Grant: AFC316-17
Title: Further Characterizing Respirable Coal Mine Particulates: Submicron Particles, Metals and Diesel Exhaust

Organization: Virginia Polytechnic Institute and State University

Principal Investigator: Emily Sarver

Partnerships: University of Washington

Topic: Injury and Disease Exposure and Risk Factors
Priority Area: Surveillance and Epidemiology Methods

Problem Statement and Justification: Even with decades of efforts aimed at understanding and reducing occupational lung diseases amongst coal miners, much is still unknown about characteristics of respirable particulates in underground mines and their impacts on health. This problem is related to a variety of factors, not the least of which is that respirable dust exposures are regulated – and thus most often studied – very generally on a mass basis. In the US and elsewhere, for instance, personal exposures to respirable dust in coal mines are quantified by total mass concentration over the exposure period and mass fraction of quartz.

While measuring and targeting reductions of these quantities undoubtedly led to dramatic declines in disease incidence over several decades, in some regions (e.g., central Appalachia in the US) the downward trends in incidence rates have stalled or even appear to be reversing more recently. To date, this alarming observation is still unexplained, but key factors could certainly include lesser-known dust characteristics. For example, submicron particles or trace chemical constituents may exist in such concentrations as to negatively affect health – despite contributing relatively little to the dust mass. To shed light on worker health outcomes, a more fundamental understanding of respirable particulate characteristics is critical.

Impact of the Research: The specific aim of this project is to expand the understanding of respirable particulate characteristics in coal mining environments. In an ongoing study led by the PI, we are already determining dust characteristics that have been scarcely considered until now, namely coal to total mineral mass ratios, and size and compositional distributions of supramicron particles (i.e., 1-10μm). Here, we propose to further that work by investigating additional characteristics, which have been suggested as disease risk factors, but not explicitly studied in coal mine samples. These include: 1) size and compositional distribution of submicron particles (i.e., 0.1-1 μm); 2) mass concentration of potentially bioavailable metals (e.g., Fe, Al) and trace elements (e.g., As, Ni, Mn, Pb); and 3) mass concentration of polyaromatic hydrocarbons (PAHs). We will additionally measure 1-nitropyrene (1-NP), a PAH that is specifically associated with diesel exhaust (DE).

The primary impact of this work will be via new insights into the range of respirable particulate characteristics to which underground coal miners may be exposed. Resulting data will be valuable to both medical and epidemiological researchers studying possible causal factors for the onset and progression of lung or other diseases observed in coal miner populations; and to mining professionals seeking to reduce occupational health risks. Through these contributions, most importantly, this project will impact coal miners by leading to development of more informed best practices for dust monitoring, exposure reduction interventions, or health surveillance.

Objectives and Research Approach: As part of an ongoing project, we have collected an extensive set of respirable dust samples from underground coal mines across Appalachia. Due to use of non-destructive analytical techniques on that project, a total of 209 samples are available for further analysis. They represent multiple sampling locations (e.g., in intake and return airways, near production activities) in eight different mines. Briefly, our research objectives are to define submicron particle size and compositional distributions and measure metal, 1-NP and other PAH mass concentrations in these samples; and to determine if correlations exist between these and mine-specific variables (e.g., major particle generation activities) in locations where samples were collected. This analysis will provide quantitative data on respirable particulate characteristics that have not been measured before. It will thus help the research community bridge the gap between our heretofore only very generalized understanding of occupational exposures and miner health outcomes.

Grant: AFC316-42
Title: Removal of DPM, Silica, and Coal Dust Using High Volume Fog Generation

Organization: Clemson University

Principal Investigators: John R. Saylor, John R. Wagner

Partnerships: Lhoist North America, Joy Global, Inc.

