Particle Number and Mass Distributions above 10^{-4} cm Radius in Sand and Aerosol of the Sahara Desert

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ABSTRACT

Measurements of the particle size distribution in surface air and bulk soil (soil surface and 10 cm depth) were performed in the Sahara desert. This desert is a very important source for mineral dust transported over the Atlantic Ocean. Measurement restrictions limited the size range under investigation to 10^{-4} to 10^{-1} cm radius. In that range the size distributions in aerosol (toluene-insoluble component) and soil material (water-insoluble component) are similar in shape, except for a secondary maximum in soil particle size distributions.

The results indicate that the aerosol and the soil size distributions are influenced by the soil and wind conditions over large areas. Differences between the soil surface and at depths of 10 cm were not observed within the precision of the measurements. Changes in the shape of the size distribution in the soil or surface air during and after a heavy sandstorm were not observed either—an indication that the loss of sand during a sandstorm is small compared to the reservoir of sand. Comparisons with measurements in surface air over the Atlantic Ocean in the northeast trade-wind region allow the conclusion of a redeposition of giant particles within the source area Sahara, thus contributing to the characteristic shape of the size distribution of particles in the soil.

1. Introduction

Recent investigations on the island of Barbados (Delany *et al.*, 1967) and aboard the research vessel *Meteor* (Jaenicke *et al.*, 1971) have confirmed the importance of the Sahara desert as a source of aerosol particles. This source does not only influence continental aerosols but, after appropriate alteration and transport, the marine and background aerosols as well. The efficiency of this source depends on such parameters as particle supply in the surface layer, soil humidity content and surface formation, and wind speed and degree of turbulence.

Especially in spring, strong sandstorms blow in the northern part of the Sahara desert. As is known from the literature these sandstorms cause the "red" dust which may be deposited over wide areas of the Mediterranean, Europe, the mid-Atlantic, and as far as the Caribbean Sea. Since the Sahara desert is a very abundant particle source in the tropical atmosphere, studies of aerosol size distribution are of special interest. Other reasons to select this desert are:

1) Large areas of the Atlantic ocean in the trade-wind region are influenced by the dust transport. Measurements from that region are available now and suitable for comparisons with data from the desert itself.

2) As a source, the Sahara seems to be quite homogeneous so that first measurements from selected sites can be of general value.

3) The aerosol from such a large source is an important parameter influencing cloud physics, atmospheric optics, and the general radiation budget of the earth.

While few if any studies of the Sahara aerosol size distribution have been made, Sahara soils have been investigated. Most of this work has concentrated on its mineral structure and the mass distribution of the sand particles. The important parameter which influences the atmospheric processes mentioned above is the particle number size distribution which usually can only be derived very poorly from a published mass distribution. Direct measurements, therefore, are required.

Prior to our investigation, two papers should be mentioned in more detail which motivated our work.

On the Island of Barbados, Delany *et al.* (1967) collected airborne dust from the northeast trade winds. Although their method of particle collection with big nylon nets was not without shortcomings with regard to the collection efficiency of these nets, important qualitative results have been obtained. Mineralogical analysis of the samples and comparison with Atlantic deep-sea sediments showed that Sahara dust is transported regularly over the Atlantic Ocean. The dust transport can also be shown by weather maps and satellite data. In addition to mineralogical analyses, mass distributions of the dust were determined; due to the method of measurement, how-

ever, these results are rather crude. Their conversion to particle number distribution (Junge, 1968), however, was in general agreement with known values of the background aerosol.

Measurements of aerosol size distributions made during the Atlantic expedition of the research vessel *Meteor* in spring 1969, gave clear evidence of wide-range mixing of mineral dust with tropospheric air (Junge and Jaenicke, 1971). Some 1500 km off the African coast, the particle concentration in dust-carrying air masses from the Sahara desert increased—compared to undisturbed conditions—by approximately one order of magnitude in the size range from 10^{-5} to 10^{-3} cm radius. Since a mineralogical analysis of these samples was not carried out, the origin of the dust could only be estimated by trajectories and satellite photos.

After these two papers it seemed logical to measure the aerosol size distribution directly at the source, if possible also during sandstorms, and to examine the soil material for its particle supply.

Reviewing the literature for a suitable method to measure the number size distribution in soil was unsuccessful, because the mass distribution obviously has been of main interest. This literature study, however, indicated a considerable concentration decrease in soil from small to large particles. With such a distribution, conversion from mass to number size distribution is very inaccurate because the determination of the scanty masses of the small particles is methodically rather vague.

