Solution

Master's degree in environmental science and engineering

Occupational and environmental health

5.1 Physico-chemical - properties

1) Falling speed limit

What is the sedimentation rate in cm per hour of quartz particles with an average physical diameter of 1.75μ m and a density of 2.65 ?

$$\text{Stokes } v = \frac{2}{9}\frac{(\rho_{sph}-\rho_{air})}{\eta} g r^2$$

η = viscosity, air = $1.82\ 10^{-5}$ N s m^{-2}
φ = density (kg m^{-3})
for air φair = 1.20 kg m^{-3}
for quartz φ quartz = 2'650 kg m^{-3}
φquartz -φ air = 2'648.8 kg m^{-3}
g = 9.81 m s^{-2}

$D_{AE} = D \cdot (d/F)^{1/2}$ to calculate the falling speed of the particle, we must use its aerodynamic diameter and not its physical diameter.

With a form factor F of 1.36 for quartz particles and using the density of water to find the equivalent diameter, we get:

D_{AE} = 2.4μ m
r = 2.4/2 = 1.2 10^{-6} m r^2 = 1.44 10^{-12} m^2
The fall rate becomes:

→ v = 4.6 10^{-4} m/s

2) And... another story of a fall

A quartz particle (aerodynamic diameter: 1.75μ m) and a glycol ether droplet (physical diameter: 3μ m) are emitted 1 meter above the ground. The Quartz particle reaches the ground first, explain why ?

M: 90.1 [g/mol], D: 8.10^{-6} [m^2 /s], P_s : 1.4 [kPa],ρ : 0.9 [g/cm^3] for glycol ether.

It is possible to calculate the falling speed of the two particles (correct theoretical answer). But, being a volatile product, the glycol ether droplet undergoes evaporation. This evaporation is very fast because of the large exchange surface (relative to its mass).

The application of Fick's law to a spherical droplet is written:

$$J(t)_j = 4 \cdot \Pi \cdot r(t) \cdot D_j \cdot M \cdot \frac{(P_{\mathrm{si}} - P_{\mathrm{ai}})}{R \cdot T}$$

With

T: 293 [°K]

P_s Saturation vapor pressure, P_{ai} vapor pressure in air

M: molecular weight

The (theoretical) order of magnitude of the initial evaporation of the droplet can be calculated by considering that the vapor pressure in the ambient air is zero.

$$J(t)_j = 7.9 \cdot 10^{-9} [g/s]$$

Now, the mass of the particle is

$$m_{\mathrm{goutellette}} = \rho_{\mathrm{LIQ}} \frac{4}{3} \pi r_0^3 = 1.3 \cdot 10^{-11} g$$

the liquid droplet **will evaporate completely before it hits the ground**.

3) Inhalable fraction

Explain why it is useful to define conventions for particle size fractions in relation to their penetration into the respiratory system.

The purpose of air sampling in occupational health (occupational hygiene) is to evaluate risks for the health of exposed persons. In the case of dusts, it is thus a question of estimating the quantity ("dose") that will reach the target organ.

For dusts containing systemic toxicants (reaching a "system" [target organ, immune system, reproductive system, hematopoietic system, etc.]), what matters most is the quantity that enters the body (inhalable fraction).

For a dust acting on the bronchial tubes (e.g. flour), the thoracic fraction will be the most significant for the risk evaluation (in this case, of asthma caused by flour).

For dusts acting deep in the lungs (alveoli), the alveolar fraction will be the one to be evaluated for risk assessment, since it is the one that will penetrate the area of interest. Quartz (silica) is an example.