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Measurement of air aerosol size during the 2001/2002 harmattan season at Uturu, Nigeria.

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Abstract

The measurement of air aerosol size during the 2001/2002 harmattan season at Uturu, Nigeria is of interest. Aerosol size distributions were measured making use of a zeiss micrometer which is inserted on the diaphragm inside the eyepiece of Olympus binocular microscope. Dust samples collected by direct deposition within the months of October 2001 to February 2002 on a Whatman filter paper made of cellulose were placed on a glass slide and viewed under a microscope. The mean value of the measured aerosol diameter and the standard deviation is 2.74 ± 1.7μm. The mean of the calculated surface area distribution of the aerosols is 38.33 ± 9.3 square μm.

Keywords: aerosol size; aerosol surface area; zeiss micrometer; microscope.

1.0 Introduction

Charlson (1995) noted that atmospheric aerosol consists of super micrometer (μm) and sub micrometer – sized particles of liquid and solid materials suspended in the air. Particle size, concentration, and chemical composition are usually the aerosol properties of most interest. The Air Quality Archive (2003) observed that Air borne particulate matter varies widely in its physical and chemical composition, source and particle size, PM_{10}-particles (the fraction of particulates in air of very small size (<10μm) are of major current concern, as they are small enough to penetrate deep into the lungs and so potentially pose significant health risks. Larger particles of radius greater than 1μm are readily removed relatively efficiently from air by sedimentation. The extent to which these aerosols can be a health hazard is dependent on the ability of these aerosols to penetrate the respiratory system. Chiemeka (2006) noted that the number, size and composition of particulate matter (PM) may all have an important role in health effects like discomfort to the respiratory system and associated ailments. Oleka (2006) observed that aerosols may be linked to the increasing incidence of asthma. Johnson (2004) observed that mass fraction of inhaled aerosol that deposits in the pulmonary region is influenced by a number of factors, including breathing frequency, breath volume and mouth versus nose breathing, particle size distribution and the individual's respiratory tract morphology. Masayuki (1983) estimated from light scattering measurements the refractive index and size distributions of aerosols and the mean radius and standard deviation of the size distribution of aerosols approximated by the log normal distribution function are 0.138 μm and 2.56 respectively. Wardle, (1997) observed that the size distribution of an aerosol is closely related to its source. Coarse particles are generated mainly from mechanical processes, such as wind, whereas fine particles are produced by chemical reactions. Size distribution and chemical contents of aerosols are important factors determining global climate change and visibility. Aerosols have a cooling effect, which offsets, in part, the warming effect of green house gases. The measurement of air aerosol size is of interest from the stand point of potential health effect.

1.1 Theoretical Background

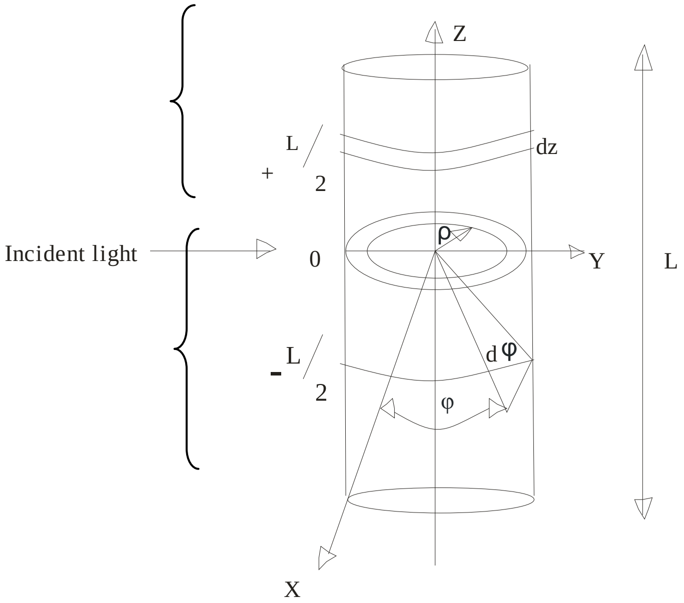

Figure 1: Cylindrical coordinate used to obtain expression for the average number of particles.