Therefore, a method for measuring the number size distribution in soil had to be developed. The first part of this paper describes the method used while in the second we submit and discuss the results from selected sampling sites in the Sahara desert.

2. Sampling and measuring technique

It can be expected that aerosol and sand distributions are somehow related. To achieve comparability between both types of distributions, similar evaluation methods were desired. Tests showed that this could be best achieved by bringing the aerosol and the soil sample into fluid suspension, where homogeneous mixing due to the large viscosity of the suspension can be maintained, and sufficiently small samples for further analysis can be drawn off. Before discussing this in detail, the sampling procedure will be presented. Because of the similar evaluation of the samples, aerosol particles as well as sand particles must be sampled physically. For aerosol particles, therefore, optical size classification systems had to be excluded. Impactors do not collect sufficient material because they concentrate the collected particles on small areas and adhesion lowers as the thickness of the deposit increases.

The aerosol particles were thus collected on fiber filters mounted in a high-volume sampler. Using Microsorban[1] filters with an effective surface area of approximately 500 cm^2, the volume flow capacity of the samples amounted to ~ 60 m^3 hr^{-1}. Fiber filters, especially Microsorban filters, best meet our requirements for aerosol sampling, because high retention capacity and low flow resistance allow considerable flow rates, thus providing a sufficient collection of particles. The sampling system was adapted for aerosol concentrations on days without sandstorms. During a sandstorm the filter can easily be clogged by the large amount of particles. To avoid such clogging a special filter holder was designed (Fig. 1). The filter was mounted in a vertical position, so heavy particles could bounce off and not clog the filter surface. The bounced-off particles were collected in an attached collection box. The interchangeable collection box served as container for the exposed filter after termination of the measurement. This mounting of the filter guaranteed, even during heavy sandstorms, a sufficiently long sampling time. The content of the box was later dissolved with toluene and the sample was ready for evaluation as a solution, as will be described later.

The collection efficiency of any aerosol sampling device depends on sedimentation and inertial characteristics of the particles and the flow parameters of the sampler. It will, in general, be unity only under special conditions. Despite high flow rates, large particles may not reach the sampling tube and the filter surface. This problem had to be taken into account since particles with radii above 10^{-2} cm were to be collected during a sandstorm with wind speeds up to 20 m sec^{-1}.

Unbiased aerosol sampling, even of large particles and at high wind velocities, is possible if the sampling is done isokinetically with a tube adjusted along the wind direction with an inlet flow speed equal to the wind speed. In the atmosphere with changing wind directions and gusty winds, such a device requires extensive sensing and electronic equipment which could not be done in the desert. Therefore, isokinetic sampling was attempted by manual adjustment and numerical correction of the evaluation. During sampling the sampling tube was manually adjusted according to wind direction within half-hour intervals. In order to adjust the flow speed to the actual wind speed, interchangeable apertures with various openings were mounted in the entrance of the tube (see Fig. 1). The size of the apertures were calculated for various wind velocities assuming a constant suction rate of the high-volume sampler. Calculations, following the theoretical considerations of Davies (1968), showed that under non-isokinetic sampling conditions any size selective separation can be neglected for the instrument setup, if the particles are smaller than 7×10^{-4} cm

[1] Produced and distributed by Delbag, Berlin.

