Effective density of particles from different combustion conditions and engineered TiO_2 nanoparticles

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It is widely accepted that combustion derived particulate matter (PM) is related to adverse health effects in humans. However, it is still unclear, what is the mechanism behind these effects, and which properties of the PM (size, shape, chemical composition, surface properties) besides of mass concentration are relevant (Mills et al. 2009). Therefore, detailed analyses of the PM properties are needed.

Density is a fundamental property of particles, and by one definition, links the particle mass m_p and mobility diameter in relation of

$$\rho_{ef} = \frac{m_p}{\frac{\pi}{6} d_{el}^3}$$

Density is also the link between electrical mobility diameter d_{el} and aerodynamic diameter d_{ae}, which enables measurements with impactors and classifiers to be compared. However, errors in determination of particle size arise as particles deviate from ideal spheres with standard density. One of the key properties in particle sizing is the fractal dimension D_f,

$$\rho_{ef} = D' d_{el}^{D_f - 3},$$

where D' = constant and D_f = mass related fractal dimension (Park *et al.*, 2003). Combustion derived soot agglomerates, readily found in atmospheric samples, are a typical example of non-standard, fractal particles that are shown to have significant role in particle mediated health issues.

In this study, we compared experimental results as follows: the effective densities ρ_{ef} of particles in various size fractions (<1 µm) from i) different biomass grate combustion situations (Torvela et al. 2011), ii) biomass gasification combustion experiments (Nuutinen et al. 2010) and iii) synthesis of TiO_2 nanoparticle (Backman et al. 2009). An APM-SMPS method was applied to determine effective densities of particles.

In Fig. 1 the measured effective densities are shown as function of d_{el}. According to the equation above, the slope of these graphs is related to the fractal dimensions of those particles.

The effective density was found to be connected with the source of the particles and with combustion conditions. In biomass combustion a relatively small change in the combustion conditions (air staging and fuel feeding) caused significant differences to ρ_{ef}, even for particles of approximately same mobility diameter. This was due to differences in both chemical composition and morphological properties of the particles, observed by single particle analyses by TEM.

The fractal dimension was not constant for the smallest particles in Fig 1 (slope of the graph). However, larger particles seem to have a clear fractal structure (close to constant D_f).

As a conclusion, no single value can be used for effective density of biomass combustion particles. Rather, effective density should be determined for each particle type separately.

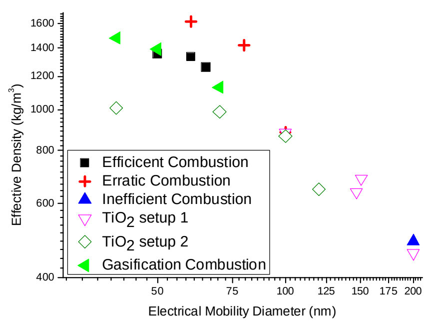

Figure 1. Effective density of particles from biomass combustion (Efficient: low CO-emission, Erratic: elevated CO and Inefficient: high CO), gasification combustion and TiO_2 particles in log-log graph.

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