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CORRELATION OF SOLAR RADIATION AND SUNSHINE DURATION IN RIYADH, SAUDI ARABIA

J.A. SABBAGH, A.A.M. SAYIGH and E.M.A. EL-SALAM

College of Engineering, University of Riyadh, Saudi Arabia

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Abstract. This paper presents the measurements of the intensity of incident solar radiation on a horizontal surface and sunshine duration during clear days in Riyadh. These measurements have been studied and presented in tabular and graphical form.

Empirical formulae based on sunshine duration are suggested for estimating solar radiation on a horizontal flat-plate.

The measurements of solar radiation and sunshine duration in many countries appear in several publications.[1-3] Despite this knowledge, there is a need to calculate the solar radiation for other parts of the world, where there is no solar data available.

Several authors have proposed formulae for calculating solar radiation using altitude angle of the sun, and optical air mass.[4,5]

This paper gives an analysis of the sunshine duration in Riyadh and proposes empirical formulae for calculating the intensity of solar radiation using the sunshine duration.

Solar Radiation. The site of the actinometer (at the Department of Water Resources Development, Hydrology Division, Riyadh) was chosen so as to ensure that the sensing element was free from obstructions above. The recorder was located indoors and could be inspected as often as desired. The radiation measurements were made continuously. During the period of investigation, the actinometer was inspected at least once a day, and the glass-bulb wiped clean.

Sunshine Duration. The sunshine duration in Riyadh is measured at the Department of Water Resources Development, Hydrology Division (24° 42′ N, 46° 43′ E and 594 meter above S.L.) with a sunshine recorder which could read correctly up to 0.15 g cal cm^{-2} min^{-1}. The recorded sunshine time is dependant not only on the actual time of sunshine but also on the sensitivity of the apparatus for measuring radiation when the sun is at a low altitude, which is a function of atmospheric conditions, humidity and precipitation.

The results of these measurements are shown in Fig. 1, while Table 1 shows the time of sunshine recorded during perfectly clear days in Riyadh as a percentage of the astronomical time of sunshine.

Table 1 shows that the percentage is higher in the winter season (Oct–March) than in the summer season (April–Sept). The reason for this is that in winter the amount of water vapour content and dust particles in the atmosphere are always less than in summer.

Monthly values of the sunshine hours, as obtained from the traces of the sunshine recorder are given in Table 2. The mean monthly values of the possible sunshine (100 for astronomical time of sunshine) are also listed.

The total number of hours of sunshine per year is about 3370, of which 1475 hr occur during October–March, and 1826 hr occur during April–September corresponding to about 74 and 76 respectively, of the possible sunshine duration.

The percentage of possible sunshine duration is nearly steady for July, August, September and October, but it increases from May to June as well as decreasing from October to November. It was also noticed that the maximum occurs in September and the minimum in May. These variations can be explained by the clear sky conditions in summer, the sand-storms in May and the rainfall in November, as shown in Figs. 2 and 3 which give the variation of wind speed and the amount of rainfall during the year.

Table 3 shows the sunshine hours per day which exceed 3, 5, 7, 9, 10 and 11 hr of sunshine and the number of these days as percentage of the total sunny days in each month of the year.

It is clear from Table 3 that the sunshine duration has exceeded 3 hr in 97 cases out of 100 and 11 hr in 22 cases out of 100 for the whole year. The data did not reveal any period of sunshine that equals or exceeds 12 hr. The limit of 11 hr is never reached during the period from October to March,

