Grant: AFC820-43

Title: The Effect of Coal and Mine Respirable Dust Size on Lung Cells and Exposure Assessment

Organization: Colorado State University

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Topic: Injury and Disease Exposure and Risk Factors

Priority Area: Respiratory Disease

SYNOPSIS

Problem Statement: Exposure to mine dusts has been recognized as a hazard for decades, and studies have shown that exposure can exceed permissible exposure limits (PEL) in some underground tasks (Glover and Cram 1997, Tomb, Peluso et al. 1998, Naidoo, Seixas et al. 2006, (NIOSH) 2011, Grove, Van Dyk et al. 2014). Inhalation of fine airborne dust particles, such as coal or silica dust, can cause various types of occupational lung disease, including coal workers' pneumoconiosis (CWP), progressive massive fibrosis (PMF), chronic obstructive pulmonary disease (COPD) and silicosis. Submicrometer particles have been reported in the mining environment since the 1950s (Brown, Cook et al. 1950), and the general dangers of exposure to small dust particles were known even earlier (Drinker and Hatch 1936). Modern mining uses larger and more powerful mining equipment, which is more efficient and increases the volume and speed of coal loading and transportation and thus increases the productivity of coal mine extraction. However, an increased amount of total dust is generated from highly productive equipment, and the dust can contain a high proportion of very small particles. The coal mining process, which includes roof bolting, continuous mining, rock dusting, shuttle car driving, bracing and other activities, creates and *exposes miners to a mixture of small particles of respirable size*. Coal dust of submicron size or smaller is constantly generated and inhaled by miners during normal operations at the face area, along with billions of other particles. These very small particles are deposited in the respiratory tract system, specifically in the alveoli region (ICRP 1994), and have much larger surface area per unit volume than larger-sized particles, thus leading to much more biologically active (toxic) interactions (ICRP 1994, Oberdorster, Maynard et al. 2005, Elsaesser and Howard 2012). The prevalence of PMF reached historic lows in the 1990s, but a new outbreak has occurred in recent years, with a sharp increase in 2015-2016 (Blackley, Crum et al. 2016). A report published by the National Academies in 2018 clearly stated the concerns regarding exposure to submicrometer and micrometer particles in the mining environment, along with the need to investigate and evaluate in a timely manner those particles associated with coal production, rock dust use and diesel engine emissions (National Academies 2018). These submicrometer- and nanometer-sized particles are greatly underestimated with regard to miner exposure due to their very low mass and inability to be measured using the traditional gravimetric method. This issue represents a potentially serious but largely unstudied exposure risk in the mining environment.

Research Approach: We will characterize a range of micrometer- to nanometer-sized coal and rock dust using a different metric, particle number count, in addition to mass. We will study toxicity markers indicative of pulmonary disease development for fractions of coal and rock dust of different sizes, including particles in the nano-size range (less than 100 nm). For toxicity assessments, we will use primary human bronchial epithelial cells cultured at the "air-liquid interface" as a 3D cell model representing both the structural and functional aspects of human lung airways. This model will be used for toxicity testing of exposure to nanometer-, submicrometer and micrometer-size particles from coal/rock dust and can also be utilized for future biomarker discovery work. We will study relevant toxicity endpoints including cytotoxicity, oxidative stress, inflammation, cellular uptake of particles and dose dependency of the effects associated with the different fractionated particle sizes. For dust preparation and evaluation, we will use coal dust bulk materials from an underground coal mine and rock dust

to prepare size-fractionated dust samples for the cellular studies. Coal and rock dust will also be characterized, measured and collected on-site at an underground coal mine to evaluate exposure levels and dust constituents in order to correlate exposure levels with the *in vitro* cell studies. We will use two types of sampling techniques including 1) methods available for regulatory compliance such as the personal dust monitor (PDM) and other dust sampling, and 2) nanoparticle sampling methods capable of analyzing submicrometer (including nanometer) and micrometer particles using electron microscopy following collection.

Impact of the Research: Completion of this work will provide new information on the most harmful particle sizes within the respirable size range, such as those less than 100 nm or 500 nm. We will be able to correlate the cellular response effect with dust concentration and size. Based on various endpoints, we will determine the major factors that induce relevant pulmonary diseases such as CWP, as well as other chronic obstructive pulmonary diseases, including asthma and silicosis. In addition, our assessment of airborne coal and rock dust released from practical operations on-site at an underground coal mine will provide novel information on very small-sized particles (including those of nanometer size), such as typical concentrations and elemental composition. Using the results from our on-site assessments, coal/rock dust characterization and the dose-response effect data, we will suggest appropriate methods for measuring the most harmful portions of respirable coal/rock dust and reducing miner exposure to this toxic dust. We will also provide data to suggest no-observed-adverse- effect-level (NOAEL) and lowest-observed-adverse-effect-level (LOAEL) values for exposure to the small-sized dust portion. The generated knowledge concerning hazardous levels of exposure, particularly for nanometer-sized particles, can be used to protect miners and reduce the prevalence of respiratory disease in this population.