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Emission Factor for Equipment Engaged in an Underground Coal Mine

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Abstract: This article provides a new methodology for estimating emission factor for Side discharge loader (SDL) machine used for loading, hauling & discharging coal in underground coal mining projects. The approach is developed as the equipment's being used in transporting coal from face to other end point below ground. The findings are of the recent field study for the mining activities from 2012-2016 in different underground mining complexes of a subsidiary of major coal producing company of India. We successfully sampled 35 equipment, with 522 data sets in 9 mining complexes situated in different districts of Jharkhand, India. Emission factors (EF) for the equipment was derived from measurements, which are in consistent with the results. First we identified "heavy emitters" in the working coal mines under study area. SDL is one of the equipment contributing most of emission of greenhouse gas amongst all equipment deployed below ground. The emission factor as tabulated for SDL is 6.21 kg CO_{2e}/ton of coal production and 37.07 kg CO_{2e}/ working hour. During the study period it was found that 74% & 26% of emission from development district and depillaring district respectively where SDLs were deployed. In this research paper attempt has been made to draw futuristic scenario in terms of GHG emission due to deployment of SDL at different mining complexes of the leading coal company of India as whole and on the basis of completed, existing, future projects. All together 0.29 Million tons of GHG emission is estimated to be released at the working face of the underground coal mine by deployment of SDL for the period from year 2017-2020.

Key word: Emission Factor, GHG Emission, Mining Complex, SDL

1.0 Introduction

Introduction Climate change and its effects are a harsh reality faced today. Much has been spoken and written on the need for a shift in the way climate change is perceived, mitigated and adapted to.The issue of climate change has risen up political and corporate agenda at an astonishing rate. Widespread acceptance of the basic science of climate change and recognition of the potential threat that it poses to our ecosystem and way of life has made the pursuit of CO_2 reduction a major priority for many governments and companies. At an earlystage in the development of carbon reduction strategy it is necessary to analyse the main source of CO_2 emission and identify those activities upon which carbon mitigation measures should be targeted.

Coal being the prime source of electricity and needs to be cleaner. Emission in the coal mining revolves round the diesel-powered vehicles (c-balance, Manoj&Sangeeta et. al. 2015) and is one of the source of urban, regional and global pollution. Theside discharge loader under study is electrical operated and is environmental friendly as per GHG emission is concerned. The scope of emission fall in Scope-2 for use of purchased electricity and oxidation of lubricants being used.

2.0 Objective

In this study, the objective is to derive Emission factors for side discharge loader and extrapolating the greenhouse gas (GHG) emissions set to be released due to its deployment in different subsidiaries of major coal company of India.

3.0 Methodologies

The methodology for specific emission factors (EFs) for equipment under study involves calculating the total emissions from the specific equipment and dividing that figure by the total amount of coal produced hereby termed as production (P) or time taken by specific equipment in hours, hereby termed as working hour (W_H). Data for the quantities of coal produced, working hour and lubricant consumption for specific equipment within dedicated mining complexes were collected from different mining complexes, and their corporate offices and dedicated websites. The equipment under study is the side discharge loader hereby termed as SDLworks below ground. Total emissions were calculated by applying the appropriate default emission factors as per Guidelines for National Greenhouse Gas Inventories (IPCC 2006).

