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Development of Empirical Model to Predict Particulate Matter

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Abstract. The Particulate Matter (PM) pollution is one of the major concerns for many mining industries. The workers as well as residents residing near mines are prone to various respiratory diseases due to PM pollution. Assessment and maintaining of green belt environment in mine and surrounding area is necessary to get the project approved by Environmental Impact Assessment (EIA). The tools used for dust dispersion are useful to determine the pollution level of the ambient air with dust and to implement various control techniques to reduce their concentration. In the present research work, the dust dispersion models were developed using multiple regression analysis method and were used for determining the dust concentration of PM10 during drilling operation. The models were developed using the data of mine-1 and the data collected from the second mine-2 was used for validation. The results show that the developed models predict dust of PM10 at 70% reliable outputs, with an 30% of error. These models can be used for predicting the dust concentration level of PM10 in atmosphere at Coal mines.

INTRODUCTION

Dust is defined as small particles that is suspended in the atmospheric, these dust particles are further cannot be divided in to a small particle. The dispersion of dust carried out because of turbulent action of air in the atmospheric and mechanical disturbance of finer material [1]. The dust formation occurred in each every stage of the mining operation[2]. The dust producing in mining are classified in to three groups namely point source, line source and area source. The point sources are like Drilling, Loading, OB dumping and Coal dumping similarly line sources are like Haul roads and unpaved roads and area sources are like OB dump yard and Coal Dump yard. The dust producing from various activities cannot completely reduce but some extent can modify the process. The haul road could be produce more fugitive dust compared to other operation and after that drilling is only the source produces the fugitive dust [3], [4].

The dust produced by drilling operation is usually in fugitive form and it discharges into the environment in a defined flow stream. The dust emanating from drilling sources will have different sized particles and are more harmful in nature. The particulate matters are one of the major pollutants in mining activities, it comprises of PM2.5, PM10 and these are the most harmful to human health [5]. Generally the metrological parameters were more influenced to dust dispersions and dust dispersion was more in winter season [6]. The dust dispersion was usually found in downwind distance and dust concentration was found more up to 500m from the source [2], [7], [8].

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MATERIALS AND METHODS

Field investigations were carried out in two opencast coal mines, one at southern side of India and another opencast coal mine from north side. The dust produced by drilling operation was monitored by three personal dust samplers and two ambient point sampler. The personal dust samplers were fixed to ranging rods at a height of 2m above the ground level. These were placed at different distances with respect to downwind distance from the drilling operation, initially to know the background concentration of source one instrument was kept in up wind direction. Before placing the Dust monitoring instruments the metrological station was installed nearer to drilling operation and set in hourly basis. The various metrological parameters were taken from metrological station. This procedure was followed for each day of testing for field studies at both the coal and sandstone benches.

Determination of influence properties

As rock properties plays a major role in emanating the dust during drilling operation, some sandstone and coal samples were collected during the field investigations from different locations of the mine. The samples were brought to the laboratory and the required tests were carried out. The various test are like moisture content, density, compressive strength, Schmidt rebound hardness number and Silt content. To determine dust concentration level in field, initially metrological data were obtained from metrological station which was installed in the mine. Metrological parameters are like temperature, relative humidity and wind speed. Vertical dispersion coefficient (σ_z) and Horizontal dispersion coefficient (σ_y) were determined based on downwind distance from the Pasquill-Gifford graphs [9].

RESULTS AND DISCUSSION

Initially the first field investigations were carried out in opencast coal mine-1. Total 30 samples were collected from coal benches, 20 from sandstone benches, for the emission which ranged between 0.170 gm/m^3 to 0.912 gm/m^3. Similarly about 42 samples were collected for dust concentration. The values are ranged between 90 to 380µg/m^3. The second field investigations were carried out in open cast coal mine-2. Total 21 samples were collected from coal benches, 19 from sandstone benches, for the emission which ranged between 0.222 gm/m^3 to 1.210 gm/m^3. The values are ranged between 275 to 662µg/m^3.

Development of dust dispersion model

Dust prediction models were developed by multiple regression method was used to develop mathematical equations for dust emission and dust concentration. Equations were developed using Statistical Package for Social Sciences (SPSS) software, which is effectively being used for statistical analysis. To develop a dust dispersion models, mine-1 data were used. Another coal mine-2 data were used for validation of the models.

