NUMERICAL INVESTIGATION OF THE INHALABLE FRACTION OF AEROSOL PARTICLES AT LOW WIND SPEEDS

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The inhalable fraction is the mass fraction of aerosol particles which can be inhaled by nose or mouth. The determination of inhalable fraction under given conditions is an important problem in assessing the risk to the human health. The American Conference of Governmental Industrial Hygienists (ACGIH) have established the criterion for inhalable particulate mass (IPM) aerosol samplers by the equation

$$\text{IPM} = 0.5(1+\exp(-0.06 d_p)) \tag{1}$$

This criterion is suitable for particles with the aerodynamic diameter $d_p \leq 100$ μm at wind velocities between 1 and 4 m/s. However, actual workplace wind speeds is much less that corresponds to the case of aerosol aspiration in calm and slowly moving air. Experimental [1,2] and theoretical [3] studies have shown that for intermediate particles diameter the inhalable fraction is less than values by the formula (1) and the IPM sampling criterion needs correction.

The mathematical model and results of numerical investigations of the particles inhalable fraction for the human manikin geometry and the idealized spherical sampler were presented. For the human manikin model the velocity field of carrier phase is found by numerical solution of the Navier-Stokes equations using Fluent code. For the spherical sampler the velocity field is found analytically in the approximation of potential flow of incompressible fluid [4]. The particle trajectories are calculated in the found flow field by numerical integration of the motion equations.

In the undisturbed air flow far from the human head and the sampler the wind speed is given by U_0 which corresponds to indoor air flow speeds. In the plane of the human mouth orifice and the inflow face of the sampler the breathing pattern is modeled by stationary velocity U_a. The aspiration efficiency A (inhalable fraction) which defines the ratio of the mean concentration of inhaled particles to that in undisturbed flow is calculated. In the undisturbed air aerosol particles move with the velocity $\overline{U}_1 = \overline{U}_0 + \overline{V}_s$, where $\overline{V}_s = \tau \overline{g}$ is the settling velocity, $\tau = \rho_p d_p^2 / 18\mu$ is the relaxation time, ρ_p and d_p are the particle density and diameter, μ is the air viscosity. On the base of calculating the particle trajectories the tube of limiting trajectories is determined, which divides the sampled particles from the unsampled. The cross-section area S_p of the tube of limiting trajectories far from the object allows the calculation of the aspiration efficiency to evaluate by the formula

$$A = \frac{U_1 S_p}{Q} = \frac{S_p \sqrt{U_0^2 + V_s^2}}{S_m U_a}$$

where $Q = S_m U_a$ is air flow rate through inflow face with area S_m.

Dependencies of inhalable fraction on the particles diameter are shown in fig.1. The results for the human manikin and the spherical sampler is greater than values obtained by the formula (1). This confirms other studies conclusions about need to develop the criterion for inhalable fraction at slowly moving air. Values of the aspiration efficiency for the manikin is less than numerical results in [3] that is apparently due to taking to account "secondary aspiration" in this work. The dependence for spherical sampler agrees with other results satisfactorily. Thus the model of an idealized spherical sampler can be used in the investigations of inhalable fraction.

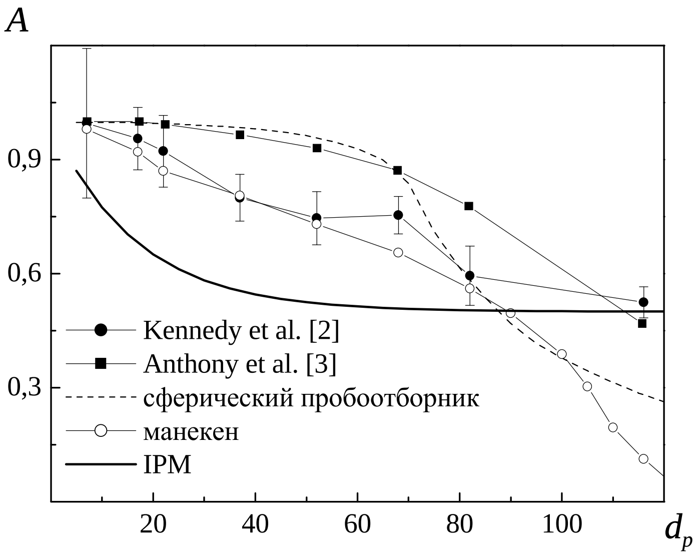

Fig. 1. The dependence of inhalable fraction on the particles diameter.

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