Journal of Powder Metallurgy & Mining (JPMM) is a semestral, scientific journal that publishes theoretical and empirical peer-reviewed articles, which contribute to advance the understanding of phenomena related with all aspects of Powder metallurgy and mining. It is very diverse, has the potential to create many new materials blending fine powdered materials, pressing them into a desired shape (compacted), and then heating the compressed material in a controlled atmosphere to bond the material.

Journal of Powder Metallurgy & Mining publishes, the most exciting researches with respect to the subjects of Powder metallurgy and mining to provide a rapid turn-around time possible for reviewing and publishing, and to disseminate the articles freely for research, teaching and reference purposes.

Journal of Powder Metallurgy and Mining

Editors & Editorial Board

http://omicsgroup.org/journals/jpmmhome.php

OMICS Publishing Group
Assessment of Environmental Impact of Drilling Equipment

Ali Lashgari* and Vladislav Kecojevic
Department of Mining Engineering, West Virginia University, Morgantown, West Virginia, USA

Abstract

The major environmental issues in drilling operations are related to air pollutants and sound exposure. The environmental impact is assessed through the equipment exhaust and dust emissions, and sound pressure level. Exhaust emissions contain gases such as carbon dioxide, carbon monoxide, nitrogen oxides (NOx), sulfur oxides (SOx) and volatile organic compounds (VOCs). Dust generation is expressed through the particulate matter (PM10) and total suspended particulate matter (TSP). In this study, the modeling of environmental impact of drilling equipment was conducted using Microsoft Visual Studio.NET software. The results show that the annual fuel consumption for eight drilling machines in the mine was 1.62 million liters, hourly CO, NO NOx, SOx, and the total hourly and annual CO2 emission for all drills in the mine were determined to be 1,720 kg and 4,344,570 kg, respectively. The results of this work may be used by mining professionals to aid in quantifying environmental impact of drilling equipment.

Keywords: Drilling equipment; Environmental impact; Drilling machines; NEMS; EPPA

Introduction

The main goal in selection of drilling equipment is to maximize production rate while minimizing overall cost and environmental impact. Major environmental issues in drilling operations are related to air pollutants and sound exposure. Air pollutants include particulate matter (PM10), total suspended particulate matter (TSP), carbon dioxide (CO2), carbon monoxide (CO), nitrogen oxides (NOx), sulfur oxides (SOx) and volatile organic compounds (VOCs).

A number of studies have been conducted to analyze emissions from mining and construction equipment. Lewis et al. [1] described governmental regulations that limit emission of air pollutants. Sharrard et al. [2] conducted research on the environmental and energy implications in the construction industry and concluded that the fuel consumption of equipment is almost twice the level indicated in various governmental reports; that the impact of air emission is 30% greater for particulate matter and almost twice the levels for NOx and VOCs. Kean et al. conducted a study to determine emissions of NOx and PM10 for off-road diesel equipment based on the diesel fuel consumption. Gautam et al. [3] used an in-field testing method to determine emission factors for diesel powered off-road engines, including excavators, front-end loaders, dozers, and street sweepers. Bogunovic and Kecojevic [4] conducted research to determine CO2 emissions of surface mining equipment. Lewis et al. [5] estimated fuel consumption, exhaust, and dust emissions of excavators, track loaders, wheel loaders, backhoes, dozers, off-road trucks, and motor graders. Frey et al. [6] used a portable emission monitoring system to gather data from excavators, backhoes, dozers, track type loaders, wheel loaders, graders, generators and off-road trucks. Dallmann and Harley [7] conducted a research to determine the emission exhausts for NOx and fine particulate matter (PM2.5) from mobile equipment using a fuel-based methodology. Kecojevic and Kojic [8] determined the quantity of CO2 emitted by haul trucks and associated costs that may arise from potential CO2 legislation.

Organiscak and Reed [9] described the average and instantaneous peak dust levels 30 m from haul roads. The authors also published the results of research related to the evaluation of safe following distance for equipment in order to avoid overexposure to respirable dust from lead trucks [10].

Overexposure to sound is an important health hazard. According to Kovalchik et al. [11], many health hazards associated with mining operations have improved, with the exception of hearing loss. Excessive sound levels are detrimental to mine workers. Bolt et al. [12] established empirically-based relationships of heavy equipment sound exposure as a function of horsepower. In 1982, the Federal Highway Administration (FHWA) published a standardized construction sound model called Highway construction noise model [13]. More recently, a number of models have been developed for the prediction of sound exposure in construction projects, such as CadnaA, SoundPLAN, and the Environmental Noise Model [14]. In these models, equipment sound data is expressed as a sound pressure level at a reference distance.

The objective of this study was to assess environmental impact of drilling equipment in surface coal mining. This research is a portion of a broader project on the development of software systems for the selection of productive, cost-effective, and eco-friendly mining systems. It is sponsored by the Appalachian Research Initiatives for Environmental Sciences (ARIES).

Method

Data for this project was collected from an operating surface coal mine in West Virginia. The mine has been active since the early 1970s. Geologic formations in the mine consist of sandstone overburden, with some shale streaks, five coal seams of varying thicknesses interspersed by layers of interburden. The mine produces approximately 2.5 million tonnes of coal and about 32 million cubic meters of overburden per year.

To achieve the objectives of this research, modeling of environmental impact of drilling equipment was conducted using Microsoft Visual Studio.NET software package. The following sections provide mathematical equations that are used for determining the exhaust and dust emissions, and sound levels of the equipment.

