551.510.42 : 66.082 : 543.7 (547.1)

Environmental concentrations of some of the major inorganic pollutants at the BARC site, Trombay, Bombay

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ABSTRACT. Aggregate monthly averages of some of the major inorganic pollutants in the atmosphere, at the BARC site at Trombay, Bombay over the past few years are presented. With a view to broadly assess the extent of air pollution at the sampling site, the results are compared with known international air quality standards.

1. Introduction

With increasing population and growing tempo of industrialization air pollution in India may reach hazardous levels, particularly so in the big industrial cities, if effective steps are not taken for its abatement and control (Zutshi 1968).

With a view to assess the existing levels of some of the important inorganic pollutants around Bombay, we have been doing air analysis at the Bhabha Atomic Research Centre site, at Trombay during the last few years. The Bhabha Atomic Research Centre is located about 10 km due northeast of the centre of the city of Bombay. On the western and southwestern sides of the BARC are located, a thermal power plant, a couple of oil refineries, a production unit of the Fertilizer Corporation of India and a few other chemical industries. The results of measurements at this site are presented in this paper. Unfortunately, the sampling could neither be done more extensively nor very regularly*, as such most of the results are presented as averages for the various months during these years instead of monthly values for each year separately. Therefore, besides presenting the general levels of the various pollutants around the BARC site, Trombay no detailed correlations or interpertations are attempted here. Regular and more extensive sampling is necessary for any serious attempt in this direction.

*Following is roughly the period covered by our experimental sampling of the pollutants :

Year	Gaseous Pollutants	Particulates
1966	Feb to Dec	Sep to Dec
1967	Jan to Dec	Jan to Dec
1968	Jan, May and Dec	Jan to Jun
1969	Jan to Mar	Nil

2. Analytical Procedures

(1) *Particulate matter*

A high volume air sampler (Staplex brand in our case) is used to sample the environmental air at a flow rate of about 150 litres per minute. Glass fibre filter papers, which are thoroughly washed with distilled water and dried, are used to collect the suspended particulates from the sampled air. Most other filter papers which are commercially available are found to contain appreciable and variable amounts of common radicals, *e.g.*, sulphates, chlorides, nitrates and ammonium etc.

(*a*) *Total dust load* — The filter paper is preserved in a desiccator for at least 24 hours prior to weighing both before and after the collection of the particulate sample. The difference in the two weights gives the total dust load (M, $\mu g/m^3$) for a known volume of air.

(*b*) *The benzene soluble organics* — The filter paper along with the total contents is refluxed with about 50 ml of analar grade benzene for a period of about an hour. The insoluble fraction is separated and the remainder is dried under an infrared lamp, and weighed. This gives the weight of the benzene soluble organics (m_o, $\mu g/m^3$).

(*c*) *Water soluble fraction* — The fraction from (*b*) which is insoluble in benzene is boiled with distilled water and the soluble and insoluble fractions are again separated. A fraction of the water soluble part is evaporated to dryness under low heat and weighed, thus giving the total water soluble fraction (m_w, $\mu g/m^3$). The remaining fraction of the water soluble matter in solution is used to analyse the following —

(*i*) *Sulphates* — The barium chloranilate method, proposed by Bertolacini and

TABLE 1

Percentage frequency distribution of samples with concentrations (ppm) between the indicated ranges

