THE INFLUENCE OF BACKGROUND AEROSOL ON SPECTRAL TRANSPARENCY OF URBAN AIR

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The relations between distribution of city aerosol particles on dimensions and spectral transparency of aerosol layer of atmospheric air pollution in Baku city conditions. The power and logarithmically-normal functions are used for city aerosol modeling.

INTRODUCTION

The urban air transparency essentially depends on background aerosol pollution layer which forms during many decades [1-3]. The optically active particles of submicron dimension range with particle dimensions from $r=0,1\mu m$ up to $r=1\mu m$ having the atmospheric nature origin are the main components of background aerosol [1,4].

The spectral transparency method is the important investigation one of polydisperse structure (distribution on dimensions) of aerosol particles in natural conditions of their existence and influence evaluation of aerosol on optical thickness of atmospheric air. This method is connected with use of natural data on spectral transparency of aerosol medium with the purpose of practical problem solving of light diffusion theory of aerosol particles [4,5].

In the present paper the big massive actinophotometric measurement data of Sun direct radiation carried out in Baku is used with the purpose of parameterization of spectral transparency dependence of urban background aerosol and its microstructural parameters. The measurements are carried out with the help of apparatus with accuracy not more than 3% considered in [6].

CALCULATION TECHNIQUE

Initial relations. The aerosol particle dimension distribution is its important characteristics.

1. Yung's power law is often used for the description of spectrum of aerosol particle dimensions [4]:

$$dN/dlgr = Cr^{-b}, \tag{1}$$

where C constant of L^{b-3} dimensionality depends on N particle concentration and b exponent defines the distribution curve inclination.

2. The asymmetry of observable aerosol dimension distributions is more satisfactory approximated by logarithmically normal function [1]:

$$f(lnr) = \frac{1}{\sqrt{2\pi}\nu} exp\left[-\frac{1}{2\nu^2} ln^2 \frac{r}{r_m} \right], \tag{2}$$

where r_m is particle modal radius, ν is distribution half-width which is close to 0,7 for submicron particles [1].

The estimations of N_c aerosol particle cumulative concentration are often used for comparison of different models of their dimension distribution (polydisperse structure) [4]:

$$N_c = \int_r^{r_0} \frac{\partial N}{\partial r} dr, \tag{3}$$

where r_0 is given particle radius value.

The (1) and (2) distributions will be used for calculation of polydisperse characteristics of light diffusion: τ_λ is optical thickness and transparency $T=exp(-\tau_\lambda)$ of urban background aerosol. These characteristics are defined by measurement data of S_λ brightness in dependence on m atmosphere optic mass to Sun direction by Buger-Lambert method [2,3]. Let's suppose that polydisperse composition of aerosol particles in limits of urban background aerosol layer is homogeneous one the height of which achieves 1km [1,4]. Then according with Mie light diffusion theory we obtain [4]:

$$\tau_\lambda = N \int_{r_1}^{r_2} Q(\rho, n) \pi r^2 f(\ln r) d \ln r. \tag{4}$$

Here we will use Van den Hulst approximation [4] for calculation of $Q(\rho, n)$ diffusion efficiency factor:

$$Q(\rho,n) = 2 - \frac{4}{\psi} sin\psi + \frac{4}{\psi^2}(1 - cos\psi). \tag{5}$$

Here $\psi=2\rho(n-1)$; $\rho = 2\pi r/\lambda$ is Mie parameter, n is real refraction index.

Calculation formulas. To find (1) and (2) distribution parameters the integral equation (4) is solved by inverse problem method [4].

After substitution r by ρ the formula [4] is easily transformed to following form [4]:

$$\tau_\lambda = 0,434\pi C(\lambda/2\pi)^{2-b} K, \tag{6}$$

where

$$K = \int_{\rho_1}^{\rho_2} Q(\rho, n) \alpha^{1-b} d\rho. \tag{7}$$

As calculations show integral (7) in visible spectral region practically doesn't depend on λ light wavelength and (6) formula coincides with known Angstrem formula [4]:

$$\tau_\lambda = C_1 \lambda^{-b1} \tag{8}$$

where $b_1 = b$-2, C_1 coefficient doesn't depend on λ.

