Quantification of Environmental Impacts of Coal Mining in Samaleswari Opencast (Surface) mine of IB Valley Coalfields of Odisha, India using Life Cycle Assessment (LCA) Model

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Abstract *The aim of the study is to assess the life cycle environmental impacts of water use, land use, energy use, abiotic resource depletion, and climatic change impacts due to coal mining in Samaleswari opencast(surface) mine of Ib Valley Coalfields of Odisha, India considering cradle-to-gate Life Cycle. The study used the general principles of the ISO 14040-49 series Life Cycle Assessment (LCA) standards, modifying them whenever and wherever necessary. The functional unit was defined as "one tonne of coal processed coal" at the mine gate. The relative mass-energy-economic value method, with some modification, was used to scope the product system. Life cycle potential water use impact is 61.91 litres/tonne of coal produced at the mine gate. The potential land use impact and energy use impact were assessed to be 9.48 m² -year/tonne and 107.66 MJ/tonne respectively. CO_2 emissions from HSD consumption alone is 3.3 kg/tonne of coal, whereas, emissions from electricity consumption and explosives is 1.01 Kg and 2.95 Kg respectively. LCA is a perfect and prominent tool for comparison of various systems based on the impacts. So, more mines needed to be included in the study for a better comparison and decision making.*

Keywords Abiotic resource depletion, Climatic change, Coal Mining, Energy use, Land use, Life Cycle Assessment (LCA), Water use

1. INTRODUCTION

Coal generates about more than half (57.3% as in June,2018) of the electricity used in India [22] and India stands as the third largest electricity producer in the world. Projection up to 2020 predict that increases in coal consumption for electricity generation, will result in an annual coal production growth rate of about 8.8% [5],[6]. Apart from electricity generation, coal happens to be the main fuel stock in other industrial process such as steel making, cement production, and paper making [12].

Surface or Open cast coal mining operations account for about three fifth (60% in 2017-18) of total coal production in India[12]. Opencast Mining methods are important for coal extraction as they are very much amenable to higher productivity compared to underground mining systems.

In the present scenario, in spite of importance of coal, there have been increasing concerns over environmental problems associated with extraction and use of coal. Coal mining has severe impacts on water, land, abiotic resources and also climate conditions which is caused by Greenhouse Gas (GHG) emission [7],[9],[10]. Though, we have other problems related to coal such as acidification, photochemical oxidation etc. but the former impacts are considered to be major impacts for coal mining process. Life Cycle Assessment (LCA) provides systematic and quantifiable measure for assessing environmental burdens of products and processes occurred.

2. LIFE CYCLE ASSESSMENT (LCA)

Life Cycle Assessment (LCA) is a tool for the systematic evaluation of the environmental aspects of a product or service system through all stages of its life cycle [11],[13]. LCA provides an adequate instrument for environmental decision support. Reliable LCA performance is crucial to achieve a life-cycle economy. This is a comprehensive tool for quantifying and interpreting environmental impacts of a product or service from the cradle to grave. However, depending on the nature and intended purpose of an LCA study, the boundaries of the system under study may be modified appropriately resulting in either a cradle-to-gate or gate-to-gate assessment[14],[15],[16],[17],[18],[19].

3. RELEVANT WORKS

Many LCA works have been done on the complete life cycle of coal (cradle-to-grave), where whole extraction process is considered as a black box. Very few LCA studies have been conducted on the main mining process, i.e. cradle-to-gate approach [3], [4]. The limited number of mining LCAs undermines the many life cycle inventories that have been

developed, since every product system consumes the products of mining directly or indirectly (e.g., by utilizing electricity produced by coal-fired power plants). In spite of the low application of life cycle thinking to decision making in the mining industry, some examples of mining LCA studies can be found in the literature [1],[2],[4],[8],[20],[24],[25],[25]. In fact, the lack of LCI data on coal mining has been cited as one of hindrances to the accuracy of LCI data. A search on the International Journal of Life Cycle assessment gives only 19 results with "coal mining" which reflects the relatively low application of LCA studies in coal mining or even in mining industry.

