CHARACTERIZATION OF ATMOSPHERIC AEROSOLS ACCORDING TO ATMOSPHERIC-ELECTRIC MEASUREMENTS

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Atmospheric-electric measurements consist of considerable information about the atmospheric aerosols. The data collected during long time continuous measurements of the atmospheric electric quantities in more than ten stations situated in various countries is stored in the World Data Centre for Atmospheric Electricity (Dolezalek, 1992). The correlation of atmospheric electrical data with aerosol particle concentration has been pointed out by Russian scientists (e.g. Svarts, 1980) but the collected data and the running measurements are insufficiently used in aerosol research until now.

Integral measurements

The most essential atmospheric-electric concepts for interpretations in terms of aerosol science are the slow (large) ions and the fast (small) ions. In physical sense they are recpectively the charged aerosol particles and the cluster ions. The average concentration of fast ions

$$n^* = \frac{n^+ + n^-}{2}$$

depends on the ionization rate q and on the amount of particulate matter in the air (asterisk * denotes the average over two polarities). The dependence can be described by a model (Tammet, 1991)

$$N_d\, n^* \approx (4300\ \mathrm{m^{-2}s})\, q, \qquad (1)$$

where N_d is the linear size density of the aerosols that could be expressed by the length of a chain composed of all particles in a volume unit. The example

$$q = 10\ \mathrm{cm^{-3}s^{-1}}, \qquad n^* = 430\ \mathrm{cm^{-3}}, \qquad N_d = 1\ \mathrm{km/m^3}$$

corresponds to the typical results of atmospheric electric measurements in unpolluted continental air. The variations of the ionization rate are much smaller than those of the aerosol density, and so model (1) could be used while interpreting the atmospheric electric data.

Atmospheric electric conductivity λ is more frequently measured than the ion concentrations. With a good approximation, the conductivity can be transformed into the concentration of fast ions:

$$n^* = \lambda^*/(e\, k^*), \qquad (2)$$

where e is the elementary charge and k^* is the average electrical mobility of fast ions.

If we want to determine the concentration of aerosol particles more precisely, we can use the relationship (valid in steady state):

$$q = \alpha\, n^{*2} + \beta\, Z\, n^*, \qquad (3)$$

where α is the recombination coefficient of fast ions, β is the effective integral attachment coefficient of fast ions onto aerosol particles, and Z is the total number concentration of aerosol particles. Product βZ can

be interpreted as the coefficient of adsorption of fast ions by aerosol particles. Term $\beta Z n^*$ exceeds the term αn^{*2} typically more than ten times in the tropospheric air.

Spectral measurements

Detailed information about the size distribution of aerosol particles is obtained analyzing the data about the spectral measurements of slow ions. Let us consider:

- the distribution function of space charge density ρ versus mobility k (or the mobility spectrum) $\rho(k) = \mathrm{d}\rho/\mathrm{d}k$, and
- the distribution function of the particle number concentration Z versus particle radius r (or the size spectrum) $z(r) = \mathrm{d}Z/\mathrm{d}r$.

In steady state the mobility spectrum is expressed by the equation (Salm, 1988)

$$\rho(k) = e\sum_{i=1}^{\infty} i\, z(r_i)\, p_i(r_i) \left|\frac{\mathrm{d}r}{\mathrm{d}k}\right|_{r_i} \qquad (4)$$

where i is the number of elementary charges, r_i is the radius of the aerosol particles that corresponds to the preassigned values of k and i, $p_\mathrm{i}(r_\mathrm{i})$ is the probability to carry i elementary charges, and $\left|\mathrm{d}r/\mathrm{d}k\right|_{r_\mathrm{i}}$ is the Jacobian of the transformation of the differential distribution function of particles from r-space to k-space.

For calculations of probability $p_\mathrm{i}(r_\mathrm{i})$ we have used the equation by Tammet (1991), which approximates the tabulated results of Hoppel and Frick (1990). Function $k(r)$ is calculated by the means of Stokes-Cunningham-Millikan equation.

