Emission factors for the quantification of dust in Indian coal mines

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The increasing trend of opencast coal mining tends to release huge amount of dust. But there is no well defined method of estimating dust emission due to coal mining activities. This paper examines the sources of dust emission due to coal mining activities and focuses on the quantification of dust emission with the use of emission factors or prediction type equations. Because of site-specific nature, emission factors developed for one site may not give the correct results for another site. In the present investigation prediction equations are utilized for the development of emission factors and they are used for the quantification of dust generation due to opencast coal mining. For the applications of this concept one large opencast coal project of Bharat Coking Coal Ltd (BCCL) was investigated and the amount of dust emitted due to different mining activities was quantified. This paper also focuses on the significance of this study in the field of environmental protection and likely impacts of such study. The paper concludes that once the amount of dust generation is estimated, the impact on air quality can be assessed appropriately and a proper air pollution control strategy can be developed.

Keywords: Opencast, Dragline, Box cut, Hauls road, Prediction equations, Batch load

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Introduction

The main air pollution problem in a mining area is due to the presence of particulates, which may be coal, soil or rock dust. Strip mine air pollution source can be divided into two categories, point sources and fugitive sources. Point sources typically include stationary exhaust stacks. Fugitive sources are open sources like the exposed soil of OB and coal. Vehicular traffic on haul road has been identified as the most prolific source of fugitive dust and can contribute as much as 80 per cent of total dust. Cowherd et al. estimated that about 50 per cent of the total dust released during journey time of dumper on unpaved haul road while 25 per cent for both during loading and unloading of dumper. Chadwick et al. estimated that 0.02 per cent of the coal is lost during loading and unloading. Nair and Singh estimated that road dust contains more than 4 per cent of respirable dust. Another major source of fugitive dust is wind erosion from stockpiles. Jacko gave estimates of fugitive dust from some mining activities. Emission factors from surface coal mining operations in the Power River Basin of Wyoming Surface Mine includes emission factor data as a function of distance from the source. The U.S. Environmental Protection Agency (EPA) published a compilation of air pollution emission factors (commonly referred as AP-42), a handbook, which use the A to E quality rankings. Mayer originally developed the compilation of emission factors from the technical literature and a report. More editions appeared including Duprey and USEPA.

Sinha illustrated the technique of exposure profiling method, specially designed and fabricated for the study to develop methods to quantity fugitive dust emission for vehicular traffic on unpaved haul road.

Emission Factors

In coal mine planning, an estimate of dust generation is to be made to check the likely level of air pollution in the mining area due to proposed project activities. Typically this can be obtained by using emission factor or prediction type equations. Jacko gave estimates of fugitive dust from some mining activities. Emission factors from surface coal mining operations in the Power River Basin of Wyoming Surface Mine includes emission factor data as a function of distance from the source. The U.S. Environmental Protection Agency (EPA) published a compilation of air pollution emission factors (commonly referred as AP-42), a handbook, which use the A to E quality rankings. Mayer originally developed the compilation of emission factors from the technical literature and a report. More editions appeared including Duprey and USEPA.

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Prediction Equations

The above-mentioned norms are thumb rules only. Because of site-specific nature of dust, emission factors derived for one site may not give the correct results for another site. Many factors such as...
brittleness and hardness of the materials being handled, clay or silt and moisture content of the rock material, wind speed of the region, the size of the earth moving machinery in operation control the amount of dust being formed and dispersed in the area. The prediction equations give better estimation of dust formation in opencast mines. A few prediction equations are given below.

(a) Continuous Load in Operations

Bucket wheel excavators with stacker conveyors are being used in many of the surface mines. The following equation allows in estimation of the fugitive particulate emissions from such an operation.\(^{(15,16)}\)

\[
e_{\text{cont.in}} = \frac{0.0018 (S/5) (U/S) (h/10)}{(M/2)^2},
\]

where,
- \(e_{\text{cont.in}}\) = Particulate emission expressed as lb/ton of materials loaded in,
- \(S\) = Silt content of aggregate or road surface materials per cent,
- \(U\) = Mean wind speed 4m above the ground, mi/h,
- \(h\) = Drop height (ft),
- \(M\) = Unbound moisture content of material per cent.

