CHEMICAL SPECIATION AND MORPHOLOGICAL ANALYSIS OF RESPIRABLE DUST IN FOUNDRIES

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Various studies have related dust exposure of foundry workers to mixed-dust fibrosis,[1-4] bronchial obstruction,[5] and lung cancer.[6] The relationship between silicosis and pulmonary cancer has been constantly mentioned in the last ten years[7-9] leading to the inclusion of silica in the IARC list of compounds which should be regarded as probably carcinogenic to humans.[10] However, many of the epidemiological studies[6-8,11,12] have indicated the almost impossible task of establishing a dose-effect relationship in foundries because of the complexity of workers' exposure, and the lack of data on cumulative exposure to etiologic agents.

The aim of this work was thus to selectively collect foundry dust with granulometric fractions of biological significance and to carry out a comprehensive analysis of these fractions.

Methods

Dust samples were collected at fixed stations with cascade impactors, cyclones and closed cassettes in three ferrous foundries, one aluminum foundry and one copper smelter. Dust characterizations were performed by scanning and transmission electron microscopes fitted with energy dispersive X-ray analyzers (EDXA); X-ray photoelectron spectroscopy (ESCA), secondary ion mass spectrometry (SIMS), X-ray diffractometry, infrared spectrophotometry and atomic absorption spectroscopy.

Results

The melting technique, size of the industry, variety of compositions and whether the installation has dust control equipment are obviously highly related to the observed changes in dust composition. However, in this short presentation, results that are thought to be relevant to the toxicity of these dusts will be emphasized.

Ferrous foundries

The three ferrous foundries (A, B and C) cast ductile iron and gray brass in various types of sand moulds without any organic resins. Figure 1 gives a representative example of

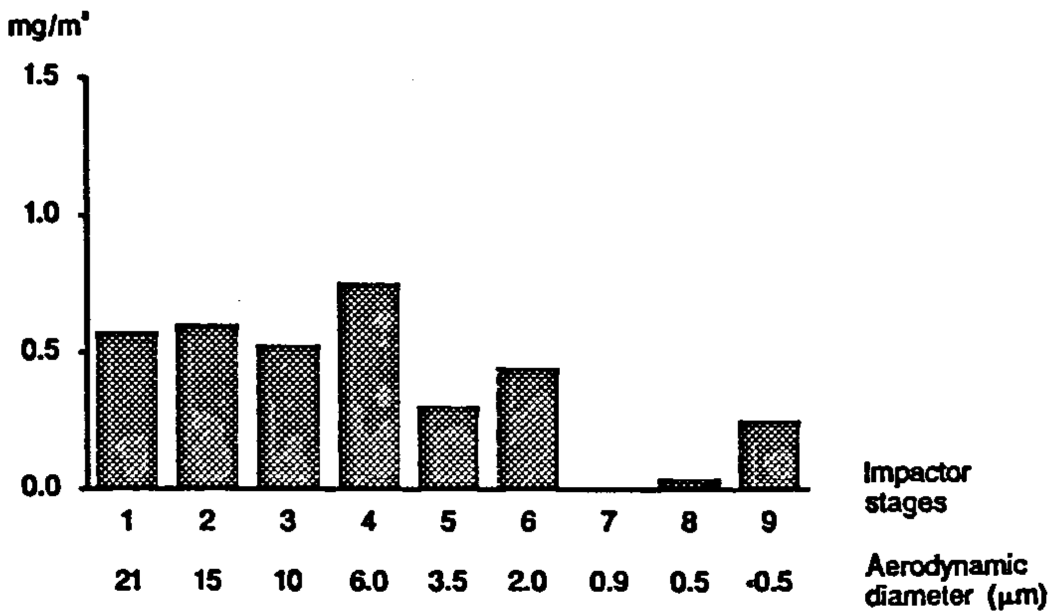

Figure 1. Example of the bimodal distribution of foundry dust as collected with a Sierra Cascade Impactor.

the bimodal distribution of foundry dust as particulate dust (> 2 μm) and fumes (< 0,5 μm) as observed by Dams and Zhang.[13-14]

In this instance, the dust concentration results as sampled with the cascade impactors in the general environment of the casting facility of each foundry can be conveniently separated into three fractions, each fraction being the sum of three successive impactor stages. The average dust concentrations can then be summarized as being 1.7, 1.5 and 1.6 mg/m^3 for particles having aerodynamic diameters larger than 10 μm; 1.3, 2.5 and 0.8 mg/m^3 for particles between 1-10 μg; and 0.3, 2.9 and 0.1 for particles smaller than 1 μm which we will describe as fumes. The striking feature of these results is the comparability of large-particle dust concentrations in the three foundries as compared to the variability of respirable dust and fume concentrations.

