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Studies on the size distribution of the suspended dust particles in the atmosphere of Qena, Egypt

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सार — क्वेना (ऊपरी मिश्र) के वायुमंडल में निलंबित धूल कणों के आकार, रूप और वितरण का अध्ययन किया गया है परिणाम यह दर्शाते हैं कि इन कणों का जमाव जंग पावर नियम आकार वितरण $n(d_p) = \ln 10\, C\, (d_p)^{-(\alpha+1)}$ के अनुसार परिमाण वृद्धि के साथ-साथ घटता है। घातांक α परास के मान 1.3 से 2 माइक्रोमीटर तक हैं। अनियमित आकार सहित कणों की अधिकतम संख्या का आकार 2 माइक्रोमीटर से कम होता है। प्रभावकारी माध्य व्यासों का परिकलन किया गया।

ABSTRACT. Studies on particle size, shape and distribution for the dust particles suspended in the atmosphere of Qena (upper Egypt) have been carried out. The results show that the concentration of these particles decreases with increasing size according to Junge power law size distribution $n(d_p) = \ln 10\, C\, (d_p)^{-(\alpha+1)}$. The values of exponent α range from 1.3 to 2. The largest number of particles have sizes less than 2 μm with irregular shape. Effective mean diameters were calculated.

1. Introduction

The actual atmosphere is more than a dry mixture of permanent gases. It has other constituents such as vapour of both water and organic liquids and particulate matter held in suspension. When such constituents exist at levels injurious to human, plant or animal life or property, or interfere unreasonably with the comfortable enjoyment of life and property, the constituents may be defined as air pollutants (Ledbetter 1972). The pollutants can be of natural or man-made origin and disperse in the atmosphere through the action of air currents or turbulence (dispersion aerosols). They can also be formed in the atmosphere when supersaturated vapours condense or when gases react chemically to form a non-volatile product (condensation aerosols). Both the dispersion and condensation aerosols are inescapable part of air pollution (Patterson 1983). They are influenced by a variety of factors, such as weather patterns, terrain features, the place of emission, the location of receptors and many other factors. Condensation aerosols are in the order of 0.5 μm in diameter or even smaller. Dispersion aerosols are, in most cases, considerably coarser and comprise a range of particle size wider than condensation aerosols. When the dispersed phase is solid, the dispersion aerosols are called dust and usually consists of individual or slightly aggregated particles of irregular form. In condensation aerosols, solid particles are often loose aggregates having a large number of primary particles of regular crystalline form. In many cases a combination of dispersion and condensation aerosols are encountered (Patterson 1983).

Much of the concern about particulate matter suspended in the atmosphere arises because particles of certain size can be inhaled and retained by the human respiratory system. Concern also arises because particulate matter in the atmosphere absorbs ultraviolet (UV) radiation from the sun to the extent that UV deficiency can cause rickets in children unless their diet is supplemented with vitamin D (Stern *et al.* 1987).

In this paper, study on the dust particles suspended in the atmosphere of Qena has been carried out. The study includes particle size and shape as well as a count of the number of particles of each size range. Statistical and theoretical treatments of the results have also been accomplished.

2. Experimental

Suspended dust particles have been collected from the atmosphere on membrane filters SM 11304, using dust sampler SM 16711. Sites of collection are marked in Fig. 1 which represents a map of the sampling area. Station 1 represents a desert area while station 2 is urban area. In this way, the collection sites cover the most important sources of the dust particles suspended in the atmosphere of Qena. Particles size distribution was carried out, by taking equal areas of the membrane filters, upon which the suspended dust particles were collected, and transfering them on slides for microscopic analysis decking with cover slides, which are fixed by using DPX mountant (Merk product). The slides are then examined under oil immersion objective lens of

