FURTHER STUDY ON RATIONAL TURBIDITY FACTOR AT UNIT AIR MASS

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The Rational Turbidity Factor, T_r has been correlated with Angstrom-Schuepp Turbidity Coefficient, B for different values of precipitable water, W, at unit air mass so as to eliminate the effect of virtual variation with air mass. It is shown that due to interaction between B and W within the absorption bands of water vapour, it is not possible to isolate the effects of B and W.

In our earlier paper[1], a new measure of total atmospheric turbidity, termed as ' Rational Turbidity Factor, T_r, was defined in order to overcome the limitations of Linke's Turbidity Factor, T. T_r is made up of three components, namely, (*i*) pure and dry air (the basic effect), (*ii*) precipitable water vapour, W and (*iii*) aerosol particles in the atmosphere (dust, moke, haze). Naturally, one would like to know how T_r, compares with existing measures of turbidity, none of which is likely to be free frcm virtual variation, with air mass. The only reliable measure of turbidity based on measurement of total direct solar radiation at normal incidence (i.e. without filters) is the Angstrom-Schuepp turbidity coefficient, B[2], defined by

$$a_d = B\,(2\lambda)^{-1\cdot 5} \tag{1}$$

where a_d is the extinction coefficient due to aerosols, and λ is the wave length of monochromatic radiation. The constant value of the exponent, *viz.*, $-1\cdot5$, is based on the assumption of a fixed particle-size distribution which is a serious limitation of the turbidity coefficient, B.

The object of the present paper is to correlate T_r with B and W at unit air mass so as to eliminate the effect of any possible virtual variation with air mass. The effect of variation of air mass will be considered in a subsequent paper.

CORRELATION OF T_r WITH B AND W FOR UNIT AIR MASS $m_r=1$

Based on elaborate computations, Schuepp[3] developed a diagram for estimating direct solar radiation at normal incidence as a function of B, W, and m_r. This diagram, according to Schuepp, is not completely self-sufficient. Four kinds of corrections have to be applied: (*1*) for atmospheric pressure, (*2*) for limitations in the construction of the graph, (*3*) for differences in the ozone content, and (*4*) for the reduction to mean solar distance. With the corrections applied as suggested by Schuepp[4], the residual error in estimating direct solar radiation at normal incidence I is claimed to be within $\pm$ 3%.

We have made use of Schuepp's chart with due corrections, and the values of I obtained for different values of B (O to 1) and W ($0\cdot5$—10 cm) are presented in Table 1 for unit air mass ($m_r=1$). We have assumed a mean atmospheric ozone content of $O_3=0\cdot34$ cm NTP (IGY scale), since its actual variation, seasonal or otherwise, has been found to have little effiect on T_r. The corresponding values of T_r are also given in the same table, where T_r is given by[1] (for $m_r = 1$).

$$T_r = \left(\frac{0\cdot32491 - \log I}{0\cdot072375} \right)^{1/0\cdot57} \tag{2}$$

It is known[4] that attenuation of solar radiation due to water vapour varies practically as $W^{0\cdot3}$ for most practical purposes. This is exemplified in Fig. 1, in which T_r is plotted against $W^{0\cdot3}$ for different values of B, from Table 1. We may, therefore, be justified in expressing T_r in the form

$$T_r = a + b\,W^{0\cdot3} \tag{3}$$

TABLE 1

INTENSITY OF DIRECT SOLAR RADIATION AT NORMAL INCIDENCE I IN CAL/CM^2 MIN, AND RATIONAL TURBIDITY FACTOR (T_r) FOR UNIT AIR MASS (m_r=1) IN RELATION TO B AND W AT MEAN SOLAR DISTANCE

(I values extracted from Schuepp[3] with due corrections)

Atmospheric pressure $\approx$ 1000 mb, O_3=0·34 cm NTP (IGY Scale)

B	W cm							
	0·5		2		5		10	
	I	T_r	I	T_r	I	T_r	I	T_r
0	1·56	2·86	1·49	3·66	1·40	4·89	1·31	6·35
0·1	1·37	5·35	1·27	7·09	1·18	8·99	1·11	10·71
0·2	1·19	8·76	1·10	10·97	1·01	13·61	0·940	16·02
0·4	0·921	16·74	0·835	20·36	0·775	23·31	0·715	26·70
0·6	0·718	26·52	0·650	30·95	0·595	35·14	0·545	39·52
1·0	0·477	46·59	0·423	53·39	0·380	59·78	0·345	65·81

