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DUST PART1CLES-SIZE DISTRIBUTION

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Abstract

The particle-size distribution (PSD) of dust samples collected in Sudan is studied. The analysis of the sample PSD is carried by hydrometer and pipette methods; which are based on the sedimentation of the particles in water. The measurements have shown that dust may contain particles with equivalent diameter in the range from 0.1 to 300 micron. The PSD cumulative curve can he approximated fairly accurately, by straight line equation. The 1east squared method is used to estimate the values of the straight line constants. The straight line approximation of dust PSD is used to determine the number fraction distribution. The probability density function is found to be inversely proportional to the third power of the diameter.

Keywords: microwave propagation, scattering.

Introduction

In the recent years a large development has occurred in the use of microwave signals in tropical, semi-desert and desert regions, for communication, remote sensing and weather studies purposes. Due to this development, the effect of dust storms on the propagation of microwave signals found some interest in literature. All published works in this area, however, sufferer from lack of information about the dust (air-borne soi1 particles) characteristics, e.g. size, shape and dielectric constant. In order to investigate the scattering properties of the dust storms, the size of the suspending (scattering) particles is an important parameter to be known.

Dust PSD was studied by a number of researcher's. The results obtained for the Sudan [1,2,] have indicated that dust particles may have an equivalent diameter D* in the range $0.1 < D < 300$ micron. Hadded et al [3] reported that dust samples collected in Iraq have a mean diameter of 133 micron. This mean is seen to be large compared with the Sudan samples, which have a mean diameter less than 50 micron. Bogland [4] pointed out that sand storms may contain particles with equivalent diameter in the range from 80 to 300 micron, with an average value of 150 micron, while dust storms contain partic1es with diameter less than 100 micron. Gillete [5] found that particles with diameter less than 20 micron composed a small fraction of the air-borne particles. However, this little data on dust particle size revealed in literature is not sufficient for the theoretical prediction of the electromagnetic waves scattering by dust. Thus, the aim of this work is to reveal some recent findings concerning the size of airborne soil particles.

The term dust used herein to classify air-bone soil particles with at least 80%, by weight, of the particles having diameters less than 60 micron. If more than 20% of the air borne particles has diameters greater than 60 micron the storm is called sand storm.

Sample Collection

The dust samples were collected at the ground level after precipitation of dust on clean surface. With dust, some organic materials such as fragments of dry leaves arid grass were also collected. Thus to have a dust sample free of organic material, dust samples must be passed through a sieve. It was noticed that the 75 micron sieve can be used to separate the organic material from the dust sample without losing much of the dust sample (less than 1%). To obtain a dry sample for

* D is the diameter of a circle the area of which equal to the area of two dimensional projection of the particle.

the PSD test, the sample is placed in an oven at 105^0C for 24 hours.

Particle-Size Measurements

The PSD analysis was carried out for twelve dust samples collected in 1981, 1982 and 1983 in Khartoum and Atbara (about 300 Km north-east of Khartoum). Two methods were used for the PSD analysis:

1. the pipette method, and
2. the- hydrometer method.

The above methods are standard techniques; both methods are based on the same theory, that is, Stokes' theory of sedimentation. A large error (5-10%) is expected in the results obtained by these methods for a number of reasons. These include the fact that all calculations are based or, Stokes' law for. spherical particles which is not the actual geometry of the particles of interest. Dust particles have irregular random shape. However, the pipette and hydrometer methods are the most suitable and accurate techniques available for the PSD determination for sample such as dust, in which the particles size varies over a wide range. The fraction of the sample mass formed by particles with diameters greater than 63 micron however is determined by sieving. The average PSD of Khartoum and Atbara dusts had been published e1eswhere, however for the sake of completeness the average PSD for samples collected in Sudan is given in Table (1)

Table 1 : Average PSD of dust:

Particle Diameter (micron)	Probability
300.0 - 100.0	0.012
100.0 - 50.0	0.232
50.0 - 10.0	0.404
10.0 - 5.0	0.091
5.0 - 1.0	0.141
1.0 - 0.5	0.060
0.5 - 0.1	0.062

Analysis 0f Particle-Size Distribution Curves

Figs. 1 and 2 give the PSD curves (cumulative curves) for five dust samples collected in Sudan. It is seen from these plots that the PSD cumulative curves can be best fitted by the straight 1ine equation:

$$F(D) = a + bD \qquad ...1$$

where F(D) is the fraction by weight formed by particles having equivalent diameters less than D micron,
a and b are constants that depend on factors on which the PSD depends.

