11 MINING SECTOR

Emissions from mining activities are estimated based on the empirical formula derived by Chakraborty et al. (2002). The formula is used to estimate emissions of different pollutants from coal and iron ore mining. The empirical formulae (Eq. 30, 31, and 32) used for estimating the emission rates of different pollutants are:

$$E_{PM} = [u^{0.4}a^{0.2}\{9.7+0.01p+b/(4+0.3b)\}] \quad (30)$$

$$E_{SO_2} = a^{0.14}\{u/(1.83+0.93u)\}\times[\{p/(0.48+0.57p)\}+\{b/(14.37+1.15b)\}] \quad (31)$$

$$E_{NOx} = a^{0.25}\{u/(4.3+32.5u)\}[1.5p+\{b/(0.06+0.08b)\}] \quad (31)$$

where, E_{PM}, E_{SO_2} and E_{NOx} are emissions rate of pollutants PM, SO_2 and NO_x, respectively from mining activities. u = wind speed (m/s); a = area of pit (km^2); p = mineral production (Mt/year); b = Overburden (OB) handling (Mm^3/year)

The production, overburden removal and number of mines for each coal mining company for the year 2016 have been taken from the *Coal Directory of India 2016–17*. Since the data on mining area of all mines in India are not available, the ratio of coal production to area of production (0.039 Mt/km^2) calculated for the state of Odisha is used for other states also. Wind speeds of respective states have been taken from Climatological tables of India published by Indian Meteorological Department (IMD). The ratios of PM_{10} and $PM_{2.5}$ in the total PM were assumed to be 0.5 and 0.1, respectively (GAINS-ASIA). Emissions estimated in this method was also validated using the emission factor method developed by Ghose (2004). Due to lack of detailed data on mine-wise area and location of each mine for iron ore mining, emissions from iron ore mining were estimated using the emission factor developed by Ghose only. Emission factors for mining operations developed by Ghose (2004) are shown in Table 36.

Table 36 Emission factors for mining operations

Mining activity	Material	Emission factor for PM (g/kg)
Overburden (topsoil removal)	Overburden	0.029
Dumper loading of overburden (by power shovel)	Overburden	0.018
Unloading	Overburden	0.001
Total EF for OB removal	Overburden	0.048
Transportation in haul road	Overburden	2.25*
Loading	Coal	0.014
Unloading	Coal	0.033
Total EF for coal mining	Coal	0.047

Transportation in haul road	Coal	2.25*

Using Ghose's emission factor, emissions from both coal and iron ore mining activities are estimated based on the production, overburden removal, and number of mines using Eq. 33 and Eq. 34:

$$E_{OBR} = OBR_T \times EF_{OBR} \quad (33)$$

$$E_M = P_T \times EF_M \quad (34)$$

where, E_{OBR} and E_M are emissions from overburden removal and mining respectively and OBR_T is the total overburden removal; P_T is the total production; and EF_{OBR} and EF_M are total emission factors for overburden removal and mining, respectively. Emissions are also estimated due to transportation of both overburden and coal/iron ore in haul road. The emissions due to transportation of overburden and coal/iron ore in haul road are estimated using Eq. 35:

$$E_{Tr} = VKT_M \times EF \quad (35)$$

where, E_{Tr} is the emissions due to transportation of overburden and coal/iron ore in haul road; VKT_M is the vehicle kilometer travelled; and EF is the emission factor. VKT_M was calculated using Eq. 36:

$$VKT = h \times c \times Q_{MT} \quad (36)$$

where, h is the average length of haul road which is 0.5 km for overburden and 0.7 km for coal/iron ore; c is the average capacity of the dumper used to transport which is 85 tonnne and 58 tonne respectively for overburden and coal/iron ore, respectively.

The data for production, overburden removal and number of mines in coal mining sector is taken from the *Coal Directory of India 2016–17*, whereas the corresponding data for iron ore mining sector is taken from the *Ministry of Mines Annual Report 2017–18*.