Topic: Health and Safety Interventions
Priority Area: Respirable Dust

Problem Statement and Justification: The problem that will be addressed in the proposed research is the elevated risk of respiratory illness that exists for the mining work force, which is caused by exposure to airborne particles in the mining environment. In particular, diesel particulate matter (DPM) is a growing concern in metal/nonmetal mines where more than 18,000 miners work in approximately 200 underground mines. DPM is a significant concern since the particles formed are virtually all submicron in size and easily penetrate into the lung. Furthermore, DPM particles reside in the mining environment for long periods due to an essentially zero settling velocity. DPM has been classified as a known human carcinogen and chronic exposure increases the risk of cardiovascular, cardiopulmonary, and respiratory disease. Evidence continues to accumulate suggesting that diesel exhaust in general and DPM in particular increase the risk of cancer. Because DPM is mostly confined to the nanoscale particle diameters, methods for removing it from vehicular exhaust are challenging, since the particles have virtually no inertia at these small diameters, and inertia is an effective way to force particles to impact a filter or other type of impactor. Hence, effective removal of DPM and other nanoparticles must rely in the diffusive motion of these small particles. Since the characteristic length of diffusion tends to be small for the time scales of a particle traveling through a finite sized scavenging system, the overall process of removing nanoparticles can be problematic. Though the problem that is the focus of the proposed work is DPM, the resulting technology will be effective at removing nanoparticles of any type of particle, including coal and silica. Furthermore, since nanoparticles are the more challenging type of particle to remove, success in this small diameter range will also be easily translated to larger coal and silica particles as well. The proposed technology is therefore universal in that it is effective on any type of particle as long as the source is localized.

Impact of the Research: The specific aims of the proposed research are to develop what is referred to here as a "fog scrubber" which is a method whereby a very large number density of fog drops are generated and are combined with the DPM particles in diesel exhaust. By combining nanoscale DPM particles with the relatively large fog drops (5um to 10um in diameter), the DPM particles are effectively "packaged" in drops that can be removed via proven inertially-based particle removal technologies, specifically, a cyclone separator, thereby providing a device for reducing dust levels in mines. The research community's knowledge of how drops can be used to scavenge particles will be significantly developed by the proposed research.

Objectives and Research Approach: The major output will be a fog scrubber capable of removing particles down to the 10nm range. This will enable removal of these dangerous particles of all kinds from point sources. Gaps in our knowledge of how nanoparticles and drops interact will be addressed.

Grant: AFC316-49
Title: Experimental Testing and Design of Protective Measures for Communications and Tracking Systems Subjected to Catastrophic Events in Underground Coal Mines

Organization: The University of Kentucky

Principal Investigators: Jhon Silva, Thomas Novak

Partnerships: None

Topic: Mine Escape, Rescue, and Training
Priority Area: Communications and Tracking Survivability

Problem Statement and Justification: Post-accident emergency communications and tracking (C&T) systems are now installed in all underground coal mines, as required by the Mine Improvement and New Emergency Response Act (MINER Act) of 2006. However, many questions remain about whether C&T installations will survive catastrophic events, as intended by the MINER Act. To date, no in-depth testing has occurred to answer these questions or to make recommendations to help ensure the operational survival of these systems. The proposed research will investigate experimentally the forces created by catastrophic events, particularly explosions and roof falls, and their effects on the survivability of C&T systems. Additionally, practical measures will be investigated and recommended to improve survivability based on these findings.

Impact of the Research: Practical measures for protecting C&T systems will be defined to improve their survivability following explosions and roof falls. Improving the survivability of C&T systems following a mine catastrophe will increase the probability of miners escaping or being rescued in a shorter period of time, compared to a scenario where no in-mine information is available because the C&T system is not operational. Knowing the exact locations of miners, or having communications with them after a disaster, will significantly expedite search and rescue efforts. Also, if trapped miners can communicate with rescue teams, the safety of the teams will increase considerably.

Objectives and Research Approach: The overarching objective of the proposed work is to improve a miner's chance for self-escape or being rescued following a catastrophic event by investigating and improving the post-accident survivability of C&T systems. The proposed research will focus on investigating the forces created by catastrophic events (explosions and roof falls) and their effects on C&T systems. To accomplish this, the following objectives are proposed:

- To identify the common installation techniques and system layouts presently being used for the various types of communication systems, e.g. wireless nodes, wired nodes, and leaky feeder systems.
- To find the ideal detonation in a shock tube, equivalent to the MSHA recommended pressure curve time of 15 psi for C&T system elements.
- To assess the damage extent and failure modes of the C&T system elements using as minimum the explosive force of design.
- To assess the post-explosion survivability of the C&T system elements.
- To identify practical protection measures to improve the survivability of the C&T system components against explosions.
- To improve the survivability of the C&T system elements for flying debris.