4. OBJECTIVE OF STUDY

Life Cycle Assessment (LCA) provides systematic and quantifiable measures for assessing environmental burdens of products and processes occurred. Many LCA work studies have been done on coal use but particularly in electricity generation which contains the assessment relating to the data on coal from mine gate to power generation. But the coal mining stage [from cradle- to-gate] has been neglected. This situation has resulted in incomplete assessment of sustainability of coal extraction/mining and use. This study is undertaken to prepare a Life Cycle Inventory of energy, water and land usage for various processes in Samaleswari Opencast Coal Project (Mine) of Ib Valley Coalfield of M/s Mahanadi Coalfields Ltd. located in Jharsuguda district of Odisha, India and to estimate cradle-to-gate environmental impacts of the mining process per functional unit from the inventory analysis calculations.

5. LOCATION OF THE STUDY AREA

Samaleswari Opencast Coal Project (Mine) is located in the southern part of Ib Valley Coalfield and lies in Jharsuguda district of Odisha, India. The area is well connected by rail and road to important business centres in Odisha like Rourkela, Jharsuguda, Sundargarh and Bhubaneswar. The Howrah-Mumbai railway line of the South-Eastern Railway passes through the coalfield. Brajrajnagar and Jharsuguda are the important Railway Stations through which the mine is approachable[21]. The location map of Samaleswari Opencast Coal Project (Mine) in Ib Valley Coalfield is given at Figure 1 & 2. (a) & (b)
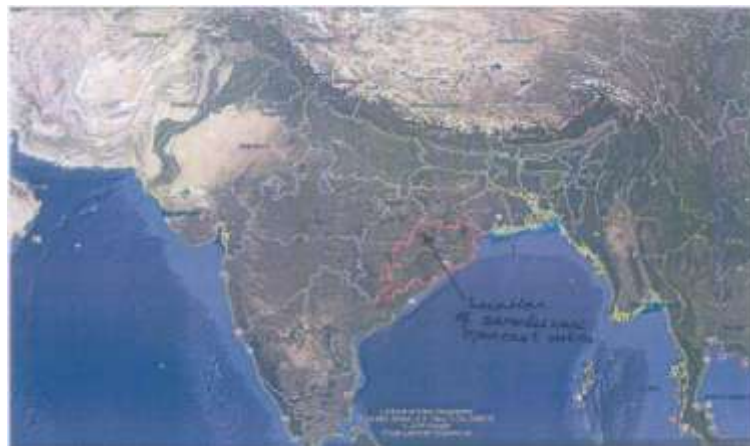

Fig.1: Location of Mine in Odisha in the satellite map

Fig.2(a)

Fig.2(a)

Fig.2(a) & (b): Location of mine in the political map

6. PHYSIOGRAPHY

Samaleswari Opencast Coal Project (Mine) has undulating landscape with elevation ranging from 245 m to 320m above mean sea level. The mine is drained mainly by Ib River.

7. METHODOLOGY

A complete system flow of coal mining from cradle-to-gate of the mine is prepared. System boundary for LCA is selected. An appropriate functional unit is selected. Life Cycle Inventory (LCI) on resource inputs and emissions for production of coal in Samaleswari Open Cast Coal Project (Mine) is prepared. The life cycle impacts for categories of energy-use, water-use, land-use, resource depletion, climate change is assessed.