Month	Nitrogen Oxides		Sulphur Dioxide				Oxidants		Ammonia			
	<0·01	>0·01 <0·05	<0·01	>0·01 <0·05	>0·05 <0·1	>0·1	<0·01	>0·01 <0·05	<0·01	>0·01 <0·05	>0·05 <0·1	>0·1
January	100	—	57·5	42·5	—	—	60	40	—	47	36	17
February	100	—	48·5	51·5	—	—	65	35	5·0	37·0	42	16·0
March	93	7	52·0	48·0	—	—	58·0	42	3·0	10·0	38·0	49·0
April	71	29	62·0	33	5·0	—	79	21	—	—	—	—
May	100	—	56·0	40·0	4·0	—	95	5	—	—	—	—
June	97	3	74·0	26	—	—	96	4	—	—	—	—
July	100	—	20	40	12·0	28·0	100	—	—	—	—	—
August	100	—	16·0	53·0	31·0	—	94·0	6	—	—	—	—
September	95	5	50·0	37·0	13·0	—	100	—	—	—	—	—
October	100	—	69·0	31·0	—	—	100	—	—	—	—	—
November	100	—	71·0	26·0	3·0	—	—	—	—	56	37	7·0
December	100	—	80·0	20·0	—	—	62·0	38·0	10·0	33·0	44·0	13·0

TABLE 2

Data on suspended particulates (monthly averages)
Station : Bhabha Atomic Research Centre, Trombay

Month	Concentration in $\mu g/m^3$							
	Total	Water soluble fraction					Organics	
		Total	SO_4	Cl	NO_3	NH_4	Total	Benzene soluble
January	363	46·3	6·0	5·0	2·3	1·3	20·2	16·7
February	319	90·0	17·8	13·0	4·0	0·37	57·0	30·0
March	543	96·0	11·3	7·7	1·7	2·7	88·0	13·0
April	368	48·2	9·1	12·7	0·42	1·5	66·0	7·0
May	170	44·0	8·9	—	0·44	—	40·0	—
June	224	23·8	3·7	5·2	0·66	2·8	26·0	—
July	377	22·8	3·5	13·8	0·15	0·76	50·0	—
August	306	73·7	4·9	9·8	0·12	3·6	57·0	9·5
September	163	42·1	8·3	8·9	0·5	6·3	41·2	9·5
October	138	18·5	6·8	5·5	1·2	1·8	46·3	6·0
November	189	38·5	6·0	4·1	1·7	1·9	32·1	17·0
December	261	40·6	11·1	3·9	0·8	1·6	50	14·6

Barney (1957) is used to estimate the sulphate content.

(*ii*) *Chlorides*—The mercuric thiocyanate method (Morgan *et al.*—*see* reference) is used to estimate the chloride content in the samples.

(*iii*) *Nitrates*—Phenoldisulphonic acid method is used to estimate nitrates, and as suggested potassium hydroxide is used as the basifier instead of ammonia solution (Hora and Febba 1960).

(*iv*) *Ammonium radical*—Nessler's reagent is used for this estimation. Rochelle salt is added to the sample (before the Nessler's reagent) to inhibit the possible interference by calcium and magnesium (Morgan *et al.*—*see* reference) which are usually present in the samples.

(*d*) *HCl soluble fraction*—The water insoluble fraction from (*c*) is dried under low heat and weighed. The same is again ashed and weighed. The difference in the above two weights gives the

Benzene insoluble organic fraction (m_{IO} $\mu g/m^3$). The ash is boiled with 1:1 HCl and filtered on cooling. The filtrate is evaporated to dryness and weighed giving the acid soluble fraction (m_A, $\mu g/m^3$).

(*e*) *Acid insoluble fraction*—The deduction of the weight of the acid soluble fraction m_A from the weight of the total ash in (*d*) above gives the weight of the acid insoluble fraction in the samples (m_{IA}, $\mu g/m^3$).

2. Gaseous Pollutants

The gaseous pollutants are individually sampled by bubbling air at about 3 l/min through bubblers carrying appropriate absorption mixtures. The following analytical procedures are employed.

(*a*) *Oxides of Nitrogen*—Nitrogen dioxide is estimated by using the Saltzman method (Szltzman 1954). Nitric oxide is determined by first oxidising to nitrogen dioxide by bubbling it through acidic potassium permanganate solution (Thomas *et al.* 1956, Taft 1965). The interference due to the presence of SO_2 is inhibited by adding a few drops of 1 per cent H_2O_2 solution in acetone to the absorbing mixture after sampling.