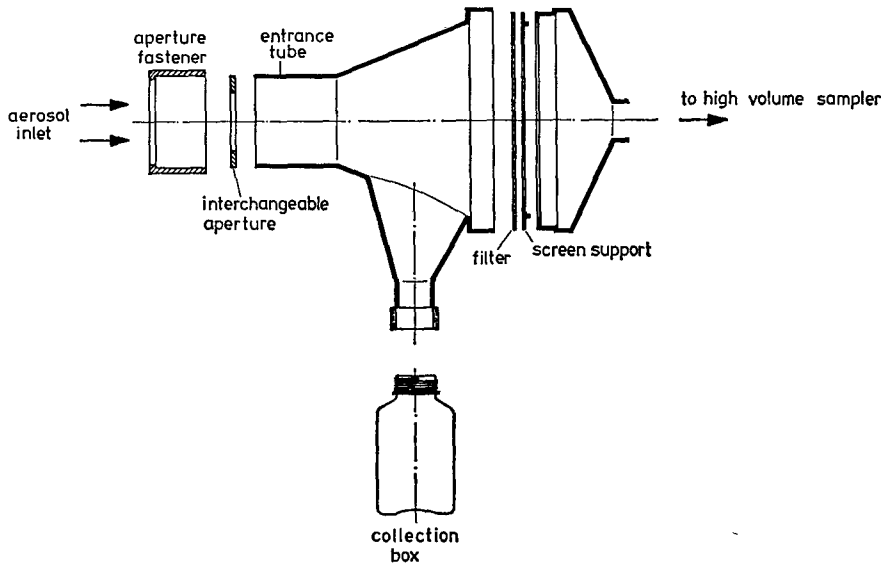

FIG. 1. Exploded diagram of the disassembled filter holder. Interchangeable apertures with various diameters are used to approach isokinetic sampling conditions. The collection box is used to collect the larger particles which bounce off the filter during sampling and to store the exposed filter when sampling is terminated. The device is connected by a pipe to a high-volume sampler.

radius and the wind speeds are less than 2.7 m sec^{-1}. For larger particles and higher wind speeds the evaluated size distribution was corrected according to Badzioch (1959).

Compared to the aerosol samples, soil samples could be collected easily. The soil samples had to be comparatively large to minimize any particle size selection during collection. The soil samples were taken with an aluminum scoop from a 1-cm thick surface layer and from a depth of 10 cm in order to estimate depth-dependent variations. Addition of water to the sample resulted in a homogeneously mixed suspension from which representative small samples could be taken for further evaluations.

After aerosol and soil samples had been brought into suspension, their further processing was similar, except for the wet sieving as we will discuss later. The use of a fluid suspension to achieve homogeneous mixing is not without problems. Because of the changed adhesive forces between the particles when being suspended in a fluid rather than in air, aggregates may break up into single components. This problem will be discussed later.

Any determination of a number distribution is best done by counting individual particles. An automatic device to do this, the Coulter counter (Wood and Lines, 1966) was not available, so the counting had to be done by visual inspection, using either an electron or optical microscope. For reasons beyond our control, an electron microscope could not be used, although it would have allowed an evaluation of particles $<10^{-4}$ cm radius. Light microscopy, therefore, was used with 10^{-4} cm as the lower limit for an accurate radius determination. Test examinations of size distributions in desert sands showed the prevalence of small particles and a concentration decrease of approximately nine orders of magnitude in the size range 10^{-4} to 10^{-1} cm radius which was similar to the aerosol. It is known that a concentration decrease of three orders of magnitude can be observed in a sample if visual inspection is used.

In order to cover the concentration decrease we had to divide the size range into subranges with approximately three orders of magnitude of concentration decrease. Particles with radii $>10^{-2}$ cm are difficult to count in a microscope because quite large areas have to be inspected in order to obtain results which are statistically valid. The larger particles, therefore, were sorted by sieving; the largest width of screen used determined the upper limit of our investigations as 10^{-1} cm radius. Due to the large amount of material required for sieving, it was applied only to the soil samples. The aerosol samples were evaluated with the light microscope with the upper limit determined by statistical limitations.

After this general survey of the evaluation method, we now discuss the various subranges and the techniques applied in further detail. The separation of the complete size range into three subranges was done by sedimentation and sieving. The particles in the range 1.6×10^{-3} cm$\leqslant r\leqslant 10^{-1}$ cm were separated from the suspension by wet sieving and analyzed by size grading. Of both possible methods we preferred wet sieving to dry sieving in order to separate particles completely.

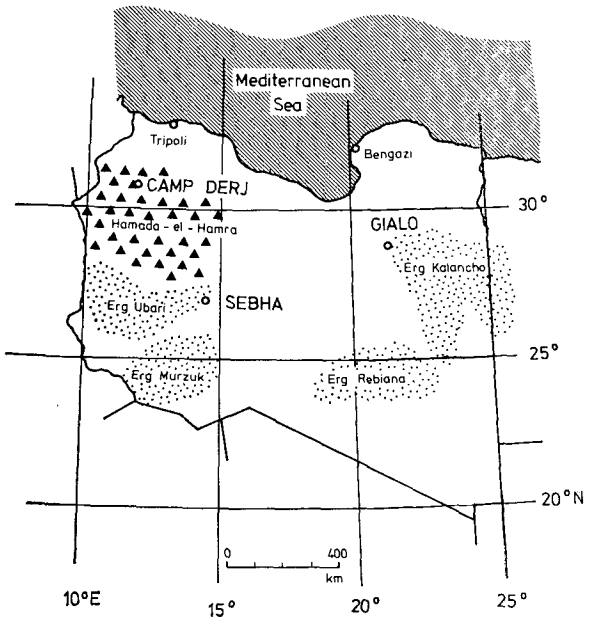

FIG. 2. Libyan Arab Republic with location of the measuring sites in Camp Derj and Sebha in relation to the rock desert (Hamada-el-Hamra, triangles) and different sand seas (Ergs, stippled).