(b) Batch Load in Operations

Included in batch load in operations are the dragline, front-end loaders and rail car dumping. The equation was originally developed for front-end loaders, rail car dumping operations for shovel, but has been extrapolated for dragline.\(^{(15,16)}\)

\[
e_{\text{batch-in}} = \frac{0.0018 (S/5) (U/5) (h/5)}{(M/2)^2 (Y/6)^{0.33}},
\]

where,
- \(e_{\text{batch-in}}\) = Emission expressed as lb/ton of materials loaded in,
- \(U\) = Mean wind speed 4m above ground, mi/h,
- \(h\) = Drop height, (ft),
- \(M\) = Unbound moisture content per cent,
- \(Y\) = Dumping device capacity, yd\(^3\),
- \(S\) = Silt content per cent,
- \(V\) = Average vehicle speed, mi/h,
- \(W\) = Average vehicle weight, t
- \(n\) = Average number of vehicle wheels,
- \(d\) = Number of dry d/ y

(e) Unpaved Haul Roads

Cowherd et al.\(^{(16)}\) suggested the use of the following equation for estimation of particulate emission from haul trucks on an unpaved road surface.

\[
e_{u} = 5.9 \left(\frac{S}{12}\right) \left(\frac{S}{30}\right) \left(\frac{n}{3}\right)^{0.7} \left(\frac{W}{4}\right)^{0.5} \left(\frac{d}{365}\right)
\]

where,
- \(e_{u}\) = Unpaved road emissions as lb-particulates vehicle make travelled (Particles smaller than 30µm with a density of 2.5g/cm\(^3\))
- \(S\) = Silt content per cent,
- \(V\) = Average vehicle speed, mi/h,
- \(W\) = Average vehicle weight, t
- \(n\) = Average number of vehicle wheels,
- \(d\) = Number of dry d/ y

(d) Active OB Storage Pile wind Erosion

\[
e_{\text{pile}} = 0.05 \left(\frac{S}{1.5}\right) \left(\frac{d}{235}\right) \left(\frac{F}{15}\right) \left(\frac{D}{90}\right)
\]

where,
- \(F\) = per cent of time unobstructed wind speed exceeds12 mph at a mean pile height,
- \(D\) = Duration of material storage,d.

Applications

The indigenous coking coal production in India is not fulfilling the demand of steel industry for which about 7 Mt of coking is being imported annually.\(^{(17)}\) The extraction of coking coal is increasing rapidly to meet the demand. Block II OCP, one of the largest opencast projects of coking coal owned by BCCL, was selected for the application of this work. It has 34.6 Mt quarriable reserve of coal. The project report was sanctioned in the year 1982 for a targeted production of 2.5 Mt/y and the life of the project was 17 y. The quarry was being worked in two patches through separate box cuts. Working depth during the study period was about 60 m in box cut section 3. Work was going on in X seam having thickness 9.62 m. The project is located in the northwest of JCF in Dhanbad, Jharkhand. It covers an area of about 6.8 sq km. Many other opencast and underground coal mines surround it. The main drainage of the region is through Jamuni River. The region has a tropical monsoon type climate. The general wind direction is from the west with few clouds from December to February. Air originating from the sea to the east and the south brings about 80-85 per cent of annual rainfall in June through August. The winter season extends from November to February with temperature as low as 5°C. The summer season is from March to
June and the highest temperature experienced is 48°C. The rainy season starts in late June and it ends in September. The southwest monsoon brings the major precipitation. The annual rainfall in this region is 1197mm.

Methodology
The sources of dust generation were identified. The geological setting of the area was recorded. Different machineries used for drilling, mining, removal of overburden, transportation system were also recorded. Different mining activities like topsoil removal, overburden removal, coal extractions, size reduction and total quantity handled per day in each case were also recorded. Parameters like mean wind speed, drop height, unbound moisture content, dumping device capacity, silt content, average vehicle speed, average vehicle weight, average number of vehicle wheels, number of dry d/y percentage of time unobstructed vehicle wheels, wind speed exceeds 12mph at a mean pile height, and duration of material storage were evaluated.