7.1 System Boundary

To collect all the data for the entire unit processes connected to coal is impractical because of resource and time limitations. As a result, the system boundaries for the LCA had to be scoped to ensure a manageable volume of data within the constraints of available resources. Since the system under study is a cradle-to-gate system, the unit processes include drilling, blasting, excavation, loading and hauling of coal to the mine gate. The processes downstream of mining, such as coal processing, transportation of coal to places for use, the use of coal and disposal of any end waste products, such as fly ash are being excluded from the system boundaries. While selection of system boundaries, care had been taken that the critical environmental flows in the life cycle of coal were not excluded.
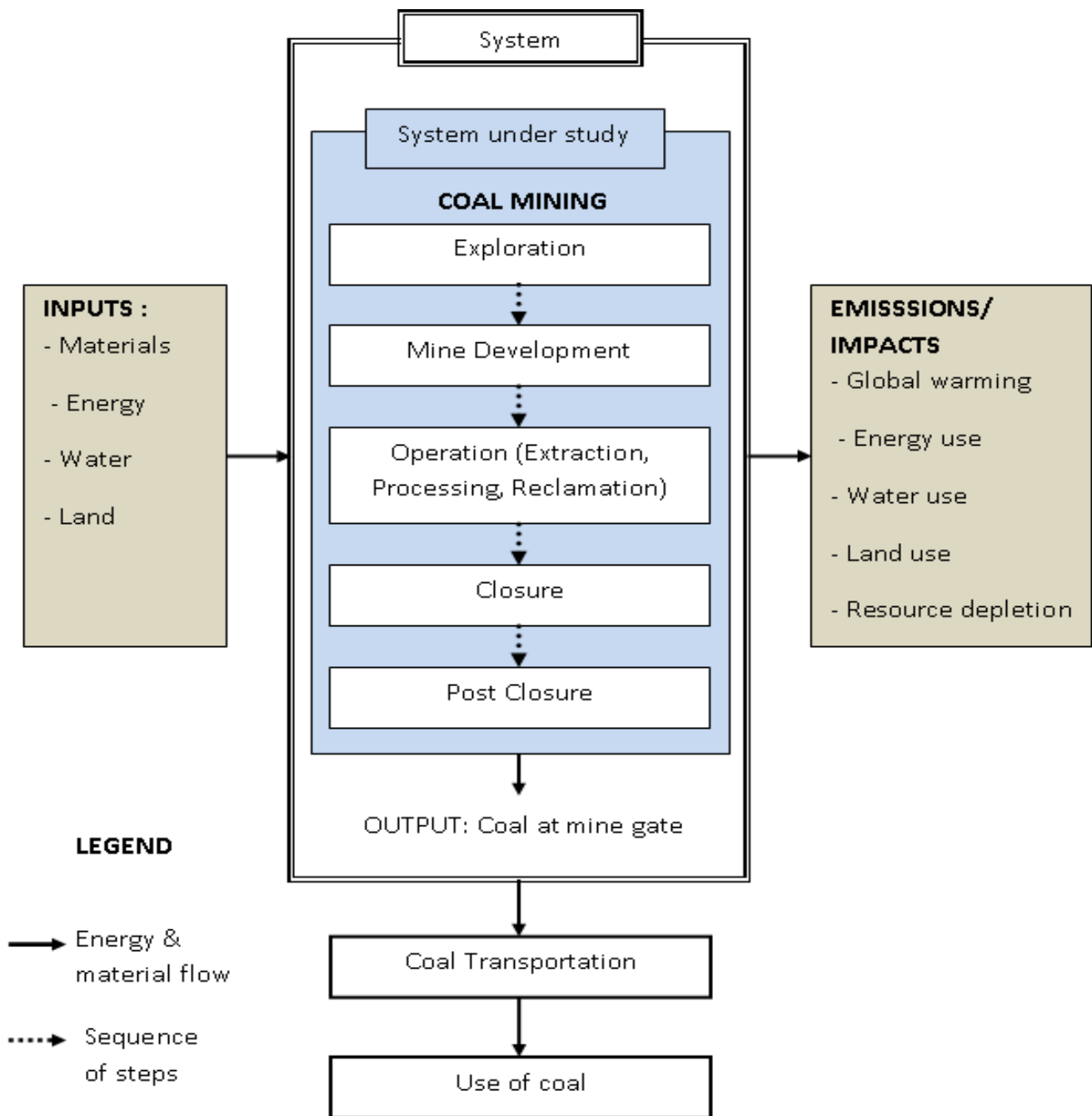
Fig.3: System Boundary in the Cradle-to-Gate Life-Cycle Assessment of Coal