Moreover, wet sieving prevents particles, small enough to pass all the screens, from becoming attached due to adhesive forces to any part of the instrumentation. Thus they remain in suspension. This advantage of wet sieving is one of the two reasons we preferred to work with fluid suspensions; the other, as mentioned above, is that of representative separation of samples due to homogeneity. Actually neither wet nor dry sieving are perfect methods for comparison with aerosol size distributions since both methods break up agglomerates of the soil which perhaps would have stayed intact had they become airborne. The results of the measurement are reproducible, however, which could be proved for the case of wet sieving. In the range 1.6×10^{-3} to 10^{-1} cm the samples were divided into individual sieve fractions, weighed, and converted to number size distribution. The particles with $r<1.6\times10^{-3}$ cm, not restrained by sieving, appeared in water suspension, and were further prepared in a sedimentation cylinder, the same used for preparation of the toluene suspension of the aerosol samples.

This sedimentation cylinder was used to divide the particle size range in the suspension into two fractions using the different sedimentation velocities of the particles. Considering the concentration decrease we choose 5×10^{-4} cm radius as the limit between both fractions. Within a correspondingly selected period of time, particles larger than this separation size are deposited at the bottom of the sedimentation cylinder on a membrane filter. The filter was dried and made transparent by immersion oil having the same index of refraction as the filter material. The particles on the filter were counted and sized with the microscope using dark field illumination.

After the sedimentation time required to remove particles larger 5×10^{-4} cm radius from the suspension, only smaller particles remained in suspension. However, this could not be used for analysis, because the size distribution in the range below 5×10^{-4} cm had changed due to the sedimentation of these particles. Of course, these particles were not removed from the suspension completely, but some of them had settled on the cylinder's bottom. To deposit all particles greater 10^{-4} cm in this cylinder by sedimentation requires approximately 25 hr. This procedure, therefore, was abandoned. However, due to the concentration decrease in the size distribution a physical separation of particles smaller than 5×10^{-4} cm was not necessary because the larger particles were present in diminishing numbers only if the complete suspension was inspected. Before the sedimentation procedure was applied, a small volume was withdrawn from the homogeneously mixed suspension using a syringe with a filtration device which deposited the particles on a membrane filter. It contained particles of all sizes present in the suspension. By appropriate selection of the withdrawn volume a sufficient number of particles in the size range $10^{-4}\text{ cm}\leqslant r\leqslant5\times10^{-4}$ cm could be selected and be counted and sized with the microscope. The few particles with radius $r>5\times10^{-4}$ cm on the filter do not influence the counting procedure for smaller particles.

Summarizing the applied procedures, the aerosol samples and the soil samples were prepared as toluene and water suspensions, respectively. Because of the large particles present in the water suspension, the soil samples were presorted by wet sieving, in the radius interval $1.6\times10^{-3}\text{ cm}\leqslant r\leqslant10^{-1}$ cm. The remaining water suspension and the toluene suspension were separated into two size fractions by sedimentation in a specially designed sedimentation cylinder. These fractions, $10^{-4}\text{ cm}\leqslant r\leqslant5\times10^{-4}$ cm and $5\times10^{-4}\text{ cm}\leqslant r\leqslant1.6\times10^{-3}$ cm, were counted and sized microscopically. The evaluated size distribution was thus determined in three steps.

The selection of time and sites for sampling in the Sahara was based on meteorological and travel conditions, and led to sampling at two sites in the Libyan Arab Republic during the months of April and May 1970 (Fig. 2). Camp Derj is situated in the Hamada-el-Hamra, a rock desert whose surface is covered with approximately fist-sized, weather-worn rocks. Sebha, on the other hand, is located at the eastern edge of a big sand sea, the Erg-Ubari. Anthropogenic sources of aerosols were not observed at either sampling site. The spring season was selected for the expedition because heavy sandstorms could be expected with good probability.

