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Total suspended particles and solar radiation over Cairo and Aswan

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Abstract

Measurements were carried out at Cairo (30.05°N, 31.17°E) and Aswan (23.58°N, 32.47°E) in Egypt for three years (1990–1992) by the Egyptian Meteorological Authority. The measurements were done using an Eppley ultraviolet radiometer to measure the global ultraviolet solar radiation (UV), Eppley pyranometers to measure the global solar radiation (G) and the pyrgeometers with silicon dome from Eppley to measure the atmospheric infrared radiation (IR). The clearness index (K_t) and the diffuse fraction (K_d) for both regions have been calculated. Finally the total suspended particles for Cairo and Helwan and their interaction with the solar radiation has been found. © 2001 Elsevier Science Ltd. All rights reserved.

1. Introduction

The solar radiation going through the atmosphere is partially absorbed by its constituents, partially reflected back to space and partially diffused, with the remaining reaching the ground as direct solar radiation.

On a planetary scale, 17% of solar radiation is absorbed by the atmosphere, 30% is reflected by the constituents of the atmosphere, and 53% reaches the surface of the earth, 31% of it as direct solar radiation and 22% as diffuse radiation. In addition to the absorption and diffusion of solar radiation by the usual constituents of the atmosphere, aerosol particles and water (liquid and solid) also absorb and cause diffusion of solar radiation quite significantly. A more intensive use of solar energy implies the need to have analyzed and reliable information about solar radiation. The information should be available in a form that is easy to handle. The design methods

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and mathematical models utilized to calculate and define the solar energy need to use external meteorological variables [1].

Thus it's necessary to analyze them in order to know the behavior of the former variables and to get the mathematical formulations for them. These formulations could easily be incorporated into the procedures of analysis, design, and simulation of these systems. The percentage of the ultraviolet solar radiation outside the atmosphere is 8.03% and for the infrared is 46.41%, but for the visible solar radiation it is 46.40% from the solar constant.

Diffuse solar radiation is that solar radiation received from the sun after its direction has been changed by reflection and scattering by the atmosphere. It has no fixed direction at any instant. It is scattered in all directions. Evidently a portion of this radiation reaches the surface of the earth [2].

Therefore, the percentage of solar radiation finally reaching the surface of the ground depends on the turbidity of the atmospheric mass over the examined area and consequently on the concentration of pollutant materials [3].

Any form of gas or solid compound emitted into the atmosphere, in such concentrations that they become a danger to the people's welfare and property, is regarded as an atmospheric pollutant. The harmful effects of these contaminants are both widespread and variable. There are physical, biological, psychological and economic effects in nature. The outward manifestations of air pollution are: decreased visibility, damage to vegetation, deterioration of materials, ill-health and discomfort to human-beings in various degrees. The pollutants are in the form of gases, liquid droplets or particles. An example of gases is ozone. Liquid droplets are sometimes classified separately from aerosol, particularly in the case of clouds. Dust is a good example of particles [4].

2. Monthly variation of solar radiation components

2.1. Global solar radiation

The measured data here are the global solar radiation in the wavelength 280 to 2800 nm. These data are three years' data for Cairo and Aswan collected from the Egyptian Meteorological Authority.

Fig. 1 shows the monthly variation of global solar radiation for the mentioned areas, where the highest intensity values lie in the summer months while the lowest values are in the winter months. The highest intensity values lie in June for Cairo and Aswan while the lowest intensity values for the two regions lie in January [5].

The annual average intensity for Aswan has a value of 6.2 kW/m^2 while it is 5.03 kW/m^2 for Cairo. The reason for the higher value for Aswan is due to the dry weather because Aswan lies in the tropical region and is characterized by its clean atmosphere, while Cairo lies in the Mediterranean region and is characterized by a very high polluted atmosphere due to its crowded traffic which leads to a large amount of smoke which absorbs the global solar radiation.

From Fig. 1 the difference between the maximum values (summer values) for

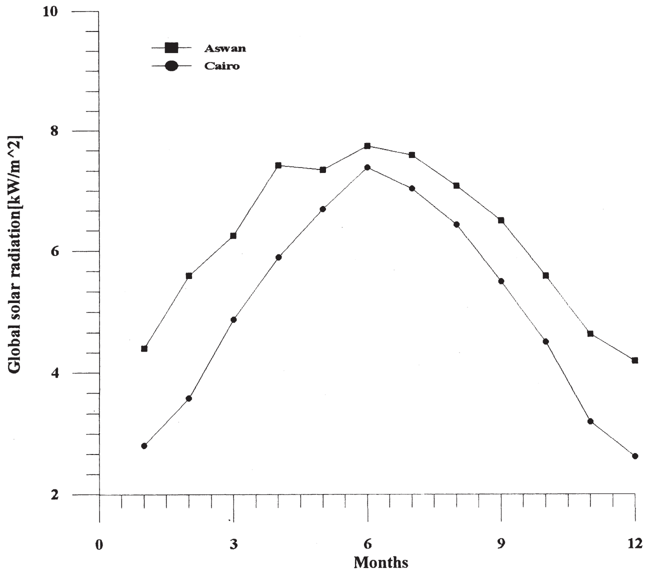


Fig. 1. Monthly mean variation of global solar radiation for Cairo and Aswan in kW/m^2.