After the mobility spectrum $\rho(k)$ has been measured, an inverse problem is to be solved to find the size spectrum of aerosol particles z(*r*). We have used the *KL*-model (Tammet, 1988) of the size spectrum for this task:

$$z(r) = \frac{\mathrm{d}Z}{\mathrm{d}(\ln r)} = \frac{a}{(r / r_x)^K + (r_x / r)^L}, \tag{5}$$

where a spectrum is described by the values of four parameters *a*, r_x, *K*, and *L*. Interpretation of the parameters of the *KL*-model is shown in Fig. 1. The values of the parameters were estimated according to the principle of least squares fitting the measured mobility spectrum by varying the parameters of the *KL*-model.

Measurements at Tahkuse Observatory

Mobility spectra of slow and fast air ions have been measured at Tahkuse Observatory since 1988 (Hõrrak *et al.*, 1994). The measurement point is located in a rural site, 27 km north-east from the city of Pärnu, far from industrial enterprises. The range of mobilities 0.00032–0.15 $\mathrm{cm^2V^{-1}s^{-1}}$ is logarithmically divided into 8 fractions. Corresponding range of the particle diameter is from 3 to 90 nm.

We are presenting the measurement results obtained during a 14-month period from September 1, 1993 to October 27, 1994. The mobility spectrum has been measured in every 5 min. Hourly average spectra are saved in the case of routine measurements. Starting from the mobility spectra, the corresponding size spectra of aerosol particles were calculated according to Equations (4) and (5). The monthly average parameters of the size spectra are presented in Table 1. Time variations of the total number concentration and of the mean diameter of particles are shown in Fig. 2 and Fig. 3.

Average values of the *KL* parameters for the 14-month period are: a = 5500 cm^{-3}, r_x = 38 nm, K = 2.09, L = 0.72. The variation coefficients of the monthly averages of a, r_x, K, L are 18%, 11%, 11%, 13% respectively. The average total number concentration of particles is 8500 cm^{-3}, and the average diameter of particles is 59 nm. A diagram of the distribution with indicated parameters is shown in Fig. 4.

A weakness of the particular conclusions is that they are based on the measurements with a low upper limit of the particle size range. The *KL*-model assumes that the right asymptote of the distribution curve would exactly follow the power law. In the real situation, the descent of the right asymptote is steeper in the subrange of large particles. As a result, the values of K presented above are probably underestimated when compared with the values of K determined according to the best fit of the spectrum over the wide size range. According to the classic model by Junge, the average value of K should be about 3. We hope that the error in estimating the value of K does not follow any essential error in estimating other parameters, as the number concentration of particles is rapidly decreasing when considering the particles with a size of more than 100 nm.

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Table 1. Monthly average parameters of the *KL* size spectra at Tahkuse observatory

Month and year	a/cm^{-3}/	r_x/nm/	*K*	*L*	Concentra-tion /cm^{-3}/	Mean radius /nm/
09.93	6210	28.9	2.10	0.71	9120	23.7
10.93	5930	37.0	2.44	0.64	9210	24.8
11.93	6940	40.0	2.58	0.97	8040	31.5
12.93	4010	43.5	2.02	0.76	5790	37.8
01.94	3910	40.4	1.92	0.76	5690	37.4
02.94	6860	41.0	2.00	0.78	9730	36.6
03.94	5240	37.0	1.95	0.69	8040	32.1
04.94	5880	44.2	2.15	0.80	8110	36.9
05.94	6610	30.2	1.72	0.62	10930	29.9
06.94	5070	41.6	1.90	0.64	8240	35.7
07.94	5820	38.5	1.86	0.66	9280	34.6
08.94	5060	38.0	2.25	0.69	7580	28.3
09.94	5450	39.8	2.21	0.68	8290	29.9
10.94	4270	37.0	2.12	0.62	6900	27.8