*Corresponding author: Ali Lashgari, Department of Mining Engineering, West Virginia University, Morgantown, West Virginia, USA, E-mail: ali.lashgari.65@gmail.com

Received January 28, 2013; Accepted January 30, 2013; Published February 07, 2013


Copyright: © 2013 Lashgari A, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.
The exhaust emission of drilling equipment (CO, NOx, SOx, VOC, and CO2) is given by equation (1):\[ E_i = E_F \times HFC \times H \] (1)

where \( E_i \) is annual emission of the substance \( i \) (kg/year); \( E_F \) is emission factor of substance \( i \) (kg/liter); HFC is hourly diesel fuel consumption (liter/hr); and H is the number of operating hours per year (hr/year). The values of emission factors were adopted from NPI [15] and EPA [16].

Dust emission is categorized according to the size range of the component particles: TSP and PM10. The TSP is the mass loading of airborne particles determined gravimetrically by a high volume air sampler. The PM10 refers to the mass loading of airborne particles that pass through a size selective inlet with a 50% efficiency cut-off at 10 \( \mu \text{m} \) aerodynamic diameter [17]. In other words, TSP is the total of all particles suspended in the air from loading operation. The PM10 refers to the subset of TSP, including particles smaller than 10 \( \mu \text{m} \) in diameter.

Dust emission from drilling operation is determined by a method given by the Environmental Protection Agency [18] and State Pollution Control Commission [19]. In this study, dust emission was determined using the following equation:

\[ E_i = \text{NH} \times E_F \times (1-CE_i/100) \] (2)

where \( E_i \) is emission rate of pollutant \( i \) (kg/year); \( E_F \) is the number of holes drilled per year; the \( E_F \) is uncontrolled emission factor of pollutant \( i \) (kg/hole); \( CE_i \) is overall control efficiency of pollutant \( i \) (%). The TSP and PM10 are pollutants \( i \).

Various pollutant emission control technologies, such as fabric filters, electrostatic precipitators, and wet scrubbers, are usually installed on some equipment to decrease the concentration of dust emitted to air. In cases where such emission abatement tools are used, the efficiency of dust collection of the abatement device needs to be considered.

The sound pressure level is the level of sound at a measuring point. Therefore, the sound produced by the equipment should be described by specifying the measurement distance along with the sound pressure level. Sound pressure level (\( L_p \)) can be expressed as [20]:\[ L_p = 20 \times \log \left( \frac{p}{P_0} \right) \] (3)

where \( p \) is sound pressure (Pa), and \( P_0 \) is the reference sound pressure (\( P_0 = 2 \times 10^{-5} \text{ Pa} \)).

An alternative way to describe sound produced by a machine is the sound power level (\( L_w \)) as given in equation (4):

\[ L_w = L_p + 10 \times \log \left( \frac{A}{\pi r^2} \right) \] (5)

where \( W \) is sound power emitted by the source (Watts) and \( W_o \) is reference sound power level (\( W_o = 10^{-12} \text{ Watts} \)).

Therefore, the relation between sound pressure level and sound power level for equipment working in surface mining area can be written as:\[ L_w = L_p + 10 \times \log \left( \frac{A}{\pi r^2} \right) \] (5)

where \( A \) is reference surface which is 1 square meter and \( A \) represents the area of measuring surface which is determined as follows:

\[ A = 2\pi \times r^2 \] (6)

where \( r \) is distance from the sound source.

Both sound power level and sound pressure level are defined on a logarithmic scale, called the decibel (dB). Decibels are a useful way of handling very small or very large scalar values, defined as follows:

\[ dB = 10 \times \log \left( \frac{\text{Quantity measured}}{\text{Reference level}} \right) \] (7)

It is important to note that the decibels defined for sound power and sound pressure level are completely different, because the reference level for sound pressure level is \( P_0 = 2 \times 10^{-5} \text{ Pa} \) while the reference level for sound power level is \( W_o = 10^{-12} \text{ Watts} \). It is a means for comparing two sounds and can be defined by comparing the sound level with a reference sound.

Results

Figure 1 shows an example of software module that is developed for the determination of environmental impact of a drilling machine. Since the project was completed for a North American-based company, all values in the module are presented in English units. The annual fuel consumption for eight drilling machines in the mine was calculated to be 1.62 million liters. Hourly CO, NOx, SOx, and VOCs for all drills are shown in figure 2, while the annual emissions of the various gases are shown in figure 3. The total hourly and annual CO2 emission for all drills in the mine were determined to be 1,720 kg and 4,344,570 kg, respectively.

There are many empirical models with a range of values for the cost of CO2 emission, and they are based on potential CO2 legislation. Two of the most recognized models include the U.S. Energy Information...
The objective of this research was to determine environmental impact of drilling equipment in a surface coal mining operation. The approach used in this paper allowed determination of exhaust and dust emissions, and sound pressure level. Modeling of environmental impact of the equipment was conducted using Microsoft Visual Studio.NET software package. The results show that the annual fuel consumption for eight drilling machines in the mine was 1.62 million liters, hourly CO, NOx, SOx, and the total hourly and annual CO2 emission for all drills in the mine were determined to be 1,720 kg and 4,344,570 kg, respectively. The results of this work may be used by mining professionals to aid in quantifying environmental impact of drilling equipment.

Conclusions

The financial contribution of the Appalachian Research Initiative for Environmental Science (ARIES) is gratefully acknowledged.

References

10. Reed WMJ, Organisacij A (2005) The Evaluation of Dust Exposure to Truck Drivers Following the Lead Haul Truck. SME Annual Meeting, Salt Lake City, UT, USA.

This article was originally published in a special issue, Surface Mining handled by Editor(s), Dr. Samuel Frimpom, Missouri University of Science and Technology, USA.