Aswan and those of Cairo is smaller than the difference in the minimum values (winter values) between them. The main reason for this is the decrease in the maximum value for Aswan due to the higher amount of water vapor during the summer season than in the winter season which absorbs the solar radiation during the summer.

2.2. Atmospheric infrared solar radiation

The atmospheric global infrared solar radiation is measured in the wavelength 695 to 2800 nm. The measured data here are three years' data (1990–1992) for Cairo and Aswan [6].

Fig. 2 shows the monthly mean variation for the global atmospheric infrared solar radiation for Cairo and Aswan where the highest intensity value appears for Aswan in all months. The highest intensity value for Aswan lies in July with a value of 0.43 kW/m^2, while the lowest intensity value is in January with a value of 0.28 kW/m^2. Cairo has the highest intensity value in July with a value of 0.37 kW/m^2, while the lowest intensity value is in January with a value of 0.27 kW/m^2.

The highest seasonal value for Aswan is in summer with a value of 0.43 kW/m^2, while the minimum value is in winter with a value of 0.289 kW/m^2. The highest seasonal value for Cairo is in summer with a value of 0.368 kW/m^2, while the minimum value is in winter with a value of 0.267 kW/m^2

From Fig. 2 the difference between the maximum value (summer value) for Aswan and that for Cairo (14%) is higher than the difference in the minimum value (winter value) (4%) between them. The main reason for this is the increase in the maximum

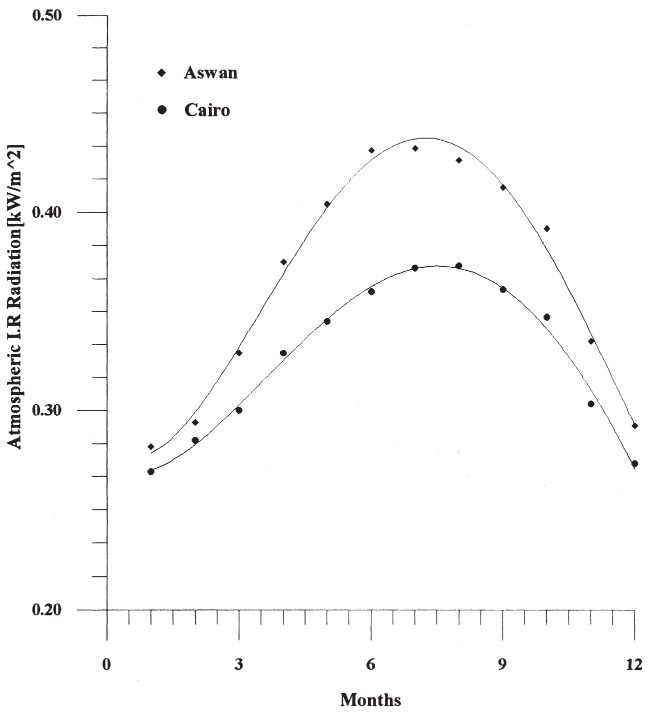


Fig. 2. Monthly mean variation of atmospheric infrared solar radiation for Cairo and Aswan in kW/m^2.

value for Aswan due to the higher amount of water vapor during the summer season which increases the atmospheric infrared solar radiation (sky radiation) in Aswan during this season.

The annual average value of the atmospheric infrared solar radiation for Aswan is higher than that for Cairo. It has an intensity value 0.367 kW/m^2 while it is 0.326 kW/m^2 for Cairo. The Aswan value is higher than that for Cairo by about 13%.

2.3. Global ultraviolet solar radiation

The global ultraviolet solar radiation was measured in the wavelength 295 to 385 nm. Global ultraviolet solar radiation has harmful biological problems such as skin sunburn, skin cancer and lens cataracts.

Fig. 3 shows the monthly mean variation for the global ultraviolet solar radiation. The highest intensity value appears for Aswan for all months. It has the highest intensity value in June with a value of 0.31 kW/m^2, while the lowest intensity value is in January with a value of 0.215 kW/m^2. The highest intensity value for Cairo is in June with a value of 0.265 kW/m^2 while the lowest intensity value is in December with a value of 0.09 kW/m^2.