(*b*) *Sulphur Dioxide*—The West and Gaeke (1956) method is mde use of to estimate sulphur dioxide. Interferenace due to the presence of nitrogen dioxide in the environment is eliminated by adding about 10 mg of sulphamic acid (West and Ordoreza 1962) after the sampling is completed.

(*c*) *Total Oxidants* (*including Ozone*)—Oxidants, which include all oxidising agents, *e. g.*, ozone, nitrogen dioxide, alkyl peroxides, etc are estimated by employing the neutral buffered potassium iodide method (Byers and Saltzman 1958, Saltzman and Gilbert 1959). The results are, however, expressed as equivalents of ozone.

3. Location and height of the sampling point

The sampling point is located on the first floor about 20 ft, above ground level and roughly in the central part of the Modular Laboratories of the Bhabha Atomic Research Centre.

4. Results

1. *Gaseous Pollutants*

The environmental gaseous pollutants investigated are nitrogen oxides (nitrogen dioxide and nitric oxide), sulphur dioxide, total oxidants (including ozone) and ammonia. The results are presented in Table 1 as frequency distributions

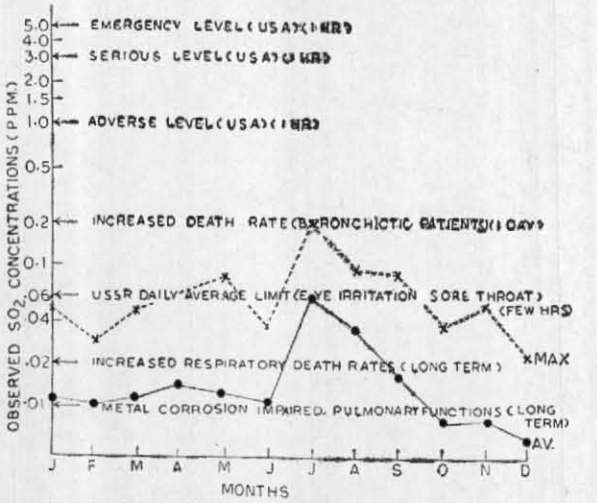

Fig. 1. Observed concentration of SO_2 in ambient ai shown in relation to likely effects of exposure
(Periods of exposure are given within paranthesis)

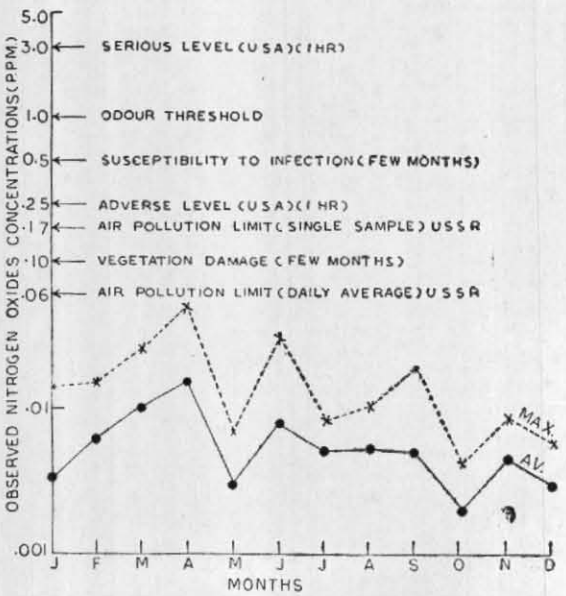

Fig. 2. Observed concentration of Nitrogen oxdies in ambient air shown in relation to likely effects of exposure
(Periods of exposure are given in paranthesis)

of their concentrations which are better indicators of their average levels.

