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Size distribution of microscopic size particles in Bombay atmosphere during a dust-episode

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सार — 6 से 10 अप्रैल 1981 की अवधि में बम्बई के वायुमंडल में धूल ही धूल छा गई और दृश्यता काफी कम हो गई। कदाचित यह धूल-भरी आंधी गुजरात और राजस्थान के शुष्क इलाकों से आए धूल के कणों से उत्पन्न हुई थी। इस अंधड़ में एरोसाल कणों के आकार बंटन की तुलना पूर्व सप्ताह के बंटन से की गई है। कणों की संख्या, आयतन का संकेन्द्रण और घनत्व जैसे व्युत्पन्न प्राचलों के लिए भी दोनों सप्ताहों की तुलना की गई है। उस अवधि में व्याप्त मौसम की दशा पर विचार करके इन कणों की गमन प्रक्रिया पर भी चर्चा की गई है।

ABSTRACT. Atmosphere of Bombay became very dusty and visibility was reduced considerably during the period 6 - 10 April 1981. Possibly this was due to the introduction of dust storm particles derived from the arid regions of Gujarat and Rajasthan. Size distribution of aerosol particles during the episode are compared with that of the preceding week. Derived parameters like number and volume concentrations and density of particles are also compared for the two weeks. Transport mechanism of these particles is discussed taking into consideration meteorological conditions persisting during that period.

1. Introduction

In the northwest region of India, atmospheric convections generate violent squalls and dust storms during the months of April and May. Giant sized particles are frequently observed in the atmosphere during summer months, particularly, in the vicinity of the desert area of Rajasthan (Murarilal and Rathor 1971). Under favourable meteorological conditions desert dust raised by storms, is known to travel long distances of thousands of kilometres. Sahara dust has been identified in South American atmosphere by Prospero *et al.* (1981) and dust transported from south Iraq has been collected in Kuwait by Khalaf *et al.* (1979).

Atmosphere of Bombay became very dusty and the visibility was reduced considerably during the period 6 to 10 April 1981. It was possible that this was due to a dust storm which took place in the desert region of Gujarat and Rajasthan about 1000 km north of Bombay. Dust samples were collected in Trombay, a suburb of Bombay, during this period and were analysed for size distribution.

2. Experimental

Weekly atmospheric dust samples are collected at B.A.R.C. hospital and are analysed for the size distribution on a routine basis. A four-stage cascade impactor (Casella MKII) is used for the size fractionation and the particles collected on the glass slides of the impactor are examined under an optical microscope (Kelkar 1975). Particles whose length to breadth ratios exceed four are rejected (Irani and Callis 1963). Samples during the dust episode were carefully analysed. A rough estimate for the density of particles in different size ranges was obtained using characteristic aerodynamic sizes for the different stages of the cascade impactor (Lippmann 1959).

3. Results and discussion

A clear increase in the number concentration from 15/c.c. to 86/c.c. was observed for the total particles above 0.3 μm during the episode. Particles above 5 μm increased from 0.026/c.c. to 0.062 /c.c. The ratios of the number concentration and the calculated volume ratios for the particles in different size ranges are shown in Table 1. The number size distribution during the episode week and that of the preceding week are shown in Fig. 1. The volume distributions calculated from the number distribution, assuming the particles to be spherical, are bimodal in both the cases as shown in Fig. 2. However, the modal sizes shift towards larger values during the dusty week. The total calculated volume increased from 23 μm^3/c.c. to about 86 μm^3/c.c. During the episode particles as large as 90 μm were observed whereas normally particles above

