

In Vitro Toxicity of Silica Substitutes Used for Abrasive Blasting

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INTRODUCTION

Silicosis, a major disabling occupational lung disease caused by the inhalation of crystalline silica, continues to occur on a worldwide basis. In industrialized countries, the disease is well recognized and can be prevented by environmental dust control. Nevertheless, workers using silica sand for the purpose of abrasive blasting remain at increased risk for silicosis and death [Shaman, 1983; Fleming et al., 1990; Abraham and Wiesenfeld, 1997]. Estimates indicate that more than 100,000 workers are employed in sandblasting operations in the United States, and that a large proportion of these workers are at high risk for silicosis [Fleming et al., 1990].

Sandblasting with silica is often associated with the sudden onset and development of acute silicosis (silicoproteinosis), a debilitating lung disease with high mortality and morbidity [Craighead et al., 1988]. The increased mortality and morbidity from sandblasting with silica continues to occur even when respiratory protection is used. In addition, workers adjacent to the sandblasting operations are also at increased risk for developing acute silicosis. Because of the high risk of acute silicosis in sandblasters, its use in many industrialized countries is banned. However, in the United States, silica sand remains the most widely used sandblasting abrasive. Because of the continued use of silica sand in sandblasting and the

increased incidence of acute silicosis in workers, there has been a growing trend to discourage or ban the use of silica in the United States. However, abrasive blasting is an important process in cleaning and preparation of surfaces for painting and other industrial uses. As a result, there is an increased concerted search for efficient and commercially economical substitutes for silica sand, which has led to the identification of some substitutes. Consideration of the substitutes identified were strictly based on three basic qualities, i.e., abrasive property, low crystalline silica content, and economic factors. Several sandblasting substitutes are now commercially available in the United States. The in vitro toxicity studies presented here focussed on a few of the most frequently used substitutes. Because of the known toxicity differences between "fresh" and "aged" crystalline silica, all the blasted particulates were tested within two hours after blasting and then aged for four weeks and tested again [Vallyathan et al., 1995].

MATERIALS AND METHODS

Six abrasive airborne blasting materials (treated sand, sand, garnet, coal slag, specular hematite, and staurolite) were collected by drawing air from a blasting area through a cyclone precipitator and then onto a 4.7 cm, 0.8 μm FWS-B filter within one meter of the operator's breathing zone. Samples of the pre-blasted and post-blasted materials were used for chemical and electron microprobe analyses and comparisons. Samples prepared on polycarbonate filters were analyzed by scanning electron microscopy and X-ray spectrometry to determine equivalent surface area diameter, number count and elemental make-up. Quartz and cristobalite content was determined (2 mg samples) by X-ray diffraction according to NIOSH method 7500 [NIOSH, 1994]. Twenty-four trace metals were determined (0.5 mg

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samples) using a Thermo-Jarrell Ash ICAP61 inductivity coupled plasma atomic emission spectrometer according to NIOSH method 7300 [NIOSH, 1994]. For toxicity studies, rat alveolar macrophages collected by pulmonary lavages were exposed in vitro to various concentrations of blasted particles. Briefly, blasted materials in concentrations from 100–500 µg/ml were incubated with 1×10^6 macrophages in one ml of buffer for one hour at 37°C to induce the release of detectable activities of lactate dehydrogenase (LDH) and *N*-acetyl-β-D glucosaminidase (NAG), (6). Cell viability was measured by the trypan blue dye exclusion method. Measurements of hydroxyl radicals (•OH) generated by the blasted particles were made in a cell-free system in the presence of a spin trap 5,5-dimethyl-1-pyrroline *N*-oxide (DMPO), and H₂O₂ [Vallyathan et al., 1995]. Lipid peroxidation potential was measured by determining the concentration of thiobarbituric acid reactive substance (TBARS) formed by the interaction of the blasted dusts with polyunsaturated linoleic acid [Vallyathan et al., 1995].

RESULTS AND CONCLUSIONS

The blasting process changed the trace metal content of all the blasted particles. Blasting generally increased the relative proportion of iron in blasted materials. This iron was apparently derived from the steel plates that were being

blasted. Blasting also resulted in the generation of particles with an average diameter of one µm. Both fresh and aged blasted particles decreased rat alveolar macrophage viability and increased enzyme release to varying degrees. Toxicity was generally more distinct for staurolite, coal slag, and garnet compared to sand (Fig. 1). The •OH generation from all freshly blasted particles were generally higher than from