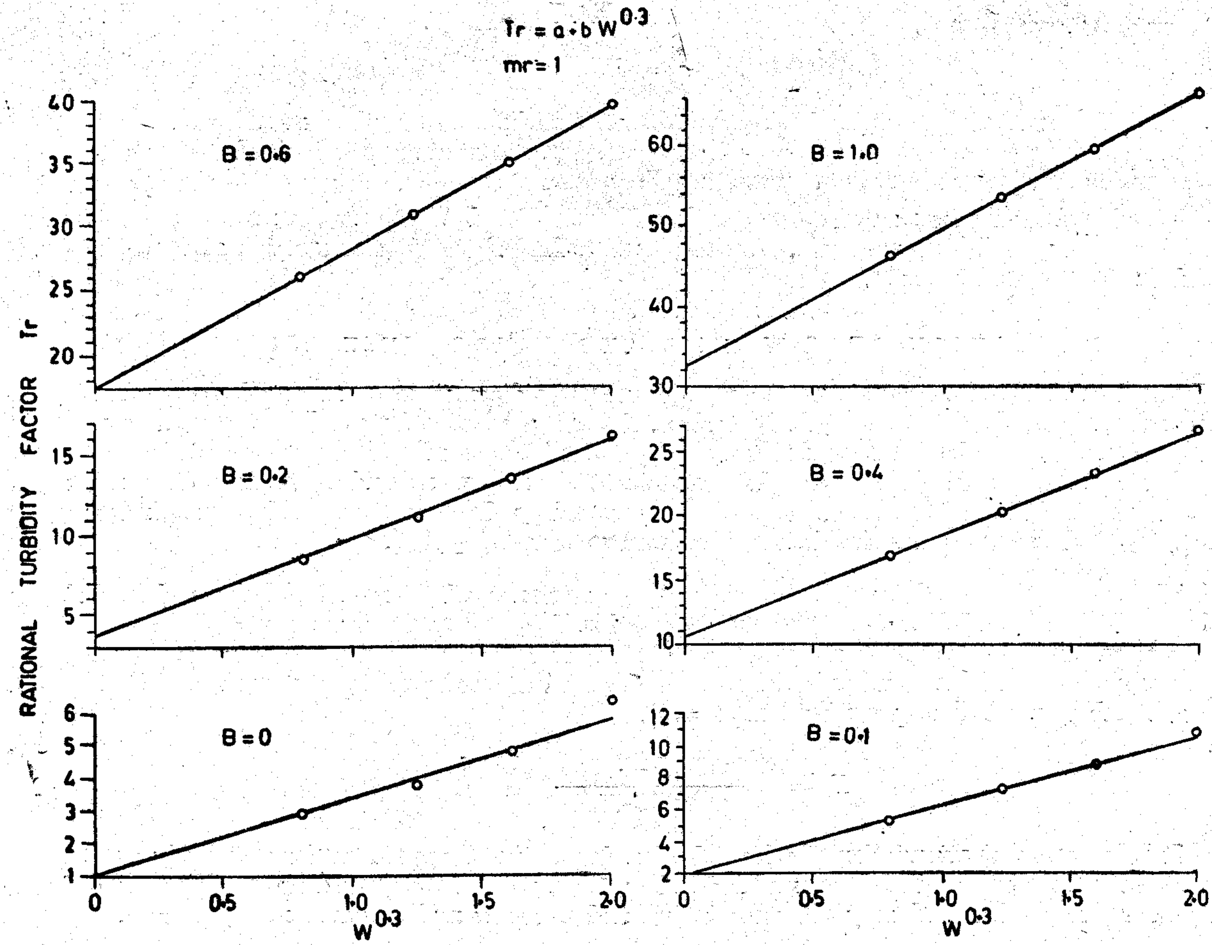

Fig. 1 Linear relationship between T_r & $W^{0\cdot3}$ at unit air mass for different values of 'B'.

where a and b are obviously related to B. For pure dry air, $W=0$ and $B=0$, so that $Tr = 1$ by definition. It follows, therefore, that $a=1$ for $B=0$. In Fig. 2, the graph $(a-1)$ plotted against B on log-log scale shows a linear relationship, from which we obtain

$$a = 1 + 33{\cdot}54\ B^{1{\cdot}479} \tag{4}$$

The Values of the slopes b obtained from Fig. 1 are also plotted against $(B+0{\cdot}1)$ on log-log scale in Fig. 3, so as to yield almost a perfect linear relationship. From Fig. 3, we obtain

$$b = 15\ (B + 0{\cdot}1)^{0{\cdot}796} \tag{5}$$

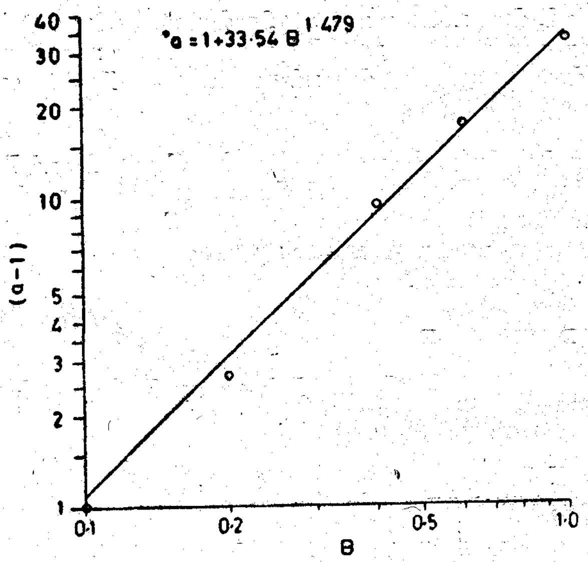

Fig. 2 (a—1) plotted against 'B' on log-log scale.

