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AN ESTIMATE OF TOTAL SOLAR RADIATIONS AT KARACHI

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Total solar radiations at Karachi is computed with a view to work out the feasibility of solar energy utilization. Sunshine hours variation and effect of humidity is also discussed. From the computed curve it is found that with the exception of monsoon months (June–August) solar energy can be utilized very effectively throughout the year.

INTRODUCTION

With the rapid industrialization and the present consumption rate of conventional fuel, the world will soon run out of all its fuel reserves. This problem is yet to be resolved and worth giving serious attention and thinking especially by the developing countries whose economical and social growth heavily leans on their energy use. It is now time to consider other alternate sources of energy if we do not have rich reserves. Among all the nonconventional sources of energy, solar energy has emerged as one of the most clean, powerful and virtually inexhaustible source of energy, world can depend on.

As there is an enormous amount of data on solar radiations at various localities for western countries, measured or estimated data for any place of Pakistan is lacking. The present work was taken up in order to estimate theoretically the total solar radiation falling on a horizontal surface at Karachi. Because for the application of solar energy in any form, a knowledge of available intensity of total solar radiation is a pre-requisite. These theoretical calculations will prove to be a forerunner for any experimental verification which may be made here.

Available Radiation. The total solar radiation received on the earth's surface consists of a direct component (direct radiations) and a diffuse component (sky radiation). The diffuse radiation arises from the fact that the part of radiation scattered or absorbed by the atmosphere may in turn be partially re-radiated downwards towards the earth's surface. Hence the intensity of radiation received on the earth's surface will change not only diurnally, monthly and annually, but will also depend on the latitude and altitude of the place on the earth's hemisphere.

Solar Constant. The rate at which the earth's surface receives solar energy is most commonly termed as solar constant. The value of solar constant used throughout this study is 2.00 Langley/min or 442 BTU/hr–sq.ft^{-1} (Langley=Calories/cm^2).

Total Solar Radiations. Several authors have tried to predict theoretically the total solar radiation for different localities. Parmelee [2] attempted a computation of diffuse radiation from clear sky whereas Liu and Jordan [1] extended it to cloudy skies as well. On the other hand, computation of direct radiation under clear atmospheric condition has been done by many authors [3,4].

Sunshine Hours Data. It is possible to use hours of sunshine or possible percentage of sunshine and cloudiness data, to empirically estimate the total solar radiations [5]. Sunshine variation and possible percent of sunshine data for five years (1975–1979) was obtained from Pakistan Meteorological Department, Karachi Airport. Tabular and graphical representation (Fig. 1) of sunshine hours variation

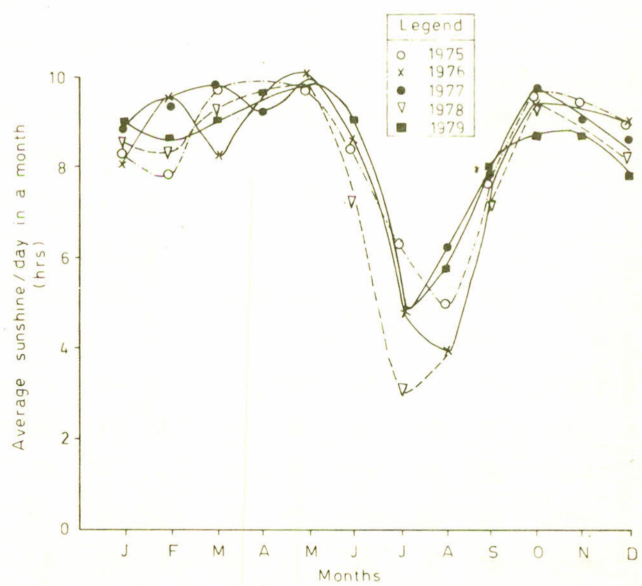

Fig. 1. Sunshine hours variation at Karachi ϕ = 24.54 N latitude.

data gives us an inference of feasible application of solar energy. The sun shines brightly over a longer period of the year. The hours of sunshine decreases remarkably by a factor of one-and-a-half during the months of June–August, as compared with the average percentage of sunshine hours from January to May. This is a repeated behaviour and five years data shows that during the monsoon months (June–Aug) this is an expected fact. During these months the sky is mostly overcast, contributing mainly to diffuse radiations. In 1978, the month of July showed exceptional decrease in sunshine hours when it was as low as 3 hr a day (average) only.