3. Results

Before the results are discussed it should be emphasized that according to the analysis the size distribution represents only the toluene-insoluble fractions of the aerosol particles, and the water-insoluble fractions of the soil material. Also, it is assumed that the loose agglomerates, present in the natural state, disintegrate into single components during suspension. This is why the results are only to a certain extent comparable with those of other authors who have used the dry sieving method. Yet it can be stated that the method used in this paper yields reproducible results, independent of the sample's origin and its actual state. Moreover, the results are not influenced by changes which each sample undergoes before its evaluation, like being moved from the sampling site, being shaken, and being subject to environmental influences.

Taking into consideration the maximum possible errors and the reproducibility of the method, we feel our concentration results include uncertainties of up to a factor of 2. Radius determination by sieving and use of the optical microscope cause the largest uncertainties because the particles are not spherical. In the process of sieving the radius of the determined particle depends on the geometry of the meshes and on the sieving technique, while radius determination by microscopy involves a subjective estimate by the observer. The radius used in this work is the volume equivalent radius. With the observed considerable concentration decreases (proportional to approximately the third power of radius), uncertainties in the radius determination are correspondingly reflected in the concentration values. This is probably the main reason for the discrepancies in concentration of up to half an order of magnitude which occurred between measuring by sieving and microscope. The accuracy of these first measurements does not allow observation of fine structure. In the size distributions the observed coarser structure, though, is far beyond the error of measurement, and should be considered real.

Aerosol size distribution is usually expressed by $dN/d\log r$ as a function of radius r, both plotted on logarithmic scales. The presentation of soil distributions is somewhat more difficult, especially for comparison with the aerosol distributions. We chose $dN/d\log r$ per unit mass of soil material rather than per unit volume of soil because it is independent of the packing density of the soil material. In addition, calculated mass distributions are correspondingly represented as $dM/d\log r$ in grams of material per cubic centimeter of air or in grams of material per total mass.

The size distributions in Fig. 3 were obtained in Sebha. They were selected from the data in such a way as to show the aerosol's considerable variations. While the few data available cannot explain these variations, all samples were taken under similar local wind speeds. It is assumed that the differences are due to the origin (wind direction) of the aerosol. The aerosols probably originate from different sources and during transport were subject to changes, dominating the locally produced aerosol.

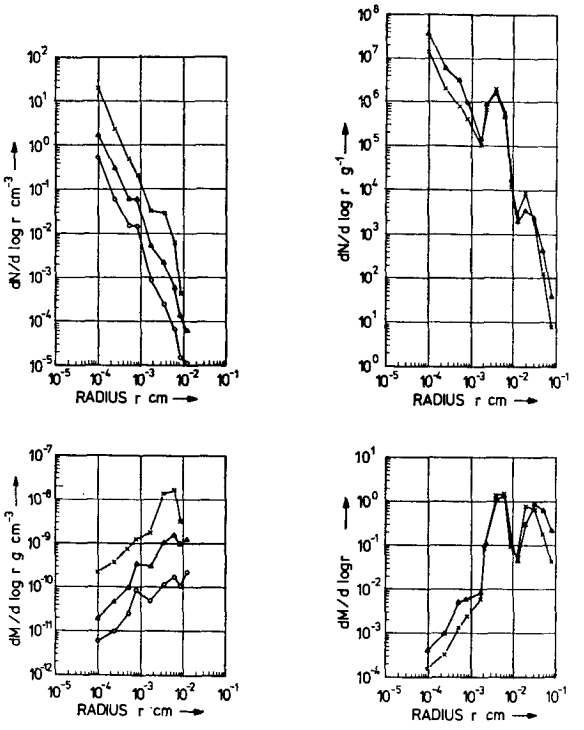

FIG. 3. Selected aerosol (left) and sand (right) size distributions with associated mass distributions in Sebha (Erg Ubari):

Left ×----× Wind NE at 8.0 m sec⁻¹
▲----▲ Wind SE at 8.7 m sec⁻¹
○----○ Wind E at 7.6 m sec⁻¹
Right ▲----▲ Surface
×----× 10 cm depth

In spite of similar local wind speeds, the size distributions in aerosol differ considerably in concentration. The distribution in surface soil and in soil at 10 cm depth shows so little difference that one can speak of a homogeneous, vertical mixing in the upper surface layers.