The highest seasonal value for Aswan is in summer with a value of 0.299 kW/m^2 while the minimum value is in winter with a value of 0.194 kW/m^2. The highest

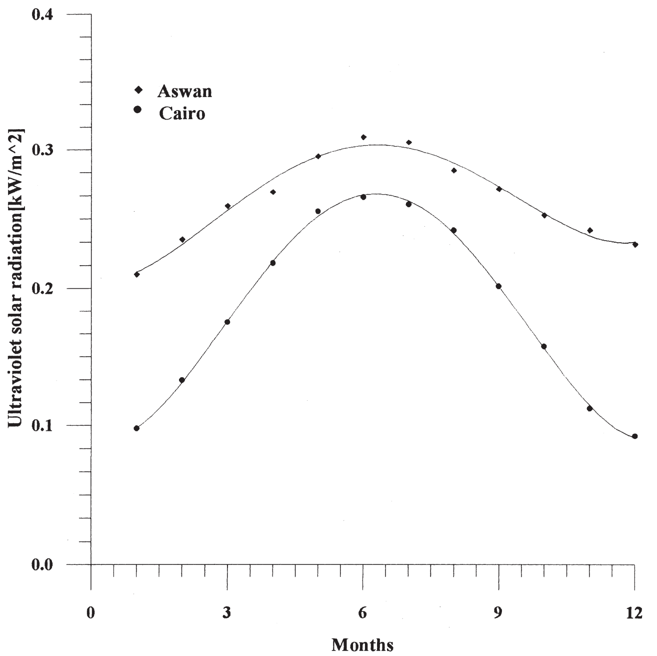


Fig. 3. Monthly mean variation of ultraviolet solar radiation for Cairo and Aswan in kW/m^2.

seasonal value for Cairo is in summer with a value of 0.255 kW/m^2 while the minimum value is in winter with a value of 0.107 kW/m^2

From Fig. 3 the difference between the minimum value (winter value) for Aswan and that for Cairo (44%) is higher than the difference in the maximum value (summer value) (14%) between them. The main reason for this is the increase in the minimum value for Aswan due to the higher amount of clouds in Cairo during the winter season which leads to a decrease in the ultraviolet solar radiation in Cairo during this season.

The annual average value of the global ultraviolet solar radiation for Aswan is higher than that for Cairo. It has an intensity value of 0.249 kW/m^2 while it is 0.184 kW/m^2 for Cairo. Aswan's value is higher than that for Cairo by about 35%.

2.4. Monthly variation of clearness index

Fig. 4 shows the monthly mean variation for the clearness index K_t for the two regions, Cairo and Aswan.

From this figure we find the clearness index for Aswan ranged from 0.71 to 0.64, while for Cairo it ranged from 0.63 to 0.47. The highest value for Aswan is due to the dry weather and clean atmosphere.

The annual average value for the clearness index for Aswan is higher than that for Cairo. Aswan has a clearness index value of 0.668, while it is 0.559 for Cairo.

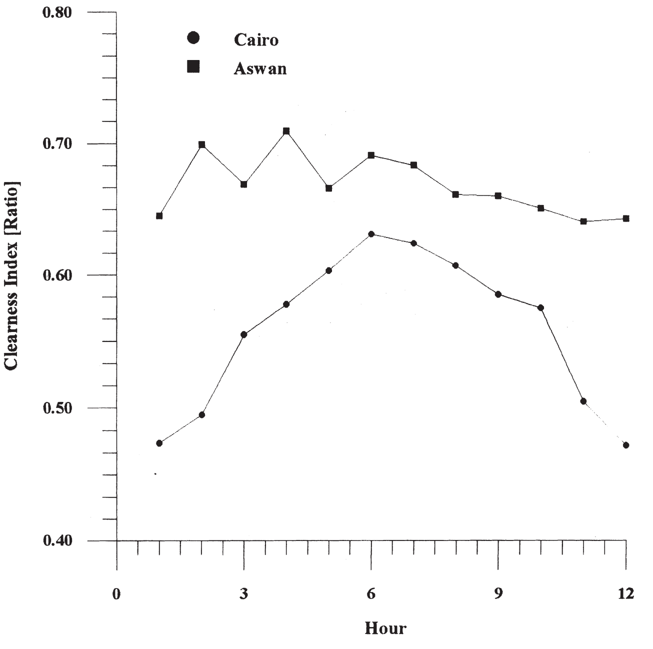


Fig. 4. Monthly variation of the clearness index for Cairo and Aswan (ratio).

3. Diffuse solar radiation and diffuse fraction

The diffuse solar radiation D can be calculated from the theoretical method from the following equations:

$$D_h = G - I\cos\theta \tag{1}$$

and the total diffuse day is:

$$D = \int_{sR}^{ss} (G - I\cos\theta)\,dh \tag{2}$$

The diffuse ratio or the diffuse fraction K_d can be calculated according to three methods which are: Collares (K_{dC}), Page (K_{dP}) and the theoretical method.

The first equation calculates the daily diffuse components of solar irradiance depending on the clearness index K_t and is given by Collares [7] as follows:

$$K_{dC} = D/G = a - bc \tag{3}$$

where a=0.775+0.00606 (H_s-90), b=0.505+0.00456 (H_s-90), c=cos (115 K_t-103), $H_s=\cos^{-1}[-\tan\varphi\tan\delta]$, $K_t=G/G_0$.