7.2 Functional unit

Functional unit is a defined fundamental unit which forms as a basis for impact assessment in any product processes or services. A functional unit can be energy-based, mass-based, currency based, processed output based, etc. A mass based functional unit is easy to work with since mining companies typically report their reserves and production information on the basis of mass. Also, the practice in coal mining industry is that material inputs, waste products and economic information are expressed on the basis of a unit mass of product [typically a Tonne (Te)]. Applying a mass-basis provides clarity, easy comparability of LCA results and also allows for scaling of results over any production scale or time period based on interest. The functional unit for this study was defined as, 'One Tonne of coal produced at the Mine Gate'. This choice of functional unit ensures consistency with the functional units used in many other coal LCA studies.
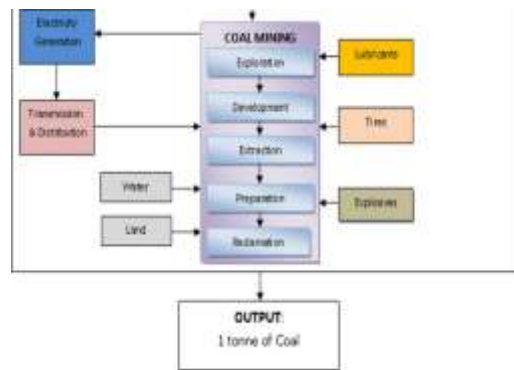
Fig.4: Functional Unit in product system of Surface/ Opencast/Open Cut Coal Mining
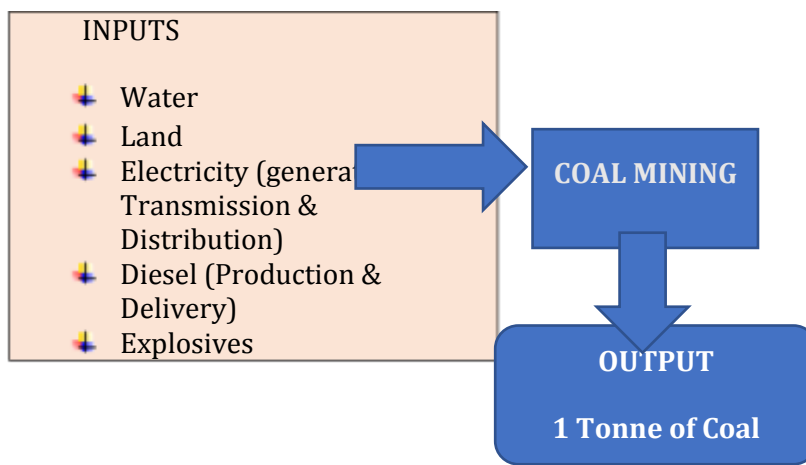

Fig 5: Inputs & Functional Unit in Final System boundaries considered for this LCA study

7.3 Life Cycle Inventory (LCI)

Life Cycle Inventory (LCI) analysis involves creating an inventory of flows from and to nature for a product system. Inventory flows include inputs of water, energy, and raw materials, and releases to air, land, and water. In this study basic inputs are Water, Land, Electricity (Generation, Transmission and Distribution), Diesel (Production & Delivery) and Explosives.
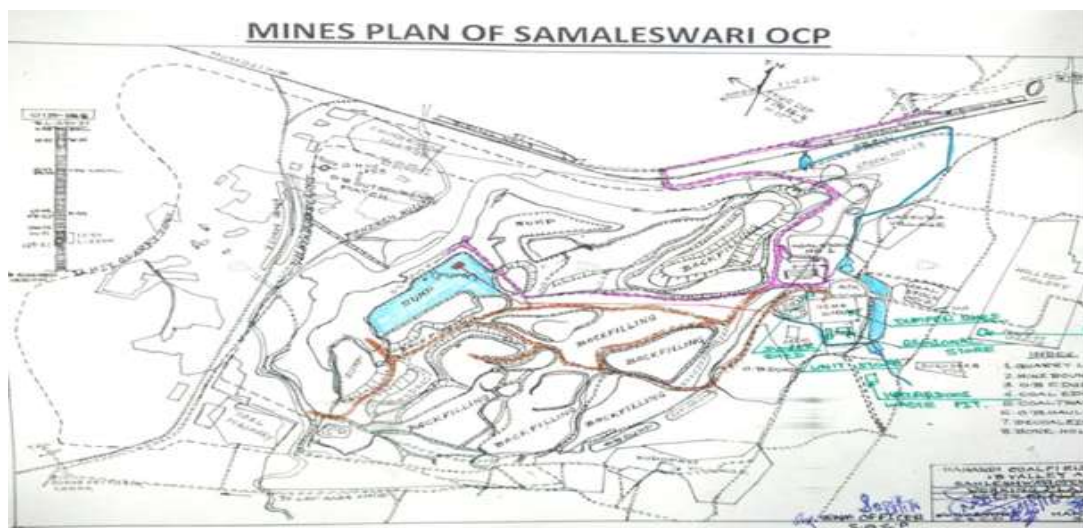

Fig.6: Plan of Samaleswari Opencast Project/Mine

7.3.1 Water use

Water consumption data for each process was collected   and classified into industrial/ mining and other domestic purposes. The data was collected in an aggregated figure but not broken down according to uses in mines.

7.3.2 Land use

Amount of Coal Reserves, Overburden and Lease holding details of land acquired by mine was collected. Break-up of the total lease hold area according to the conceptual plan was prepared. Land use calculations for the life cycle inventory analysis were determined by dividing the total land area that is likely to be disturbed throughout the life of a mine (land already disturbed by construction of facilities and coal extraction, plus coal resources areas that are yet to be disturbed) by the total reserves for the mine. Year wise disturbing and reclamation data was collected to calculate Land Occupation Impact (LOI).