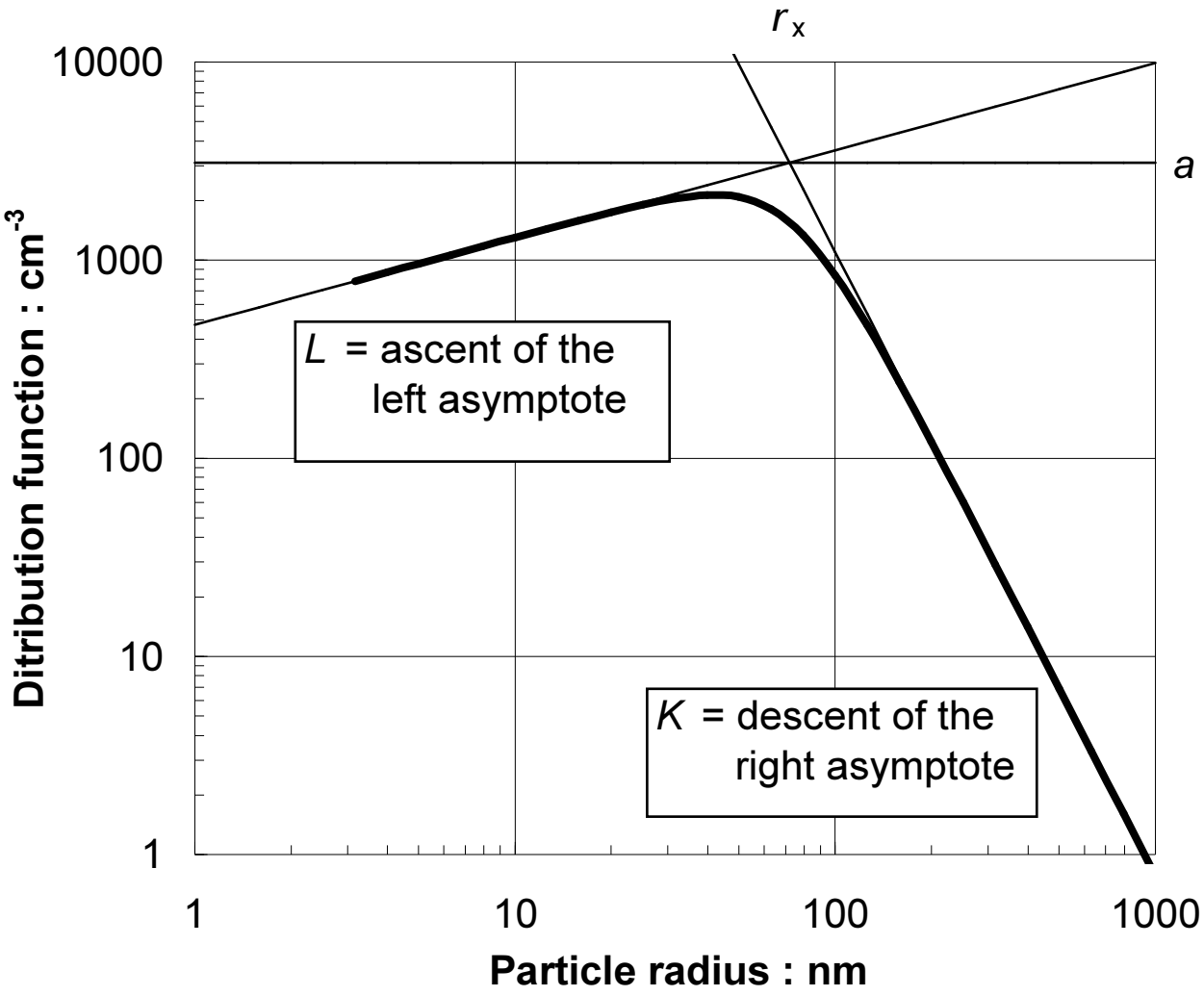

Fig. 1. The KL-model of aerosol particle size distribution. The parameters are fitted to the Smerkalov's (1984) average tropospheric aerosol size distribution.