The value of K_d lies between zero and unity, depending on atmospheric conditions; K_d approaches unity under heavily overcast conditions.

Also, the diffuse fraction can be calculated by the Page equation [8] as follows:

$$K_{dP}=1-1.13K_t \tag{4}$$

And finally K_d can be calculated according to the theoretical method as:

$$K_d=D/G \tag{5}$$

We can also compute the diffuse solar radiation from K_d as follows:

$$D=G\times K_d\ (K_{dP} \text{ and } K_{dC}) \tag{6}$$

3.1. Computation for the diffuse solar fraction for Cairo and Aswan

Fig. 5 shows the monthly variation for K_{dC} and K_{dP} for Cairo and Aswan. The K_{dC} values for Cairo are higher than the values for K_{dP} through winter and autumn months, while K_{dP} is higher than K_{dC} through summer and spring months. The annual average value for K_{dC} is higher than the annual average values for K_{dP} by 8%. The K_{dC} values for Aswan are higher than the K_{dP} values for all months, the annual average value of K_{dC} is higher than that of K_{dP} by 48%.

From Fig. 5 we notice that the resultant K_d values for the two methods are nearly the same for Cairo, while they diverge for Aswan. The results for Cairo are due to the high atmospheric pollution in Cairo, where the K_d values must be high which is compatible with the results of the two methods for Cairo, while the K_d values for Aswan must be low due to the very clear atmosphere which is compatible with the K_d values for the Page method and diverge with the K_d values for the Collares method. Therefore, we recommend using the two methods in the polluted regions, while the best method for the clear regions is the Page method [9].

Table 1 gives the equations and correlation coefficients between K_{dP} and K_{dC} against K_t for Cairo and Aswan, where we find a very high correlation coefficient between K_{dP} and K_{dC} against K_t with low RMS, where the four relations are done by using the linear regression method in the first order.

Fig. 6 shows the monthly variation for the diffuse solar radiation for Cairo and Aswan which was calculated by Eq. (6) and by using K_{dP}, K_{dC} and K_{dM} (where K_{dM} is given from the Solar Radiation Atlas as a mean of 8 years data from January 1980 to December 1988 [10]) to get the diffuse solar radiation by Page (D_P), Collares (D_C) and by Solar radiation Atlas (D_M), respectively.

D_M is higher than D_P and D_C through the winter and autumn months for Cairo, while D_P and D_C are higher than D_M through the summer and spring months. The annual average value for D_M is 1.86 kW/m^2, while it is 1.76 kW/m^2 for D_P and 1.73 kW/m^2 for D_C.

D_C is higher than D_P and D_M through all months for Aswan. The annual average value for D_C is 2.26 kW/m^2 while it is 1.89 kW/m^2 for D_M and 1.54 kW/m^2 for D_P.

The relation between the diffuse solar radiation and the global solar radiation is given from Table 2 for Cairo and Aswan. There are a very high correlations between