7.3.3 Use of electricity and other fuels

Data was collected on each unit of machinery used for coal mining processes of the project/mine. Rated Gross power, Min-Max fuel consumption for diesel operated machinery, operating rated power for electrical machines was acquired. Total diesel consumption and total electricity consumption was measured to calculate the amount of fuel use/energy use per tonne of coal produced (Functional Unit). High- Speed Diesel is used which has calorific value of 10,670 Kcal/kg. Delivery of diesel to the mine is carried out by M/s Indian Oil Corporation Ltd.(IOCL) tankers from Sambalpur, Odisha. The Abiotic resource depletion for fuel use can be assessed from the distance of delivery for the fuel from well to mine gate. Similarly, resource depletion for the electricity generated can be assessed for E-Resource mix of electricity generation data of Indian Power plants. The amount of emissions of CO_2 can be calculated from the emission factors, oxidation factors of the respective fuel.

7.3.4 Explosives

Site Mixed Emulsion or Site Mixed Slurry explosives which contain Ammonium Nitrate - Fuel Oil (ANFO) as main explosive component are used. Energy content of ANFO is MJ. Powder Factor (Kg of explosive/ Te of material) was collected. Four different powder factors were maintained in the mine as for three different types of overburden removal operations and for blasting coal. The amount of energy of explosive in MJ can be calculated per tonne of coal produced. The amount of CO_2 released from the explosive during blasting is also calculated to assess climate change impact.

8. RESULTS & DISCUSSIONS

Samaleswari Open Cast Coal Project/Mine operated by M/s Mahanadi Coalfields Ltd. a subsidiary company of M/s Coal India Limited was considered for data collection in this study. This project is under the administrative control of Ib Valley Area of M/s Mahanadi Coalfields Ltd. situated at a distance of 15 KMs by road from Jharsuguda town and 75 KMs from Sambalpur where Company's Corporate Office is located. Proved reserve of coal was estimated to be 41.25 MTe. Estimated total cost of the project is around Rs. 465.88 Crores. The elevation of this area varies from 245 m to 320m from Mean Sea Level.

8.1 Life Cycle Impact Assessment (LCIA)

The inventory results are translated to contributions to the selected environmental impact categories. Land Use, Water Use, Energy Impacts, Climate Change Impact, Abiotic Resource Depletion Impacts are the considered impact categories.

8.1.1 Land use impact

Characterizing land use impact from the transformative perspective such as changes in quality, productivity and biodiversity is complex and not recommended particularly in this case as for the lack of the respective data before the start of mining and current data. In this project, life cycle land use impacts were assessed from the occupancy perspective in which the area of land occupied and duration of occupancy[26],[27]. At Samaleswari Opencast Coal Project/Mine, though the land is reclaimed in small amounts regularly year wise, no part of land is being released from the lease hold.

Land Occupation Impact (LOI) = Area of land under Lease x (Total number of years until the release of lease or until land is restored to its original quality)/ total reserves in Te.

Total proved reserves as per data collected is 41.25 Million Te. Total lease hold area for the project purpose is 928.264Ha

and 49.855 Ha is for residential purpose. The further project life is estimated to be 10 years as per 12/15 MTY extension project report which was prepared during 2014-15. Lease for land was obtained in 1989. After the complete removal of coal, an estimated time of 5 years is considered for complete reclamation of land area and restoration of land to its original quality. Number of years from obtaining of lease hold to its release is considered to be 35+5 = 40 years.

Total mining lease hold area = 978.119Ha. Total mineable reserves = 41.25 Million Te. LOI = 9781190*40/41250000 = 9.484 m^2 – year/ Te of coal produced.

8.1.2 Water use impact

There are no characterization methods standardized in LCA methodology for the water use impact category. The amount of water consumption from the inventory analysis phase per tonne of coal was used as an indicator for water usage impact. The total Water consumption per day is calculated to be 2510 m^3 (Peak demand) including domestic and drinking purposes. Average coal production per day considering 360 working days in a year is 40537.6 Te. The water use impact was determined to be 61.91 Liters per Te of coal produced.