Here, we want to obtain an expression for the particle size distribution function within a cylindrical enclosure and how it can be used to obtain averages or define the extinction and scattering parameters for a sample of particles. We assume that the particles are spherical but of different sizes. We also assume that particles are sufficiently far from each other and that the distance between them is much greater than the incident wavelength. Thus, it is possible to study the scattering by one particle without reference to the other ones. Consequently, intensities scattered by various particles may be added without regard to the phase of the scattered waves. It is in the context of the independent scattering concept that the following discussions are based.

For a cylindrical coordinate $P(\rho,\varphi,z)$ figure 1, the infinitesimal volume $d\tau_i$ of height dz is given by

$$d\tau_i = \rho d\rho d\varphi dz \tag{2.1}$$

If there are n_i particles within the region of the elemental volume, therefore the concentration of the particles within this region is given as

$$\sigma_i = \frac{n_i}{\rho d\rho d\varphi dz} = \frac{n_i}{d\tau_i} \tag{2.2}$$

For this elemental volume, we assume that the concentration of the particles σ_i is constant in the elemental volume $d\tau_i = \rho d\rho d\varphi dz_i$ for $i = 1,\cdots,t$, where t is the maximum number of the elemental volumes. From equation 2.3, we have that $n_i = \sigma_i\, d\tau_i$. Therefore the total number of particles in the irradiated volume is given as

$$N = \sum_{i=1}^{t} \sigma_i\, d\tau_i = \sum_{i=1}^{t} \sigma_i(\rho,\varphi,z)\, d\tau_i \tag{2.3}$$

where $dz_i = \frac{i}{t}$, for all i and t very large, and L is the Diameter of the incident beam. Therefore $N = \frac{L}{t}\sum_{i=1}^{t}\sigma_i(\rho,\varphi,z)\rho d\rho d\varphi$. Putting in the value of $\sigma_i(\rho,\varphi,z)$, we have that $N = \frac{L}{t}\sum_{i=1}^{t}\frac{n_i}{d\tau_i}\rho d\rho d\varphi$.

Writing the total number of particles N in the irradiated volume in integral form, we have that

$$N = \int_{p=0}^{p=D/2}\int_{-L/2}^{L/2}\int_{0}^{2\pi}\sigma(\rho,\varphi,z)\, pdpd\varphi dz \qquad (2.4)$$

If σ is not constant, then the average number of particles over the entire volume V is given as

$$\overline{N} = \frac{1}{v}\int_{p=0}^{p=D/2}\int_{-L/2}^{L/2}\int_{0}^{2\pi}\sigma(\rho,\varphi,z)\, pdpd\varphi dz \qquad (2.5)$$

where

$$v = \frac{\pi D^2 L}{4} \qquad (2.6)$$

If we know the particle size distribution function, we can use it to write an equation that relates the scattered light intensity with the scatters. That is, we can use it to define the extinction and scattering parameters for a sample of particles. The extinction and scattering coefficients (in Units of per metre) are defined respectively as:

$$B_{ext} = \overline{N}C_{ext} = \overline{N}\pi a^2 Q_{ext} = \frac{1}{v}\int_{p=0}^{p=D/2}\int_{-L/2}^{L/2}\int_{0}^{2\pi}\sigma(\rho,\varphi,z)C_{ext}\,\rho d\rho d\varphi dz \qquad (2.7)$$

$$B_{sca} = \overline{N}C_{sca} = \overline{N}\pi a^2 Q_{sca} = \frac{1}{v}\int_{p=0}^{p=D/2}\int_{-L/2}^{L/2}\int_{0}^{2\pi}\sigma(\rho,\varphi,z)C_{sca}\,\rho d\rho d\varphi dz \qquad (2.8)$$

where Q_{ext} and Q_{sca} are the extinction and scattering efficiency factors respectively, while C_{ext} and C_{sca} are the extinction and scattering cross-sections respectively; a is the radius of the particle while $\overline{N}$ is the number of particles averaged over the entire volume.