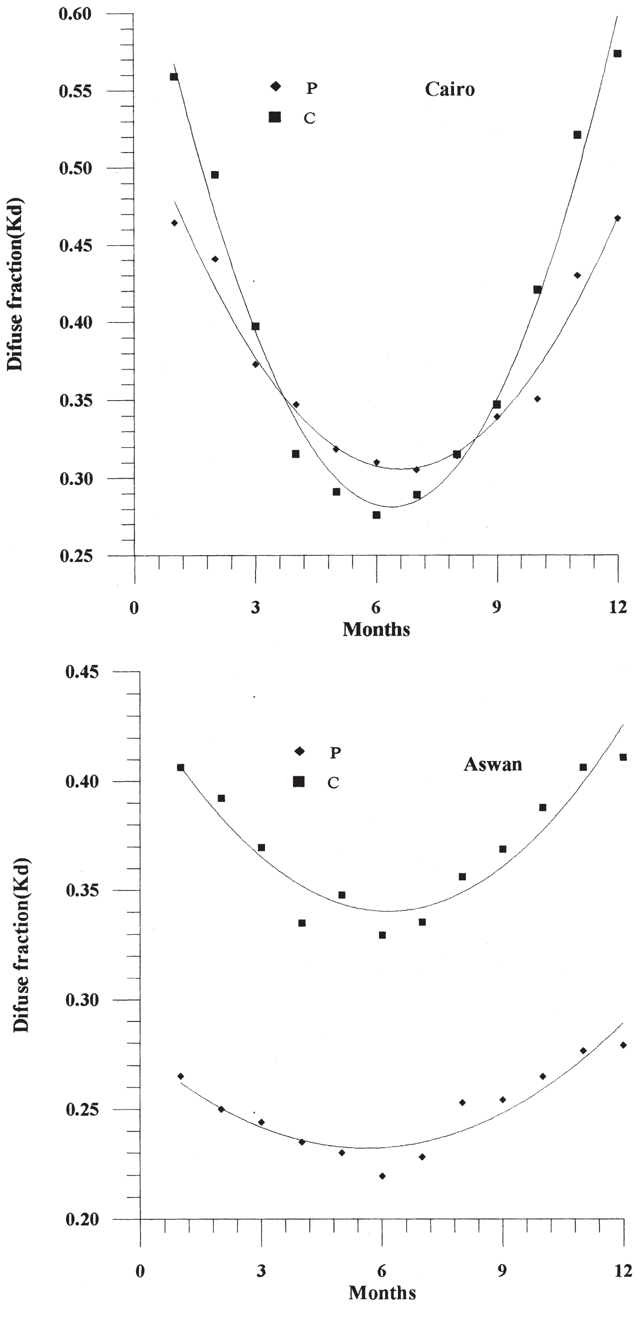


Fig. 5. Monthly mean variation of diffuse fraction K_d by two methods, Collares (C) and Page (P) for Cairo and Aswan.

Table 1
Relations between K_{dP} and K_{dC} against K_t for Cairo and Aswan

Equations for Cairo	CC%	RMS	Equations for Aswan	CC%	RMS
K_{dC}=1.37–1.78 (K_t)	93	0.018	K_{dC}=1.54–1.77 (K_t)	92	0.001
K_{dP}=0.93–1.08 (K_t)	96	0.003	K_{dP}=1.01–1.16 (K_t)	94	0.0005

G against D_C and D_P for two regions with low RMS, where the relation is done by using the linear regression method in the first order.

4. The interaction between the air pollution concentration and the solar radiation over Cairo and Helwan

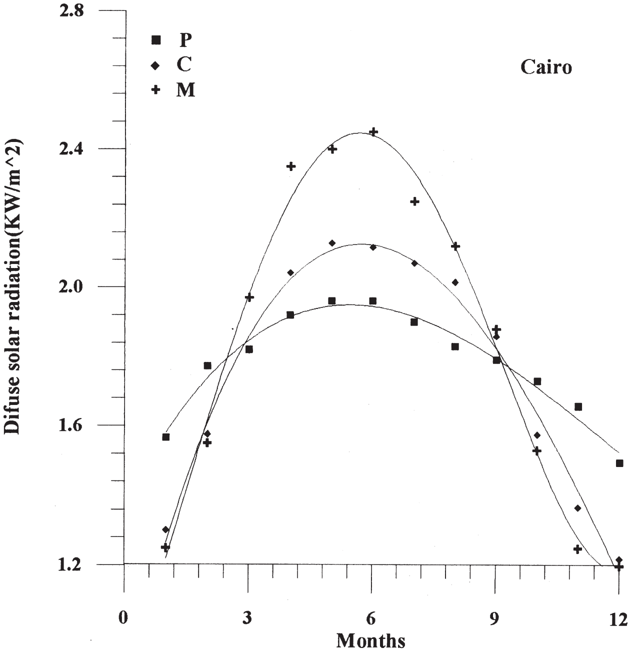
The analysis of the air pollution concentration for two regions in Cairo (Abassia and Helwan) has been measured. Our data used here are the monthly mean values for the total suspended particles (TSP), where there is five years' data for Abassia from 1990 to 1995, while for Helwan it was one year's data. Helwan lies 30 km to the south of Abassia. From March 1995 to February 1996, the data for the two regions were measured by the air sampler which depended on the absorption of the air pollution from the atmosphere [11].

4.1. Monthly variation of total suspended particles

Through the measurement of the concentration of suspended particulate matter which is available as an index of air pollution in cities and centers of industry, knowledge of the particle size distribution of suspended particulate matter is essential to assess the inhalation health hazard. This is due to the fact that the degree of respiratory penetration and retention is a direct function of aerodynamic particle size. For example, small particles of suspended matter less than 5 μm in size are considered to be more of a nuisance and of greater importance to public health and welfare [12].

Fig. 7 shows the monthly mean variations for the total suspended particles (TSP) over Cairo and Helwan, where the annual mean values for the particles falling at Cairo and Helwan are continually increasing. From Table 3, which shows the seasonal variation of the TSP for Cairo and Helwan in $\mu g/m^3$, the annual mean value for Cairo is 583 $\mu g/m^3$, which is 7 times higher than the Egyptian standard value which is 90 $\mu g/m^3$ [6], while it is 1300 $\mu g/m^3$ for Helwan, which is 15 times higher than the Egyptian standard value.