Table-1: Details of Samaleswari Opencast Coal Project/Mine

Production Capacity as per consent order	15 MTPA	
Environmental Clearance from MoEF	Environmental Clearance for 15 MTY obtained vide letter No: J11015/183/2008-1A.11 (M)	
Year of Establishment	1989	
Mineable reserve	11,00,000 Te	
Probable reserve	14,00,000 Te	
Proved reserve	41.25 M. Te.	
Project life	8 years (As per 12/15 MTY 9 expansion report)	
Mine leasehold boundary	15760 m.	
Mine Boundary	11,410 m.	
Active Mine area	6,40,000 m^2	
Total mining leasehold area	928.264 Ha	
Total Cost of the project	465.88 Cr.	
Stripping Ratio	2.24	
Area covered under plantation	322.13 Ha.	
Coal Production in FY 2015-16	14593559.96Te	
Powder Factor	Location	P.F
	Dep. OB	2.41
	Out Sourcing OB	2.04
	Dragline OB	1.32
	Coal	4.48

8.1.3 Energy use

In this category, total energy used in the mine from cradle to gate for production of 1 Te of coal is assessed. Total energy includes energy consumption by machinery comprising diesel usage and electricity consumption and energy usage during blasting in the form of explosives. Net Calorific value for HSD in India is in the range of 10100 – 10300 Kcal/Kg approximated to 10,670 Kcal/Kg.

Total annual HSD consumption from the inventory analysis calculations is measured to be 17858160 Liters.

HSD fuel consumption per Te of coal = 17858160/14593559.96 = 1.224 Litre/Te

Net calorific value for HSD is 10670 Kcal/Kg.

Density = 0.8263 Kg/Litre

Net Fuel energy consumption/tonne = 1.224*0.8263*10670=10791.54 Kcal=45.151 MJ

Total annual electricity consumption is 16.22 M KWh = 58.392 TJ [1KWh=3.6 MJ]]

Electricity consumption per tonne of coal is 4 MJ =1.1KWh

From the inventory analysis calculations, the energy content of explosives used per tonne of coal = 58.4798 MJ

The total energy usage per one Tonne of coal = 107.6618 MJ

Table 2: Energy usage calculation

CONTENT	QUANTITY
Annual HSD consumption	17858160 L
HSD cons. per Te of coal	1.2240 L
Net Fuel energy cons./ Te	45.1820 MJ
Annual electricity cons.	58.392 TJ
Electricity cons. per Te	4 .0000MJ
Explosive energy per Te	58.4798 MJ
Total energy use per Te of coal	107.6618 MJ

8.1.4 Climate change

Climate change impact is assessed from the amount of Greenhouse gas emissions added to the atmosphere per ton of coal produced. GHG emissions mainly considered for an LCA study are CO_2, CH_4. Coal bed methane emissions occupy a heavier portion in GHG emissions, but it has not been included in this study due to lack of availability of respective data. Carbon dioxide emissions from the equipment utilizing HSD and electricity are calculated. CO_2 emissions from the explosives during blasting are also accounted for.

(a)Emissions from electricity consumption

CO_2 emissions from electricity consumption are estimated based on the emission factors and oxidation potential as per statistics given by International Energy Agency (IEA). IEA table gives CO_2 emissions by an emission factor (EF) as $[CO_2]_{g/KWh}$ = 912.

CO_2 emissions from electricity cons.= $[CO_2]_{g/KWh}$ * Average electricity (per Te of coal)

(consumption per Te of coal) = 912*1.11=1.01Kg CO_2/Te of coal

(b)Emissions from HSD consumption

CO_2 emissions from HSD consumption of the machinery can be calculated with the respective CO_2 emission factor given from Intergovernmental Panel on Climate Change (IPCC) tables. As per IPCC tables, the carbon content for the HSD fuel is averaged to be around 85% by weight with being implied that Indian fuel consumption comprises of 18.7% of Indian crude and 81.3% of imported crude components. 1Kg of HSD = 0.85 Kg of carbon = 0.85 x 44/12 x 0.99kg of CO_2

CO_2 emission factor diesel = 72.97 kg/MJ of energy consumption (for HSD)

CO_2 emissions from HSD consumption = 72.97 * 45.182 = 3.297 kg of CO_2/Te of coal

(c)*Emissions during blasting*

From the inventory analysis results, the total CO_2 emissions from explosives are summed up to be 2.95 kg per tonne of coal.