The estimated emissions from open cast coal mining and open cast iron ore mining are shown in Table 37.

Table 37 Emissions of pollutants (Gg) from open cast coal mining and iron ore mining during 2016

Pollutant	Open cast coal mining		Iron ore mining	Total
	Chakraborty (2002)	Ghose (2004)		
PM_{10}	100.01	132.78	46.31	279.1
$PM_{2.5}$	20.00	26.56	9.26	55.82
SO_2			8.46	8.46
NO_x			3.04	3.04

As per the emissions estimated based on the methodology developed by Ghsoe (2004), 74% of PM emissions are contributed by coal mining and remaining 26% PM emissions are contributed by iron ore

mining. Out of this, for both coal mining and iron ore mining, 65% emissions are caused by overburden removal, 11% by mining activities and 24% due to transportation of overburden and coal/iron ore mine in haul road.

The emissions from coal mining sectors in India were allocated spatially using mining data of coal and iron ore in different districts. For iron ore mining also the emissions were distributed on the basis of production of iron ore from various states. In India, there are mainly ten iron ore producing states, i.e., Karnataka, Andhra Pradesh, Rajasthan, Tamil Nadu, Goa, Chhattisgarh, Odisha, Maharashtra, Madhya Pradesh, and Telangana. State-wise production of iron ore for the year 2014–15 was collected from Indian Bureau of Mines and was considered for emissions distribution. After that emissions from states to grid level were distributed using ArcGIS software (Figure 15).

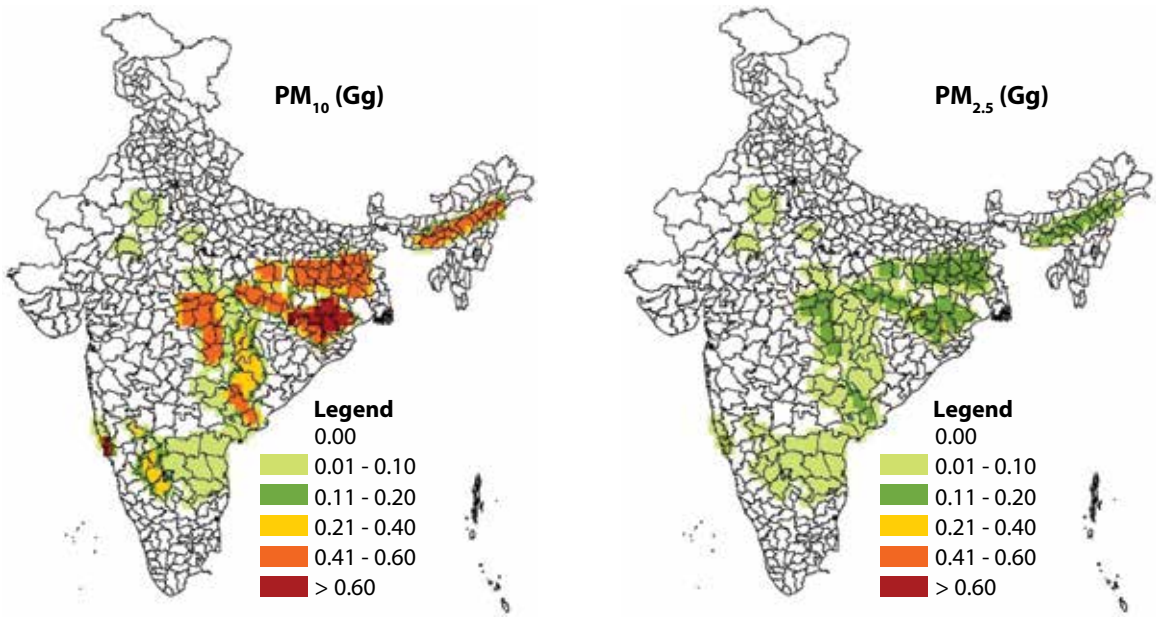

Figure 15 Spatial variation of emissions of particulate matters from the mining sector