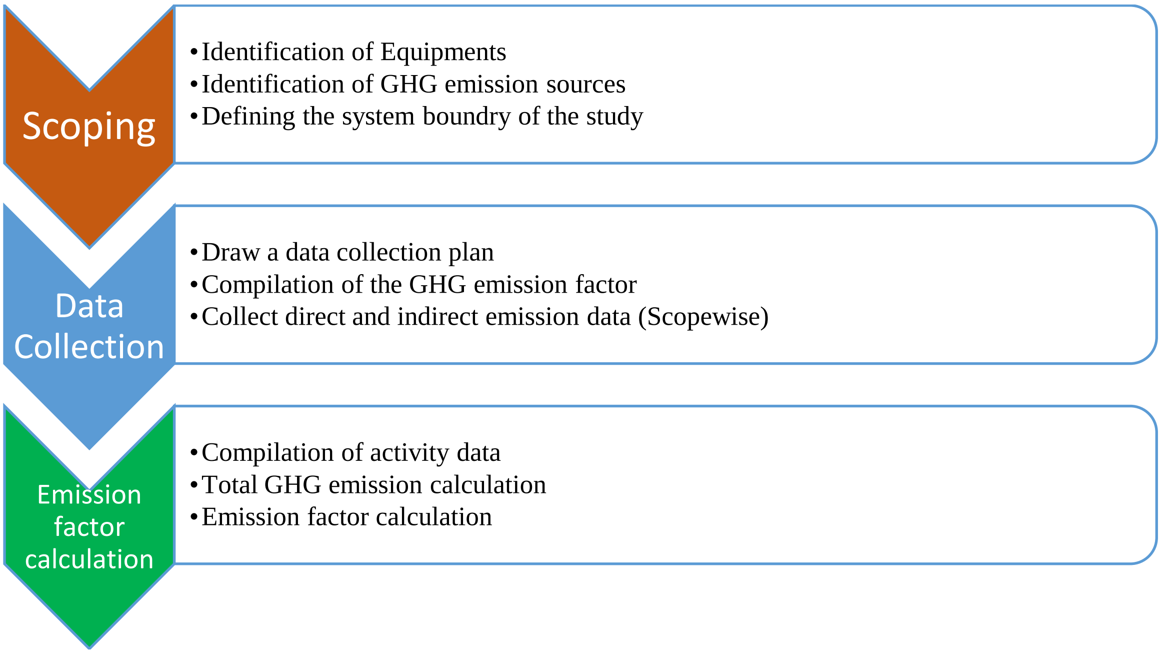

Figure1: Methodology for deriving emission factor of SDL

3.1 Identification of Equipment

The EF for the mining equipments used below ground are not available or the study are in the young stage. In this campaign study were concentrated on Side discharge loader (SDL) deployed in Underground coal mining project only and extrapolating the emission shared by the equipment in years to come specially to achieve dream 1 billion program of the coal company of India. Different approaches have been applied to evaluating machine wise EF, based on field data collected from different mining complexes. As mentioned above Observation of individual mining equipment engaged in hauling, loading and transporting were include in the study. SDL is a machine which loads through forward motion of-the machine and can discharge to the side from an end of the bucket. (fig. 2 below).

Figure 2: Side Discharge Loader

3.2 Data collection

The adaptation of data collection compared to those of our previous work of GHG emission assessment for an opencast mine (Kumar M, Sangeeta&Alok, 2015) enabled us to identify the corresponding target equipment more precisely. The protocol was flexible allowing the selection of many different types of target equipment in desired underground mining complexes. The study was conducted for nine numbers of underground mining complexes of one of the subsidiary of the major coal producing company of India situated in Jharkhand, India. This coal company is set to produce one billion tomes of coal by 2020. 47 Million tes will come from underground coal mines where SDL are to be deployed from the period from year 2017-2020. The region where the study were made is illustrated in Fig. 3.

Figure 3 *:* Location of Study area

The individual mining equipment were coded and allotted a unique number and were clustered as per there characteristic (Table 1). The data thus collected for the target equipment according to the unique number allotted to them. The lubricant consumption, electric power consumption, working hours applicable to different equipment were collected, segregated analysed and compiled (Table 2).

We selected equipment that were separated from others for data analysis and non-availability of emission factors for the equipment. In some cases we failed to collect some data for few equipment under study. We did not use this data. In some cases the data were available for larger period. In some cases data were available for shorter period (at least one year data considered), which may be due to non availability of data or may be due to recent deployment of equipment.

