Evaluation of high-temperature disposable filter elements in an experimental underground mine

A.D. Bugarski, G.H. Schnakenberg, Jr., J.A. Hummer, E.G. Cauda, S. J. Janisko and L.D. Patts
Lead research engineer, senior research scientist (retired), engineering technician,
research scientist, mechanical engineer and physical scientist, respectively
National Institute for Occupational Safety and Health,
Office of Mining Safety and Health Research, Pittsburgh, PA

Abstract

Filtration systems with disposable filter elements (DFEs) are used in the underground coal mining industry to control particulate matter emissions from diesel-powered permissible and nonpermissible coal mining equipment. This study was conducted in underground mine conditions to evaluate three types of high-temperature DFEs used in those filtration systems. The DFEs were evaluated for their effects on the concentrations and size distributions of diesel aerosols and concentrations of nitric oxide (NO) and nitrogen dioxide (NO_2). Those effects were compared with the effects of a standard muffler. The experimental work was conducted directly in an underground environment using a unique diesel laboratory developed in an underground experimental mine. After an initial DFE degreening period, the filtration system with all three DFEs was found to be very effective at reducing total mass concentrations of aerosols in the mine air. The effectiveness of DFEs in filtering aerosol mass was found to be a function of the engine operating conditions. The efficiency of the new DFEs significantly increased with operating time and buildup of diesel particulate matter in the porous structure of the filter elements. A single laundering process did not exhibit substantial effects on the performance of the DFE elements. The effectiveness of DFEs in removing aerosols by number was strongly influenced by engine operating mode. The concentrations of nucleation mode aerosols in the mine air were found to be substantially higher for DFEs when the engine was operated at high-load modes rather than at low-load modes. Initial heating of certain DFEs resulted in visible white smoke and substantially elevated aerosol number concentrations. The effects of the DFEs on the total concentration of nitrogen oxides (NO_X) were found to be minor. The NO_2 fraction was found to be generally lower for the DFEs than for the muffler. The engine-out NO_2 fraction of the total NO_X was found to be substantially higher for low-load modes than for high-load modes..

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Key words: Diesel; Ventilation; Disposable filter elements

Introduction

In recent years, health effects associated with exposure to diesel particulate matter (DPM) and other, primarily combustion-generated, nano and ultrafine aerosols have received substantial attention from the public, government agencies and academia. Pope et al. (2002) established that long-term exposure to combustion-related fine particulate pollution is an important risk factor for cardiopulmonary and lung cancer mortality. There is growing evidence suggesting that particle number, surface area, size or, perhaps, some associated structural properties may affect nanoparticle toxicity (Donaldson and Stone, 2003). Based on the above evidence, occupational health risks associated with exposure to nano and ultrafine aerosols warrant further study.

DPM is a complex mixture of solid and liquid aerosols typically present in nucleation and accumulation modes (Kittelson, 1998). DPM exposures in underground metal/nonmetal mines are currently being regulated solely on the basis of the total and elemental carbon mass per unit volume of air (30 CFR 5060). For coal mines, the total particulate mass emission rate is regulated and, in most cases, requires the use of diesel particulate filtration systems for compliance (30 CFR Part 72). Unfortunately, no reference is made in either regulation to exposure to size, number or surface area of the airborne particles. Mass-based exposure assessments are not always fully predictive of disease risk; in some cases, respirable particle surface area and detailed surface compositional or morphological properties better correlate with toxicity, or they offer an explanation of seeming anomalies in epidemiological findings of disease risk (Wallace et al., 1990). In an attempt to assess the adverse health impacts of nano and ultrafine aerosols, past studies indicate the importance of complementing mass-based exposure monitoring with measurements of size, number, and surface area of aerosols (Donaldson et al., 2000; Oberdörster,

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