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Retrofitting and repowering as control strategies for the curtailment of exposure of underground miners to diesel aerosols

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Special Extended Abstract

Reducing the contribution of heavy- and light-duty diesel-powered equipment to concentrations of aerosols and gases is essential to industry's efforts to improve air quality in underground mining operations. The results of this study demonstrated a potential of control strategies based on retrofitting existing power packages with diesel oxidation catalyst (DOC) and diesel particulate filter (DPF) systems and repowering existing systems with advanced power packages to reduce contributions of diesel-powered vehicles to concentrations of diesel aerosols and criteria gases in underground mines. The implementation of viable exhaust aftertreatment systems and advanced diesel power packages could be instrumental in the underground mining industry securing a clean, economical and dependable source of power for mobile equipment.

Introduction

Because of the extensive use of diesel-powered equipment in the underground mining industry, some miners are exposed to elevated concentrations of diesel aerosols [1]. Exposures to diesel exhaust have been linked to various adverse acute and chronic health outcomes [2–5]. In 2012, the International Agency for Research on Cancer categorized diesel engine exhaust as a carcinogen to humans (Group 1) [6]. Exposures of underground miners to aerosols and gases emitted by diesel engines could be effectively controlled through the implementation of a variety of integrated, multifaceted control strategies — elimination, substitution, engineering controls, administrative controls and the use of personal protective equipment [7]. The rapid developments in engine combustion technologies [8], exhaust aftertreatment technologies [9] and alternative fuels [10] have had profound effects on the levels of diesel emissions and the physical and chemical properties of aerosols emitted by diesel engines [11]. Those advancements could be instrumental to the underground mining industry's efforts to comply with personal exposure limits for DPM [12–13].

Methodology

The potential of selected diesel emissions control strategies based on retrofitting existing power packages with exhaust aftertreatment devices and repowering with advanced power packages were examined using the results of laboratory evaluations of two electronically controlled turbocharged diesel engines with similar power ratings, but from different generations.

The retrofit systems, a DOC system and a DPF system, were evaluated individually using a U.S. EPA Tier 2 engine. Both the DOC Model MinNoDOC from AirFlow Catalyst Systems, Rochester, NY, and full-flow DPF system Model Green Trap 1100 from NETT Technologies, Mississauga, ON, were optimized for use in underground environments by impregnating their washcoats with a catalyst formulation that was designed to suppress generation of secondary NO_2 emissions. The strategy of repowering with an advanced system was examined using a U.S. EPA Tier 4 final (Tier 4f) engine equipped with a cooled exhaust gas recirculation system and diesel exhaust fluid-based selective catalytic reduction system, but not with a DPF system. The emissions for both engines were assessed for four steady-state (SS) conditions and one transient cycle (TR). Throughout the study, both engines were fueled with ultralow sulfur diesel obtained from a single batch.

Aerosol measurements and filter samplings for aerosol characterizations were executed in exhaust diluted approximately 30 times using a two-stage partial dilution system (Dekati, Model FPS4000). The fast mobility particle sizer (FMPS, TSI Model 3091) spectrometer was used to measure the number concentrations and size distributions of aerosols. Triplicate filter samples were collected on quartz fiber filters and analyzed for organic carbon (OC) and elemental carbon (EC) using the thermal optical transmittance-evolve gas analysis (TOT-EGA) method following NIOSH Method 5040 [14]. The concentrations of CO, NO and NO_2 were measured in undiluted exhaust using a Fourier transform infrared (FTIR) spectrometer (Gasmet, DX-4000).

Key results

The results showed that, depending on the SS operating mode, the evaluated DOC reduced on average 20 to 83 percent of OC and 24 to 49 percent of EC mass concentrations in exhaust emitted by the Tier 2 engine (Figs. 1a and 1b). At TR conditions, the use of the DOC resulted in slight increases, within measurement error range, in average OC and EC mass concentrations. For the SS tests, the DOC reduced the average number concentrations of aerosols emitted by the Tier 2 engine by 22 to 52 percent (Fig. 1c). In the case of TR tests, the DOC on average increased number concentrations of aerosols emitted by the Tier 2 engine by 62 percent. When retrofitted with the DOC and operated at the SS modes, the Tier 2 engine emitted aerosols distributed in single accumulation mode with the count median diameters similar to those observed for the size distributions of aerosols emitted by the same engine operated without DOC. The peak concentrations emitted by the Tier 2 engine retrofitted with DOC were found to be somewhat lower than those of the agglomeration aerosols emitted by the same engine when operated without aftertreatment at SS modes. The increase in the average number concentrations observed after the Tier 2 engine was retrofitted with DOC and operated over TR conditions can be primarily attributed to the increase in concentrations of nucleation mode aerosols.

The evaluated DPF removed on average more than 92 percent of OC mass, 98 percent of EC mass and 99 percent of aerosols by number emitted by the Tier 2 engine at SS and TR conditions (Fig. 1). The aerosols in the DPF-treated exhaust of the Tier 2 engine were distributed between two or three modes. Nucleation mode aerosols with count median diameters around 10 nm were found in the filtered exhaust for all SS and TR operating conditions. The concentrations of nucleation mode aerosols were comparable or less than those of accumulation mode aerosols. Both the DOC and DPF achieved reductions in the aerosol emissions without adversely affecting emissions of NO_2.