The soil samples show the essential characteristics of all subsequent distributions. As in the aerosol samples a concentration decrease toward large particles is observed which is interrupted, however, by a relative maximum at 3×10^{-3}–4×10^{-3} cm radius, a more or less distinctive feature found in all soil samples. It can also be seen in the mass distribution which reaches its absolute maximum at 3×10^{-3}–4×10^{-3} cm radius. At Sebha, but not at the other site, the distributions have a second relative maximum at 2×10^{-2}–3×10^{-2} cm. There are no essential differences in distribution between soil surface samples and those taken at 10 cm depth. This indicates a thorough mixing of the upper layer of soil. All measurements confirm this, even after a sandstorm.

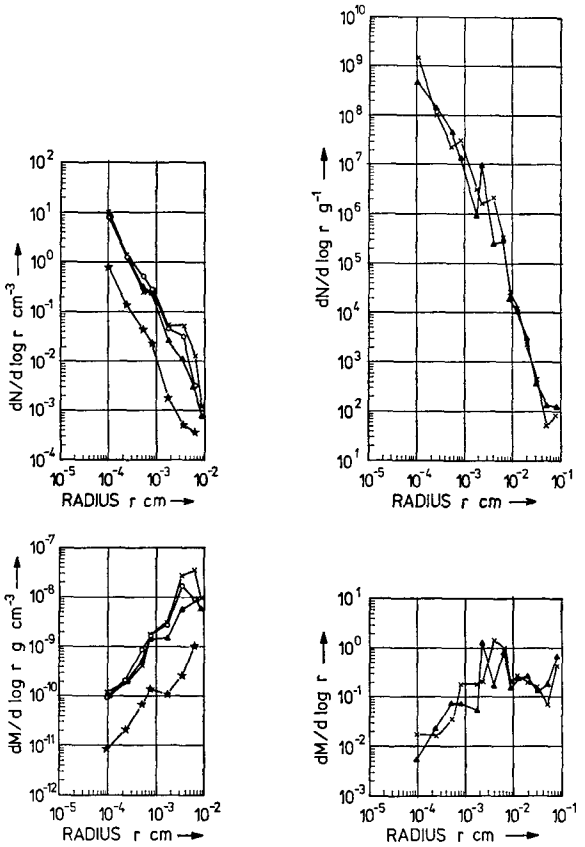

FIG. 4. As in Fig. 3 except for Camp Derj (Hamada-el-Hamra):

Left ★----★ Wind SEE at 3.0 m sec^{-1}
▲----▲ Wind S at 6.8 m sec^{-1}
×----× Wind SW at 10.5 m sec^{-1}
○----○ Wind NE at 12.3 m sec^{-1}
Right ▲----▲ Surface
×----× 10 cm depth

The aerosol size distributions are dependent on local wind speeds. The soil distributions are similar to the ones in Sebha.

Fig. 4 shows selected measurements from Camp Derj in the Harmada-el-Hamra. In contrast with Sebha data the aerosol size distributions at Camp Derj indicate a dependence on local wind velocities. The distribution with the lowest concentration level is observed at low wind velocities (~3 m sec^{-1}); above 6 m sec^{-1} the other distributions show an increase in particle concentration. The aerosols of these distributions originate from various directions. While wind direction seemed to influence the concentration at Sebha, such an affect was not observed at Camp Derj.

The aerosol is similarly distributed at both measuring sites. The concentration levels correspond, and the mass distribution shows a maximum at 3×10^{-3}–4×10^{-3} cm. The distributions can be approximated by a power function ($\propto r^{-\nu^*}$) (Junge, 1952) with negative exponent ($-\nu^*$). The slope of the size distribution is approximately proportional to an exponent $\nu^*=2$. Above a radius of 2×10^{-3}–3×10^{-3} cm the concentration slope increases.