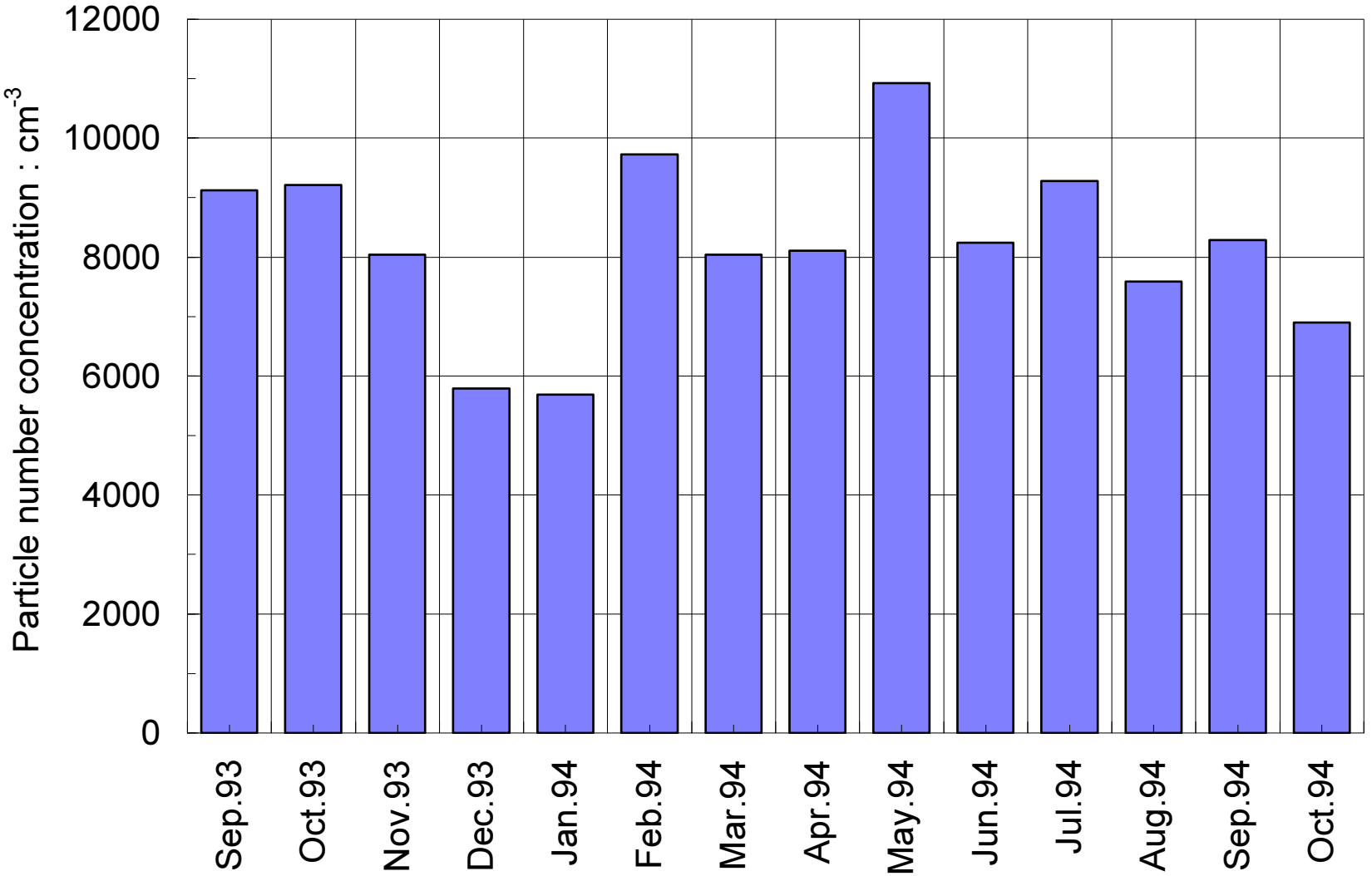

Fig. 2. Monthly averages of particle total number concentration

