rate. The months May, June, July, and August had the highest average values ranging between (9.58 to 11.53) which classified as very high exposure.

Table 2. Monthly variation of UVI over Baghdad.

Month	Max	Min	Average	S. D	Rate of variation %	Exposure category
Jan	4.20	2.40	3.30	0.51	4.3	Moderate
Feb	5.53	3.35	4.44	0.57	3.1	Moderate
Mar	7.17	4.18	5.67	0.80	5.1	Moderate
Apr	9.83	5.47	6.67	1.03	3.5	High
May	11.26	7.90	9.58	0.65	3.1	Very high
Jun	12.43	10.46	11.44	0.42	-1.7	Very high
July	12.60	10.16	11.53	0.40	-1.7	Very high
Aug	10.16	9.47	9.81	0.65	-5.1	Very high
Sep	9.80	7.10	8.45	0.78	-7.7	High
Oct	7.20	4.34	5.77	0.88	-10.2	Moderate
Nov	4.43	2.65	3.54	0.51	-5.6	Moderate
Dec	2.90	2.10	2.50	0.23	-2.3	Low

***UVI dependence on SZA*:** The impact of SZA on UVI was investigated by several research studies in all weather conditions (El-Nouby, 2011). It was found that the UVI was estimated by the following mathematical formula;

$$UVI = a - b * SZA \quad \ldots\ldots\ldots (1)$$

Where the constants, (a) and (b), were determined by the least squire fitting method. The main reason of noon data choosing yield by the minimum path distance was to avoid the influence of the atmospheric components on solar UVI.

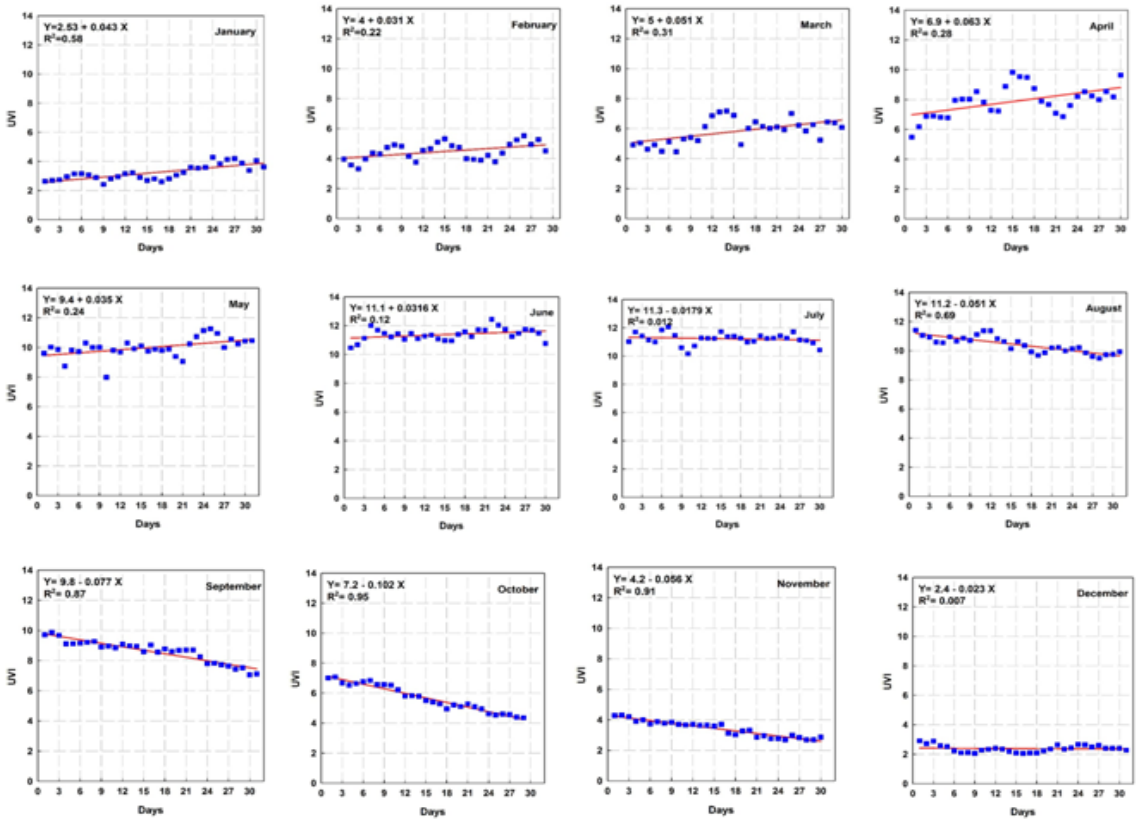


Figure 2. Daily UVI over Baghdad during the study period.

In this study a linear regression method has been applied as illustrated in Figure 3, where the daily inverse dependency of UVI and SZA shows a correlation coefficient of Equation (1) equals - 91%. It suggests that the SZA is responsible for daily UVI variations of - 91%. The monthly average, on the other hand, has a correlation coefficient of - 93%, indicating that the SZA is responsible for variations in UVI of - 93% on monthly values, as seen in Figure 4.