The size distribution of the soil samples at Camp Derj is not depth-dependent and again shows a relative maximum at 3×10^{-3}–4×10^{-3} cm, although not a very pronounced one. Neglecting the fluctuations in size distribution above 3×10^{-3} cm radius, we see that the soil mass distributions at Sebha and Camp Derj are the same. This is in agreement with a concentration slope with exponent $\nu^*=3$. This approximation by a power function also seems to be justified for the mean number and mass distribution values plotted

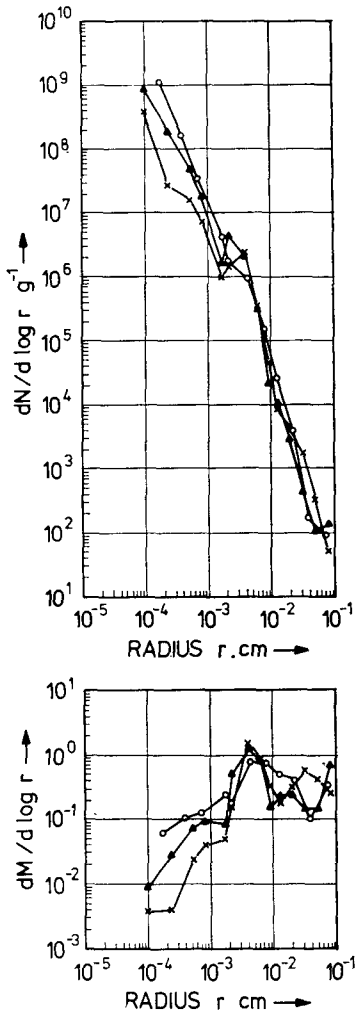

FIG. 5. Comparison of size and mass distributions in sand:

○——○ Sindowski (1959). Mean distributions of different Libyan soils.
▲——▲ Camp Derj. Mean distribution as yielded by this investigation.
×——× Sebha. Mean distribution as yielded by this investigation.

Except for the relative maximum at 2×10^{-3}–4×10^{-3} cm radius, the distribution of Sindowski (1959) differs only slightly from our distributions below 10^{-3} cm radius.

in Fig. 5. It shows as an average for radii $<3\times10^{-3}$ cm that the number distribution can be expressed by a function with $\nu^*=2$.

The regular observation of a relative maximum in the size distribution of the sand gave rise to critical discussions with respect to possible errors in the measuring method. It was especially remarkable that such a maximum had never been reported earlier. After we had finished our measurements, Gillette *et al.* (1972) published such data. They had observed similar distributions in the soil of Nebraska. In an earlier work Sindowski (1959) published data from various Sahara soils which do not show such a maximum. In particular, he measured distributions in Serir-soil, coarse dust-soil, sandy and silty dust-soil, Erg- and quicksands, and fossili-ferous weathering soil. Since these distributions are all very similar, we present them in Fig. 5 as an average distribution together with average distributions of the soil of Sebha and Camp Derj. Except for the relative maximum in the size distributions our measurements agree with those of Sindowski. His mass distribution data show a maximum at 4×10^{-3}–8×10^{-3} cm and ours at 2×10^{-3}–5×10^{-3} cm. Such differences seem to be realistic, considering the accuracy of the measurements and the widespread origin of the samples. It can be considered as confirmation of our measuring method.

Another goal of the measurements in the Sahara was the observation of sandstorms. In spite of the carefully selected season in which the probability of sandstorms is a maximum and a relatively long duration of stay, only one sandstorm could be observed (Camp Derj). But since the circumstances were typical of sandstorm conditions, it is felt that the data can be considered as representative.

Fig. 6 illustrates the mean aerosol size distribution at the Camp Derj and Sebha measuring sites as well as the sandstorm distribution. While the shape of the sandstorm distribution resembles previous distributions, it is noticed that the concentration level is generally increased by one order of magnitude. Obviously, the mechanism which causes the particles to become airborne is already effective with low wind velocities during days without sandstorms. With higher velocities the number of airborne particles increases for all particle sizes at the same rate. The data are not sufficient for exact determination of this mechanism, and further measurements are necessary.

Chepil and Woodruff (1963) and Bagnold (1965) discussed the relationship between the size at which particles become airborne and the wind speed. The former authors generally observed particles becoming airborne only above 4 m sec^{-1} (at $\sim5\times10^{-3}$ cm radius) with a strongly marked radius dependence. Bagnold, however, assumes size independence so that above 0.5 m sec^{-1} particles of all sizes become airborne. This agrees quite well with our observations, although the single measurement available is not conclusive enough to confirm Bagnold's theory.