From formula (6) one can estimate the power distribution parameters (1). Index b is found from the ratio of τ_λ values simultaneously measured on two wavelengths:

$$\frac{\tau_{\lambda 1}}{\tau_{\lambda 2}}=\left(\frac{\lambda_1}{\lambda_2}\right)^{2-b}. \tag{9}$$

C sedate distribution coefficient is obtained by formula:

$$C=\left(\frac{\lambda}{2\pi}\right)^{b-2}\frac{\tau_\lambda}{\pi K} \tag{10}$$

In case of distribution (2) the formula (4) is reduced to the form:

$$\tau_\lambda=\pi N K(\lambda), \tag{11}$$

where

$$K(\lambda)=\int_{\rho_1}^{\rho_2} r^2 Q(\rho,n) f(r)\,dr.$$

(12)

Here for n given refractive indexes τ_λ reversion is carried out by optimal parameterization method [5] from following minimization condition at different λ_i wavelengths:

$$\sum_{i=1}^{i_0}\left[\tau_{\lambda i}-\tau^{\bullet}_{\lambda i}\right]^2=\min$$

(13)

where τ_λ is measured characteristics and τ^*_λ is model one.

As optimization criteria the following functional is used:

$$F(r_m)=\sum_{i=1}^{n}\left[\frac{\tau_{\lambda i}}{\tau_{\lambda\max}}-\frac{\tau^{\bullet}_{\lambda i}}{\tau^{\bullet}_{\lambda\max}}\right],$$

(14)

where λ_{max} corresponds to maximal $\tau_{\lambda i}$. It is obvious that value of this difference doesn't depend on N and it is only r_m function. The N value is estimated on formula:

$$N=\sum_{i=1}^{n}\tau_\lambda K\left(r^{\bullet}_m,\lambda_i\right)\Big/\sum_{i=1}^{n}K^2\left(r^{\bullet}_m,\lambda_i\right). \tag{15}$$

CALCULATION RESULTS

The initial data of measurements of τ_λ optical thickness (also T_λ which is transparency) of urban background aerosol are defined by inclination of Burger curve (lnS_λ dependence on m) [4] (fig.1). Firstly the values of constants b and C of power distribution are calculated according to these data by formulas (9) and (10) and the parameter values, r_m modal radius, N nominal concentration of aerosol particles are found by reversion of τ_λ by formulas (14), (15).

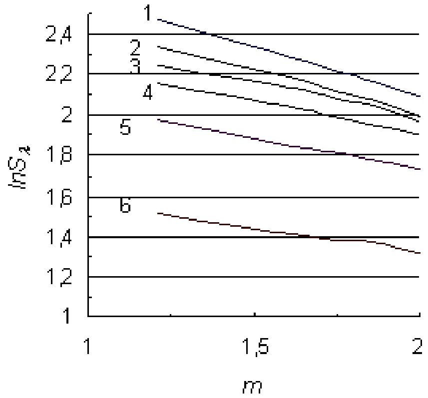

Fig.1. Burger mean curves: 1 is λ=0,45 *μm*; 2 is λ=0,5 *μm* ; 3 is 0,55 *μm*; 4 is λ =0,65*μm*; 5 is λ=0,7 *μm*; 6 is λ=0,85 *μm* (Baku, 2006-2007 г., August, before afternoon).

The numerical values of b, C and N parameters are given in table 1. As it is seen from this table at different λ the estimations of b degree of distribution (1) are very close between each other and it shows the homogeneity of polydysperse composition of aerosol particles. Simultaneously C coefficient connected with particle concentration slowly decreases at the transition into IR spectral region. It is obvious that this is connected with decrease of Mia parameter; the aerosol is more active in visible spectral region.

Table 1.

The estimations of b, C, $(\mu m)^b\cdot cm^{-3}$ and $N(cm^{-3})$parameters.