Table 1 : Details of Deployment of Equipment in Study Area

Mining Complex	Machine Number		Latitude	Longitude
MC1	*S1,S2*		*23^{o} 46' 00" - 23^{o} 47' 45" N*	*85^{o} 18' 35" - 85^{o} 20' 30"E*
MC2	*S3,S4*		*23°46'1.99"N*	*86° 1'6.02"E*
MC3	*S5,S6,S7,S8*		*23^{o} 44' 24" - 23o 45' 17" N*	*85^{o} 29'36" - 85o 31'32" E*
MC4	*S9,S10,S11*		23°45'22.86"N	*85°33'45.82"E*
MC5	*S12,S13,S14*		*23^{o} 41' 04" - 23^{o} 42' 52" N*	*85^{o} 16' 06" - 85^{o} 19' 36"E*
MC6	*S15,S16,S17,S18*		*23^{o} 40' 30" - 23^{o} 41' 34" N*	*85^{o} 03' 00" - 85^{o} 04' 00"E*
MC7	*S19,S20,S21,S22*		*23^{o} 39' 10" - 23^{o} 40' 20" N*	*85^{o} 19' 30" - 85^{o} 20' 40"E*
MC8	*S23,S24,S25,S26,S27,S28*		*23^{o} 39' 00" - 23^{o} 41' 00" N*	*85^{o} 21' 00" - 85^{o} 23' 00"E*
MC9	*S29,S30,S31,S32,S33,S34,S35*		*23^{o} 47' 10" - 23o 48' 53"*	*85^{o} 34' 35" - 85^{o} 36'*

			N	*30"E*
Note : MC # → Mining Complex number #, Sl no.$, S → SDL Sl no. * , Where # = 1 to 9, * = 1 to 35*				

Table 2: Machinewise production and lubricant consumption								
M/C Cd.	Prod.	WH	Consump. Lubricants		M/C Cd.	Prod.	WH	Consump. Lubricants
S1	74092	10180	7162		S2	62524	7998	6944
S3	41595	7476	3312		S4	48102	7582	3766
S5	19209	4396	3939		S6	21813	4627	4429
S7	39796	8129	5842		S8	13003	2346	1529
S9	38146	4454	4400		S10	37679	4322	4346
S11	21808	2764	2515		S12	17858	3327	2059
S13	18832	4226	2172		S14	27041	5566	3119
S15	29894	5750	3448		S16	19074	4389	2200
S17	31260	5742	3605		S18	35057	6327	4043
S19	13217	3122	1524		S20	24854	4268	2867
S21	14734	2393	1699		S22	19197	2934	2214
S23	33441	10605	3857		S24	20253	3411	2335
S25	36431	4751	4202		S26	43450	5755	5011
S27	43354	5512	5000		S28	38477	5187	4438
S29	11233	2553	1296		S30	60121	9000	6934
S31	35895	7025	4140		S32	32456	5685	3743
S33	34207	5433	3945		S34	276	67	32
S35	282	69	33					
Note : - MC Cd → Equipment Code, Prod → Production of Coal in Tes, WH → Working Hours in Hrs, Consump. Lubricants → Consumption of Lubricant in Liters.								

3.3 Data Analysis

Different equipment were classified on the basis of make model. By using data set collected (Table 2) GHG emission were estimated for individual equipment.

3.4 Calculation of Carbon footprint

For calculating GHG emission for individual equipment following empirical relation developed by Manoj & Sangeetaet. al. 2015 were used.

$$\boldsymbol{TE = \sum_i \sum_j \sum_k ES} \quad \text{-------------------------------------}(1)$$

Where,

TE = Total emission in kg CO_{2^e}

ES = Emission due to various activity level

$$ES = activitylevel * emmission\ factor \text{-----------------------------------} (2)$$

All together five hundred and twenty two data sets for thirty five equipment in nine numbers of mining complexes were successfully sampled, collected, segregated, analysed and compiled. By using equation (1) and (2)above emission in the study area was estimated for each data sets. It were observed that most of the emissions during the study period was from developmental district (Table 3) where these equipment were deployed for winning coal.

Table 3 : Measured Emission in Study Area due to deployment of SDL (As per measured set of Data)			
		Technology wise Emission (in %)	
	GHG emission in $TesCO_{2e}$	Development	Depillaring
SDL	14348	71%	29%

Once the total emissions from both dedicated equipment were calculated the total emission was divided by the total amount of coal production of equipment and total working hours taken to load the coal as the case may be for deriving the equipment specific emission factor. In order to calculate emissions the same steps were followed, applying the appropriate emission factors for different sources as per IPCC (2006/2011).