The Tier 4f engine emitted between 23 and 93 percent less OC and between 43 and 88 percent less EC than the Tier 2 engine without aftertreatment (Fig. 1). However, the average number concentrations of aerosols emitted by the Tier 4f engine were between 88 and 99 percent higher than the corresponding average concentrations in the exhaust of the DPF-filtered Tier 2 engine. The distributions of aerosols emitted by the Tier 4f engine were bimodal with the majority of aerosols in the accumulation mode, and the remaining aerosols distributed in less pronounced nucleation modes. It is important to note that the count median diameters of the agglomeration aerosol emitted by the Tier 4f engine were 10 to 25 nm smaller than those of the agglomeration aerosols emitted by the Tier 2 engine, when operated without aftertreatment and with DOC. At the corresponding engine operating conditions, the Tier 4f engine emitted on average between 59 and 99 percent less CO, between 70 and 93 percent less NO and between 30 and 97 percent less NO_2 than the Tier 2 engine operated without aftertreatment. ■

Disclaimer

The findings and conclusions in this paper are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of company names or products does not constitute endorsement by NIOSH.

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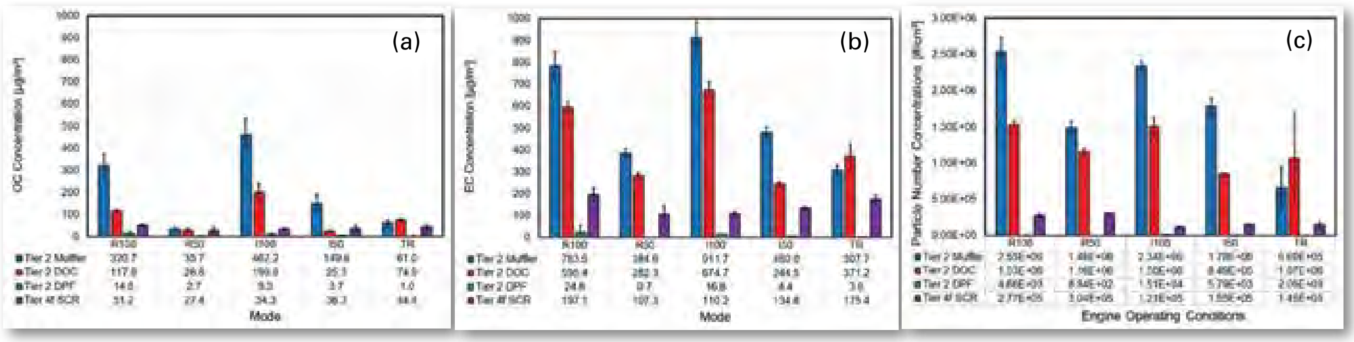

Fig. 1 Effects of the evaluated engine/exhaust aftertreatment technologies on average concentrations of (a) OC, (b) EC and (c) number concentrations of aerosols in diluted exhaust (30 times).

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The occurrence and concentration of rare earth elements in acid mine drainage and treatment byproducts. Part 2: Regional survey of northern and central Appalachian coal basins

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Special Extended Abstract

Many modern industries rely on rare earth elements (REEs) to produce products that are essential to both civil and defense applications. In a prior study (Vass et al., 2019), we showed that REE grades in acid mine drainage (AMD) and associated byproduct precipitates from AMD treatment (AMDp) warrant evaluation as a feedstock for REE production. The current work extends that effort through a broad survey of 141 AMD treatment sites in Northern and Central Appalachia. In this study, 185 raw AMD and 623 AMDp field samples were obtained and analyzed to assess the REE and major metal concentrations. Results show that an average of 282 µg/L and 724 g/t of REEs occur in AMD and AMDp, respectively. Additionally, both basins contained similar distributions of REEs, and these distributions tended to favor heavy and critical REEs when compared with traditional REE ore deposits.

Background

REEs are essential for many industrial processes and advanced-technology end-use applications, including catalysts, metallurgy, petroleum refining, catalytic converters, ceramics, glass additives, phosphors, magnets and electronics. In recent years, growing concerns over the REE supply chain as well as the risks associated with REE supply shortages have prompted many stakeholders to identify and evaluate alternative and unconventional REE resources.

The presence of REEs in coal has long been established by many researchers, dating back to at least the 1960s and 1970s. The first paper in this series showed that this REE enrichment also extends to acid mine drainage, a deleterious byproduct generated through coal mining [1]. In that study, we suggested that the generation and treatment of AMD is analogous to a natural heap leach, and these processes provide an initial stage of REE concentration. A prospecting survey of nine AMD treatment sites showed that the AMD treatment byproducts (AMDp) had an REE concentration 7.8 times greater than that of U.S. coal and 2.5 times greater than the average crustal abundance. We also showed that the availability of REEs from AMD is likely to be between 771 and 3,400 t per year, based on two distinct estimation procedures.

Given the promising findings in the initial survey, we pursued a comprehensive sampling program to characterize the AMD-based REE resource in two important Eastern U.S. coalfields. The program included 141 AMD treatment sites in the Northern and Central Appalachian (NAPP and CAPP) coal basins. The sites were extensively sampled to determine regional production, storage and elemental distributions of REEs and critical minerals within the AMD-based resource.

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