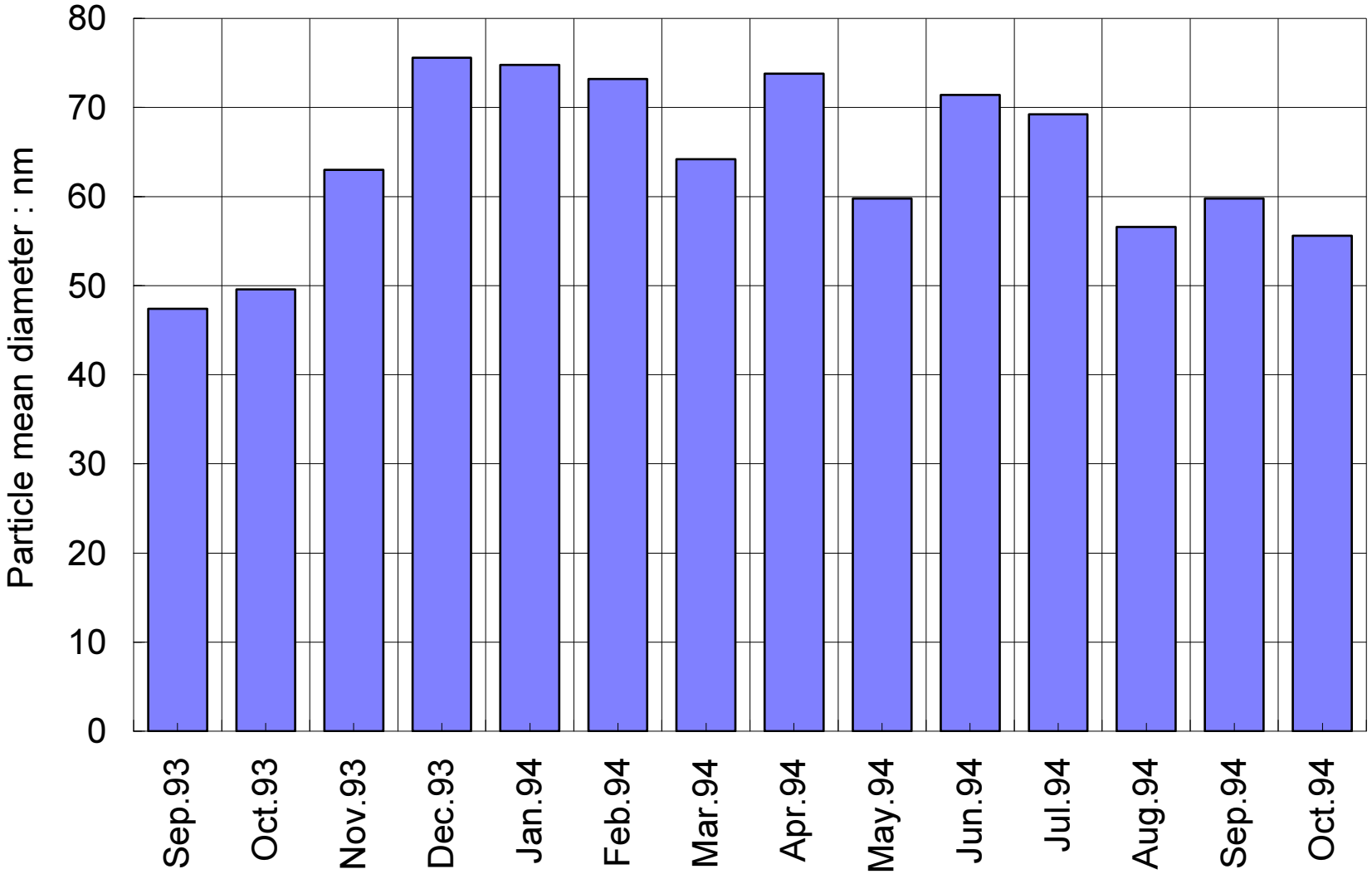

Fig. 3. Monthly averages of particle mean diameter.