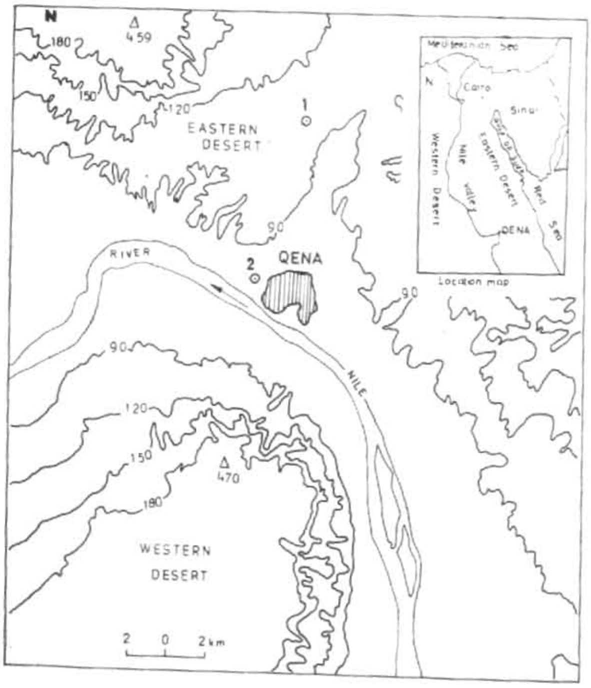

Fig. 1. A map of the sampling area

TABLE 1

Mean diameters of the suspended dust particles in the atmosphere of Qena

Station	Date of of measure-ment	d_n (μm)	d_{pln} (μm)	d_{psn} (μm)	d_{pvn} (μm)	d_{vs} (μm)
1	21 Sep 87 M	7.4	11.2	9.1	10.5	13.9
	Do. E	5.8	8.7	7.11	8.3	11.5
	23 Sep 87 M	6	9.8	7.6	9.2	13.2
	Do. E	5.4	8.3	6.7	7.9	11.2
2	3 Oct 87 M	5.7	9.9	7.5	9.1	13.5
	Do. E	4.6	6.2	5.5	6.1	8.2
	4 Oct 87 M	5.8	9.1	7.3	8.6	12.1
	Do. E	4.2	5.8	5	5.8	7.8

M and E denote to the morning and evening measurements

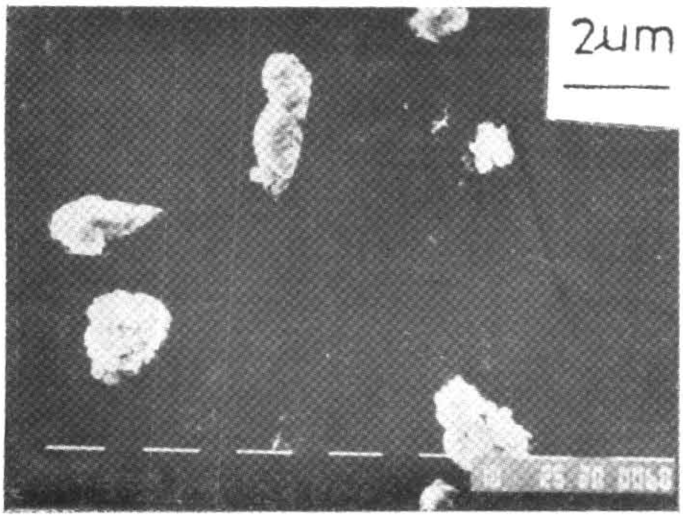

Fig. 2. Electron micrograph of fraction of a desert suspended dust sample (station 1)

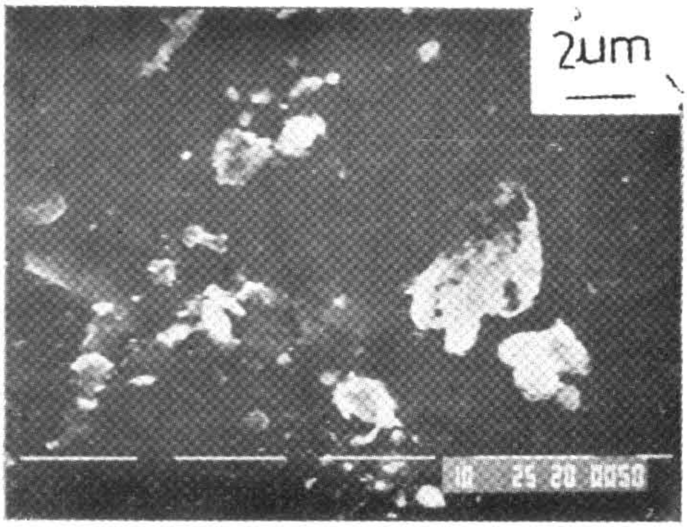

Fig. 3. Electron micrograph of fraction of an urban suspended dust sample (station 2)

magnification power (100 X) in combination with calibrated filar micrometer eyepiece of magnification power (8 X). The resolution of the microscope graticule was equal to 1 μm, then particles can be classified according to size. Particles counting was carried out using Leitz orthopan microscope. Electron micrography of the particles was carried out using scanning microscope (Model JSM-T 200).

3. Results and discussion

The samples were collected between 19 and 26 Sep 1987 at station 1 and between 29 Sep and 6 Oct 1987 at station 2. In order to distinguish between samples at different times of the day, the measurements were carried out in two periods, one in the morning and the other in the evening. The duration of sampling was always four hours.

3.1. *Particles size and shape*

The results of the microscopic analysis of the dust particles suspended in the atmosphere of the inspected region lead to the following conclusions :

(*i*) Most of the particles have diameters less than 2 μm in all measurements. Their range is from 25% to 46% of the total number of particles.