From the average percentage of sunshine hours for the year shown in Table 1, it is concluded that the availability of sunshine for our utilization purpose is well above 65% and hence this is an encouraging percentage for looking forward towards solar energy as a possible future source for our country.

Method for Estimation of Total Solar Radiation. S.J. Reddy [6] has developed a formula for computing the daily total solar radiaton, received at the earth's surface, given as below:

$$R_t = K \frac{(1+0.8s)(1-0.2t)}{\sqrt{h}} \quad \text{cal/cm}^2\text{/day}$$

Where: $K=(\lambda N+\psi\cos\phi)\ 10^2$ cal/cm^2/day; $\lambda=0.2/(1+0.1\phi)$, Latitude factor; $\phi=24^o.54'$N (Latitude); $\psi=$ Seasonal factor, $N^*=$ Mean length of the day during the day; $s=n^*/N^*$, where n=mean hours of bright sunshine per day during a month; $t=r^*/M$, where r=number of rainy days and M=number of days in a month; h^*=mean humidity per day in a month.

Employing the above parameters in the Reddy's formula, the total solar radiation (direct+diffuse) was calculated for Karachi (Lat. $24^o.54'$N). For example the calculations for May 1975 are shown as below:

Substituting the values of the parameters; $\phi=240.54'$N, $N^*=13.33$., n= 9.87, $\psi=2.05$, (taken from Reddy's paper, for May, Northern hemisphere), r^*=zero (for May 1975) and M=31 (May 1975) and h^* = 73% (for May 1975) the total solar radiation for the month of May 1975 is 488 cal/cm^2/day. These calculations were extended for a period of five years (1975–1979) in order to check the consistancy of our results. On a clear day the intensity of direct radiation is determined by the amount of water vapours, dust particles etc. Clouds cause an appreciable reduction in the intensity of direct radiation. Due to large variation in cloudiness, the intensity of direct and diffuse radiation also vary.

From the computed values of the intensity of solar radiation of Karachi, we observe a decrease for the months, Jun–Aug and this is a permanent feature every year. (Fig. 2). This reduction in solar radiation is due to the

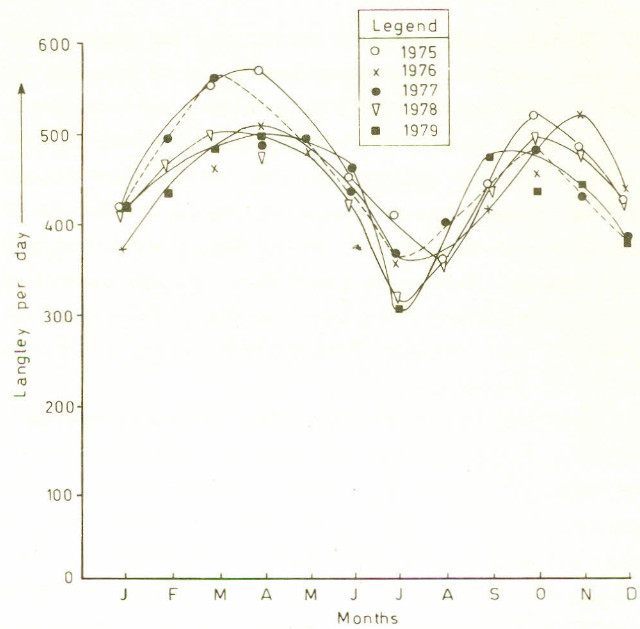

Fig. 2. Total solar radiation at Karachi 1975–1979.