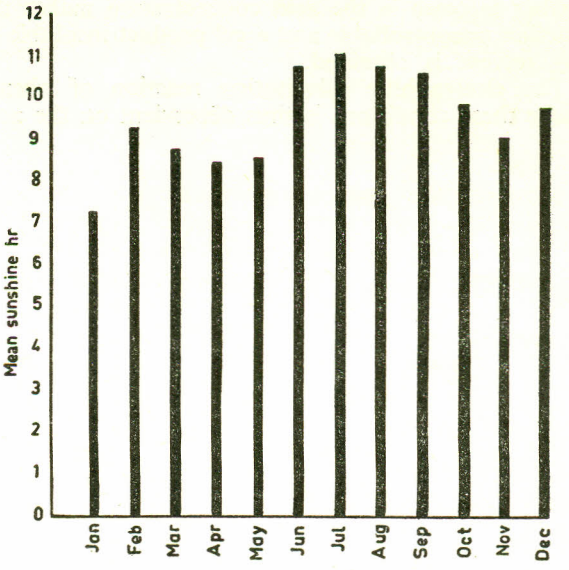

Fig. 1. Mean sunshine hours in Riyadh.

TABLE 1. SUNSHINE HOURS AS A PERCENTAGE OF ASTRONOMICAL HOURS OF SUNSHINE RECORDED DURING PERFECTLY CLEAR DAYS IN RIYADH.

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
93	89	79	78	76	74	74	76	82	87	88	95

TABLE 2. MONTHLY VARIATIONS OF THE HOURS OF THE SUNSHINE FOR RIYADH.

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1971	*	244.2	279.3	269.7	248.6	324.0	336.4	332.9	317.1	302.3	244.2	254.8	
1972	223.5	221.9	259.4	234.7	276.6	319.1	348.6	330.5	315.3	296.8	221.9	*	
Mean	223.5	233.1	269.4	252.2	262.6	321.5	342.5	331.7	316.2	229.5	233.1	254.8	3370
Possibility (%)	67	71	68	67	65	79	83	81	86	83	71	77	75

*Data were not available.

TABLE 3. NUMBER OF DAYS AS A PERCENTAGE OF ALL DAYS FOR WHICH THE HOURS OF SUNSHINE DURATION HAS EXCEEDED THE LIMITS GIVEN IN THE FIRST COLUMN.

Sunshine (hr)	Riyadh 1971–72												Year
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	
> 3	100	96	97	94	95	100	100	100	100	100	96	96	97
> 5	90	96	92	92	85	100	100	100	100	100	93	96	96
> 7	61	96	87	76	74	98	100	100	100	100	81	84	74
> 9	6	79	63	58	55	92	100	97	100	93	15	0	68
>10	0	14	29	28	42	83	93	93	92	32	0	0	47
>11	0	0	0	10	17	66	74	55	3	0	0	0	22

TABLE 4. NUMBER OF DAYS FOR WHICH THE SUNSHINE DURATION IS LESS THAN 3 HR.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1971	—	—	1	—	1	—	—	—	—	—	—	1
1972	—	—	2	4	1	—	—	—	—	—	4	2

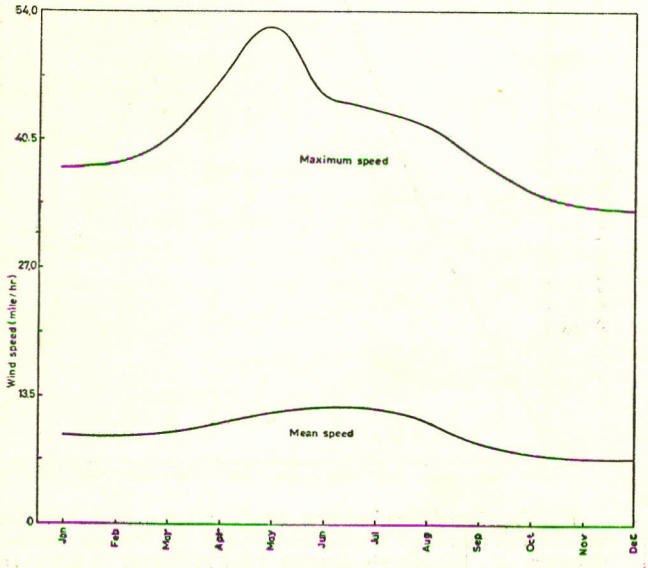

Fig. 2. Variation of wind during the year in Riyadh.