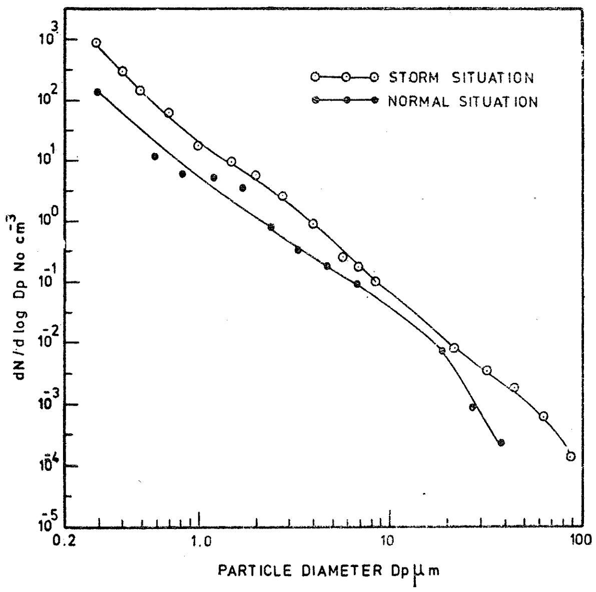

Fig. 1. Number size distribution

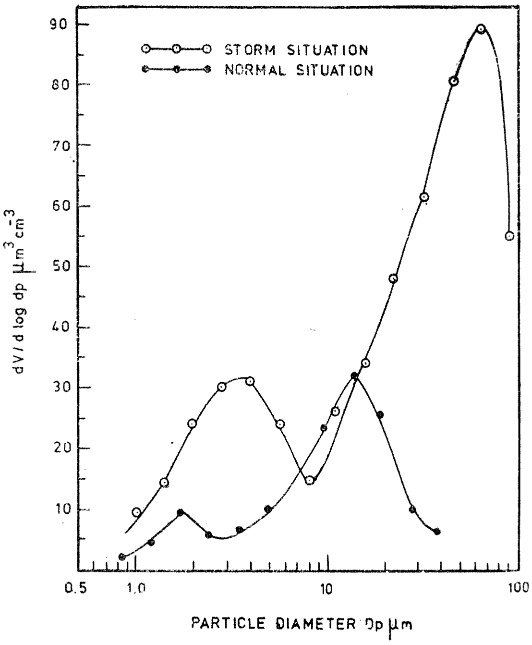

Fig. 2. Volume size distribution

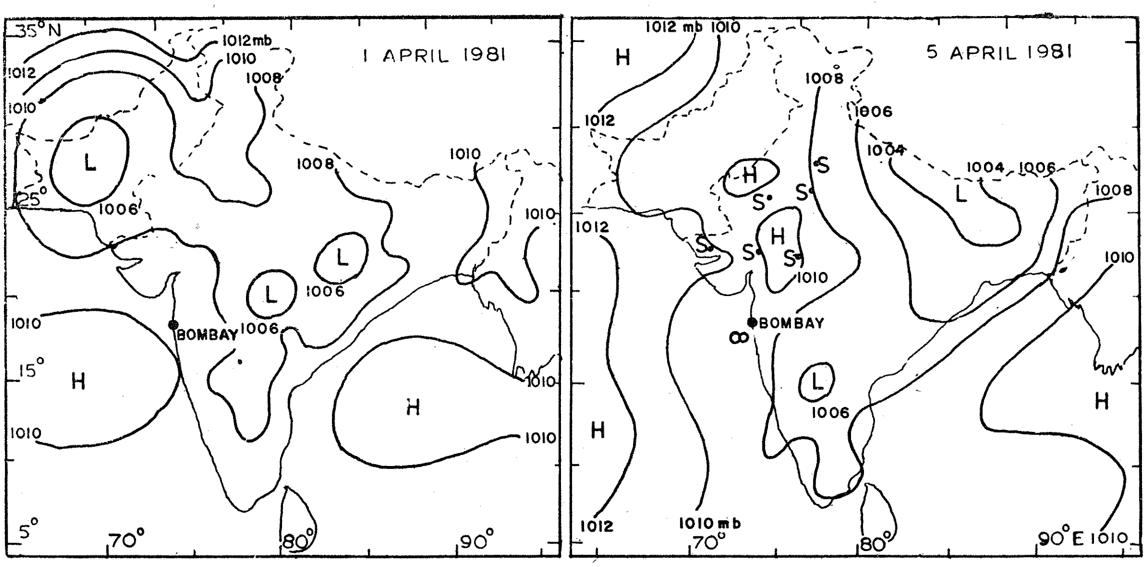

Fig. 3. Daily weather maps

TABLE 1

The ratios of number and volume concentration of particles during storm situation to that during normal situations in different size ranges

	Size range (μm) 0.3-1.0	1.0-5.0	5.0-25.0	25-100
Number concentration	5.55	3.76	2.29	5.53
Volume concentration	6.74	3.03	1.52	18.05

TABLE 2

Density of particles collected on different stages of cascade impactor for two situations

	Density (gm/c.c.) Stage No. 2	Stage No. 3	Stage No. 4
Normal situation	1.6	1.3	1.8
Storm situation	2.6	2.5	1.5

38 μm are rarely present. Although the number size distribution of atmospheric aerosol is governed by the source characteristics (Kelkar 1977), large sized particles generated by soil erosion and resuspension of settled particles are more important in determining the volume and mass distribution, especially in arid climates like ours.