3.0 Materials and methods

Microscope is made use of in this work, because particle counting and sizing by a microscope is not very complex. The sizing of the particles depends on our being able to distinguish one edge of the particle from another on the opposite side. In this work, we made use of binocular light microscope (Olympus) in measuring the sizes of the particles. Dust samples collected by direct deposition on a cellulose filter paper were placed on a glass slide and viewed under a microscope.

The particle sizes were measured in millimeters (mm) using an eyepiece graticle micrometer (zeiss). The mean values were multiplied by 4µm equivalent to one division of the eyepiece graticle micrometer (zeiss). The stage graticle which is inserted on the diaphragm inside the eyepiece of a microscope is a micrometer engraved on a glass and set in an aluminum slide.

4.0 Results and discussion

The mean size of the collected harmattan dust samples determined at Uturu is 2.74μm. From table 1 it becomes obvious that the sizes of the particles determined at Uturu for the harmattan season is giant particles and belongs to the fraction of particulates in air of size less than 2.5μm and less than 10μm which are small enough to penetrate deep into the lungs and so potentially pose significant health risks.

The measured aerosol size, *D*, and the number of occurrence, *N*, and the surface area calculated is as shown in Table 1.

Table 1: Measured aerosol size and calculated surface area distributions

D(µm), size	**N**	**Log D (µm)**	**S(µm)^2, area**
2.8	2	0.45	24.62
3.0	1	0.48	28.26
3.2	2	0.51	32.15
1.6	3	0.20	8.04
2.0	3	0.30	12.56
1.2	2	0.08	4.52
0.8	2	-0.10	2.00
1.0	1	0	3.14
6.0	2	1.68	113.04
4.8	1	0.75	72.35
5.6	1	0.78	98.47
4.4	1	0.64	60.79

The number distribution of aerosols obtained by averaging many sets of measurements at Uturu is as shown in Figure 2. The surface area distributions based on aerosols size measurements at Uturu is as shown in Figure 3.

5.0 Conclusion

In this work, we made use of binocular light microscope (Olympus) in measuring the sizes of the particles. Dust samples collected by direct deposition on a cellulose filter paper were placed on a glass slide and viewed under a microscope.

The particle sizes were measured in millimeters (mm) using an eyepiece graticle micrometer (zeiss). The mean values were multiplied by 4µm equivalent to one division of the eyepiece graticle micrometer (zeiss). The stage graticle which is inserted on the diaphragm inside the eyepiece of a microscope is a micrometer engraved on a glass and set in an aluminum slide. The mean value of the measured aerosol diameter and the standard deviation is 2.74 ± 1.7µm. The mean of the calculated surface area distribution of the aerosols is 38.33 ± 9.3 square µm.

