551.510 : 551.594.7 (541.2)

ON THE DISPERSAL CAPACITY OF THE AIR ENVIRONMENT OVER METROPOLITAN CALCUTTA

1. Calcutta is a big industrial city with a population of more than 3 million. It was estimated that 632 tonnes of pollutants of which 64.7 tonnes of sulphur dioxide are emitted into the atmospheric environment every day. The maximum and average concentration of sulphur dioxide and suspended particulate matter for 24 hours in the atmosphere of Calcutta as reported by National Environmental Engineering Research Institute (1975) are 239, 44 and 1200, 406 $\mu g/m^3$ respectively. The standards under consideration by Indian Standards Institution for these pollutants are 200, 60 and 500, 150 $\mu g/m^3$ (ISI 1979) respectively. It may thus be seen that the ambient air quality at Calcutta could cause harmful effects to the sensitive segments of the population and also aggravate illness amongst persons with pre-existing respiratory ailments. One of the causes for high concentrations of pollutants is the low dilution capacity of the atmosphere.

The dispersal capacity of the atmosphere both in the vertical and horizontal can be well understood from a knowledge of the mixing depths, inversion heights and wind speeds. In the present paper an assessment is made of the dispersal capacity of the air environment over metropolitan Calcutta by studying the variations of mixing depths, inversions and wind speeds.

2. Radiosonde observations at Dum Dum and maximum and minimum temperatures at Alipore are utilised to compute mixing depths according to Holzworth (1967).

3.1. *Criteria for low dispersal capacity* — The percentage frequency of days when morning mixing depth is $\leqslant$500 m and morning transport wind is $\leqslant$4 m/sec is found to be high for January and December and least for October (Table 1a) Percentage frequency of days when afternoon ventilation coefficient is $\leqslant$6000 m^2/s (critical for air pollution potential) (Gross 1970) and afternoon transport wind $\leqslant$4 m/s attains maximum value in January, December and November and least for March (Table 1b). Table 1(c) presents both morning mixing depth $\leqslant$500 m and transport wind $\leqslant$4 m/s and afternoon ventilation coefficient $\leqslant$6000 m^2/s and transport wind $\leqslant$4 m/s. It is seen that higher values are attained in December and January and lower in March and October. An examination of this table points out that January and December satisfy the criteria for low dispersal capacity. The table also points out that the air pollution potential at Calcutta appears to be decreasing slightly. This may be due to higher turbulence as a consequence of increasing urbanisation and industrialisation.

TABLE 1

Percentage frequency of occurrence of days

Month	1976	1977	1978
(a) Morning mixing depth $\leqslant$500 m and morning transport wind speed $\leqslant$4 m/sec			
Jan	86	72	95
Feb	67	47	69
Mar	61	67	55
Oct	43	31	—
Nov	69	52	—
Dec	79	91	—
(b) Afternoon ventilation coefficient $\leqslant$600 cm^2/sec and afternoon transport wind $\leqslant$4 m/sec			
Jan	60	41	35
Feb	33	16	27
Mar	21	27	10
Oct	32	38	—
Nov	51	40	—
Dec	68	39	—
(c) When both (a) & (b) occur			
Jan	53	38	23
Feb	25	05	16
Mar	21	22	00
Oct	38	20	—
Nov	14	21	—
Dec	57	35	—

Comparison of the dispersal capacities of the air environment at Delhi, Visakhapatnam and Calcutta is given in Table 2.

3.2. *Possible sulphur dioxide concentration levels* — Box model is the simplest to study the qualitative aspects of air pollution. Lettau (1970), Tennekes (1976), Gifford and Hanna (1971) and Hanna (1972) have used the box model to study the air pollution problems in urban areas and concluded that this simple model is ideally suited for the study of air pollution climatology and environmental impact assessment.

The box model represents the urban air shed by a shallow box with the upper boundary of the box being determined by the effective height of turbulent dispersion. The mixed layer on which vertical dispersion depends determines the height of box. In this model it is assumed that the urban pollutant source strength is uniform, the pollutants are well mixed inside the box and advection is absent. The concentration χ in the

TABLE 2

Comparison of the dispersal capacities of the air environment at Delhi, Visakhapatnam and Calcutta

	Delhi	Visakhapatnam	Calcutta
Location	Inland City	Coastal town	City on the bank of Ganges, about 30 km away from sea
Climate	Extreme	Moderate	Moderate
Industrialisation	Industrial	Developing	Big industrial city
Ground inversion in winter (%)	94	15.5	86
Ht range of high percentage of ground inversion (m)	101-200 m	201-300 m	301-400 m
Wind speed associated with high percentage of inversions (m/s)	4	4	Between 2-4 and >4
Winds in winter	Strong	Calm	Moderate
Lapse rate >50° C/km	Frequent	Rare	Noticed in Dec
Highest percentage of ground inversion	98 (Nov)	18.8 (Feb)	96 (Dec)
Range of morning mixing :			
(*a*) depth (m)	6-185	184-533	216-579
(*b*) lowest in month	Nov	Feb	Dec & Jan
Range of afternoon mixing :			
(*a*) depth (m)	1145-2705	1390-2004	1373-1483
(*b*) lowest in month	Dec	Jan	Dec
Range of morning ventilation :			
(*a*) Coefficient (m^2/s)	06-533	478-1449	611-2170
(*b*) Lowest in month	Dec	Feb	Dec
Range of afternoon ventilation :			
(*a*) Coefficient (m^2/s)	5315-18935	5726-8418	4962-11381
(*b*) Lowest in month	Dec	Jan & Feb	Dec
Afternoon ventilation :			
(*a*) Coefficient (m^2/s)	<6000	<6000	<6000
(*b*) Month	Dec 74	Feb 78, Jan 77	Jan & Feb
Months of low dispersal capacity	Oct-Mar	Dec-Feb	Dec & Jan

box model is computed as:

$$\chi = Q/uhA$$

where,

Q = source strength, u = wind speed,

h = mixing depth and A = area of the city

Computations were made to obtain the maximum concentration and average concentration over 24 hours. The source strength for sulphur dioxide is taken as 64.7 tonnes/day (NEERI, 1975). Mean minimum and average ventilation coefficients for the period of October to March as determined in this study are used. The total area of Calcutta is taken as 104 sq. km (Jain 1979). The possible maximum and average concentrations of sulphur dioxide in Calcutta came out to be 471 & 84 $\mu g/m^3$ respectively. During a survey in 1973-74, NEERI (1975) reported corresponding values as 236 and 44 $\mu g/m^3$ respectively. The difference between the box model values and the values actually realized is presumably due to the assumption of absence of advection in the model. However, the purpose of presenting the values by the authors is to bring out the high pollution potential of the environment over Calcutta which could build up the sulphur dioxide concentrations to the possible maximum levels obtained by the box model.

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