Several tests will be developed in the explosives research facility at the University of Kentucky. Various components of C&T systems will be subjected to a series of explosions (non-destructive and destructive) in a shock tube that simulates the most likely methane and/or coal dust explosions that may occur in an underground coal mine. Initially, the C&T system elements will be subjected to explosions for different orientations and without any level of protection. Once the failure mechanism and level of damage of the C&T components, and the magnitude and characteristics of the explosive forces, are determined, different protection techniques will be investigated. Furthermore, to simulate flying debris associated with explosions and roof falls, the C&T elements will be subjected to impact tests in a modified Hopkinson-Bar apparatus. Based on the test results, protection schemes will be generated. These schemes must be practical while maintaining the functionality of the C&T system.

Grant: AFC316-53
Title: Linkage of Active Miner Surveillance, Former Miner Disability Evaluations, and Mortality Data Sets to Evaluate and Prevent Lifetime Risk of Cardiopulmonary Disease in U.S. Miners

Organization: University of Illinois

Principal Investigators: Robert Cohen, Cecile Rose

Partnerships: National Institute for Occupational Safety and Health, Department of Labor

Topic: Injury and Disease Exposure and Risk Factors
Priority Area: Surveillance and Epidemiology Methods

Problem Statement and Justification: There are an estimated 83,000 coal, 71,000 metal/non-metal and 99,000 stone/sand/gravel miners actively employed in the United States. The number of former miners is more difficult to ascertain but is likely much higher; the United Mine Workers of America (UMWA) health and pension funds provide for more than 77,000 miners, which represent only a portion of former coal workers. Miners suffer an excess of chronic respiratory diseases as well as other adverse health effects from their occupational exposures despite modern mining technology, dust control methods, and dust control regulations. Coal miners are a unique subset of miners for whom several national data sets exist that allow in-depth study of their health, data that has broad applicability to other populations of miners. Occupational exposure to coal mine dust can cause a broad spectrum of respiratory diseases, includng lung funciton impairment, and chronic obstructive pulmonary disease (COPD), encompassed by the term coal mine dust lung disease (CMDLD). Despite remarkable progress in reducing pneumoconiosis in coal miners after implementation of the Federal Coal Mine Health and Safety Act of 1969 (The Act), recently this trend has reversed. Equally disturbing is the increased incidence of rapidly progressive pneumoconiosis (RPP) and progressive massive fibrosis (PMF) now being seen in relatively young coal miners. Recent studies have drawn attention to the causal importance of the respirable silica component of coal mine dust in these diseases. The U.S. mining population is also exposed to the stress of noise, vibration, shift work, and diesel exhaust, all of which have been associated with adverse health outcomes with the potential for increased mortality.

Impact of the Research: Our research builds on findings from our first Alpha Foundation project in which we analyzed 50,000 Department of Labor (DOL) Black Lung Benefits Program (BLBP) claims filed between 2000 and 2013. This data showed substantial lung function impairment and a higher proportion of severe pneumoconiosis on radiographs of coal miners who started working after passage of dust control regulations in 1970. Our current proposed study will link demographic, radiologic, and physiologic data from two large miners' lung health data sets for the first time. These are the National Institute for Occupational Safety and Health (NIOSH) Coal Workers' Health Surveillance Program (CWHSP) of younger active miners and the DOL BLBP data on mainly former miners, and add mortality data from the National Death Index (NDI). Specific Aim 1 will link these data sets to better characterize miner populations over the adult lifespan and factors associated with participation in each program. Specific Aim 2 will examine these data sets to identify factors that affect the severity and rate of progression of lung disease. Specific Aim 3 will analyze all-cause mortality as well as cause-specific mortality rates to examine the burden of cardiopulmonary disease among miners compared to non-miners from the National Vital Statistics System (NVSS) and the National Health and Nutrition Examination Survey (NHANES). Findings will provide in-depth information on workplace and personal risk factors for these diseases and their progression in miners; inform targeted health promotion and prevention strategies; and support evidence-based policies for use by industry, labor and regulatory bodies to meet the emerging health needs of the U.S. mining population.

