Geochemistry, structure, bioaccessibility and health effects of inhalable metal and carbonaceous particles in cast iron foundries

[a]Moroni B, [a]Cappelletti D, [b]Viti C

Epidemiological and in vivo studies suggest that transition metals and carbonaceous compounds may be responsible for a number of adverse health effects, including cancer. This fact poses serious questions of health risk in iron foundries, where numerous sources of inhalable metal and carbon particles are present. Knowledge of the nature, sources, routes, and fate of the chemical species when interacting with biologic tissues is needed to understand the mechanisms lying beneath the observed outcomes. In this work, detailed characterization of morphological, chemical, structural and textural features of metal and carbonaceous particles in iron foundries was carried out in order to correlate particle features with epidemiological and toxicological evidences in this working environment.

Aerosol dust samples from different working stations in cast iron foundry plants were analyzed by scanning and transmission electron microscopy, coupled with image analysis, EDS microanalysis, electron diffraction, and phase contrast imaging. The concentration and the solubility degree of Fe and other metals of potential health effect (Mn, Cr, Ni, Zn, and Pb) in the bulk samples were determined by inductively coupled plasma atomic emission spectrometry (ICP-AES).

The metal particles consist of Fe-rich magnetite nanocrystals, typically 5 to 50 nm in size. Measured d-hkl spacings are slightly larger than those of reference pure magnetite, due to frequent replacement of Fe by Si, Mn, Zn, and Pb. Results from solubility tests reveal Fe and Pb as the most abundant, least soluble elements, while Mn and Zn are the most soluble elements in the aerosols. Due to this fact, and to the small size of particles, direct diffusion into the cell and chemical release of toxic elements into the cytosol may be assumed for moderately soluble particles, while the soluble transition metals may be directly involved in cellular DNA damage.

Carbonaceous material consists of C spherulites, 20 to 100 nm in size, with typical concentric onion-like structures similar to those observed in soot and carbon black. Measured d-spacing are consistent with graphite, while SAED patterns indicate poorly-crystalline structures. Graphite lattice fringes are often overlapped to Fe-rich particles, suggesting the metal particles be embedded in a poorly crystalline graphitic matrix. This occurrence, which is regarded as a potential source of oxidative damage by persistent-free radicals and metal complexes activity, points at mutual interactions between metal and carbonaceous particles.

Low solubility is a common feature of metal and carbon particles in the aerosols. For insoluble particles, measurement of surface area provides a better estimate of the dose than the usual gravimetric expression. This led to magnetite doses of exposition well exceeding threshold limit values resulting from toxicological studies. This observation emphasizes the necessity of employing surface area instead of gravimetric measurements when evaluating occupational exposure.

[a] *Department of Civil and Environmental Engineering, University of Perugia (b.moroni@tiscali.it)*
[b] *Department of Earth Sciences, University of Siena*