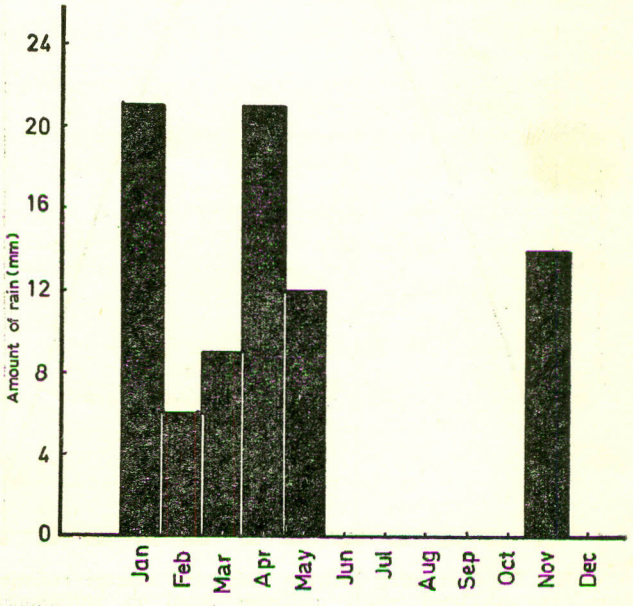

Fig. 3. The amount of rainfall during the year in Riyadh.

while it is found to be greater than 11 hr in 62 cases out of 100 during the period from April to September.

Table 4 shows the days where the sunshine duration is less than 3 hr, for the different months of the year for the same period.

Correlation Between Sunshine Hours and Solar Radiation. From the analysis of sunshine duration and the total solar radiation intensity on a horizontal plane, the following formula, is proposed to estimate the theoretical solar radiation on a horizontal plane for Riyadh, using the astronomical time of sunshine:

$$I = (A + B \ln n)D \qquad (1)$$

where A, 35; B, 11; and n, 1, 2, 3, 4, 5, 6, 6, 5, 4, 3, 2, 1 for the months from January to December, and D, in hours, is the astronomical time of sunshine.

Figure 4 shows a good agreement between the estimated solar radiation intensity for Riyadh using the above formula and the calculated values from ref. 6, while Fig. 5 also shows a good agreement between the estimated and the calculated values for Cairo.

An attempt to correlate the actual sunshine duration with the measured solar radiation intensity on a horizontal plane for Riyadh, gave the following formula:

$$I = (42 + 12 \ln n)\, D' \qquad (2)$$

where D' is the actual sunshine duration.

Fig. 6 shows the actual solar radiation on a horizontal plane for Riyadh and the estimated values.

The previous analyses were carried out for several towns at different latitudes in the Kingdom of Suadi Arabia, and the estimated results using formula (1) gave an error of 4% while using formula (2) gave an error of 10%.

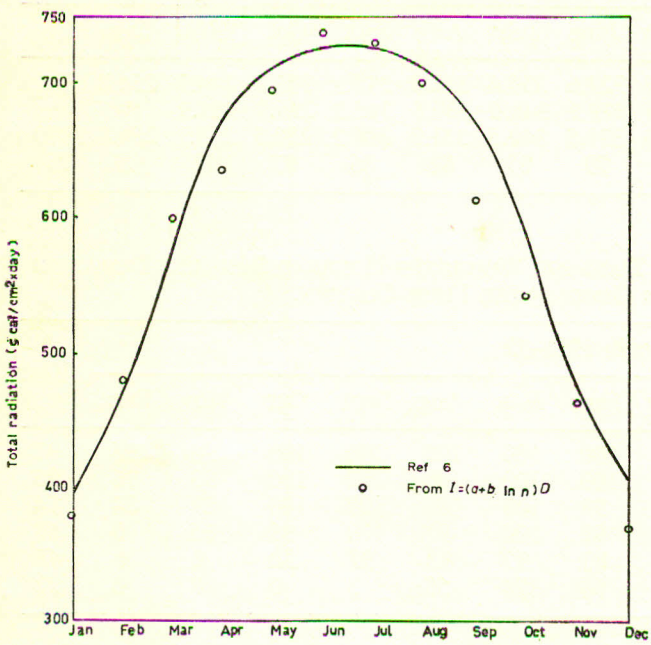

Fig. 4. Correlation between theoretical average radiation and the calculated yearly radiation based on astronomical sunshine in Riyadh.