From Table 1 we observe nitrogen oxides and oxidants usually have relatively lower concentrations as compared to sulphur dioxide and ammonia. To bring out this fact more strikingly we have plotted the average monthly values of each one of these pollutants against the back ground of some international standards of clean air. They are presented in Figs. 1, 2 and 3. In these figures various ill-effects caused as a result of different periods of exposure at different concentrations of the pollutants are also shown for

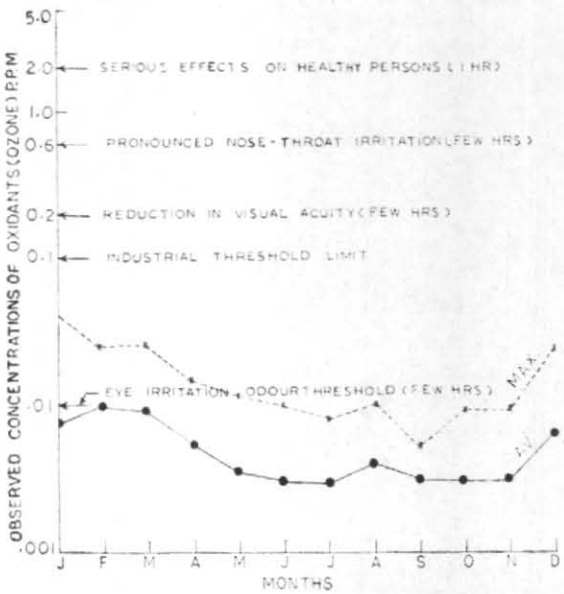

Fig. 3. Observed concentrations of oxidants in ambient air shown in relation to likely effects of exposure

(Period of exposure are given in paranthesis)

(Ozone is Radomimetic, hence there is no sage level)

Figs. 1—3 are based on the U. S. Dept. of Health, Education and Welfare, Phase II, 1966 and California Standards Tech. Rep. for ambient air quality

TABLE 3

Concentration ($\mu g/m^3$) in suspended particulates

Station : Bhabha Atomic Research Centre, Trombay

	Sulphates		Chorides		Nitrates		Ammonium	
	Max.	Av.	Max.	Av.	Max.	Av.	Max.	Av.
Representative monthly averages for USA	101·2	10·6	—	—	39·7	2·6	75·5	1·3
January	9·8	6·0	11·4	5·9	3·5	2·3	2·1	1·3
February	26·6	17·6	21·8	13·0	6·2	4·0	—	0·37
March	12·7	11·3	8·5	7·7	2·8	1·7	2·8	2·7
April	9·5	9·1	—	12·7	0·53	0·42	—	1·5
May	—	8·9	—	—	—	0·44	—	—
June	8·0	3·7	—	5·2	—	0·06	—	2·8
July	—	3·5	—	13·8	—	0·15	—	0·76
August	—	4·9	—	9·8	—	0·12	—	3·6
September	10·1	8·3	14·9	8·9	1·0	0·5	10·1	6·3
October	10·2	6·8	9·4	5·5	2·2	1·2	3·3	1·8
November	8·6	6·0	6·3	4·1	2·8	1·7	3·2	1·9
December	12·1	11·1	6·2	3·9	1·2	0·8	2·1	1·6
Yearly averages		8·1		8·2		1·3		2·4

emphasising the necessity of a cleaner atmosphere. From these figures it is evident that we have certainly to guard ourselves against any further increase in the concentrations of sulphur dioxide and perhaps, ammonia also. The levels of nitrogen oxides and total oxidants are so far not alarming, at least at the BARC site, Trombay.

Though the data is yet meagre there are indications that the concentration of these pollutants are higher at Trombay during the periods February-March-April and July-August. We shall discuss this aspect later.