The data obtained were put in the prediction equations developed for different operations and emission factors were evaluated for each activity. Statistical average of the rate at which dust released as a result of some activity were multiplied by that activity. Thus the rate of emission of dust per unit of a given activity was computed, which is known as the emission factor and expressed as per tonne of mineral mined, per tonne of mineral crushed, etc. An estimate was made for the number of such processes. The total emission then equals the product of emission factor times of the number of such sources. Emission thus will represent the best values for different mining activities. Typical air pollution factors thus obtained are summarized and presented in Table1.

Quantification of Dust
Opencast mining generates large quantities of dust during its various operations. Different mining activities include topsoil removal, overburden removal, coal extraction, size reduction, etc. The mine was producing 2500t of coking coal/d i.e. 0.75 Mt/y. during the study period. The stripping ratio was 3.98, i.e. 24875 t of OB was removed/d. Out of this, the average topsoil removal was 2400 t/d. The whole OCP was divided into two parts — one box cut section and one dragline section. During the study period, 60 per cent of production of coal was from box cut section 3 and 40 per cent from the dragline section.

<table>
<thead>
<tr>
<th>Source</th>
<th>Emission factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Overburden excavation</td>
<td></td>
</tr>
<tr>
<td>Scraper loading</td>
<td>No data</td>
</tr>
<tr>
<td>Shovel excavation</td>
<td>1.0 to 3.0 kg/t</td>
</tr>
<tr>
<td>Bucket wheel excavation</td>
<td>0.7 to 2.0 kg/t</td>
</tr>
<tr>
<td>Loading in vehicles</td>
<td>0.7 to 0.4 kg/t</td>
</tr>
<tr>
<td>(b) Transportation</td>
<td></td>
</tr>
<tr>
<td>Conveyor belt</td>
<td>0.5 to 0.1 kg/t</td>
</tr>
<tr>
<td>*Dumper</td>
<td>Each transit point</td>
</tr>
<tr>
<td>*Total emission will be</td>
<td>1.5 to 3 kg/km of tunnel earthen dry surface</td>
</tr>
<tr>
<td>kg/vehicle/km/d</td>
<td>0.1 to 3 kg/km of tunnel soiled surface</td>
</tr>
<tr>
<td>(c) Unloading and Piling</td>
<td></td>
</tr>
<tr>
<td>Conveyor system</td>
<td>0.8 to 1.5 kg/t</td>
</tr>
<tr>
<td>Dumper-Bull dozer</td>
<td>1.5 to 4.0 kg/t</td>
</tr>
<tr>
<td>(d) Mineral excavation</td>
<td></td>
</tr>
<tr>
<td>Bucket excavator</td>
<td>0.5 to 1.0 kg/t</td>
</tr>
<tr>
<td>Shovel</td>
<td>0.8 to 1.5 kg/t</td>
</tr>
<tr>
<td>Loading conveyor belt</td>
<td>0.08 to 0.1 kg/t</td>
</tr>
<tr>
<td>Loading dumper</td>
<td>Each travel point</td>
</tr>
<tr>
<td></td>
<td>0.07 to 0.3 kg/t average</td>
</tr>
<tr>
<td>(e) Transport</td>
<td></td>
</tr>
<tr>
<td>Conveyor belt</td>
<td>0.05 to 0.1 kg/t</td>
</tr>
<tr>
<td>Dumper/truck</td>
<td>Each travel point</td>
</tr>
<tr>
<td>Dumper/truck</td>
<td>1.5 to 3.0 kg/km Travel dry surface</td>
</tr>
<tr>
<td></td>
<td>0.2 to 0.5 kg/km Travel by soiled road</td>
</tr>
<tr>
<td>(f) Stock piling/loading</td>
<td></td>
</tr>
<tr>
<td>Conveyor</td>
<td>1.0 to 2.5 kg/t</td>
</tr>
<tr>
<td>Dumper/manual</td>
<td>1.5 to 4.0 kg/t</td>
</tr>
<tr>
<td>(g) Size reduction</td>
<td></td>
</tr>
<tr>
<td>Jaw crusher</td>
<td>1.5 to 2.5 kg/t</td>
</tr>
<tr>
<td>Screening</td>
<td>2.5 to 5.0 kg/t</td>
</tr>
<tr>
<td>Loading</td>
<td>0.8 to 1.5 kg/t</td>
</tr>
<tr>
<td>Stock piling and retrieval</td>
<td>1.0 to 4.0 kg/t</td>
</tr>
</tbody>
</table>