Dust prediction modeling using multiple regression method

To develop a mathematical model using multiple regression analysis, 50 sets of data was used for emission rate equation and 42 sets of data was used for dust concentration equation. To develop dust dispersion model Opencast coal Mine-1 data were used.The best fit of the model was assessed using the R^2 value, the R^2 value obtained for emission equation is 0.82 and for concentration is 0.76. Also, F test and P- test carried out using ANOVA analysis has also resulted in better validation of the model. Equation-1 is developed to predict emission rate and equation-2 for concentration for the drilling operation. Similar to the Emission Rate, from R^2, Prediction resulted in around 76 per cent satisfactory level with 36.5 per cent error.

$$\mathbf{E_d = 0.499 - 0.037m + 0.015S} \quad \text{----------eqn.(1)}$$

where,

E_d =Emission from drilling (gm/m^3)
m =Moisture content (%)
S =Silt content (%)

$$C_d = 366.89 + 335.791E - 2.954R_h - 0.997D \text{ ----------eqn.(2)}$$

where,

Cd =Concentration from drilling activity (µg/m^3)
E =Emission (gm/s)
D =Distance form source (m)
R_h =Relative Humidity (%)

Results of SPSS model predicted values with field measured values from mine-2 of Emission Rate and Concentration values are having percentage of error is within 30% in both cases, indicating developed models are moderately satisfactory. Plots drawn between actual field measured values from mine-1 data with predicted values from models in case of Emission rate and Concentration, resulted in R^2 value of 0.82 and 0.86 respectively, which shows better correlation. Further to validate the developed models, the results of SPSS model predicted values with field measured values from mine-2 of Emission Rate and Concentration values are having percentage of error is within 30% in both cases, indicating developed models are moderately satisfactory.

Comparison of Developed models with United States of Environmental Protection Agency (USEPA) Model

To validate the developed models in predicting the PM10 concentrations due to drilling activity in sandstone and coal benches, all the models developed were compared with USEPA Model. The results show that the USEPA model predictions has high error of 96%, whereas, SPSS models predicts with error of 30%. From comparison results Figure 1, it is observed that "SPSS" model predicted values are very close to the field measured values, implying that SPSS model has better predictions with more accuracy. It could be concluded that the "SPSS" Model equations may be used to predict PM10 Dust Concentrations from drilling activity in sandstone benches.

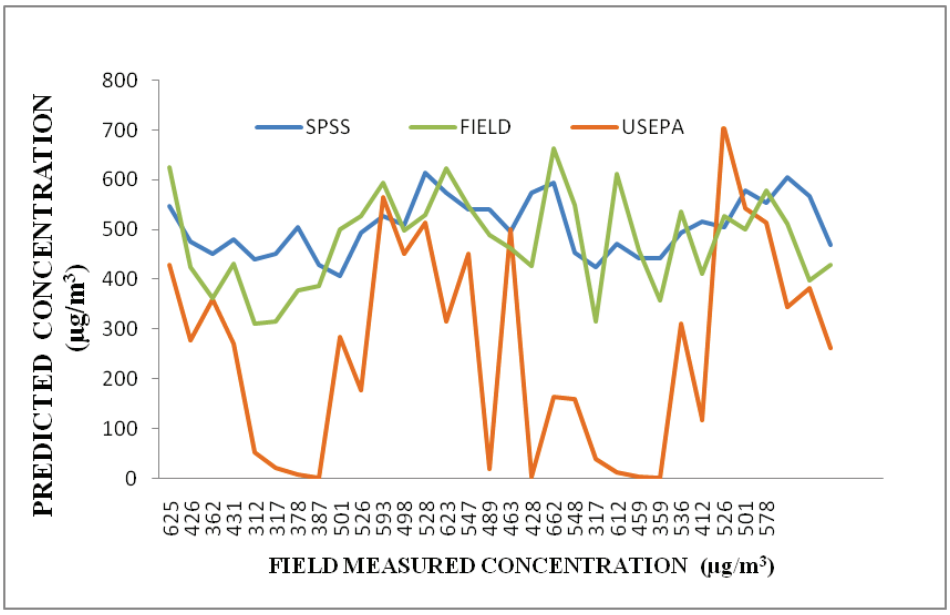

FIGURE 1.

CONCLUSIONS

In the present study, a detailed experimental and theoretical investigation were carried out to develop dust prediction models based on the investigations carried out in opencast mine-1 and the following conclusions are drawn.

- Multiple regression correlation coefficients for emission and concentration model are 0.82 and 0.76 respectively, for 5% level of significance.
- Variable Influence factors (VIF) of the input variable is lower than 10 that indicated there is no collinearity.
- Based on stepwise regression analysis, moisture content is negatively influencing to dust emission rate. Silt content is positively influencing to dust emission rate.
- Based on multiple regression analysis, silt content were found to be more influencing to produce emission rate.
- Results shown that the "SPSS" models predicted values are within 30 per cent compared to field measured values.

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