λ, *μm*	0,45	0,50	0,55	0,65	0,70	0,85	Aver.
B	3,011	3,105		3,008	3,015	3,022	3,032
C_*10E-11	3,889	3,475	3,188	2,591	2,460	2,021	2,937
$N*10^3$	9	8	8	5	4	3	7

The particle power distribution constructed on fig.2 is satisfactory described by following function.

$$dN/lnr = 2{,}94r^{-4,\,03}. \tag{16}$$

Here b_1=4,03 degree takes the value attached to urban aerosol [4]. The curve of logarithmically-normal distribution (2) for different model aerosol particle sizes is given on fig.3.

Let's compare the influence of choice of two most different aerosol models (1) and (2) by N_c (fig.4) concentration value and τ_λ, T_λ (рис.5) light diffusion characteristics. The N_c cumulative concentrations of aerosol particles for these aerosol models defined by data of figures 2 and 3 are given on fig.4. From this figure it is seen that the main contribution to concentration give the small particles. In the comparison with (2) distribution in case of distribution (1) N_c concentration is decreased one and it strongly decreases with particle dimension growth. Simultaneously as it follows from fig.5 in the comparison with measurement values, τ_λ calculation values become increased ones but T_λ transparency calculation values become decreased. According to results of other works [4] the power distribution can be used for description of narrow interval of aerosol particle dimensions. This distribution for strong increase of big particle concentrations with their dimension growth is used with high accuracy. From comparison of measured and calculated data of τ_λ, T_λ characteristics it follows that distribution of urban background aerosol best of all is approximated by logarithmically normal curve.

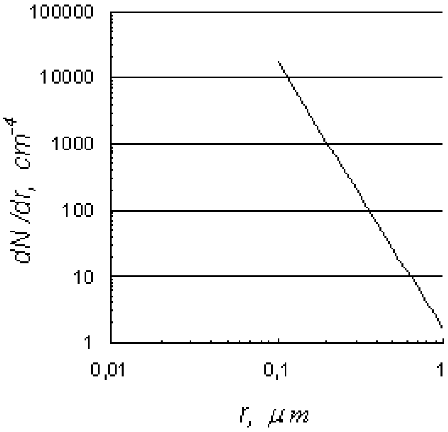

Fig.2. Power dimension distribution of aerosol particles on table 1 data.

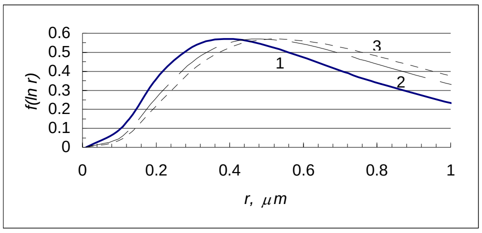

Fig.3. Logarithmically normal dimension distribution of aerosol particles: 1is r=0,30, 2 is r=0,389; 3 is r= 0,530.

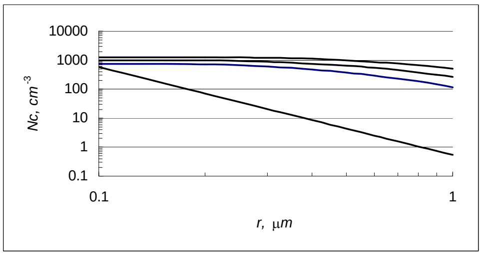

Fig.4. Aerosol cumulative concentration:1is on (1) model; 2-4 is on (2) model at ν=0,7; 2 is r_m=0,30 μm, 3 is r_m=0,389 μm, 4-is r_m=0,530 μm.

For Baku conditions the background concentration of atmospheric aerosol achieves to N =7· 10^3cm^{-3} value in the mean. For pure atmosphere the aerosol concentration doesn't exceed N=3,5 · 10^3 cm^{-3} value in the mean [1,4]. From this it follows that Baku urban air is always characterized by higher concentration of background aerosol.

