Health effects of Inhaled Nanomaterials

Ulla Vogel

National Research Centre for the Working Environment, Copenhagen, Denmark. Email: ubv@nrcwe.dk

Most nanoparticles are more hazardous (by mass) by inhalation compared to larger particles with the same chemical composition. This is especially true for nanoparticles with low solubility and low toxicity. Carbon nanotubes constitute a group of highly toxic nanomaterials when inhaled and other high-aspect-ratio nanomaterials may potentially have similar toxicity.

Inhalation of nanomaterials results in pulmonary deposition deep in the lung in the alveolar region. Particle clearance is low in the alveolar region, resulting in accumulation of particles in the lung even at relatively low air concentrations. The presence of foreign material in the lung initiates a number of biological defense reactions such as inflammation, acute phase response and generation of reactive oxygen species. The biological defense reactions are linked to pulmonary diseases, cancer and cardiovascular disease.

The two high-tonnage nanoparticles, black pigment carbon black and white pigment titanium dioxide are classified as possibly carcinogenic by inhalation by IARC, WHO’s International Agency for Research in Cancer. Carbon black nanoparticles are efficient generators of reactive oxygen species and this is the likely cause of the mutagenicity. One specific long and thick multiwalled carbon nanotube has been classified as possibly carcinogenic by IARC, and was recently shown to induce cancer by inhalation. Other long and thick but not short and thin carbon nanotubes have been shown to be carcinogenic.

In mice, inhalation and pulmonary exposure to a number of different nanoparticles and other particles has been shown to induce long-lasting time and dose-dependent pulmonary inflammation and acute phase response. Both inflammation and pulmonary acute phase response was shown to be proportional to the total surface area of the pulmonary deposited particles.

The acute phase response is the systemic response to acute and chronic inflammatory states caused by for example bacterial infection, virus infection, trauma and infarction. It is characterized by differential expression of ca. 50 different acute phase proteins including C-reactive protein (CRP) and Serum amyloid A (SAA). Blood levels of these two acute phase proteins are closely associated with each other and with risk of cardiovascular disease in epidemiological studies. A 5-fold increase in SAA levels was associated with 3-fold increased risk for cardiovascular events defined as death from coronary heart disease, nonfatal myocardial infarction or stroke, or the need for coronary-revascularization procedures in the Nurses’ Health Cohort.

Inhalation of carbon nanotubes induces sustained inflammation with low no-effect-levels. Pulmonary exposure to carbon nanotubes also induces long lasting pulmonary acute phase response. Physicochemical properties of carbon nanotubes have been shown to predict pulmonary toxicity. Thus, carbon nanotube diameter correlated positively with DNA strand breaks (a risk marker for cancer), whereas BET surface area was a predictor of pulmonary inflammation.
Based on animal studies, NIOSH (National Institute of Occupational Safety and Health in the USA) suggested occupational exposure limits of 0.001 mg/m³ for carbon nanotubes and 0.3 mg/m³ for nanosized titanium dioxide.

In conclusion, inhalation of nanomaterials can be linked to risk of cancer and cardiovascular disease. Accordingly, occupational exposure to nanomaterials should be carefully assessed.

Reference List