Table 3: CO_2 Emissions calculation

Type	Unit emissions	Total CO_2 emissions
HSD	72.97kg/MJ	3.3 Kg
Electricity	0.912 kg/kWh	1.01 Kg
Explosive	0.17 g/gram of ANFO	2.95 Kg

8.1.5 Abiotic resource depletion

The abiotic resource depletion impact indicators relate life cycle inputs to the extraction of minerals and fossil fuels. The Center of Environmental Science of Leiden University (CML) has developed characterization factors called Abiotic Depletion Potentials (ADP) for different minerals and materials including energy sources. The ADPs are based on mid-point modeling and a standard of 'kg antimony equivalent/kg resource extraction'.

Abiotic Resource Depletion = $\sum$ (ADP_ix m_i) Where;

ADP_i is the Abiotic Depletion Potential of resource i

m_i is the quantity of resource i extracted to provide inputs for the life cycle system.

The resource depletion potentials were characterized with respect to fossil fuels such as coal, natural gas and crude oil only which comprises the major percentage of resources utilized for electricity generation in India.

Table 4: Abiotic resource depletion potential calculations

Abiotic Resource	Amount used to generate 1 kWh of electricity	Amount used per Te of coal (1.11 kWh)	ADP-CML 2001	ADP (g Sb- eq.)
Coal	0.4717 Te	0.5235	0.00671 kg Sb-eq./ kg	3.512685
Natural Gas	0.0002862833 m^3	0.000317 m^3	0.0187 kg Sb-eq./m^3	0.005928
Crude oil	0.07 Gallons	0.0003 kg	0.0201 kg Sb- eq./kg	0.00603

Crude oil which is used for the delivery of fuel from mine well to the gate of mine should also be accounted. HSD is delivered to the mine from Sambalpur which is at a distance of 70 km from the mine gate using oil tankers of capacities 18kl and 12kl.

8.1.6 Data quality and uncertainty

CH_4 emission from coal bed forms a major portion of Greenhouse Gas (GHG) emissions leading to climate change. Lack of CH_4 emission data has been a major drawback for this study. Lack of data representing the coal processing plant led to not including the process in the system boundaries. When mine specific data was not available, data obtained from various other reports and studies was included in this study. Maximum amount of work has been put to avoid uncertainties in data or Life Cycle Inventory analysis calculations [23].

9. CONCLUSIONS

The life cycle water use impact for the production of coal from surface mining has been determined to be 61.91 liters per tonne of coal produced.

The potential land use impact, assessed from the perspective of land occupation has been calculated to be 9.484 m^2-year/tonne of coal.

The potential energy use impacts including electricity, diesel and explosives aggregated amount to 107.6618 MJ. Energy content of explosives used contributed the largest share of energy use impact.

CO_2 emission from HSD consumption alone is calculated to be 3.3 Kg per tonne of coal. Whereas, emissions from electricity consumption and explosive utilization amounted to be 1.01kg and 2.95kg respectively.

Abiotic resource depletion potentials for the resources involved in electricity production which is consumed in mine have been evaluated.

10. RECOMMENDATIONS

The followings are the recommendations for future works:

- LCA is a perfect and prominent tool for comparison of various systems based on the impacts. So, more mines needed to be included in the study and thereby compared further based on impacts.
- More impact categories could be considered for study to address more resource inputs and emissions to air, water and ground. Impact categories which are used for study in LCA studies for coal mining product usage should be included as possible in the study to reduce LCI data gap for the products.

REFERENCES

[1] Awuah-Offei K, Checkel D, Askari-Nasab H (2008a) Evaluation of belt conveyor and truck haulage systems in an open pit mine using life cycle assessment. CIM Bulletin, Vol. 102, Paper 8, pp 1–6

[2]Awuah-Offei K, Checkel D, Askari-Nasab H (2008b) Environmental life cycle assessment of belt conveyor and truck haulage systems in an open pit mine. SME Annual Conference, 24–27 Feb 2008, Salt Lake City, Utah. Conference Volume Paper 11, pp 78-84

[3]Benetto, E., Dujet, C. and Rousseaux, P. (2006). Fuzzy-Sets Approach to Noise Impact Assessment. Int J.LCA, Ecomed publishers, Landsberg, Germany, Vol.11, No.4, pp.222-228

[4]Bovea M-D, Saura Ḹ Ferrero JL, Giner J (20 07) Cradle-to-gate study of red clay for use in the ceramic industry. Int. J of LCA 12(6), pp 439-447

[5] Coal Power Station, India Energy. Accessed from India Energy website on the 18/07/2018 at http://indiaenergy.gov.in/iess/supply_coalpower.php

[6]Coal Reserves of GOI, Ministry of Coal. Accessed from GOI, Ministry of Coal website on the 18/07/2018 at https://www.coal.nic.in/content/coal-reserves