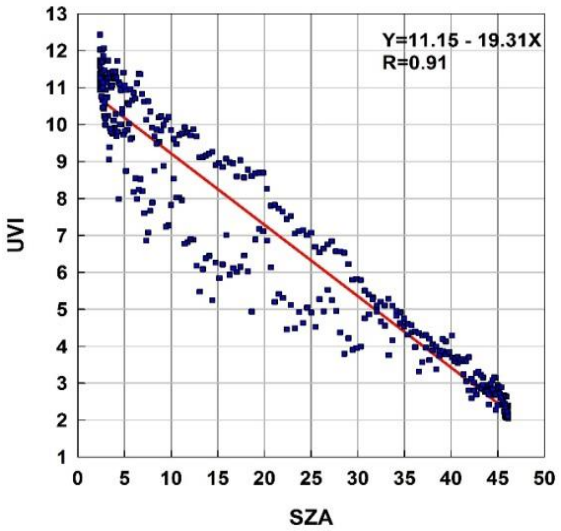


Figure 3. Dependence of UVI on SZA over Baghdad on daily basis for the 1 January 2019 – 31 December 2021.

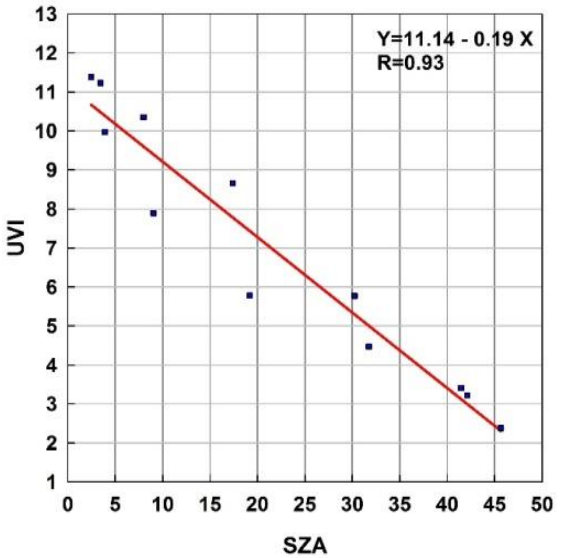


Figure 4. Dependence of UVI on SZA over Baghdad on monthly basis for the 1 January 2019 – 31 December 2021.

***The empirical equations of estimations for UVI from global solar radiation*:** In present section of this study, we will employ the relationships between UVI and G illustrated for the considered three stations to propose the linear regression equations relation the tow variables at each station. The locations and available data periods for our three main stations are tabulated in table 3. The regression equations that been proposed for the considered stations employing the available daily UVI and global radiation data can be written as the following forms:

$$UVI_{Mousl} = 1.473 + 0.0137\ G \quad \ldots\ldots\ldots (2)$$

$$UVI_{Baghdad} = 1.412 + 0.0148\ G \quad \ldots\ldots\ldots (3)$$

$$UVI_{Bastah} = 1.843 + 0.0127\ G \quad \ldots\ldots\ldots (4)$$

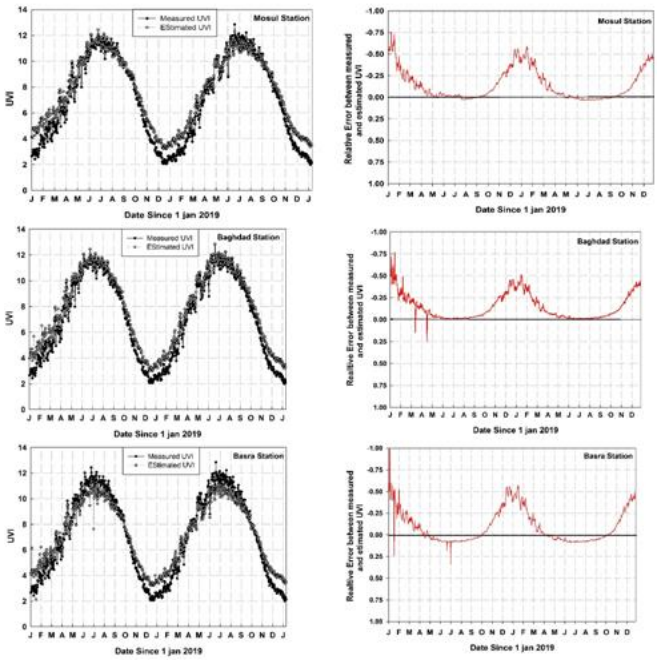
Table 3. Monthly variation of UVI over Baghdad.