Objectives and Research Approach: Our research approach will provide the first-ever linkage of three large data sets (CWHSP, BLBP and NDI) using deterministic and probabilistic methods to evaluate cardiopulmonary disease during and after mining employment. Major expected outputs include: 1) information on demographic, geographic and employment characteristics of diseased miners who appear in both the CWHSP and BLBP data sets; 2) insight into risk factors for and rates of longitudinal lung radiographic progression and physiologic decline in these populations; and 3) information on all-cause mortality as well as cause-specific mortality with a special focus on respiratory and cardiovascular causes in deceased miners in relation to demographic, personal, clinical, and occupational risk factors. These findings will inform future efforts focused on prevention and early detection of cardiovascular disease and mining-related lung disease.

Grant AFC316-54
Title: Chronic Obstructive Pulmonary Disease (COPD) Mortality and Diesel Exhaust in Miners

Organization: University of California, Berkeley

Principal Investigator: Ellen A. Eisen

Partnerships: National Cancer Institute, Division of Cancer Epidemiology and Genetics

Topic: Injury and Disease Exposure and Risk Factors
Priority Area: Surveillance and Epidemiology Methods

Problem Statement and Justification: We propose to study chronic obstructive pulmonary disease (COPD) mortality among underground and surface miners in the Diesel Exhaust in Miners Study (DEMS). We focus on COPD, rather than asthma, because the airway inflammation enhanced by diesel particles appears to play a role in a broader array of respiratory and allergic diseases. In the original DEMS study, the SMR for COPD was 0.86, suggesting a slightly protective effect of work in the mines. Results stratified by work location were even more counterintuitive; the SMR was higher for miners who worked only on the surface than for miners who worked underground, 0.95 versus 0.80, respectively. Rather than accepting these SMRs at face value, we believe that together with the biologic literature, they provide compelling evidence of bias. SMRs rely on the general population as the unexposed reference group – a group which is not comparable to miners in terms of underlying health status since it includes individuals unfit for work. Thus the SMR for chronic lung diseases likely obscures the true diesel hazard in mines, particularly for underground miners. In a recent published review of the literature, we concluded that the evidence suggests diesel exhaust increases the risk of COPD, but that quantitative exposure metrics are needed to specify the exposure-response relation.

Impact of the Research: We propose to examine diesel exhaust-related risk of COPD, using data from DEMS, a NIOSH and NCI study of 12,315 miners in 8 U.S. non-metal mines. We will examine quantitative estimates of long term exposure to diesel exhaust, measured as respirable elemental carbon (REC), in relation to COPD mortality in miners who worked at the surface or below ground. We will apply the parametric g-formula, implemented as intervention studies designed to assess risk of COPD under a series of exposure scenarios based on plausible exposure limits for diesel exposure in mines. This approach addresses the healthy worker survivor effect (HWSE), as characterized by a time-varying confounder (leaving work) that is also caused by prior exposure and therefore on the causal pathway from exposure to death. Because the REC estimates were based on an extensive retrospective exposure assessment conducted by NIOSH scientists, this study will fill the scientific research gap. Because our analytic strategy addresses HWSE bias, we will be able to estimate the unbiased risk of COPD under specified exposure limits of diesel, which can be used to guide standards for both surface and underground mining.

Objectives and Research Approach: We will estimate a quantitative exposure-response curve for diesel exhaust and COPD mortality based on the NIOSH exposure assessment, using an internal reference group of lower exposed miners, and adjusting for confounding by smoking. We will also address the HWSE bias that arises when miners with respiratory symptoms leave work or transfer from underground to surface jobs with lower exposure. We will produce two manuscripts that will clarify the long-term risk of COPD and provide the health basis for considering diesel standards in mines.