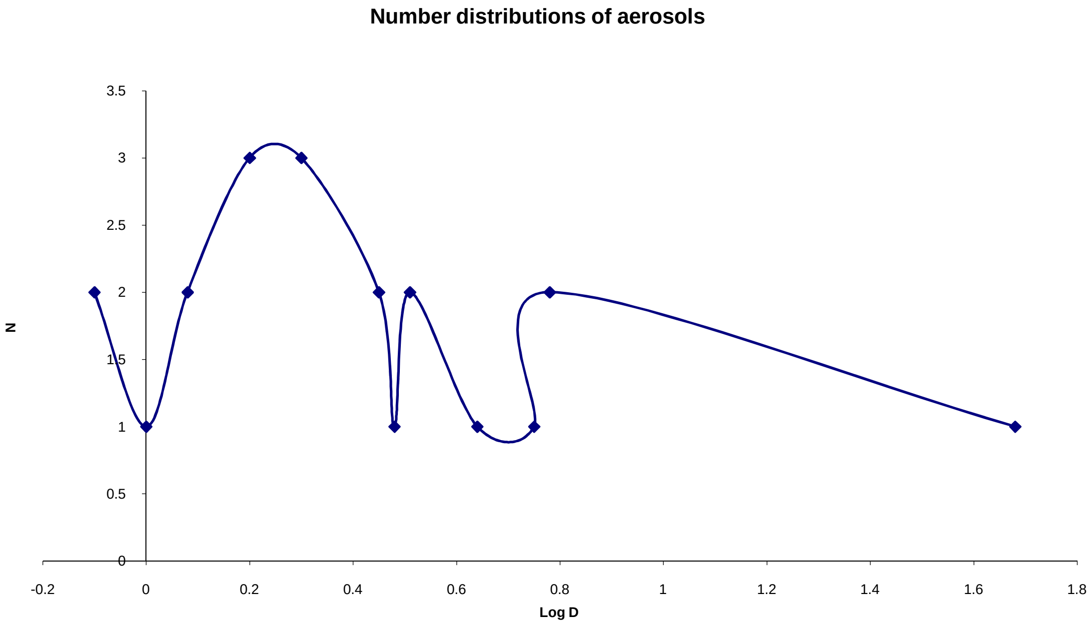

Figure 2: Number distributions of aerosol against size

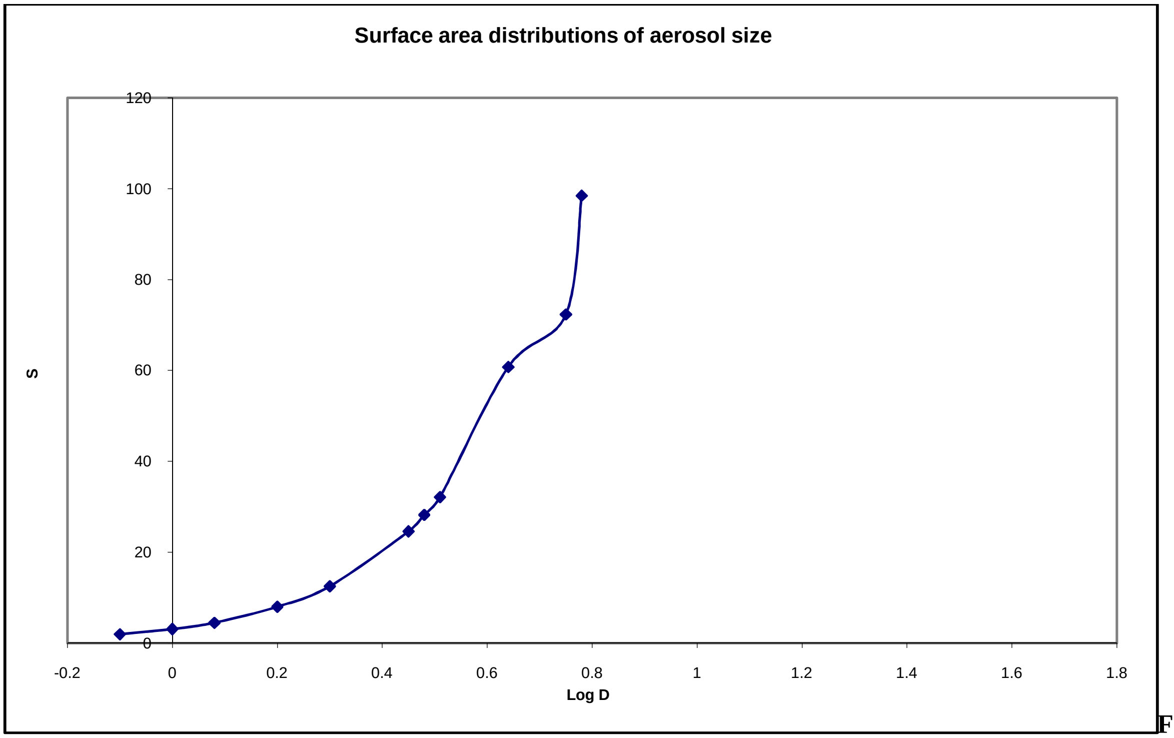

Figure 3: Surface area distributions of aerosol against size

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