Table 1. Sunshine hours variation at Karachi.*

Percentage of possible sun shine hours

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average percentage of sunshine hours for the year
1975	77	69	82	76	74	61	47	39	63	83	87	84	70%
1976	75	81	68	76	76	63	35	30	61	82	83	85	68%
1977	82	82	82	72	74	62	36	48	64	83	83	82	71%
1978	79	74	77	77	74	53	22	30	59	81	78	86	66%
1979	83	76	76	73	74	66	36	45	66	78	80	75	69%

*Data obtained from Pakistan Meteorological Department, Karachi Airport.

approach of monsoon during the later half of June in which water vapours gradually appear in the atmosphere [7].

The theoretical results obtained for Karachi were compared with the published work of Reddy [6] for Trivandrum (Lat. 8°.30′N), both being coastal stations. The shape of the estimated curve for Karachi (Fig. 3), is in very good agreement with that of Trivandrum, except for the months of Oct–Nov. This may be explained on the basis of the fact that in Karachi we have monsoon rains once a year and rain in winter is occasional or rare. But the station Trivandrum receives regular winter rains during the months of Oct–Nov as well [8]. This results in the decrease of solar radiation intensity for these months. Theoretical curve (Fig. 3) for Karachi is obtained by taking the average of the total solar radiations from 1975–1979.

Effect of Humidity. As the total solar radiation intensity is affected by the presence of dust, clouds, ozone and water vapours in the atmosphere, these components contribute to the diffuse radiations. Karachi being a coastal station has on the average about 67.5% humidity throughout the year, reaching upto a maximum of 78–80% in the months of July–August. During these months the percentage of sunshine hours is very low as the sky is mostly heavily overcast. Perhaps the presence of humidity in the atmosphere results in the marked decrease in the intensity of total solar radiation (Fig. 2) falling over Karachi.

DISCUSSION

The estimated values for total solar radiations are encouraging from application point of view because of the

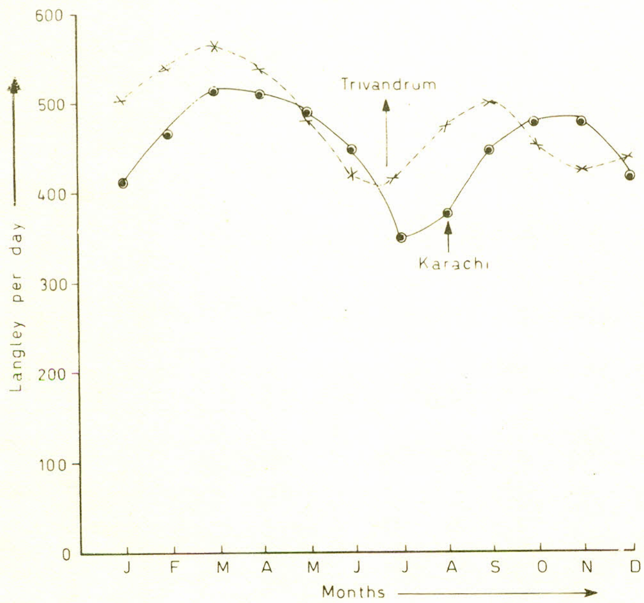

Fig. 3. Estimate of total solar radiation (average) on Karachi and Trivandrum, ϕ = 8.30′ N Trivandrum; ϕ = 24.54′ N Karachi.

Fig. 4. Average total solar radiation per year.

consistent and intense availability of total solar radiations. From Fig. 4, one can conclude that the prospects of solar energy utilization are bright as every year the average solar radiation received at Karachi is well above 400 cal/cm^2/day. In the winter months, the sky is mostly clear and the direct to total radiation ratio is high. During the peak summer months (Apr–Aug) mostly due to overcast sky the contribution to the direct radiation is somewhat less. The precentage of direct radiation is more in the months of Oct–Nov where it reaches upto a maximum of 80–85%. It is to be noted that almost every year the months of Oct–Nov are invariably a second summer in Karachi. The sun shines brightly in winter (clear sky) and, therefore, due to high percentage of direct total solar radiation the winter months are more suitable for utilizing the intense bright and clear solar radiations than in summer months. In spite of higher percentage utility in winter months the utility factor during summer months is also not too bad. As such months of both these seasons are suitable for solar energy utilization at Karachi. Nature is, therefore, favouring Karachi to have two peak cycles during summer and winter every year.

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