The least square method was used to estimate the values of the constants a and b from the measured data. The estimated values are given in Table 2 for all samples considered (twelve samples). From these results it is noticed that: the constant b is always within the range 0.0110 to 0.0196, while a is within the range $-0.3551 < a < 0.046$. The average values of a and b were found to be -0.090 and 0.0144 respectively.

Table 2: PSD Curves Parameters:

Sample* no	straight line constants	
	a	b
1/KH/82	0.0467	0.0129
2./KH/82	0 .1239	0.0110
3/KH/82	-0.0204	0.0136
4/KH/82	-0.3505	0.0196
1/KH/83	-0.2961	0.0189
2/KH/83	-0.0393	0.0129
3/KH/83	-0.1130	0.0139
4/KH/83	-0.0511	0.0140
5/KH/83	-0.1516	0.0139
6/KH/83	-0.0554	0.0144
7/KH/83	-0.0312	0.0137
1/AT/83	0.0141	0.0140

* KH : Khartoum sample ... AT: Atbara samples

It is noticed that for some samples a has a positive value, these positive values, which are not logical since that mean sample contain some particles with negative diameter, are due to the fact that, the presence of particles with diameters less than 0.2 micron makes the behaviour of the curve in this region uncertain, since Stokes' theorem cannot be applied here.

Now consider a dust sample of mass K kg. Let δm be the mass element composed by particles. having diameters within the interval D to D+ δD. From equation (1), δm is given by :

$$\delta m = bK\,\delta D \qquad 2$$

Let the element volume occupied by the above particles be δv. From equation (2) we have:

$$\delta v = \frac{bK}{\rho_s}\delta D$$

Let the number of particles in the sample having diameters within the range D to D+ δD be N'. Using equation (3) and the expression for volume of A sphere, N' is obtained as:

$$N' = \frac{6K}{\pi\rho_s}\frac{6}{D^3}\delta D \qquad (4)$$

For unit volume of dust K = ρ_s and N' = N(D).dD (the umber of particles whose diameter are between D and dD per unit volume of dust, small interval is considered now). Using these results equation (4) can be rearranged to give:

$$N' = \frac{6b}{\pi}\frac{1}{D^3}dD \qquad (5)$$

From equation (5), the total number of particles (N_T) is given by:

$$N_T = \int_{D_o}^{D_h}\frac{6b}{\pi}\frac{1}{D^3}dD$$

$$= \frac{3b}{\pi}\left[\frac{1}{D_o} - \frac{1}{D_h}\right] \qquad (6)$$

D_o and D_h are the minimum and maximum diameters of particles respectively.

The probability of finding a particle within the interval D to D+dD is immediately obtained by :

$$\frac{N(DdD}{N_T} = \frac{2}{D^3}\frac{D_oD_h}{D_h - D_o}$$

$$= \frac{a'}{D^3}dD \qquad (7)$$

Thus the probability density function is given by:

$$n(D) = \frac{a'}{D^3} \qquad (8)$$

(n(D) is the probability density function)

Generally, for all samples considered D_h » D_o, then the constant a' is approximated by:

$$a' = 2\,D_o^{\,2} \qquad (9)$$

From equation (1), D_o can be obtained by setting F(D)=0, i.e.

$$D_o = -(a/b) \qquad (10)$$

Substitute for a' from equations (9) and (10) in equation (8) to get:

$$n(D) = \frac{a^2}{b^2}\frac{1}{D^3} \qquad (11)$$

Using the average values obtained above for a and b, the average probability density function can be written as :

$$n(D) = \frac{78}{D^3} \qquad (12)$$

The mean diameter is given by

$$D_a = \int_{D_o}^{D_h} n(D)\,D\,dD$$

$$= a'\left[\frac{1}{D_o} - \frac{1}{D_h}\right] \qquad (13)$$

Using the average value of a' (=78), and the average va1ues of D_o (=6.75micron) and D_h (=75.3 micron) , the average mean diameter of dust was found to be about 11 micron.

It is noticed that: the minimum diameter is always within the range $0.2 < D_o < 18$ micron, with an average value of 6.25 micron. The maximum diameter is always within the range $68 < D_h < 83$ micron with an average value of 75.3 micron. The diameter mean varies from 0.4 to 36 micron, with an average value of 11.4 micron.