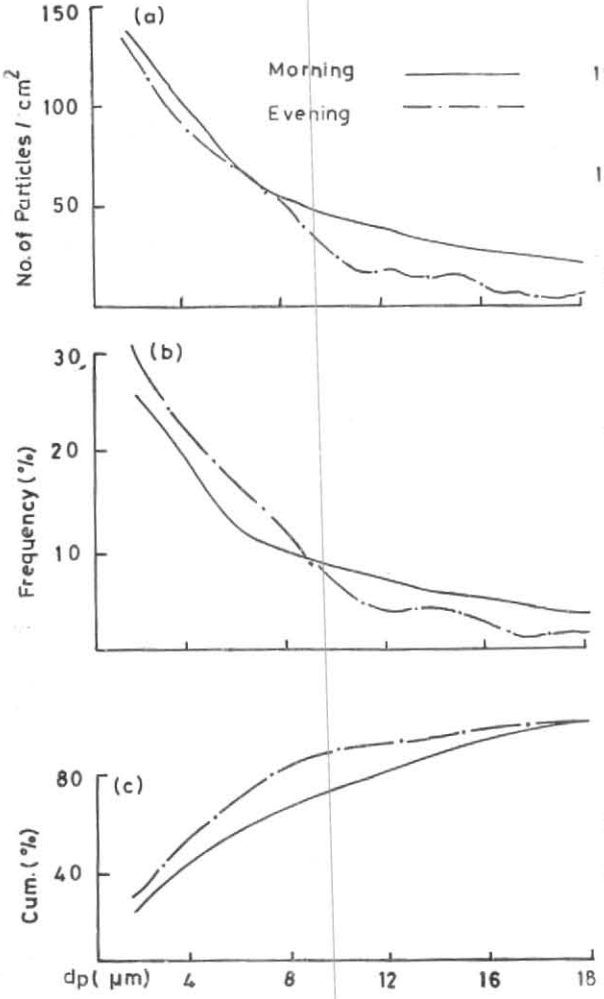

Fig. 4. Size distribution of suspended dust particles at station 1 (21 Sep 1987)

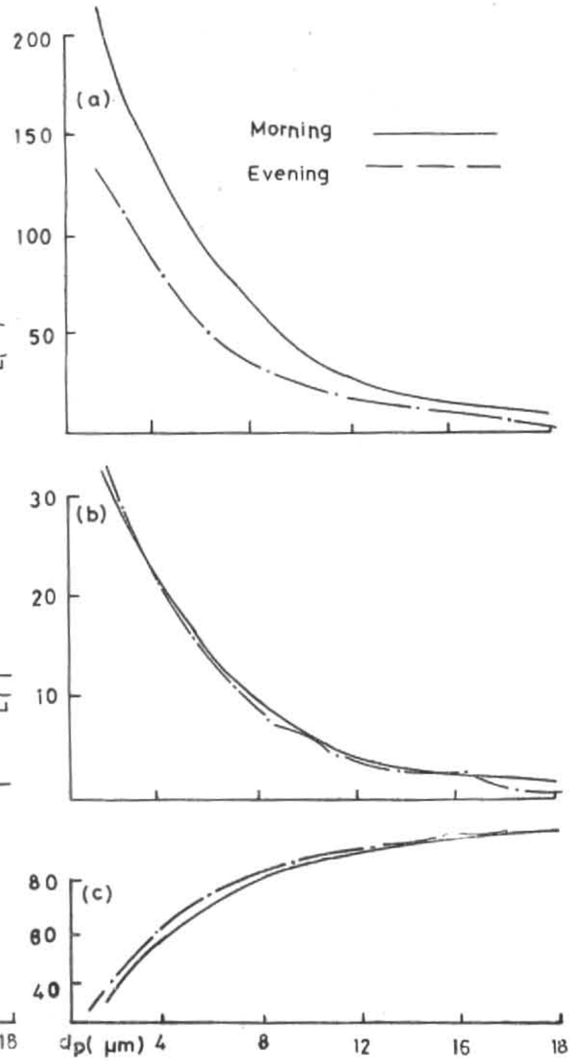

Fig. 5. Size distribution of suspended dust particles at station 2 (3 Oct 1987)

(*ii*) The remainder of these particles is distributed within larger size intervals up to 20 μm. Gravity prevents particles with size > 20 μm to rise into the atmosphere (Toba 1965). The distribution of particle size is discussed in the next section. Micrographs, taken by the above described electron microscope, confirm the above conclusion. Figs. 2 and 3 illustrate electron micrographs of two fractions of suspended dust samples at stations 1 and 2 respectively with indication of the range of sizes. The figures show that the most particles have sizes less than 2 μm and irregular shape.