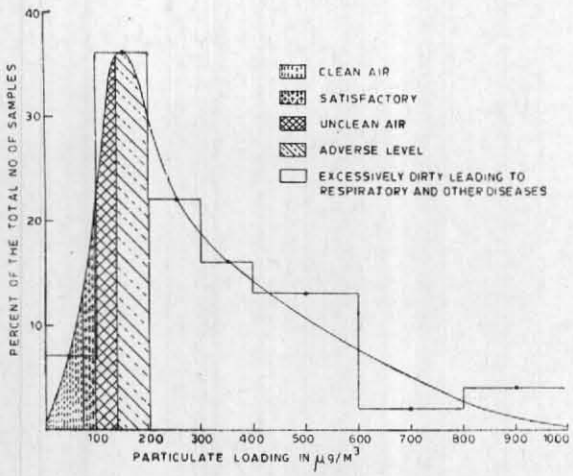

Fig. 4

2. Particulate Pollutants

These measurements were limited to the suspended particulates in the atmosphere. The environmental concentrations ($\mu g/m^3$) of total suspended solid matter as well as of sulphates, chlorides, nitrates and ammonium radicals together with the total and Benzene soluble organics are presented in Table 2.

In Table 3 the average and maximum values observed during different months for sulphates, chlorides, nitrates and ammonium radicals are separately shown. For comparison, comparative average figures for a number of urban stations in the United States are also given. From Table 3 we see that the average sulphate content of our suspended dust has reached the level of the more advanced country and we are in excess with regard to the ammonium radical. We are poorer in nitrates. We could not get any figures for chlorides for comparison.

In Table 4 we present a few months' data of fallout dust, which also includes corresponding figures for New York and the average for fourteen cities in Japan. If at all, we are on the excess side.

In Fig. 4 we have presented the total dust load of the environmetal air at Trombay as a sample-frequency distribution curve against concentration, $\mu g/m^3$. This histogram has been plotted against a background of some international standards for clean air.

Again from Table 2, we observe that there are indications that the suspended particulate pollution at Trombay is perhaps higher during the periods February-March-April and July-August

TABLE 4

Dustfall at Bhabha Atomic Research Centre, Trombay (1966)
Fallout (tons/km²/30 days)

Period of sampling	Organic part	Inorganic part	Total
17 Feb to 17 Mar	0·36	28·14	28·5
22 Mar to 26 Apr	0·41	21·51	21·92
26 Apr to 26 May	0·19	27·83	28·02
Average for 14 cities in Japan during 1960*			21·0
Average for New York City 1954-65**			25·6

*Toshio Toyama—'Air Pollution and its health effects in Japan.' *Archives of Environmental Health*, **8.** p. 153, Jan 1964.

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which also happens to be the case for the gaseous pollutants, as observed earlier.

5. Conclusions

The present results are a consequence of measurements conducted at the BARC site, Trombay which is located approximately 10 km due NW from the heart of the city of Bombay and as such they are not representative of the metropolitan city. At best, they can be regarded to represent the levels at the outskirts of the city. This may, perhaps, be the reason for the relatively low concentrations of nitrogen oxides which principally originate from automobiles, since automobiles mainly operate within the city itself. Also, the oxides of nitrogen undergo photochemical reactions and in the presence of the relatively high concentrations of olefinic

hydrocarbons from the automobiles and the refineries they are readily converted to the irritants known as the peroxy-acetyl-nitrates (PAN), before being detected as nitrogen oxides at larger distances from the centre of the city.

From a review of normal wind directions in the Greater Bombay region we find that south-westerly winds are more frequent during the periods March-April and July-August, which can bring the city air directly to the Trombay region. As mentioned in the text it is around this period we observe maxima for pollutants, both gaseous and particulates. However, we hold this conclusion tentative until a more exhaustive survey is undertaken.

Finally, we restate that the present work is merely exploratory, giving the general levels of some of the pollutants at only one location. We would, however, impress that the levels quoted herein particularly for the gaseous sulphur dioxide and the suspended particulates are bad enough by themselves and we feel very sure that they will only be exceeded if sampling is done nearer the centre of the city.

6. Acknowledgement

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