There is also work done by the Tebeen Institute for Metallurgical Studies (1995), where they performed a report as an environmental study for the dust in the air which surrounds the cement companies over Helwan (from Maadi to Tebeen) from 39 observation places. The annual mean value for the TSP over these regions ranged



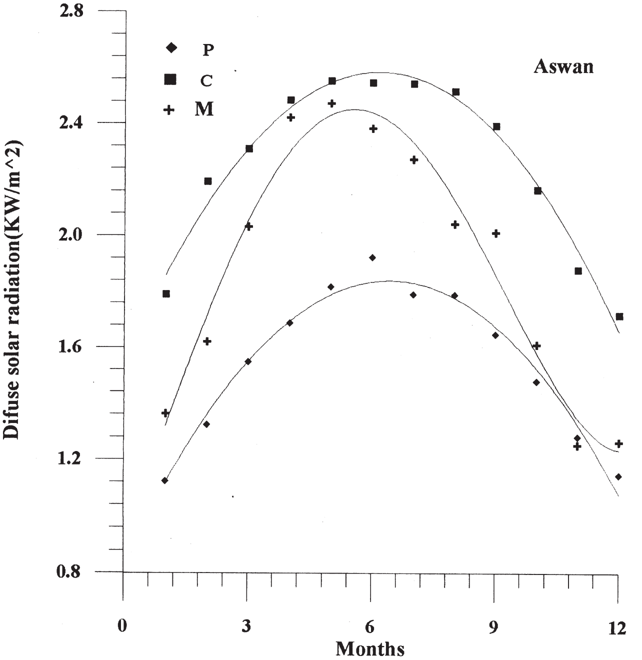


Fig. 6. Monthly mean variation of diffuse solar radiation computed by three methods, Page (P), Collares (C), and Measured (M) for Cairo and Aswan.

Table 2
Relations between D_P and D_C against G for Cairo and Aswan

Equations for Cairo	CC%	RMS	Equations for Aswan	CC%	RMS
D_C=1.37–0.08 (G)	93	0.04	D_C=0.8–0.24 (G)	98	0.035
D_P=0.78–0.2 (G)	97	0.08	D_P=0.26–0.21(G)	97	0.044

from 792 to 1900 μg/m^3, which gives us that these values are from 9 to 21 times higher than the Egyptian standard value [13].

From the results of the last two studies done by Rahoma [14] and the Tebeen Institute for Metallurgical Studies [13] we find a similarity to the results of the annual mean value of TSP for the same region (Helwan), where it is 1300 μg/m^3 for Rahoma, while it is 1346 μg/m^3 for the Tebeen Institute, where the two values are nearly 15 times the Egyptian standard value.

The highest TSP concentrations lie in the summer months for Cairo and Helwan, where the data was measured by the air sampler which measures the light particles which are affected by the high ambient temperature through the summer months. Helwan TSP data are higher than for Cairo for all months. The average value for the spring months for Helwan is about 2.5 times higher than that for Cairo, while it is about 2.4 times higher for the summer and it is about 2.6 times higher for the autumn and finally it is about 1.3 times higher for the winter months.

The highest concentration of TSP value is in June for Cairo with a value of 831 μg/m^3, which is 9 times higher than the Egyptian standard value, while the lowest concentration value is in December with a value of 465 μg/m^3, which is 5 times higher than the Egyptian standard value.

The highest concentration of TSP value is in July for Helwan with a value of 1800 μg/m^3, which is 20 times higher than the Egyptian standard value, while the lowest concentration value is in January with a value of 600 μg/m^3, which is 7 times higher than the Egyptian standard value [14].

Regarding the global solar radiation data for Cairo and Helwan, it is found that Helwan's annual mean value was 5.48 W/m^2, which is higher than that for Cairo which was 5.03W/m^2, while the TSP annual mean value for Helwan was 1300 μg/m^3, and 583 μg/m^3 for Cairo. Also, the smoke annual mean value for Helwan was 52 μg/m^3, while it was 132μg/m^3 for Cairo as shown in Table 4 [3].

From Table 4, it is found that the G value for Helwan is higher than for Cairo by 8.2%, the TSP value for Helwan is higher than for Cairo by 55%, and the smoke value for Cairo is higher than for Helwan by 61%. Also, it is found that the increase in the G ratio for Helwan is due to the presence of the higher value of TSP which contains elements that have large sizes, such as calcium that has a value of 622 μg/m^3 which represents 48% from the total TSP value, and iron that has a value of 582 μg/m^3 which represents 45% from the total TSP value. The presence of these two elements leads to a diffusion of the beam solar radiation to become diffuse solar radiation D which is added to the G value and substitute the reduction in it due to the reduction in the direct solar radiation I according to Eq. (1), while the major