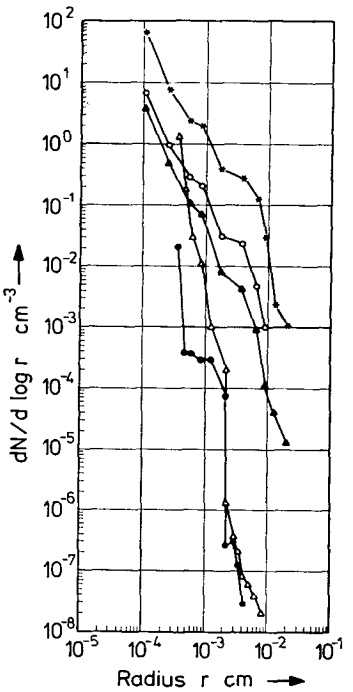

FIG. 6. Comparison of aerosol size distributions:

✳——✳ Sandstorm at Camp Derj.
○——○ Mean distribution at Camp Derj.
×——× Mean distribution at Sebha.
●——● Atlantic (7S,30W, 14 April 1969), insoluble part of maritime aerosol (Jaenicke *et al.*, 1971).
△——△ Atlantic (3N,30W, 17 April 1969), insoluble part of Sahara aerosol (Jaenicke *et al.*, 1971).

During a sandstorm the concentration of the aerosol is increased by one order of magnitude over undisturbed conditions. The distribution shape is similar. The distribution of maritime and continental air masses over the Atlantic differs by more than one order of magnitude in the concentration of particles with radii $<2\times10^{-3}$ cm. Particles with radii $>2\times10^{-3}$ cm are present in the source aerosol but are subject to removal during transport.

For further comparison, Fig. 6 shows two aerosol distributions as measured over the Atlantic at 7S,30W and 3N,30W (Jaenicke *et al.*, 1971). The first measurement was made during absence of continental air masses, the second one in dust-laden continental air masses. Only the distribution of the water insoluble part is plotted which, for sandstorms, practically means the distribution of the mineral fraction. A comparison of both measurements confirms that only mineral particles $<2\times10^{-3}$ cm in radius reached the ship. It could not be proven at that time if the source lacked larger particles or if depositions of larger particles from the aerosol occurred during transport. Fig. 6 shows conclusively the presence of giant particles at the source and their removal during transport. Even at usual wind speeds these giant particles are found in Saharan air over the source in relatively high concentration

compared with other continental size distributions (Jaenicke and Junge, 1967).

Although these giant particles do become airborne, they remain essentially in the source area, as opposed to particles $<2\times10^{-3}$ cm radius. This can be shown by the following consideration which is of preliminary nature because of the few data available. The measurements of Jaenicke *et al.* (1971), 1500 km off the Sahara desert's Atlantic coast, showed that, at least within this distance, the giant particles are deposited from the aerosol. Assuming that the Sahara and its neighboring deserts have an extension of approximately 6000 km in length in an east–west direction, and that easterly winds prevail, an average of 75% of the giant particles are redeposited at the source while 25% reach the ocean (based on the 1500 km mentioned above). However, this is valid only for particles $>2\times10^{-3}$ cm radius. The smaller ones certainly stay airborne which means the major portion is removed from the source. The size distribution of the soil should therefore show a relatively large number of giant particles.

All points considered, this is in agreement with the measurements. The soil's relative maximum in size distribution is the limit between the reduced number of smaller-sized particles and the relatively numerous giant particles. For particles $>3\times10^{-3}$ cm radius, the distribution is represented by a concentration slope of $3<\nu^*<4$, while below 3×10^{-3} cm radius $\nu^*\approx2$ is observed.

Although the Sahara source is steadily drained of small particles, to maintain the high aerosol concentration level these particles are present in great numbers in the soil. If we assume an equilibrium of production of particles in the soil and removal through aerosol transport, then the small particles must be produced in great quantities in the soil. They are probably produced by disintegration of larger particles which are present in comparatively large numbers as the secondary maximum in the size distribution of the soil shows.

4. Summary

The data, although preliminary because they are based on a limited number of measurements, represent the first attempts to compare the Sahara dust components of the aerosol at their source with the size distribution of the soil. In spite of the difficulties encountered during the process of sampling and evaluating, the data yield the following information:

The size distribution in soil and aerosol show characteristic differences from those of the usual distribution in natural aerosol. Both have the same concentration slope toward larger radii (described by a power function) with an exponent of $\nu^*=2$ below 2×10^{-3}–3×10^{-3} cm radius, and greater than $\nu^*=3$ for larger radii. The soil distribution shows a distinct maximum at $\sim3\times10^{-3}$ cm. The measurements and comparison with other data indicate that because of sedimentation of the giant particles within the source area only smaller particles are mixed within the troposphere and transported worldwide.

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