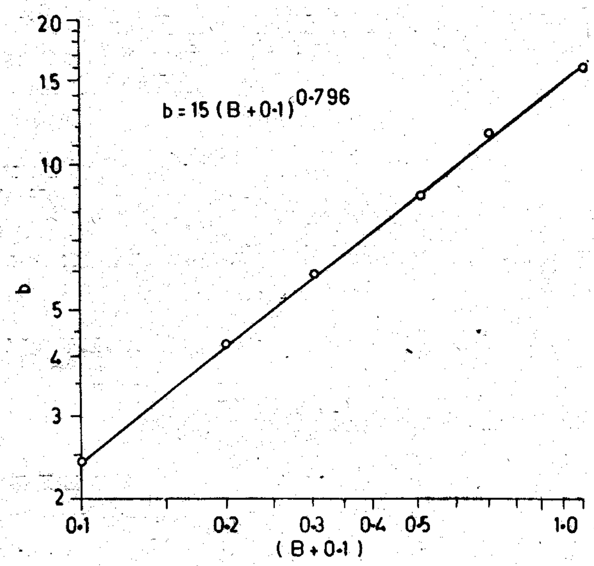

Fig. 3 b plotted against (B+ 0·1) log-log scale.

The final formula connecting T_r with B and W for unit air mass $(m_r=1)$ is therefore

$$T_r = (1 + 33{\cdot}54B^{1{\cdot}479}) + 15\ (B + 0{\cdot}1)^{0{\cdot}796}\quad W^{0{\cdot}3} \tag{6}$$

The interaction between B and W is clearly indicated by the second term on the right hand side of equation (6).

PREDICTION OF DIRECT SOLAR RADIATION FROM B AND W FOR UNIT AIR MASS

With the knowledge of the Rational Turbidity Factor T_r, one can immediately estimate the intensity of direct solar radiation at normal incidence I with the help of the formula[1].

$$log\ I = 0{\cdot}32491 - 0{\cdot}072375\ (m_r\ T_r)^{0{\cdot}57} \tag{7}$$

For unit air mass $(m_r=1)$, the above equation reduces to

$$log\ \ I = 0{\cdot}32491 - 0{\cdot}072375\ T_r^{0{\cdot}57} \tag{8}$$

In order to avoid tedious co mputational work, a nomogram was presented in the earlier paper.

Values of I computed from (8) have been plotted in Fig. 4. against values of I from Table 1 on log-log scale. The agreement between the two sets of values, as can be seen from the figure, is almost perfect.

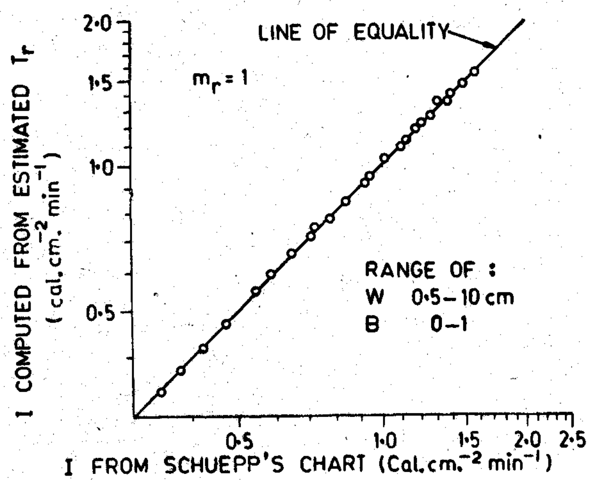

Fig. 4 I computed from proposed formula compared with I obtained from schuepp's chart for different values of 'W' & 'B' at unit air mass.

DISCUSSION

None of the existing measures of atmospheric turbidity has been found to be free from virtual variation with air mass. Angstrom-Schuepp Turbidity Coefficient B has the further limitation that it is based on a fixed particle-size distribution. Angstrom's Turbidity Coefficient β is also based on a fixed particle-size distribution. The exponent of λ is $-1\cdot5$ in the former case and $-1\cdot3$ in the latter. Estimation of B requires the knowledge of precipitable water W while that of β does not require the knowledge of W, its effect being eliminated by use of the red filter, since the absorption bands of water vapour are located in the infra-red region of solar radiation. Estimation of precipitable water vapour in the atmosphere, however, does not present any serious problem as shown in our earlier papers[5,6].

The Rational Turbidity Factor T_r on the other hand, does not assume any fixed particle-size distribution of aerosol particles, which is its chief merit. However, it is also not likely to be free from virtual variation with air mass which, according to Linke, is due to spectral dependence of the Extinction Co-efficient a.

In the present paper, it has been clearly demonstrated with the help of (6) that the effect of B and W are inseparable. This is because scattering of radiation by aerosol particles and absorption of the same by water vapour coexist within the absorption bands of water vapour, so that the two effects cannot be isolated from each other. This interaction becomes more pronounced with increasing size of particles, since the negative exponent of λ in (1) approaches zero for large particles[7].

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