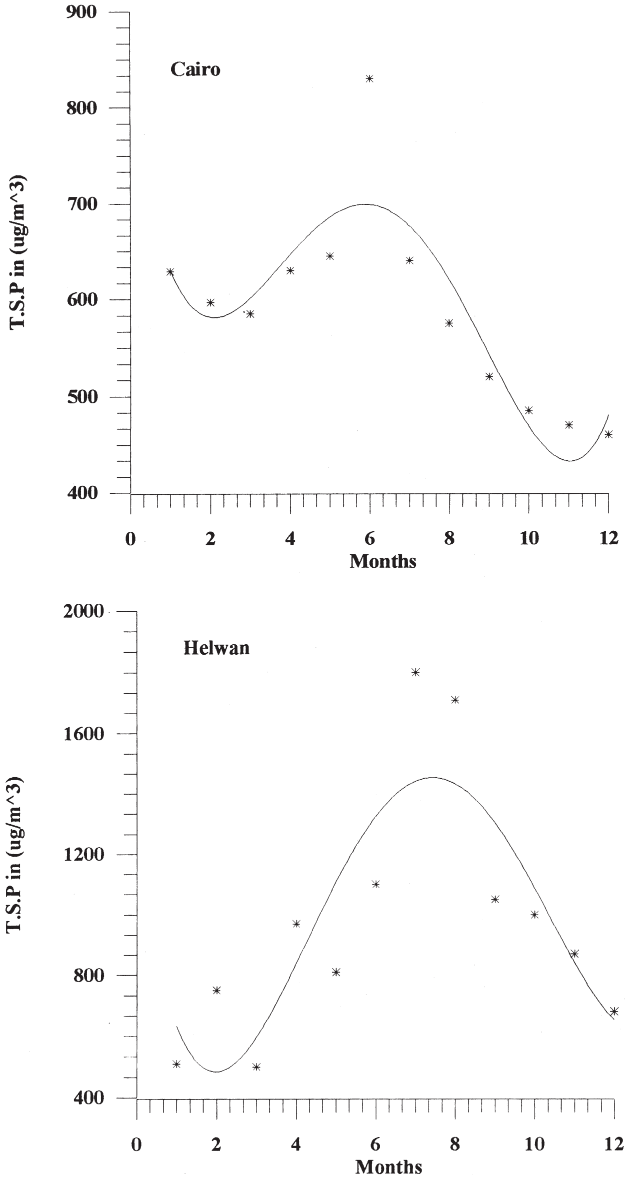


Fig. 7. Monthly mean variations of the total suspended particles for Cairo and Helwan (Rahoma).

element in Cairo is the smoke which makes more absorption than diffusion for the beam solar radiation. This makes a reduction in the global solar radiation value.

Also, the higher value of G for Helwan is due to the wind direction for this measuring station where it lies to the east of the major pollution source and the wind direction in Helwan is north to north-east [15].

Table 3
Seasonal variations of the TSP for Cairo and Helwan [Rahoma] in (μg/m^3)

Season	Helwan	Cairo
Spring	1500	606
Summer	1600	672
Autumn	1300	498
Winter	750	557
Mean	1300	583

Table 4
Annual mean value of G, TSP and smoke for Cairo and Helwan

Region	G (W/m^2)	TSP (μg/m^3)	Smoke (μg/m^3)
Cairo	5.03	583	132
Helwan	5.48	1300	52

5. Conclusions

1. For global solar radiation G, the monthly variation for G for two regions (Aswan and Cairo) gives us that the highest intensity value is in the summer months (June) for Cairo and Aswan, while the lowest is in the winter months (December) for both. The annual average value for G for Aswan is 6.2 kW/m^2, while it is 5.03 kW/m^2 for Cairo.
2. For atmospheric infrared solar radiation IR, the monthly mean variation for IR is higher for Aswan than Cairo in all months. The annual average value of IR for Aswan is 0.367 kW/m^2, while it is 0.326 kW/m^2 for Cairo. Aswan is higher than Cairo by about 13%.
3. For global ultraviolet solar radiation UV, the highest intensity value for UV appears for Aswan for all months. The annual average value of UV for Aswan is 0.249 kW/m^2, while it is 0.184 kW/m^2 for Cairo. Aswan is higher than Cairo by about 35%. There is a big difference between the annual seasonal variation of UV values for Cairo, where it reached 25% between the spring season of 1989 and the spring season of 1991.
4. For the clearness index K_t, Aswan is higher than Cairo for the mean monthly values for K_t. The annual average value of K_t for Aswan is 0.668, while it is 0.559 for Cairo.
5. For the diffuse fraction K_d, the K_{dC} values for Cairo are higher than the values for K_{dP} through the winter and the autumn months, while K_{dP} is higher than K_{dC} through the summer and the spring months; the K_{dC} values for Aswan are higher than the K_{dP} values for all months. The relations between K_{dP} and K_{dC} against K_t for Cairo and Aswan are very high.
6. For the diffuse solar radiation D, the annual average value for Cairo for D_M is

1.86 kW/m^2 while it is 1.76 kW/m^2 for D_P and 1.73 kW/m^2 for D_C; but for Aswan D_C is 2.26 kW/m^2 while it is 1.89 kW/m^2 for D_M and 1.54 kW/m^2 for D_P. The relations between the D_C against G for Cairo and Aswan are very high.