$$EF_{SDL\,(p)} = \frac{\sum_{i=1}^{i=n} [\{(W_H \times R \times f \times EF_{Grid}) + (W_H \times R \times f \times EF_{GridAT\ \&C})\} + \{C_{Lub} \times ODU_{Lub} \times \rho_{Lub} \times CC \times (NCV \times {}^{1}/_{1000}) \times M_R\}]}{\sum_{i=1}^{i=n} (P)} \text{------------- (3)}$$

$$EF_{SDL\,(W_H)} = \frac{\sum_{i=1}^{i=n} [\{(W_H \times R \times f \times EF_{Grid}) + (W_H \times R \times f \times EF_{GridAT\ \&C})\} + \{C_{Lub} \times ODU_{Lub} \times \rho_{Lub} \times CC \times (NCV \times {}^{1}/_{1000}) \times M_R\}]}{\sum_{i=1}^{i=n} ()(W_H)} \text{------------(4)}$$

Where,
$EF_{SDL(P)}$ - Emission factor of SDL on Production basis in Kg CO_{2e} / tons
$EF_{SDL(WH)}$ - Emission factor of LHD on Working hours basis in Kg CO_{2e} / hrs
P - Coal Production in Tons by the equipment
W_H - Working Hours in Hrs of Equipment
EF_{grid}:Emission factor of purchased Electricity in Kg CO_{2e} / KWH
$EF_{gridAT\&C}$ - Emission factor due to AT&C losses in Kg CO_{2e} / KWH
R - Rating of motor in Kilo Watt
f - Factor considering design factor, cycle time, work efficiency etc of the equipment
C_{Lub}- Consumption of Lubricants in Litres by the equipment
ρ_{lub} - Density of lubricant
ODU_{LUB} - Oxidising Unit for Lubricant In no. (from 0.1 – 1.0)
CC -Carbon Content in kg C/GJ
NCV - Net Calorific Value in TJ/Gg
M_R - Mass Ratio ie CO_2 /C (=44/12)

Emission Factor thus derived by using empirical equation 3, 4are tabulated as below :

Table 4: Derived Emission factors		
Equipment	Emission factor on Production basis in Kg CO_{2e} / tons	Emission factor on Working hours basis in Kg CO_{2e} / hrs
SDL	$EF_{SDL(P)} = 6.21$	$EF_{SDL(WH)} = 37.07$

The emission factor so derived can be used for calculating total GHG emission where these equipment are deployed and can be calculated as under :

Table 5: GHG emission Estimation - Type of equipment				
Emission on Production basis	Tonne	x	Emission factor	Total Kg CO_{2e}
SDL		x	6.21	
Emission on working hours basis	Hours	x	Emission factor	Total Kg CO_{2e}
SDL		x	37.07	

4.0 USE OF EMISSION FACTOR

The emission factor derived for SDL can be used in futuristic estimation of GHG emission for the mining complexes where these equipment are deployed. The emission factor calculated above may be used as emission inventory estimation and would encourage mine managers in taking corrective steps towards sustainability.

4.1 Emission Inventory Estimation

Total emissions can be calculated by multiplying the emission factors by activity data as per table 5 to give annual emission rates (in Kg CO_{2e}per year). Dividing this estimate by 10^3gives standard GHG emission in tons CO_{2e}per year.The above estimates were applied for one of the major coal producing company of India set to produce one billion tons by year 2020. The 118 mining complexes where SDLs are deployed and are set to be produce about 46.83 million tes in three years ie from 2017-20. Fig. 4 shows the percentage share in emission year-wise for 2017-18, 2018-19 & 2019-20. The cumulative share of emission (Fig 5) for different types of projects will be 53%, 33%, 2 % & 12% respectively for Completed, Existing, Futuristic & ongoing.