Grant: AFC316-61
Title: Systematic Evaluation of Multi-axial Suspension to Reduce Whole Body Vibration Exposures in Heavy Equipment Mining Vehicle Operators

Organization: Oregon State University

Principal Investigator: Jeong Ho Kim

Partnerships: Northeastern University, University of Washington, Bose Corporation

Topic: Injury and Disease Exposure and Risk Factors
Priority Area: Musculoskeletal Disorders

Problem Statement and Justification: Mining vehicle operators suffer from a high prevalence of musculoskeletal disorders (MSDs). These operators are exposed to multiple risk factors for MSDs, including whole body vibration (WBV) and sedentary work (prolonged, static sitting). Mining vehicle operators are exposed to high levels of WBV exposures, one of the leading risk factors for the development of MSDs (especially, low back disorders) in professional vehicle operators. Current engineering controls to reduce WBV exposures rely on a passive vertical (z-axis) suspension system. However, in off-road vehicles such as mining vehicles, WBV exposures are multi-axial in nature, meaning that the predominant WBV exposure axis is not necessarily limited to the vertical (z-axis) but can be either fore-aft (x-axis) or lateral (y-axis). Therefore, the current industry standard seats with single-axial (vertical) passive suspension may be less effective in reducing the multi-axial components of WBV exposures among mining vehicle operators. Furthermore, because of the substantial mass of the torso and head, such multi-axial components of WBV exposure can not only substantially increase shear forces in the back and neck, but also muscle loads to counterbalance the inertia of the torso and head. Given the extended vehicle operation hours (i.e. prolonged exposed to multi-axial WBV), the increased muscle loads can cause overuse and damage to the low back and neck muscles. Therefore, mining vehicle operators exposed to multi-axial WBV are at even greater risks for MSDs, especially in the low back and neck as compared to on-road drivers whose WBV exposures are predominantly on the vertical axis (vertical-axial WBV).

Impact of the Research: With the high prevalence of injuries and MSDs in the mining industry, this research will have direct impact on mining vehicle operators by reducing WBV exposures through engineering interventions (evaluation of multi-axial active suspension and alternative seat suspension systems); we will in turn improve their musculoskeletal health. Aim 1's impact will be the reduction of multi-axial WBV exposures and the associated biomechanical loading on the low back and neck through an engineering intervention, a multi-axial active suspension seat for mining vehicles. Aim 2's impact will be to identify other affordable alternative engineering controls (seats) to reduce WBV exposures for mining vehicle operators. The knowledge gained during this project will be translated into practice with the short-term objective of providing mining vehicle operators and industry stakeholders with effective seating recommendations for reducing WBV exposures and the long-term objective of reducing MSDs affecting mining vehicle operators.

Objectives and Research Approach: The primary objective of this study is to determine whether there are differences between a single-axial passive suspension seat (current industry standard) and a new multi-axial active suspension seat in reducing the mining vehicle operators' exposures to WBV and the corresponding biomechanical loading. This primary objective will be achieved by Aim 1 & 2: Determine the efficacy of different engineering controls (mining vehicle seat suspensions) in reducing the multi-axial WBV exposures in mining vehicles and the associated biomechanical loading on the musculoskeletal system. Using a repeated-measures design, we will evaluate the WBV attenuation performance of the two main engineering controls (Aim 1) and two lower-cost alternative engineering controls (Aim 2) in a laboratory setting. Using actual field-measured mining vehicle WBV exposures played back into a large scale motion platform for four hours, we will collect and compare WBV exposures (per ISO 2631-1 and 2631-5 standards), muscle activity, and joint torques in the neck and low back between a single-axial passive suspension and multi-axial active suspension seat (Aim 1). Lower-cost alternative passive seat suspension technologies will also be evaluated in the similar manner (Aim 2). The expected outcomes of Aim 1 & 2 will be identifying effective engineering controls to reduce WBV exposures in mining vehicle operators and associated biomechanical loading.