7. The annual mean value for the total suspended particles for Cairo is 583 μg/m^3 which is 7 times higher than the Egyptian standard value, while for Helwan it is 1300 μg/m^3 which is 15 times higher than the Egyptian standard value, where the highest concentration is in June which is 831 μg/m^3 which is 9 times higher than the Egyptian standard value, while the lowest concentration is in December which is 465 μg/m^3 which is 5 times higher than the Egyptian standard value, while the highest concentration for Helwan is 1800 μg/m^3 which is 20 times higher than the Egyptian standard value, while the lowest concentration value is in January with value 600 μg/m^3 which is 7 times higher than the Egyptian standard value.
8. There is a similarity between two different measurements for Rahoma [14] and Tebeen Institute [13], where the results for the two measurements give us the annual mean values of TSP over Helwan, which is 15 times higher than the Egyptian standard value.

References

[1] Hgazy NA. Effect of air pollution visibility and penetration of solar ultraviolet radiation. Ph.D. Thesis, Cairo University, Chap. 1–4, 1973.

[2] Abdel Salam MS, Higazy NA. Solar data application to Egypt, In: T. Nejat Veziroglu, editor, Proceedings of the International Symposium Workshop on Solar Energy, vol. I, 1978:20–40.

[3] Mosalam Shaltout MA, Abd El-Hady K, Abd El-Aziz A, Hassan AH, Fathy AM. Atmospheric turbidity over Menia. In: The 2nd Symposium and Exhibition on Renewable Energy and Modern Technologies for Environment Protection (AREEP), 14–16 September 1998, Ismailia, Egypt, 1998.

[4] McCormac BM. Introduction to the Scientific Study of Atmospheric Pollution. Dordrecht, Holland: D. Reidel Publishing Company, 1971.

[5] Mosalam Shaltout MA, Fathy AM. Studying ultraviolet and visible solar radiation over Cairo and Aswan and their correlations with environmental and climatological parameters, 4th International Conference, Solar Energy Storage and Applied Photochemistry, 1–6 January, Cairo, Egypt, pp. 37–45, 1997; and Proc. Indian Acad. Sci. (Chem. Sci.) 1998; 110(3):361-371.

[6] Mosalam Shaltout MA, Hassan AH, Fathy AM. Studying ultraviolet, visible, infrared solar radiation over Cairo and Aswan and their correlations with environmental and climatological parameters. In: 4th IEEE International Conference on Electronic Circuits and Systems, ICECS, 15–18 December, Cairo, Egypt, 1997:781–5.

[7] Collares M, Pereeira A, Radl AA. The average distribution of solar radiation correlations between diffuse and hemispherical and between daily and hourly insolation values. Solar Energy 1979;22(2):155–64.

[8] Liu BYH, Jordan A. The interrelationship and characteristic distribution of direct, diffuse, and total solar radiation. Solar Energy 1960;4(3):1–19.

[9] Mosalam Shaltout MA. Atmospheric transmission and diffuse fraction of solar energy over Egypt. In: Mobarak A, El-Agamawi H, editors. Proceedings of the International Symposium on Application of Solar and Renewable Energy, ASRE 86, Cairo, Egypt, 23–26 March, 1986.

[10] Mosalam Shaltout MA. Egyptian Solar Radiation Atlas, Edited by New and Renewable Energy Authority, Ministry of Electrical and Energy (Egypt) and financed by the United States Agency for International Development, p. 194, Cairo, Egypt, 1991.

[11] Mosalam Shaltout MA, Hassan AH, Fathy AM. Studying ultraviolet and visible solar radiation over Cairo and Aswan and their correlations with environmental and climatological parameters. 4th International Conference, Solar Energy Storage and Applied Photochemistry, 1–6 January, Cairo, Egypt, pp. 37–45 (1997); and Proc. Indian Acad. Sci. (Chem.Sci.) 1998;110(3):361-371.
[12] Katz M. Some aspects of the physical and chemical nature of air pollution. Air Pollution 1961;46:113.
[13] Az El-Deen S, Nasr Allah MM. Environmental study for the dust in the air which surrounds the cement companies over Helwan. The final report for the first year, edited by Tebeen Institute for Metallurgical Studies, Tebeen, Helwan, Cairo, 1995.
[14] Mosalam Shaltout MA, Hassan AH, Rahoma UAlI. Measurements for suspended particles and aerosols in Helwan atmosphere. In: Proceedings of the 6th International Conference on Energy and Environment, vol. 2, Cairo, Egypt, 18–21 May, 1998:467–478
[15] Mosalam Shaltout MA, Abd El-Hady K, Abd El-Aziz A, Hassan AH, Fathy AM. Comparison study for the solar radiation components between Menia and Helwan. In: The 2nd Symposium and Exhibition on Renewable Energy and Modern Technologies for Environment Protection (AREEP), 14–16 September, Ismailia, Egypt, 1998.