MWO no	Station	Long (E)	Latitude (N)	Altitude (m)	Period of measurement (days)
40608	Mosul	43.15	36.31	223	1088
40650	Baghdad	44.44	34.30	32	1073
40689	Basra	47.78	30.52	2	1012

***The UVI calculations*:** Figure 5A, B shows the measured and estimated UVI values for the period from January 1, 2019, to December 31, 2020. It demonstrates a significant correlation between measured and estimated UVI values, especially between May and November for all stations taken into consideration. The global solar radiation values of each station were applied to the available data using the linear regression equations shown in equations 2, 3, and 4, respectively, to assess their accuracy. Table 4 shows the regression coefficients and root Mean Square Error (RMSE). Mean Absolute Error (MAE) and Correlation Coefficients (CC) between UVI and G for each station. From the considered evaluation statistical indicators tabulated in Table 4 (RMSE, MAE, and CC) show that Mosul station has the highest correlation (85.5) corresponding with lower RMSE and MAE, (0.854) and (0.733), whereas Basra station shows a lower accuracy among the proposed experimental equations where achieved lowest correlation coefficient (0.815) with a highest RMSE and MAE, (0.986 and 0,878) respectively, either way concerning Baghdad station shows a good statistical performance according to the statistical indicators which shown in table 4. The main of the good performance of all stations especially between the period between May and November to that these months are characterized by clear weather conditions with a less clouds and rainfall if compared with other months of the year.

Table 4. Regression coefficients, Root Mean Square Error (RMSE), mean Absolute Error (MAE), and Correlation Coefficients (CC) between measured and estimated values for each station.

Station	Regression coefficient (C_0)	(C_1)	RMSE	MAE	CC	Records of length (days)
Mosul	1.473	0.0137	0.854	0.733	0.855	1088
Baghdad	1.412	0.0148	0.964	0.830	0.841	1073
Basra	1.843	0.0127	0.986	0.878	0.815	1012



(A) (B)

Figure 5. (A) Daily measured and estimated UVI for Mosul, Baghdad, and Basra stations; (B) The relative error between measured and estimated UVI for Mosul, Baghdad, and Basra stations.

Certain parameters can affect UV rays that reach the earth's surface, among them are:

***Solar zenith angle*:** Whenever the zenith angle of the sun is high...less amount of UV radiation reaching the surface of the earth (Lamy *et al.*, 2021), and studies on Baghdad show that the highest values of UV radiation are during the summer months and the lowest during the winter months (Basheer *et al.*, 2021).

***Altitude*:** UV radiation levels increase with altitude, as the air is thinner and less UV radiation is absorbed (Radiation, 2003).

***Latitude*:** UV radiation is highest near the equator and lowest far away from the equator or near the poles (Basheer *et al.*, 2021).

***Cloud cover*:** UV radiation is highest when the sky is cloudless, but UV levels can be high even when cloud cover is present due to scattering (Bornman *et al.*, 2019).

Aerosols: solid and liquid particles have a role in the dilution of UV due to scattering (Wilson *et al.*, 2019), where desert dust (400nm) reduces the amount of water reaching the earth's surface by 55% (Morozzi *et al.*, 2021), while gaseous plankton leads to an increase in UV due to absorption.

***Ozone*:** Ozone absorbs part of the sun's UV rays, where the correlation coefficient reaches (0.84)(Wahab, 2022), and the decrease in the amount of ozone in the stratosphere due to the increase in emissions led to the arrival of a greater amount of UV radiation to the Earth's surface.

***Reflection*:** Reflective surfaces, such as water, sand, and fresh snow, increase the level of UV radiation because they reflect UV radiation and add it to the global radiation (Organization, 2021).

***Conclusions*:** The principal indicator that represents the impact of UV-B on human skin is UVI. The daily contrast of UVI is greatest on spring and summer days and lowest on autumn and winter days. The maximum values of UVI (12, 12.1, and 12,1) were found on 4 June 2019, 13 June 2020 and 22 June 2021 respectively. For the years 2019, 2020, and 2021, the minimum values of radiation recorded on the dates of December 9, 24, and 25 were 2, 2.15, and 1.9, respectively. High values indicate a high amount of dangerous radiation, so beware of exposure to sunlight in the afternoon on hot summer days. Low levels of radiation do not indicate any potential danger, so implementing precautionary measures is unnecessary. Also, the dependence of the UV Index on SZA has been investigated which showed a negative correlation of about -0.91 daily and -0.93 on and monthly basis. The study concludes that the three empirical equations used to estimate the UV Index based on global solar radiation in the cities of Mosul, Baghdad, and Basra exhibited satisfactory performance across all stations. Notably, these equations performed particularly well during the period from May to November, which is characterized by favorable weather conditions with minimal cloud cover and precipitation compared to other months throughout the year. This data must be used to determine the appropriate times for planting crops according to their ability to withstand exposure to UV rays. In the future, experimental equations can be calculated to estimate the UV index for all cities in Iraq and obtain a unified training equation for all of Iraq.

***Authors' contributions*:** Nagham T. Ibraheem, Zahraa N. Al-Montaser, Hasan M. Azeez, Practical part, diagrams and discussion of results

Ali Al-Salihi, prepared the draft; Ali J Mohammed, Review texts, sources, and the theoretical part

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***Availability of data and material*:** We declare that the submitted manuscript is our work, which has not been published before and is not currently being considered for publication elsewhere.

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