In the box cut section 3, there were three OB benches equipped with 3 power shovels (10 m³ capacity) and one coal bench with one power shovel. The average depth in this section was about 57 m. There were three drill machines in this section. The dragline section was equipped with one huge dragline (24 m³, 96 m) was handling about 40 per cent OB, i.e. 8990 t/d. The dragline was equipped to remove OB up to 35 m depth and side casted. In the box cut section 3 OB was transported through along the haul road for about 0.5 km for dumping. The number of dumpers in working condition was 15. After the removal of OB and exposure of the coal strata, coal benches were
drilled, blasted and coal was transported to the feeder breaker for size reduction. The coal was crushed to -200 mm size by a feeder breaker. Coal handled by feeder breaker was about 2500 to 3000 t/d. The crushed coal was transported to bunker by means of a conveyer belt from which loading to a dumper was done to dispatch to a railway siding. The feeder breaker consists of a crushing unit, transporting crushed coal by a conveyer belt, unloading into a bunker, and loading from the bunker to the dumper.

As calculated the dust generation by the utilization of emission factor data, topsoil removal generated 69.9 kg/d. Overburden removal operation generated 660.0 kg of dust/d; extraction of coal contributed about 256.9 kg of dust/d. Observation of dust generation due to size reduction contributed dust amounting to 6812.5 kg/d. The mining activity generated dust amounting to 7799 kg of dust/day. Wind erosion also generated a huge amount of dust of about 1569.2 kg/d. Blasting also causes a huge generation of dust but due to unavailability of emission factor data the actual quantity could not be estimated. For the calculation of dust generation the emission factor data used are shown in Table 1. The total amount of dust generated as calculated by the utilization of emission factor data was found to be 9368.2 kg/d (Table 2).
Significance of the Study

Environmental impact assessment (EIA) plays a crucial role in resolving the conflicts between developmental objectives and concern for the environmental quality. In fact EIA is considered to be a valuable planning and decision-making tool for prediction and evaluation. This has led to the preparation of environmental management plan (EMP) prior to the implementation of any project. The system of preparing EMP has been accepted as a statutory requirement for getting clearance from Department of Environment (DOEn), Government of India. All such mining projects need to be cleared by DOEn. To ensure the effective safeguard at the designing stage against the environmental hazard, DOEn has issued guidelines for preparation of EMP report for mining projects. Finally the Environmental Appraisal Committee (EAC) for mining projects examines the report before giving any clearance to the project.18

Air pollution is one of the most important parameters to be considered in preparing EIA report19. But there is no well-defined method of predicting the generation of dust due to different mining activities. A search into the technical literature available on the subject reveals that the value of emission factor and the coefficient of mathematical model have been determined to evaluate the dust generation due to opencast coal mines in several countries abroad. But such studies have not yet been reported in Indian context. The technology and methodology has its limitations in site condition, on the method of mining, geological and geomorphological setting of the area. In the present investigation, attempts were made to develop emission factors to evaluate the amount of dust generation due to opencast coal mining in Indian context. Once the amount of dust generation is ascertained, the impact on the air environmental can be evaluated and proper mitigative measures can be adopted for the reduction of air pollution in the area20. This is significant in the field of environmental projection.

Conclusions

The main air pollution problem in coal mining areas is due to the dust. For the assessment of impact on air environment quantification of dust emission is essential. Prediction equations give better estimation of dust formation in opencast mines. Data collected can be put suitably to validate the models for the evaluation of emission factors in Indian context. Emission factor data thus developed can be utilized for the prediction and assessment of dust generation due to coal mining activities. This study has an immense significance in the field of environmental protection and likely impacts of the findings are many. Once the amount of dust generation is estimated, the impact on air environment due to the project activities can be assessed appropriately and an air pollution control strategy can be developed to maintain the right kind of balance between sustainable development and environmental management. It is concluded that the study provides a sort of fundamental scientific insight in the quantification of dust emission due to coal mining activities.

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