[7]Ditsele O, Awuah-Offei K (2011) Effect of mine characteristics on life cycle impacts of US surface coal mining. Int J Life Cycle Assess (2012) 17:287-294

[8]Durucan S, Korre A, Munoz-Melendez G (2006) Mining life cycle modeling cradle-to-gate approach to environmental management in the minerals industr. JClean Prod14, pp1057.1070

[9]EPA. (1994). Acid Mine Drainage Prediction: Technical Document, EPA 530-R-94- 036/NTIS PB94-201829, December 1994, U.S. Environmental Protection Agency, Washington, DC. Accessed from EPA website on the 02/16/2010 at http://www.epa.gov/waste/nonhaz/ industrial/ special/mining/tech docs/amd.pdf.

[10]EPA (2005). Emission Facts: Average Carbon Dioxide Emissions Resulting from Gasoline and Diesel Fuel. EPA420-F-05-001, February 2005. Retrieved on 09/03/2009 a http://www.epa.gov/oms/climate/420f05001.htm.

[11]EPA (2006), Life Cycle Assessment: Principles and Practice. U.S. Environmental Protection Agency EPA/600/R-06/060, Cincinnati, Ohio, USA. Accessed on 10/12/2008 at EPA website at http://www.epa.gov/NRMRL/lcaccess/pdfs/600r06060.pdf.

[12] International Energy Assessment (IEA)'s outlook 2016, pp 10

[13]ISO. (1997). ISO 14040 Environmental Management- Life Cycle Assessment –Principles and Framework. International Organization for Standardization, Geneva, Switzerland.

[14]ISO. (1998). ISO 14041 Environmental Management-Life Cycle Assessment – Goal and Scope Definition and Inventory Analysis. International Organization for Standardization, Geneva, Switzerland.

[15]ISO. (2000). ISO 14042 Environmental Management-Life   Cycle Assessment –Life Cycle Impact Assessment, International Organization for Standardization, Geneva, Switzerland.

[16]ISO. (2000). ISO 14043 Environmental Management–Life Cycle Assessment –Life Cycle Interpretation. International Organization for Standardization, Geneva, Switzerland.

[17]ISO. (2006a).ISO 14040 Environmental Management–Life Cycle Assessment–Principles and Framework. International Organization for Standardization, Geneva, Switzerland.

[18]ISO. (2006b). ISO Standards for Life Cycle Assessment to Promote Sustainable Development–Ref.: 1019. Accessed from the International Organization for Standardization (ISO) website on 02/07/2010 at http://www.iso.org/iso/pressrelease.htm?refid=Ref1019.

[19]ISO. (2006). ISO 14044 Environmental Management–Life Cycle Assessment Requirements and Guidelines. International Organization for Standardization, Geneva, Switzerland. Land Reclamation Report on CIL. Accessed from CIL website on the 17/07/2018 at https://www.coalindia.in/Manage/ViewDocumentModule.aspx

[20]Mangena S J, Brent A C (2006) Application of a life cycle impact assessment framework to evaluate and compare environmental performances with economic values of supplied coal products. J Clean Prod 14, pp1071–1084

[21]Project Report of Samaleswari Opencast Project, MCL(CIL), 2000

[22] Power & Energy of Planning Commission, GOI. Accessed from Planning Commission, GOI website on the 18/07/2018 at http://planningcommission.gov.in/sectors/industry.php?sectors=ind

[23]Ross S, Evans D, Weber M (2002) How LCA studies deal with uncertainty. Int. J of LCA7(1), pp47–52

[24]Spitzley DV, Tolle DA (2004) Evaluating Land-use Impacts: selection of surface area metrics for life-cycle assessment of mining. J Indust Ecol 8(1–2), pp11–21

[25]Suppen N, Carranza M, Hueta M, Hernandez MA (2006) Environmental Management and Life Cycle approaches in the Mexican mining industry. J Clean Prod 14, pp1101–1115

[26]Udo de Haes HA (2005) Land-use Impacts of mining in the Life Cycle Initiative. In: Dubreuil A(ed) Life Cycle Assessment of Metals: issues and research directions. SETAC, USA, pp 159–163

[27]Van Zyl DJA (2005) Towards improved environmental indicators for mining using Life-Cycle Thinking. In: Dubreuil A (ed) Life cycle assessment of metals: issues and research directions. SETAC, USA, pp 117–122