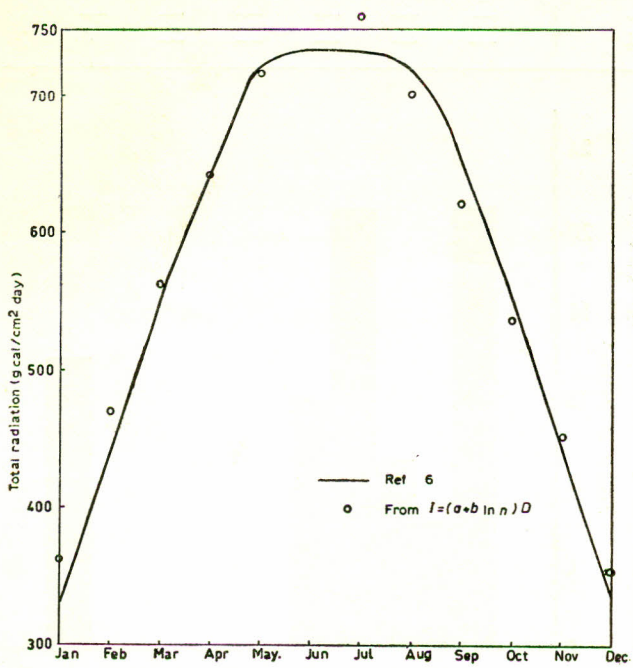

Fig. 5 Correlation between theoretical average radiation and the calculated yearly radiation based on astronomical sunshine in Cairo.

Conclusion

The previous discussion emphasises the great amount of sunshine and solar radiation available in the Kingdom of Saudi Arabia. This abundant solar energy should be utilized, and to facilitate this utiliza-

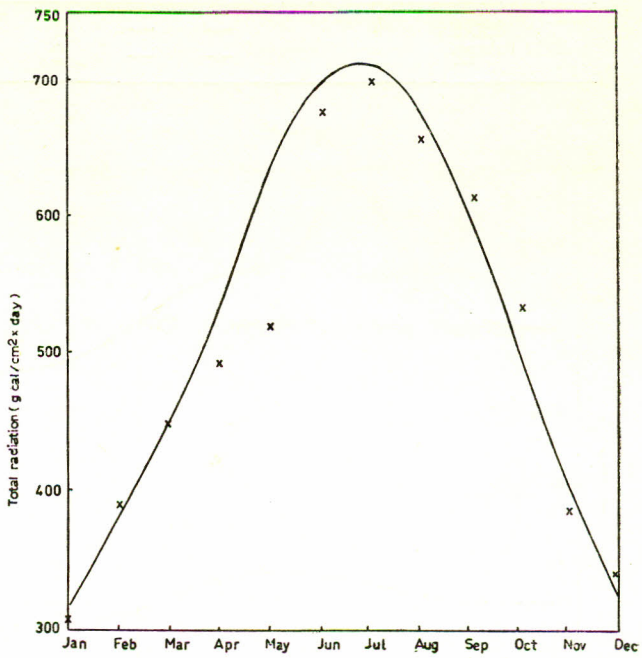

Fig. 6. Correlation between yearly average total radiation and the calculated yearly radiation based on average sunshine duration in Riyadh. —, Average total radiation; × from $I = (a' + b' \ln n)\, D'$.

tion in all parts of the Kingdom the formulae which were arrived at will give a quick and reliable estimate of solar radiation.

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