The above measured particle size gives the linear dimension related to the particle perimeter or the particle projected area diameter. It is desirable to use averages relating to definite physical properties such as surface or volume. Hatch and Choate (1929) define an average diameter as the diameter of a hypothetical particle which in some way represents the total number of particles in the sample. Their definition are as follow :

$$\text{Mean diameter} = d_n = \Sigma n d_p / \Sigma n \tag{1}$$

$$\text{Length mean diameter} = d_{pln} = \Sigma n d_p^2 / \Sigma n d_p \tag{2}$$

$$\text{Surface mean diameter} = d_{psn} = (\Sigma n d_p^2 / \Sigma n)^{1/2} \tag{3}$$

$$\text{Volume mean diameter} = d_{pvn} = (\Sigma n d_p^3 / \Sigma n)^{1/3} \tag{4}$$

$$\text{Volume surface mean diameter} = d_{vs} = \Sigma n d_p^3 / \Sigma n d_p^2 \tag{5}$$

Adopting the above definition, different mean diameters have been calculated for some of the measurements concerned in this paper. Results of these calculations are summarized in Table 1.

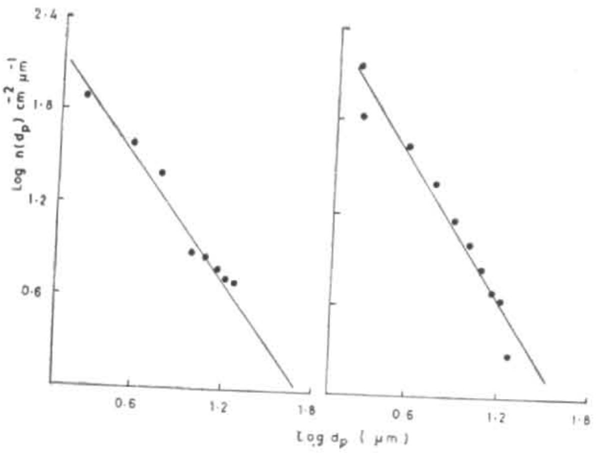

Fig. 6. Size distribution of suspended dust particles at station 1 (21 Sep 1987)

Fig. 7. Size distribution of suspended dust particles at station 2 (3 Oct 1987)

In this table, less values of the calculated mean diameters were obtained during the evenings compared to morning hours. That is due to the lower number of particles in the high size intervals (>6 μm) during the evenings hours (Figs. 4 and 5) which leads to lower values of the summations Σnd_p, Σnd_p^2 and Σnd_p^3 in such way leads to the obtained less diameters in spite of the low values of Σn during these periods.

3.2. *Particle size distribution (PSD)*

In view of the strong dependence of the physical properties of aerosols on particle size, a mean size is always not sufficient for the specification of an aerodisperse system. So the particle size distribution must be found. Figs. 4 and 5 give examples of the PSD—results of the suspended dust in the atmosphere of Qena at stations 1 and 2, respectively. In these figures, PSDs are expressed in three different manners. The lower parts of the figures represent PSD with respect to its number/cm², while the middle and upper parts represent it with respect to its percentage and cumulative frequencies respectively. The frequency distribution curves are preferable for the purpose of comparison (Millar & Frewend 1977 and Koch & Link 1970). The results of the PSD in all measurements at both stations show clearly that the number of particles/cm² as well as their frequency decrease with increasing size. This observation agrees with these of other authors (Meszaros & Vissy 1974, Junge 1955, Mathai & Harison 1980, 1982) in different study regions. The study made here assumes the Junge power law size distribution (Junge 1955) :

$$n(d_p) = \triangle N / \triangle d_p = 2.3\, c\, (d_p)^{-(\alpha+1)} \qquad (6)$$

where N is the total number of particles per unit area in the radius range from d_p to $d_p + \triangle d_p$ and c is a constant. The value of α varies from one aerosol to another and has been found to vary according to atmospheric conditions (Mathai & Harrison 1982). Its value describes also approximately the distribution of particles of a specific chemical type. Figs. 6 and 7 show examples of a plot of log $n(d_p)$ against log d_p. In the Qena region; typical values of α lie between 1.3 and 1.7 for station 1 and between 1.6 and 2 for station 2. For silicate particles in air over the Libyan desert, Schuts and Jaenicke (1974) found $\alpha \simeq 2$ in average. That seems to be in a good agreement with the above values of α found in the atmosphere of Qena, where the particles are mainly silicates dispersed from the sandy eastern desert with the aid of predominant NW-wind as taken from the Meteorological Department of A.R. Egypt.

4. Conclusion

This study of PSD was carried out in the atmosphere of Qena city (upper Egypt), where the atmospheric particles are of natural sources due to eastern desert and man's activities. The results of this study show that the greatest number of particles have sizes less than 2 μm and are of irregular shape. The study shows also that the dust particles suspended in the atmosphere of Qena follow a Junge-type power law size distribution in the observed size range from 1 to 20 μm.

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