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Assessment of Environmental Impact of Drilling Equipment

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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 (NO_x), sulfur oxides (SO_x) and volatile organic compounds (VOCs). Dust generation is expressed through the particulate matter (PM10) and total suspended particulate matter (TSP). In this work, 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 NO_x, SO_x, and the total hourly and annual CO_2 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 (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x) 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 NO_x and VOCs. Kean et al. conducted a study to determine emissions of NO_x 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 CO_2 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 exhaust emissions for NO_x and fine particulate matter (PM2.5) from mobile equipment using a fuel-based methodology. Kecojevic and Komljenovic [8] determined the quantity of CO_2 emitted by haul trucks and associated costs that may arise from potential CO_2 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.

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The exhaust emission of drilling equipment (CO, NO_x, SO_x, VOC, and CO_2) is given by equation (1)

$$E_i = EF_i \times HFC \times H \quad (1)$$

Where E_i is annual emission of the substance i (kg/year); EF_i 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 µm 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 µm 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:

$$E_i = NH \times EF_i \times (1 - CE_i/100) \quad (2)$$

where E_i is emission rate of pollutant i (kg/year);the NH is the number of holes drilled per year; the EF_i 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 (Lp) can be expressed as [20]:

$$L_p = 20 \times \log\left(\frac{p}{P_o}\right) \quad (3)$$

where p is sound pressure (Pa), and P0 is the reference sound pressure ($P_o = 2 \times 10\text{-}5$ Pa).

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

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

Therefore, the relation between sound pressure level and sound power level for equipment working in surface mining area can be written as:

$$L_W = L_p + 10 \times \log\left(\frac{A}{A_o}\right) \quad (5)$$

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

$$A = 2\pi \times r^2 \quad (6)$$

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:

$$dB = 10 \times \log_{10}\left(\frac{\text{Quantity measured}}{\text{Reference level}}\right) \quad (7)$$

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=2×10-5 Pa while the reference level for sound power level is W_o= 10-12 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, NO_x, SO_x, 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 CO_2 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 CO_2 emission, and they are based on potential CO_2 legislation. Two of the most recognized models include the U.S. Energy Information

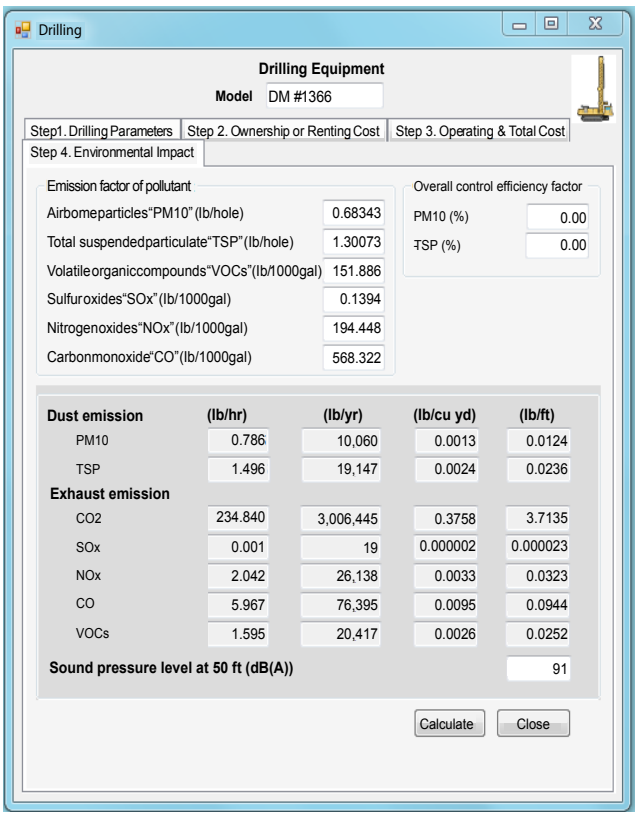

Figure 1: Module for determination of environmental impact of adrilling machine.

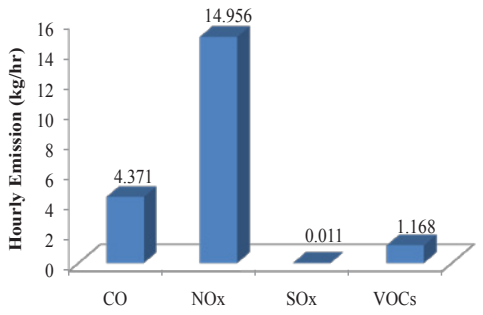

Figure 2: HourlyCO, NO_x, SO_x, and VOC emissions for all drills in the mine (kg/hr).

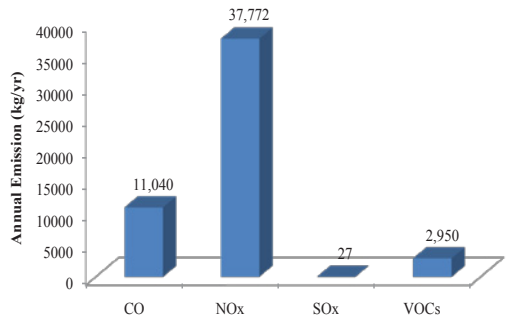

Figure 3: AnnualCO, NO_x, SO_x, and VOC emissions for all drills in the mine (kg/year).

Agency's National Energy Modeling System (NEMS) model and the Massachusetts Institute of Technology's Emissions Prediction and Policy Analysis (EPPA) model. These models consider the cost of CO_2 as ranging from \$19 to \$75 per tonne of CO_2 emitted [21]. Assuming the minimum cost of \$19 per tonne, the hourly and annual cost of CO_2 emissions would be \$32.68 per hour and \$82,546 per year, respectfully.

Conclusions

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, NO_x, SO_x, and the total hourly and annual CO_2 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.

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