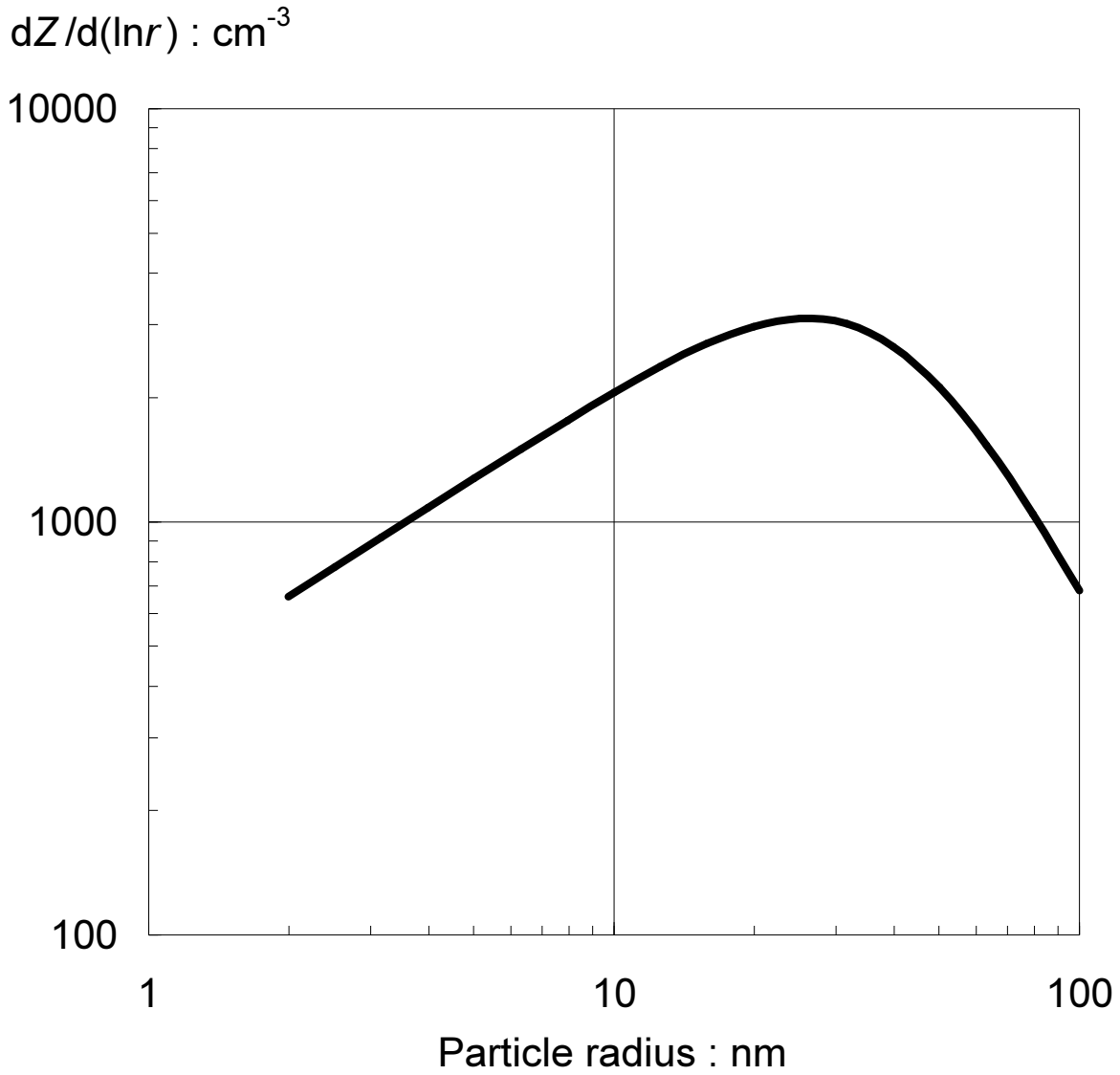

Fig. 4. The average aerosol size *KL*-distribution at Tahkuse from September 1993 to October 1994