Using the characteristic aerodynamic sizes of the Casella MKII impactor and the measured size distribution on each stage, a rough estimate of the density of particles in different size ranges was obtained as shown in Table 2. It can be seen from the table that during normal conditions the density of particles varies between 1.3 & 1.8 gm/c.c. whereas during the dusty week the variation in density is from 1.5 to 2.5 gm/c.c. It is interesting to note that the density of the large particles collected on the second and third stage during the dust episode agrees with density of 2.6 gm/c.c. for silt size particles (Gillette and Goodwin 1974) and 2.5 gm/c.c. (Loughnan 1957) for quartz coarse silt particles. This shows that the larger particles collected during the dust episode are probably sand particles coming from the desert regions in the northwest. Using these density figures the mass concentrations due to microscopic size particles work out as 35 μgm/m^3 for the preceding week (30 March to 3 April) and 207 μgm/m^3 during the episodal week (6 to 10 April). Weather maps for two days, *i.e.*, 1 April 1981 and 5 April 1981 (Fig. 3) clearly show that on 5 April, sand storms had been observed in Rajasthan and Gujarat States and also the highs in Rajasthan and lows in Karnataka on that day would favour a southward movement of the sand particles. Large β (Junge's power law exponent) values were observed for particles in the range 0.01-0.1 μm whose life times in the atmosphere are known to be small, whereas β values in the range of 2.5 to 3 were estimated for particles in the size range of 0.1 to 10 μm which can be considered as particles belonging to age dominated category. Another factor, wavelength exponent α, (which is correlated to β) has been found to be in the range of small negative values to 1 in the desert and semi-arid regions (Murarilal and Rathor 1971 b). Negative values of α are associated with large sized particles. On the other hand positive values, at places away from desert regions, have been observed by Shirvaikar (1980) at Tarapur, during the summer months. He interprets this as a bias towards smaller particles at Tarapur during summer. Higher mass concentrations of aerosol are maintained due to the variable and gale force winds and increased turbulence. Negative correlation between mass concentration of atmospheric aerosols and wind speeds upto 18 kmph has been found by Munn (1973). Monthly average mass concentration and wind speed data at Trombay supports this correlation for dry months.

Apart from turbulence, other two probable mechanisms of injection of soil aggregates into air are the direct aerodynamic entrainment of particles and sand blasting of soil surfaces. The former is a strong function of particle size, and a minimum threshold wind velocity is required for the entrainment of particles of 100 μm size, while sand blasting is a dominant mechanism for the fine soil-particles.

Once airborne the motion of large particles in the atmosphere is governed by processes like gravitational sedimentation and eddy diffusion. Sedimentation controls the upper size limit of airborne particle, which in turn depends on the ability of eddy diffusion at ground level to carry the particles at higher levels. Under the terrestrial conditions for particles of 2.5 gm/c.c. density and for minimum horizontal or frictional wind speed of 20 cm/sec, upper size limit is estimated to be 48 μm. If, however, the turbulent transport is seen to be dominant, upper size limit is estimated as 180 μm for light wind speed of 50 cm/sec.

Large particles due to their high sedimentation velocity are immediately removed from the atmosphere. However, during the storm episode, particles as large as 90 μm have been transported over a distance of about a thousand kilometre and have remained suspended in air for quite a long time. Residence time T, ignoring eddy diffusion and considering sedimentation alone, can be expressed as $T=h/v$ (where, h is the height above ground level and v the fall velocity). For $h=5$ km and for particles with density of 2.5 gm/c.c. estimated values for T are 190 days for 2 μm particles, 2 days for 20 μm, half a day for 40 μm and around two hours for 90 μm particles. In order that aerosol should remain suspended in air for a long period of time, the vertical velocity fluctuations of the turbulent air must be greater than the terminal velocity of the particles. As explained by Prospero and Carlson (1972), heating at the desert surface produces strong convective activity and a mixed layer is generated which extends upward to 5-6 km. This layer is undercut by the relatively cool and moist trade winds at an altitude of around 1.5-2 km and is again topped by a second inversion above around 4 km. The air parcel from the desert region is normally confined to a region between these two inversions.

It is found by Murarilal and Rathor (1971 a) that during hot and dry months, giant particles are introduced into atmosphere of north India due to the thermal instability and dust storms. In the situation described, the turbulent boundary layer eddy diffusion and the inversion layers formed seem to be the predominant factors in transporting larger sized particles over a distance of about a thousand kilometre.

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