The determination of the quartz content of these foundries dusts gives a partial evaluation of their pulmonary toxicity. However, it was observed that the airborne quartz concentrations as sampled with the cascade impactor were 0.08, 0.10 and 0.08 mg/m^3 for particles in the 1-10 μm range, as compared to results of 0.04, 0.05 and 0.01 mg/m^3 as sampled with a standard cyclone for respirable dust. These results can be explained by the absence of quartz in the fume fraction or by the widening of the quartz diffraction line with the decrease in particle size which makes quartz unobservable.

The metallic elements detected in the airborne dust from ferrous foundries are given in Table I in decreasing order of intensity for particles larger or smaller than 1 μm. It is easily seen that the composition of particulates larger than 1 μm is much simpler than that of the fume portion of the aerosol. In contrast to the two other foundries, in foundry B there are significant proportions of lead in the portion of the aerosol composed of particles smaller than 1 μm. Foundry B was the only one melting untreated iron scrap. Elevated lead levels in the blood of scrap metal shop workers have been reported.[14]

Al foundry

The concentrations of dust particles at the Al foundry ranged from 0.6 (>10 μm), 0.4 (1–10 μm) and 0.5 (<1 μm) mg/m^3. The sampling of total inspirable dust with a closed 35 mm—cassette gave an average of 2.6 ± 0.9 mg/m^3 s while respirable dust sampling with a cyclone gave an average of 1.1 ± 0.3 mg/m^3. The analysis of these samples by SIMS, EDXA and ESCA showed a preponderance of NaF on all granulometric fractions with Cl and traces of Zn, and of Mn in particles smaller than 1 μm. Sodium fluoride is a respiratory tract irritant and a cause of fluorosis. The time weighted average concentration for worker exposure has been fixed at 2.5 mg/m^3 as F in the United States.

Cu smelter

Dust concentrations at the reactor and the converter stages of the smelting process were determined. Cascade impactors gave 1.0, 0.3 and 0.45 mg/m^3 for the three same fractions of large particles (> 10 μm), respirable particles (1–10 μm) and fumes (< 1 μm). For comparison purposes, inspirable dust as sampled with 35 mm closed cassette showed an average concentration of 2.6 mg/m^3 and respirable dust sampled with a cyclone was 1.0 mg/m^3.

Quartz, As, Pb and Cu concentrations were compared to TLV^R values to infer a preliminary evaluation of the pulmonary agressivity of these samples. Thus, the As, Pb and Cu concentrations of inhalable dusts were respectively 0.02, 0.23 and 0.26 as compared to the accepted TLV^R of 0.05, 0.15 and 1.0 (fumes: 0.2) mg/m^3.

After extensive characterization by X-ray diffractometry and infrared spectroscopy, it was concluded that most of the lead was present as lead sulphate. The quartz concentration in respirable dust was around 5% as opposed to the 20–30% found in the flux.

In this industry, Fe, Cu and Zn are in general important and constant constituents of all particulate sizes, with lead being

Table I

Principal Elements in Foundry Dust as Measured by Secondary Ion Mass Spectrometry and Photoelectron Spectrosopy

Foundries	Particle size um	Elements (Decreasing order of intensity)
A and C	> 1	Ca, Fe, Zr, F, Zn
	< 1	Mn, Fe, Zn, Cu, Pb, Co, Cr, As, V
B	> 1	Ca, Fe, F, Zn
	< 1	Pb, Fe, Mn, Cu, Zn

Traces of Co, Cr, As, V.

Table II

Principal Elements in Dust from a Cu Smelter as Measured by Secondary Ion Mass Spectrometry (SIMS) and Photoelectron Spectroscopy (ESCA)

Instruments	Particle size um	Elements (Decreasing order of intensity)
Both	> 1	Fe, Cu, Zn (Pb)
Both	< 1	Pb, Fe, Cu, Zn, S, Sn
SIMS	< 1	Br, Ba, In, Sr
ESCA	< 1	Cd, Se

present in particles smaller than 1 µm. The presence of lead in the fume portion of the dust was similarly noted in ferrous foundries. In, Cd, Se and of Sn are also observed in fume particles as well as traces of Ni, V, Cr and As.

Conclusion

A first step has been made in the comprehensive analysis of dust in foundries indicating the following trend: foundry dust can be conveniently separated into three fractions of particles sizes closely associated with inhalable particles (> 10 µm) respirable dust (1–10 µm) and fumes (< 1 µm). The present of lead compounds is largely concentrated in the fume fractions. The presence of quartz is detected in the inhalable and respirable fractions.

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