DANGEROUS RESPIRABLE FRACTION OF NEAR-GROUND ATMOSPHERIC AEROSOL

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Different aspects of the influence of microphysical characteristics of the near–ground aerosol on the human respiratory system are discussed.

When one considers the ecological aspect of studying the microphysical parameters of the near-ground aerosol in industrial centers, one should, first of all, examine such its characteristics as chemical (elemental) composition of particles, particle size spectrum, as well as particle number density and mass concentration.

Main criteria for the air quality, as concerns the pollutant concentration, are the maximum permissible concentrations (MPCs) for populated areas, which can be divided into two groups: one–time maximum permissible concentration ($MPC_{o–t}$) and daily mean MPC ($MPC_{d\,m}$). The former corresponds to the 20–30–minute averaging interval, while the latter assumes the long time of impact without a strict limitation on its duration.[1]

For example, for dust (solid substances) $MPC_{o–t}$ is 0.5 mg/m^3, whereas for ash it is 0.15 mg/m^3 (see Ref. 2). The technique of concentration estimation for these substances reduces to determination of difference in the mass of AFA aerosol filters before and after the exposure and its relation to the volume of the air pumped through.

At the same time, it is known that the extent to which the aerosol particles inhaled are hazardous to human health is determined by the lung part where they are caught.[3] Experimental work[4] has demonstrated the relation between the size of particles and the respiratory system sections where they are caught, namely, as particles come deeper into sections of the respiratory system, their size becomes smaller and the main part of them fall out near respiratory tract turns and branching. This assumes that the mechanism of inertial fallout is mainly responsible for the aerosol particle catching.

As early as in 1931 Findayzen tried to check this assumption by constructing the simplest theoretical model.[5] He, in his calculations, used the data on the main characteristics of the human respiratory system (Table I) and has shown that, so far as concerns the particle size, most hazardous for human health are the particles 0.3–5 μm in size (because the main part of them is caught in the lung alveolar sections and being dissolved comes to the blood).

That is why this particle size interval was called the dangerous respirable fraction (DRF).

With due regard for the inertial mechanism of particle catching in respiratory organs that is similar to the operation of such a device for studying the aerosol dispersion as impactor, we has designed and constructed the four-cascade impactor, the particle distribution over cascades in which corresponds to that from the nasal cavity to the lung alveolar section. The impactor was calibrated using the polydisperse water aerosol with $\rho = 1\cdot10^3$ kg/m^3. Circulation lasted 0.5 min with the rate of 2 m^3/h. Figure 1 shows our experimental results in comparison with the results from Ref. 3.

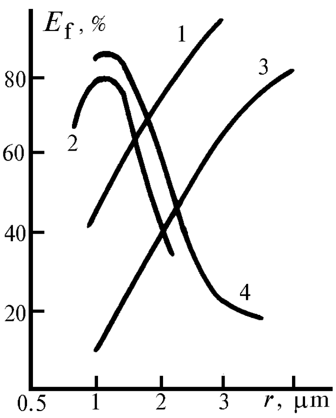

FIG 1. Efficiency of catching particles of different size in a human nasal cavity (1), in alveoles (2) and on third and fourth cascades of an impactor (curves 3 and 4, respectively).

In addition, we noticed the possibility of using the experimental results for estimation of the density range of natural aerosol particles. By comparing the distribution curves for aerosol with a known density and atmospheric aerosols, one can estimate the density range of the latter. The values for the density of aerosol substance in the atmosphere we obtained are within the range $\rho = (1–3.5)\cdot10^3$ mg/m^3.

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TABLE I.

Respiratory system sections	N	R, cm	L, cm	S, cm^2	U, cm·s^{-1}
Trachea	1	0.65	11	1.3	150
Main bronchi	2	0.37	6.5	1.1	180
First–order bronchi	12	0.20	3.0	1.5	130
Second–order bronchi	100	0.10	1.5	3.1	65
Third–order bronchi	770	0.075	0.5	14	14
Terminal bronchioles	$5.4\cdot10^4$	0.030	0.3	150	1.3
Alveolar bronchioles	$1.1\cdot10^5$	0.025	0.15	220	0.9
Alveolar tracts	$2.6\cdot10^7$	0.010	0.02	8220	0.025
Alveoles	$5.2\cdot10^7$	0.015	–	$1.47\cdot10^5$	0

Note: N is the number; R is the radius; L is the length; S is the cross section area, and U is the air speed.

TABLE II.

Range	n	1	2	3	4	5
Particle size, 10^{-6}m		0.3–0.4	0.4–0.5	0.5–1	1–2	2–5
Mean diameter, 10^{-6}m	D_n	0.35	0.45	0.75	1.5	3.5
The number of particles*, 10^{-3}m^{-1}	ν_n	657	713	574	62	38
		15058	17386	8977	442	388
Surface area*, 10^{-8}m^2	$S_n = \pi D_n^2 \nu_n$	25.29	45.34	101.37	438	138.7
		579	1105	1586	309	1494
DRF surface area*, 10^{-8} m^2	$S_{\text{DRF}} = \sum_{n=1}^{5} S_n$	315.08				
		5075				
DRF mean diameter*, 10^{-6} м	$D_{\text{DRF}} = \sqrt{\dfrac{S_{\text{DRF}}}{\pi \Sigma \nu_n}}$	0.7				
		0.616				
DRF mass concentration*, 10^{-4} mg/m^3	$C_{\text{DRF}} = \dfrac{\pi D_{\text{DRF}}^3 \rho \Sigma \nu_n}{6V}$	3.5÷12	for $\rho = (1\div3.5)\cdot10^9$, mg/m^3			
		49÷166				
Mass concentration of all particles on a filter*, 10^{-4} mg/m^3	C_{F}	0.04				
		0.23				

* The upper and lower rows correspond to Bystryanka and Barnaul, respectively.

Having the data bank on the particle distribution functions in different populated sites of Altai, obtained with the use of PKZV–906 photoelectric counter, and the data on mass concentration on AFA filters, the contribution from DRF to the total mass concentration on a filter has been analyzed. Table II presents the measurement results for Bystryanka village (September 1994) and city of Barnaul (July 1992). The DRF mean diameter is defined as the mean surface diameter, i.e. the diameter of a particle, the product of whose surface area by the number of particles per unit aerosol volume equals the total surface area of particles contained in a unit volume. It is seen from the data presented that the DRF contribution into the total mass concentration of aerosol is 0.8–3% for Bystryanka and 2–7.2% for Barnaul; the main mass belongs to the coarse aerosol fraction, while just the DRF is most significant for a human body.

Thus, in order to evaluate the atmospheric air quality in a more correct way when calculating the MPC value, one should take into account different aerosol fractions, especially DRF, as well as the aerosol substance density.

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