Numerical study of thin-walled sampler performance for aerosols in low windspeed environments

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The low wind velocity regime, intermediate between the moving and calm air cases, is important for practical indoor aerosol sampling. But there is a gap in knowledge of the performances of samplers operating in such conditions. Only the case of tube sampler facing vertically upwards for air flow moving vertically downwards has been investigated by Grinshpun \textit{et al.}, (1990). In indoor environments the air flow velocity is about 0.1-0.2 m/s and the settling velocity $V_s$ of coarse particles can reach close values (for particles with size 80 $\mu$m $V_s \approx 0.17$ m/s (Schmees \textit{et al.}, 2008). This means that the particle velocity can be comparable with $V_s$ and the gravity force will affect the aspiration efficiency.

In this work a mathematical model of aerosol sampling into a thin-walled tube facing horizontally in the slow moving air is developed. The fluid velocity field is obtained by BEM method for potential flow approximation and using FLUENT program for viscous flow model. In these fields the aspiration efficiency is studied in the range of small values of the ratio $R_a$ of the wind and aspiration velocities. The aspiration coefficient is calculated without and with possible bounce of particles from the outer wall of the tube. The fair agreement of calculated dependencies $A(R_a)$ with known experimental data and the approximate formulas of Davies (1968) and Medvedev (2002) for small values of $R_a$ is observed.

In the presence of gravity the particle motion can be defined by two nondimensional parameters: the Stokes number $St=U_s/D_t$ ($U_s$ is the sampling velocity, $\tau$ is the particle relaxation time, $D_t$ is the tube diameter) and Froude number $Fr=U_s^2/gD_t$. The cross-sectional area of limiting particle trajectory surface changes its shape from circular for large $R_a$ to noncircular for small $R_a$ (fig.1, $St=1$, $Fr=10$).

The values of the aspiration efficiency calculated with gravity influence are less than the values of $A$ without gravity (fig.2). As $R_a$ decreases up to zero the calculated aspiration efficiency tends to the values that correspond to the calm air sampling. Our results at $R_a=0$ are in agreement with the approximate formula for aspiration efficiency of thin-walled tube oriented horizontally in calm air (Vincent, 2007). The curves $A(R_a)$ in the case of acting gravity can be approximated by formula (1) that is the combination of the aspiration efficiencies $A_0$ for calm air sampling (Vincent, 2007) and $A_m$ for moving air (Medvedev, 2002)

$$A = \begin{cases} A_0 + R_a(A_m - A_0)/R_c, & R_c < R_a \\ A = A_m, & R_c > R_a \end{cases}$$

where $R_c = St/Fr$.

![Fig.1. The cross-sectional area of limiting particle trajectory surface at various $R_a$](image)

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