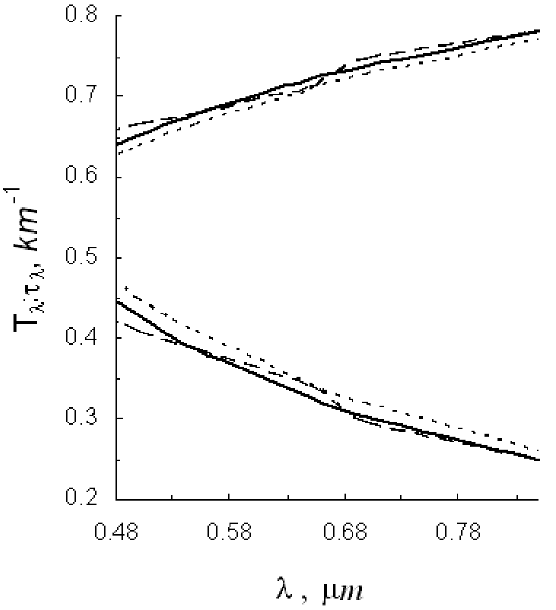

Fig. 5. The influence of aerosol model choice on T_λ transparency and τ_λ optical thickness in visible region: experimental data; aerosol model --by formula (2); ---by formula (1) (Baku, August, before afternoon).

COMPARISON OF EXPERIMENTAL AND CALCULATED DATA

The comparison of calculated and empirical data of spectral transparency of aerosol layer over Baku is given in table 2. For chosen aerosol models the accuracy of calculated data is least one from violet spectral region.

The difference between empirical and calculated data decreases with wave length increase at the transition into red spectral region. It is obvious that this is connected with revealing of Forbs effects which are amplification of absorption effects for more short waves of light radiation.

In aerosol particle dimension interval r=(0,1 – 1) μm under consideration the best correspondence of calculated and empirical data takes place for logarithmically normal distribution. The accuracy of calculated data for power distribution doesn't exceed the accuracy of empirical data. However, in this case as it follows from fig.4 at calculations the values of small aerosol particle concentrations increase and concentration values of more big particles decrease. From this it follows that power distribution according to formula (16) is really used for simplifying of calculations of spectral transparency of urban background aerosol.

Table 2.

Comparison of theoretical and empirical values of spectral transparency of background atmospheric aerosol over Baku (n = 1,5; N =7· 10^3 cm^{-3} ; b=3,03)

λ. μm	Empirical	Calculated (aerosol model by (1) formula)	Difference, %	Calculated (aerosol model by (2) formula)	Difference, %
0,45	0,623	0,605	2,9	0,641	2,8

0,50	0,651	0,638	2,0	0,664	2,0
0,55	0,679	0,665	2,1	0,685	1.0
0, 65	0,721	0,709	1,7	0,713	1,0
0,70	0,739	0,728	1,5	0,745	0,08
0,85	0,780	0,770	1,3	0,775	0.06

CONCLUSION

1. The background aerosol pollution significantly influences on Baku atmospheric air transparency the spectral transparency of which decreases and changes in interval 0,6-0,8 at transition from visible region into neighbor IR spectral region.

2. The background level of Baku atmospheric aerosol concentration achieves $N = 7\cdot\ 10^3$ cm^{-3} and approximately exceeds the background concentrations of aerosol particles out of city condition in 2 times.

3. The background aerosol of Baku atmospheric air is satisfactory approximated by logarithmically normal function. The power function with exponent b=3,03 can be used to simplify the calculations of background aerosol transparency

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ŞƏHƏR HAVASININ SPEKTRAL ŞƏFFAFLIĞINA AEROZOL FONUNUN TƏSİRİ HAQQINDA

Bakı şəhərinin şəraitində atmosfer havasının aerozol örtüyünün spektral şəffaflığı və şəhər aerozolu zərrəciklərinin ölçülərinə görə paylanması arasında əlaqələr tədqiq edilir. Şəhər aerozolunun modelləşdirilməsi üçün üstlü və loqarifmik normal funksiyadan istifadə edilir.

Ф.И. Исмаилов

О ВЛИЯНИИ ФОНОНОВОГО АЭРОЗОЛЯ НА СПЕКТРАЛЬНУЮ ПРОЗРАЧНОСТЬ ГОРОДСКОГО ВОЗДУХА

Изучаются соотношения между распределением частиц городского аэрозоля по размерам и спектральной прозрачностью аэрозольного слоя загрязнения атмосферного воздуха в условиях города Баку. Для моделирования городского аэрозоля используется степенная и логарифмически - нормальная функция.

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