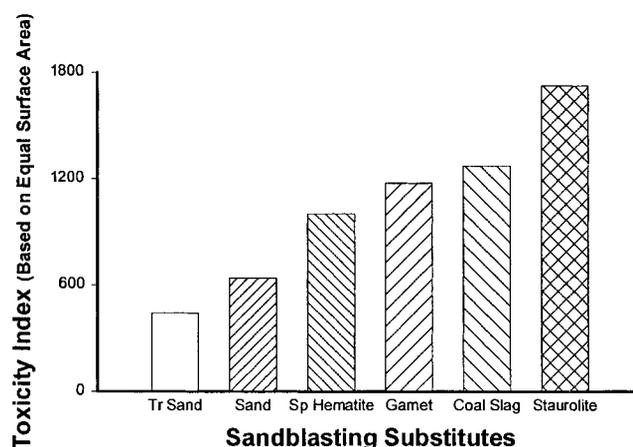


FIGURE 1. Relative toxicity of sandblasting substitutes to alveolar macrophages exposed to dust on equal surface area basis. Toxicity index was derived from the sum total of toxicity data (LDH and NAG) and normalized to equal surface area.

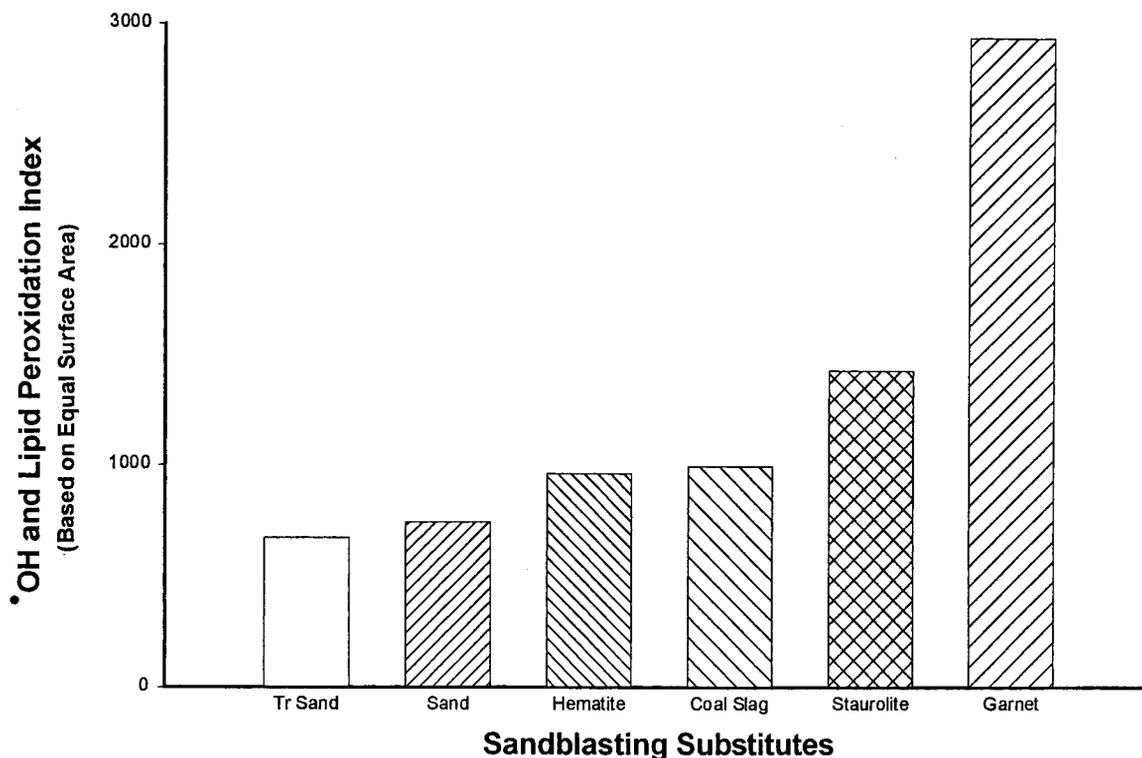


FIGURE 2. Relative •OH radical generation and lipid peroxidation by sandblasting substitutes based on equal surface area of dust. OH and lipid peroxidation index was derived from the sum total of OH generation and TBARS generation normalized to equal surface area.

aged particles. Lipid peroxidation potential was greatest for garnet and staurolite (Fig. 2).

This study demonstrates that silica sand blasting substitutes are not without biological toxic effects. Except for treated sand the toxicity of all substitutes evaluated exceeds that of silica sand on an equal surface area basis. This would indicate that abrasive substitutes may have potential adverse health effects and justifies the need for in vivo studies. The study also documents the importance of focusing on the materials collected from the ambient air, rather than pre-blast materials and materials collected from blasting areas after blasting.

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