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Monthly average sulphur dioxide concentrations in Bombay and their computational transfer to one hourly averaging period

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ABSTRACT. The procedure adopted for the estimation of monthly average concentration of sulphur dioxide at some locations in Greater Bombay is briefly described and the results of environmental measurements are presented.

Making use of Larsen's mathematical model for correlating concentrations over different averaging periods (sampling periods) the expected maximum hourly concentrations of sulphur dioxide during the year at some of the locations in Greater Bombay are calculated with the help of their monthly average data.

1. Introduction

The sulphation of lead dioxide by the oxides of sulphur in the atmosphere is widely used to estimate what is known as the sulphation rate. Different techniques of exposing the lead dioxide surface to the environment are used. We have briefly described the procedure adopted by us. Some attempts have been made by earlier workers (Stalker *et al.* 1963 and Publication No. AP-91, 1972) to correlate the sulphation rate of lead dioxide with the concentration of sulphur dioxide in the ambient atmosphere and here we have assumed their findings to be correct.

Following the above procedure we have measured the monthly average sulphur dioxide concentrations at a few locations in Greater Bombay. These results are presented in Table 1.

Recently Larsen (1971) has developed a mathematical model correlating air quality measurements. Based on a study of extensive data Larsen finds that his calculations agree fairly well with actual measurements on the entire sampling network in the USA over a period of seven years for averaging periods ranging from 5 minutes to one year.

Here, we have made use of the above model for calculating the expected hourly maximum concentrations of sulphur dioxide at nine of the locations for which a minimum of 10 monthly average values of sulphur dioxide are available during a one-year period (Table 1).

The actual equations used are briefly discussed in the text and the results of computations are presented in Table 2.

2. Procedure

Among the number of improvements that have been made in the lead dioxide method by different investigators (Hickey Jr. *et al.* 1965, Rayner 1966 and Huey 1968) the one made by Huey is a simple economical and efficient system for the estimation of mean concentration of sulphur dioxide pollution. Huey (1968) made use of 4·8 centimetre diameter plastic petridishes instead of candles and found that areawise the dishes are 19 per cent more reactive than the candles.

Following Huey (1968) we used six inches diameter glass petridishes to support the lead peroxide mucilage.

3. Preparation of sampling dishes

Ten millilitres of a thoroughly blended mucilage (containing 100 gm lead dioxide, 7 gm gum tragacanth, 10 ml absolute alcohol and 90 ml distilled water) is transferred to a glass petridish and spread uniformly all over the surface. It is then dried between 50° and 60°C and preserved for use. One from every batch of dishes thus coated is used

TABLE 1

Concentration of sulphur dioxide (pphm) during 1970-71

Location	1970						1971										
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
BARC*	1·1	1·2	1·0	0·8	0·8	1·1	1·3	1·2	1·3	1·3	0·4	1·0	1·5	0·7	0·6	0·2	0·3
Chembur†	2·6	4·47	4·5	2·2	1·9	1·7	1·6	1·8	1·6	1·5	1·9	8·1	6·6	5·3	2·6	1·2	—
Bandra	—	—	—	—	—	1·0	1·0	0·9	0·7	0·7	0·3	0·0	0·1	0·1	0·2	0·6	0·7
Deonar	—	—	—	—	—	0·9	1·1	0·8	1·0	0·8	0·5	1·7	2·6	1·5	1·4	—	—
Matunga	—	—	—	1·8	1·8	1·7	1·8	0·9	0·9	0·9	1·0	2·3	1·6	1·6	1·4	0·3	0·9
Mahul	0·6	0·6	0·4	0·5	2·5	1·7	1·8	—	0·7	0·7	0·5	0·4	0·5	0·6	0·4	0·8	0·7
Ghatkopar	0·2	0·1	0·4	0·9	0·8	0·8	0·8	0·5	0·3	0·6	0·1	0·2	0·2	0·1	0·4	0·3	0·7
Worli	—	—	—	3·1	3·1	1·2	1·0	0·9	0·7	0·7	0·3	0·1	0·3	0·4	0·7	0·8	1·2
Parel	—	—	—	1·3	2·1	2·1	1·7	1·5	1·5	0·6	0·5	0·7	0·5	0·3	0·8	0·7	1·0

* BARC (Mod.Labs.), Trombay, † Collectors Colony, pphm = parts per hundred million

TABLE 2

Expected maximum hourly concentrations

Location in Greater Bombay	Observed maximum monthly concentration (ppm)	Expected maximum hourly concentration		Period of data used from Table 1	Annual arithmetic mean concentration (ppm)
		(μg/m³)	(ppm)		
BARC, Mod, Labs., Trombay	0·013	100	0·04	Jul 70 to Jun 71	0·010
Collector's Colony, Chembur	0·081	10,500	3·75	Do.	0·028
Bandra	0·010	250	0·09	Dec 70 to Nov 71	0·005
Deonar, Chembur	0·026	1,300	0·47	Do.	0·012
Matunga	0·023	250	0·09	Oct 70 to Sep 71	0·015
Mahul	0·025	2,200	0·79	Jul 70 to Jun 71	0·010
Ghatkopar	0·009	200	0·07	Do.	0·005
Worli	0·030	4,000	1·43	Oct 70 to Sep 71	0·011
Parel	0·021	500	0·18	Jul 70 to Jun 71	0·012

as control plate for assessing the sulphate contamination.

