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Inhaled nanoparticle tracking and oxidative stress biomarkers in apprentice welders

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Inhaled exposure to welding fumes has been associated with adverse cardiovascular and respiratory health effects. Reactive metallic oxide nanoparticles (NPs) present in welding fume may translocate once inhaled and generate a cascade of oxidative stress effects as well as the release of inflammatory mediators to the circulation. Of various welding processes, Tungsten Inert Gas (TIG) welding generates NPs with aerodynamic diameters most relevant for tracheobronchial and alveolar deposition and represents an increasingly popular welding process. However, significant knowledge gaps in the actual deposited dose after inhalation of TIG welding NPs, their fate in the human body and their ability to induce oxidative stress complicate fundamental cause-effect relationships. To address this pertinent research need, we are conducting a human exposure study with healthy, non-smoking apprentice welders. Volunteers generate TIG welding fumes for one hour in a ventilated exposure cabin, and biological liquids (exhaled breath condensate, blood and urine) are collected at several time points before and after exposure. Particle translocation and several markers of oxidative stress are assessed and compared with volunteer control day measurements. A custom designed welding fume characterization mask provides comprehensive physicochemical characterization data on the TIG NPs at the personal breathing zone (PBZ). We completed the pilot phase of this study to assess Standard Operating Procedures and Limits of Detection for analysis methods. Overall, pilot phase findings assert the validity of our study methodology and analysis methods, and further demonstrate that welding fume generation within the cabin mimic workplace concentrations and remain reproducible between volunteers. Characterization results from particle counters at the PBZ demonstrate average particle concentrations of $1.76x10^6$ particles/cm^3 with peak concentrations reaching $7x10^6$ particles/cm^3 in the time immediately following completion of one welding task. These results further report an average aerodynamic particle diameter of 36 nm ±8nm and TEM micrograph analysis demonstrate chain-like agglomerates of spherical particles. Despite high particle concentrations, gravimetric measurements at the PBZ demonstrate an average mass of 0.33 mg/m^3 – well below internationally accepted welding OELs. This finding of high particle concentrations matched with low mass questions the applicability of mass based OELs, particularly for reactive metal oxide NPs. Due to the uncertainty that remains in regards to the kinetics of oxidative stress response of inhaled welding NPs, combined with widespread and increasing occupational exposure to these particles, this study will provide salient safety information for workers worldwide. The developed methodology will further allow for a non-invasive evaluation of the inhaled NPs target dose and will assess the pathways for circulatory translocation of inhaled NPs.

Keywords: Welding; Inhalation; Nanoparticle; Translocation; Oxidative Stress; Characterization