# Characterization of Dust Samples in Occupational and Environmental Medicine

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## Introduction

Nanotechnology is considered to be the key technology of the 21st century. It is expected that applications will be found not only in many areas of industry, but in new therapeutic and diagnostic procedures in the medical field as well. Nanoscale structures with dimensions entirely or partially smaller than 100 nm can actually generate new functionalities and properties. Such nanoparticles can be produced by means of the "bottom up" technique from gas and liquid phase reactions, or by means of the "top down" technique by the grinding or deforming of larger particles. Nanoparticles are also increasingly formed in modern combustion processes such as in diesel engines.

In view of these developments, it is urgent to clarify the health risks involved with nanoparticles and nanotubes (also called "ultrafine particles" in the occupational safety field). Due to their small size, nanoparticles can easily be inhaled into the lungs and arrive all the way into the alveoli. Once deposited there, the particles can no longer be removed by the biomechanism responsible for cleaning the upper and middle respiratory tracts ("mucociliary clearance") (figure 1).

If the particles deposited in the alveoli are "biostable" dust particles (i.e. they do not dissolve easily in the pulmonary liquid), then complex biochemical processes can take place which increase the potential for inflammation and even the risk of lung cancer. Penetration into the interstitium can also occur, thus allowing the nanoparticles to become systemically distributed.

An in-depth discussion about the potential hazards to human health of airborne biostable dust particles such as carbon black, modified carbon black, diesel exhaust particles or toner material requires the use of state-of-the-art characterization methods. The reason for this is that concentration measurements carried out by particle counters (aerosol photometers), which until recently have been the primary tests conducted, have not been capable of explaining the different effects on the respiratory tract. Such measurement techniques do not allow any conclusions to be drawn regarding the size of the dust particles; in addition, the agglomeration behavior of the nanoparticles causes the biologically relevant concentrations yielded to be too low. Finally, such techniques provide no information on the chemical composition or particle surface.

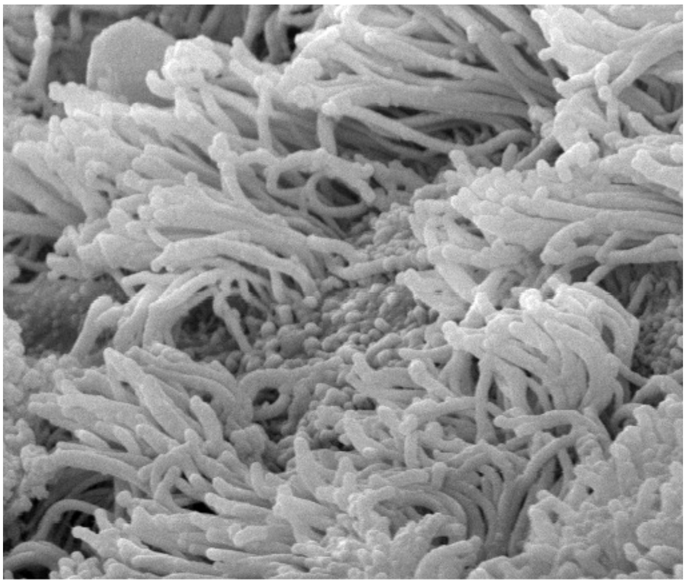

Fig. 1. Mucociliary clearance by cilia in the bronchiole wall; SEM micrograph, magnification 5000x

## Experimental work and results

A combination of electron microscopy and thermal analysis is best suited for characterization of the dust particles. Electron microscopy yields information on the morphology of the particles: dust agglomerates composed of primary particles 10-50 nm in size can be seen (figure 2). An elemental analysis (EDX) proved unsuccessful in identifying the dust for the primarily carbonaceous compounds.

Thermal analysis can be of further assistance here. TG-FTIR tests (TG 209 ***F1*** *Iris*® with Bruker Tensor 27™) in an air atmosphere show differences in transformation behavior (decomposition and oxidation) at the same heating rate (20 K·min$^{-1}$). The FTIR coupling determines the composition of the gaseous oxidation products emitted (figure 3): Carbon black and modified carbon black oxidize in one reaction step into solely $CO_2$, whereas during oxidation of the