Each plate is enclosed in a flat metallic casing with a thin wire netting (mesh size ¼″) window for safety during handling. It is then mounted at a height of about ten metres from ground level at the site and exposed to ambient air for the duration of one month in each case.

4. Analysis

After exposure the contents of the petridish are transferred into a beaker along with 20 ml of 10 per cent sodium carbonate solution and boiled for ten minutes. The insoluble lead sulphate formed during exposure gets converted to soluble sodium sulphate during this leaching process. The alkaline filtrate is then neutralised by adding concentrated hydrochloric acid to a slightly acidic medium followed by an addition of an excess of $BaCl_2$ solution. From this stage onwards the standard procedure for the gravimetric estimation of $BaSO_4$ is adopted.

The sulphation rate which is expressed as milligram SO_3 per 100 sq. cm area exposed per day is calculated as :

$$S = \frac{m \times 80}{233} \times \frac{100}{A} \times \frac{1}{N}$$

where,

S — Sulphation rate

m — Amount of $BaSO_4$ in milligrams

A — Area of the dish exposed in sq. cm

N — No. of days of exposure.

It has been found by other investigators (Stalker *et al.* 1963 and Pub. No. AP-91, 1972) that on the average the sulphation rate of 1·0 mg SO_3 per 100 sq. cm per day corresponds to 0·037 parts per million (ppm) of SO_2 in the ambient air. We have used this relation throughout and assumed that the local geographical and seasonal variations do not cause serious departure from this relation by more than about 15 per cent on either side.

5. Results

The results of the survey conducted at 9 sites in Greater Bombay during the period 1970-71 for an approximate estimation of sulphur dioxide by the lead dioxide method are presented in Table 1. These results indicate a tendency of widespread sulphur dioxide pollution with a few pockets of relatively higher concentrations.

6. Computation of the maximum hourly concentrations

The expected hourly maximum concentrations at some of the sites are presented in Table 2. These values have been calculated on the basis of Larsen's mathematical model (Larsen 1971) referred to earlier from results presented in Table 1.

The following equations derived by Larsen for a given averaging time are used.

$$S_g = \exp Z - [Z^2 - 2\ln(C/m)] \tag{1}$$

$$M_g = C/S_g^z \tag{2}$$

$$C = M_g S_g^z \tag{3}$$

In addition to the above equations the following three equations also derived by Larsen are used to calculate values for any averaging time (*b*) from the values that are available for another averaging time (*a*).

$$S_{gb} = S_{ga}{}^{V^{0\cdot5}} \tag{4}$$

$$M_{gb} = m\left(\frac{M_{ga}}{m}\right)^V \tag{5}$$

$$V = \frac{\ln(t_{tot}/t_b)}{\ln(t_{tot}/t_a)} \tag{6}$$

where,

S_g = Standard geometric deviation

Z = Number of deviations a point is located away from the median

C = Concentration

m = Arithmetic mean

M_g = Geometric mean

a = One averaging time

b = A second averaging time

t = Averaging time

t_{tot} = Total averaging time, usually 1 year (8760 hours)

It may be noted that for the present purpose the maximum concentration is taken as that concentration which is exceeded only 5 per cent of the total averaging time. For total averaging time of one year the values of Z at maximum concentrations when the averaging times are one month, one day or one hour are 1·64, 2·94 and 3·81 respectively.

7. Conclusions

It is not always possible to conduct measurement of pollutant concentrations over different averaging periods for which air quality standards are laid down by different national and international agencies. For example some standards refer to 5 min, 1 hr, 3 hr, 8 hr, 24 hr, etc, as the averaging time of pollutant concentrations. In view of the very well founded confirmation obtained by Larsen (1971) for his mathematical model from the computerized analysis of the real data for various pollutants and different sampling periods over a period of seven years from the American sampling network, we do not feel any hesitation in accepting his mathematical model and making use of it here in full confidence. It would, therefore, appear that in urban locations where the problems of air pollution are more acute it is enough to conduct surveys for a convenient averaging time over an extended period and then make use of the results to calculate the expected concentrations for the desired averaging time. In this connection, the present effort is the first attempt in our country in the field of air pollution studies.

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