The va1ues given in, Table 3 were obtained from the approximate straight line distribution discussed above. When the value of b is positive, the smallest theoretical positive diameter (0.2 micron) is taken as the minimum diameter in the sample.

Table 3 I Particle~ Statistic Prediction

Sample* No.	Mini-Mum dia. micron	Maxi-mum dia. micron	Mean dia. micron	Probab constant
1/KH/82	0.20	73.90	0.40	0.08
2/KH/82	0.20	79.65	0.40	0.08
3/KH/82	1.5	75.03	2.90	4.50
4/KH/82	17.88	68.90	26.50	640.00
1/KH83	15.67	68.58	24.20	491.00
2/KH/83	3.04	80/57	5.86	18.50
3/KH/83	8.13	80.07	14.60	132.00
4/KH/83	3.65	75.07	7.04	27.00
5/KH/83	10.91	82.85	18.94	238.00
6/KH/83	3.85	73.29	7.25	29.60
7/KH/83	2.28	75.27	4.42	10.40
I/AT/83	0.20	70.42	0.40	0.08

* KH: Khartoum samples, AT: Atbara samples

Conclusions

Hydrometer and pipette methods were used to carry out the particle-size distribution (PSD) analysis of dust samples collected in the Sudan. Dust may contain partic1es with equivalent diameters in the range from 0.1 to 300 micron. The mean equivalent diameter of dust was found to be within the range from 0.4 to 36 micron, with an average value of 11 micron. The PSD cumulative

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curves were approximated fairly accurately by the straight line equation The gradients of the straight line was found to have average value of 0.0144, while the intercept with the vertical axis has an average value of -0.09. The probability density function of the number of particles was found to be inversely proportional to the third power of the' particle diameter.

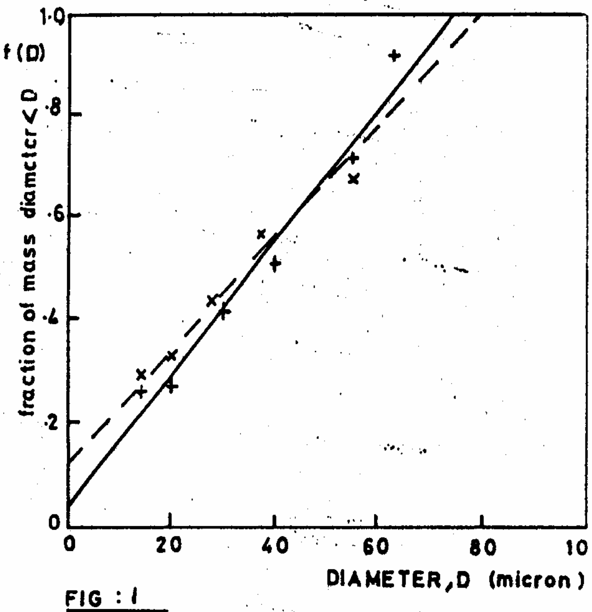

FIG : 1

PSD CURVES

——— + Sample 1/KH/82

– – – × Sample 2/KH/82

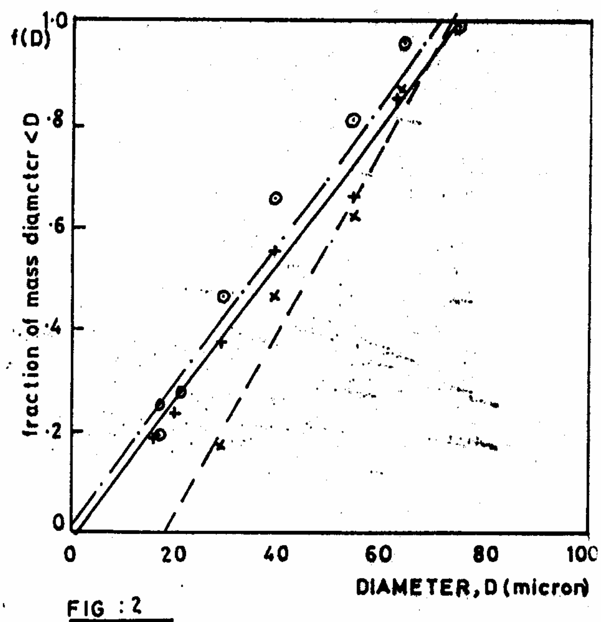

FIG : 2

PSD CURVES

——— + Sample 3/KH/82

– – – × Sample 4/KH/82

—·— ⊙ Sample 1/AT/82

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