Figure 4 :% share in emission Year-wise vis a vis Type of Project

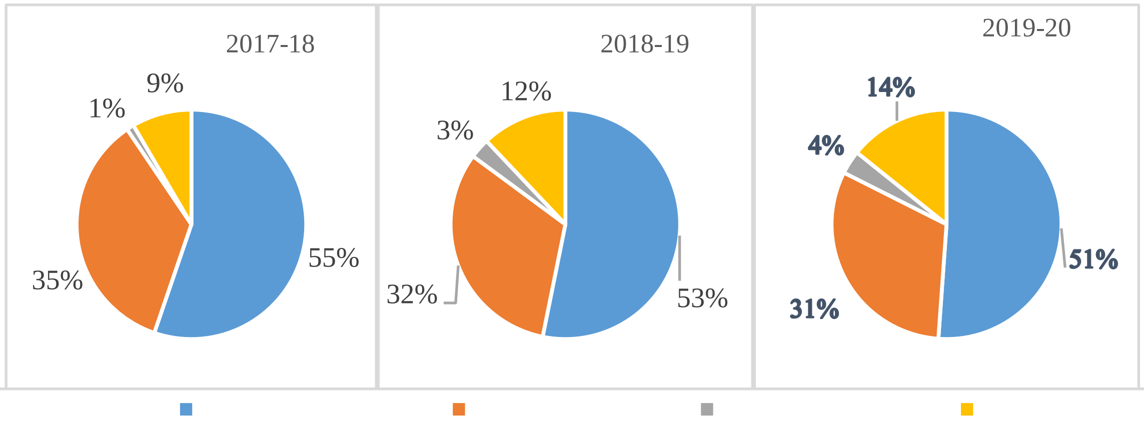

Figure 5 : % GHG emission 2017 - 2020

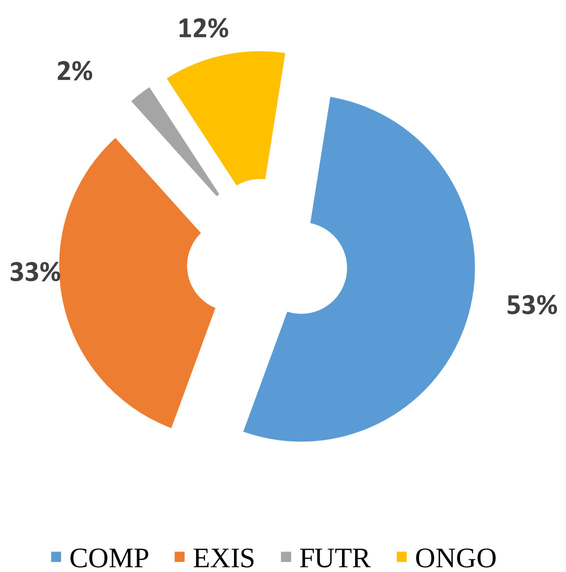

Table 6: Projected Production vis a vis Direct Emission &No. of mining complexes from 2017-2020 (As per 1 BT program of Major coal producing company of India)

	Projected Production in Million tes	GHG Emission Estimate in million tes of CO_{2e}
Completed Projects (COMP)	24.87	0.154
Existing Projects (EX)	15.34	0.095
Futuristic Projects (FUTR)	1.15	0.007
Ongoing Projects (ONGO)	5.48	0.034
Total	46.83	0.29

Table 6 above shows the results for GHG emission estimate in million tes of CO_{2e} using the emission factor derived for SDL as tabulated at table 4 & table 5 for different types of project ie completed projects, existing projects, futuristic project and ongoing projects. Altogether 0.29 million tons of GHG is estimated to be emitted from year 2017-2020.

5.0 Conclusions

The present study developed the Framework to assessthe off-road emission factor for side discharge loader. The Framework has two components, i.e. developing emission factor for SDL and thereby estimating the GHG emission at major coal company of India where these machineries are deployed.

Emission factors (EF) for the equipment are derived from measurements, which are in consistent with the results. The emission factor as tabulated for SDL is7.90 kg CO_{2e}/ton of coal production and 47.20 kg CO_{2e}/ working hour. During the study period it was found that share of emission from development district and depillaring district was 79:21.

The application has been applied for only thirty five equipment at nine locations only. It would be good to include more machinery from different locations infuture with varied size of complexes along with different geographical locations. Study for absorption, adsorption, trapping of GHG in goaves and ventilation study is required for future work for correct estimation of GHG emission to the open atmosphere due to deployment of these machinery below ground. Though the emission factor so developed has wide application in assessing GHG emission at workplace below ground coal mining working. The uniqueness of this factor is that it has both the components i.e. carbon footprints aswell as sustainability aspects of underground coal mining complexes can be estimated. Results of this would encourage mine managers in taking corrective steps towards sustainability.

6.0 Acknowledgements

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