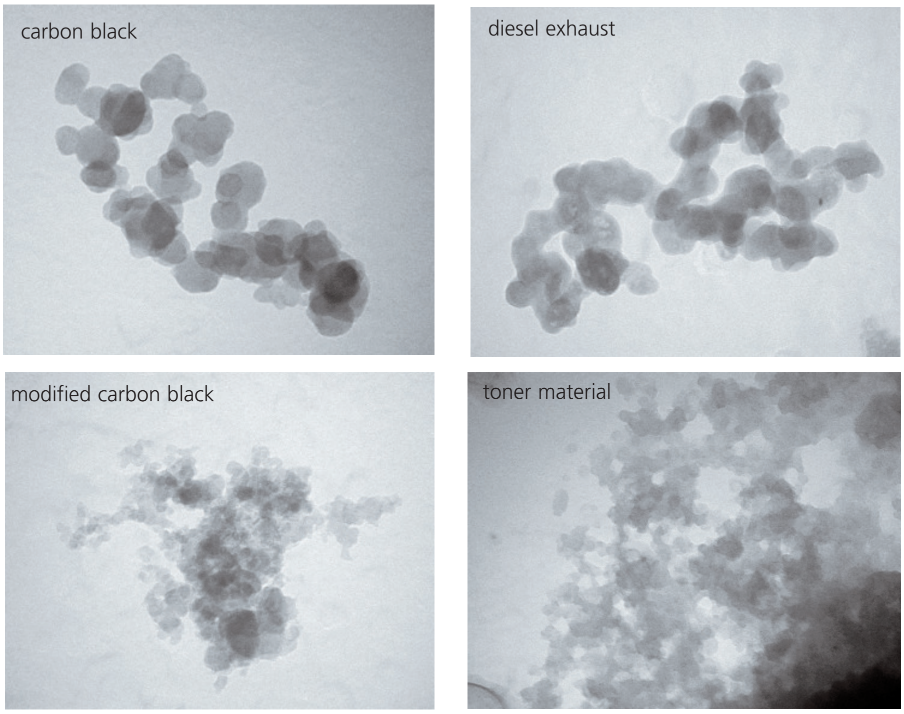


Fig. 2. TEM micrographs of the dust samples analyzed; magnification 100,000x

diesel exhaust particulates, $CO_2$ is developed in several steps and $SO_2$ is also produced (see figure 3). Toner initially generates aliphatic hydrocarbons, followed by $CO_2$ at higher temperatures.

## Conclusion

Diesel exhaust particulates, carbon black and toner dust particles of interest in occupational and environmental medicine consist of agglomerates of toxicologically-relevant ultrafine particles which can barely be differentiated from one another, either optically under an electron microscope via particle size or morphology, or by means of elemental analysis. Due to their differing thermal stabilities, however, they can be differentiated quickly and reliably by means of thermoanalytical characterization. Even small amounts in the one-digit milligram range are sufficient, as they accumulate during dust measurements in the form of filter admission. The thermoanalytical results therefore allow for evaluation of airborne nanoscale dust in the fields of occupational and environmental medicine, and help in determining any necessary preventive measures to be taken in the interest of health protection.

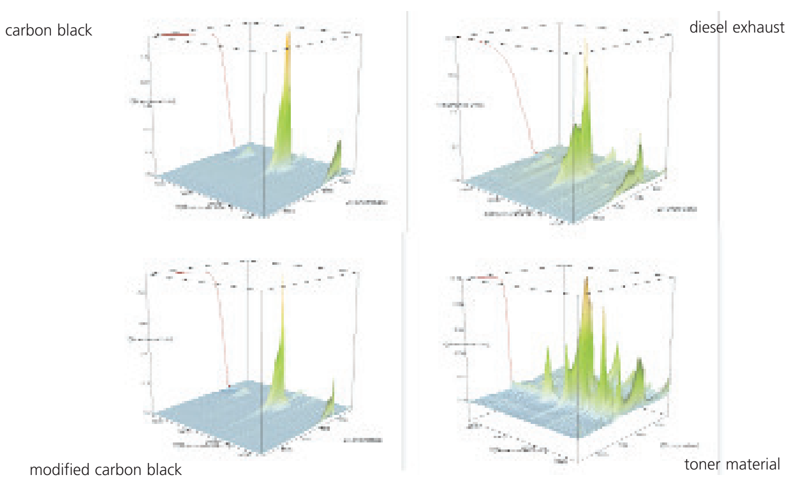


Fig. 3: Results of the TG measurements with subsequent FTIR analysis

## The Author

Dr. Dirk Walter holds doctorate degrees in both the natural sciences and human biology. In 2006, he achieved his qualification to professorship in Inorganic and Analytical Chemistry at the Technical University of Berlin. Since 2007 he has headed the Hazardous Materials Laboratories for Chemistry and Physics at the Institute and Out-Patient Clinic for Occupational and Social Medicine of the Justus-Liebig University in Giessen, Germany.