Carlo Trozzi
Results from a quarrying and mining case study

17th JOINT EIONET AND UNECE TASK FORCE
ON EMISSION INVENTORIES AND PROJECTIONS MEETING
Combustion & Industry Expert Panel
16th May 2016, Zagreb, Croatia
topics

• Quarrying and mining in the GB
• Coal Mine Case Study
• Coal mine activities modeled
• US EPA methodology (AP42)
• Coal mine activities data needs
• Case study results
• Reduction measures
Quarrying and mining in the GB

1.B.1.a Fugitive emissions from solid fuels: Coal mining and handling
   – 0501 Extraction and first treatment of solid fossil fuels
     – 050101 Open cast mining
     – 050102 Underground mining
     – 050103 Storage of solid fuel

2.A.5.a Quarrying and mining of minerals other than coal
   – 040616 Extraction of mineral ores
     – 040623 Quarrying

2.A.5.c Storage, handling and transport of mineral products
   – 6010 Transport via railways
   – 6023 Freight transport by road
   – 6110 Sea and coastal water transport
   – 6120 Inland water transport
   – 6210 Scheduled air transport
   – 6220 Non-scheduled air transport
   – 6301 Cargo handling
   – 6302 Storage and warehousing
   – 6303 Other supporting transport activities
1.B.1.a Fugitive emissions from solid fuels: Coal mining and handling

- Tier 1
  - Very gross estimates from CEPMEIP

- Tier 2
  - Technology split:
    - Open cast mining
    - Underground mining
    - Storage of coal
      - uncontrolled
      - controlled
    - Handling of coal
  - Mining from US EPA average values
  - Storage and Handling
    - Very gross estimate
    - PM$_{10}$ EFs not properly documented
    - TSP and PM$_{2.5}$ EFs obtained from PM$_{10}$ with proportion from CEPMEIP: very uncertainty estimates

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2.A.5.a Quarrying and mining of minerals other than coal

• Tier 1
  – Very gross estimates from CEPMEIP

• Tier 2 (but not a true Tier 2)
  – Technology split:
    • Low to medium emission level
    • High to medium emission level (same as Tier1)
  – Very gross estimate from CEPMEIP
2.A.5.c Storage, handling and transport of mineral products

- No Tier 1
- Tier 2 (but not a true Tier 2)
  - Technology split:
    - Storage (uncontrolled),
    - Storage (controlled),
    - Handling (uncontrolled)
  - Very gross estimate
  - PM$_{10}$ EFs not properly documented
  - TSP and PM$_{2.5}$ EFs obtained from PM$_{10}$ with proportion from CEPMEIP: very uncertainty estimates
Coal Mine Case Study

- An estimation model was developed to take into account emissions coming from extraction of solid materials in the coal mine area for the activity 05010100 Extraction of solid fuels - Open cast mining.

- All available information on amount of handled material, characteristics of coal, meteorological data on wind and precipitations, handling and transport systems were used to calculate specific emission factors to obtain average dust emissions in the area.

- The activity 04090100 Mineral products storage, handling and transport was also introduced to take into account coal transport by trucks from the coal mine to the thermal power plant.
Coal mine activities modeled (1)

• Drilling (coal and overburden) [¹]
• Blasting (coal or overburden) [¹]
• Truck loading (coal) [¹]
• Bulldozing (coal or overburden) [¹]
• Dragline (overburden) [¹]

¹ United States Environmental Protection Agency, AP 42, Compilation of Air Pollutant Emission Factors

11.9 Western Surface Coal Mining
Coal mine activities modeled (2)

• Vehicles traffic on paved road \[2\]
• Vehicles traffic on unpaved road \[3\]
• Wind erosion \[4\]

\[2\] United States Environmental Protection Agency, AP 42, *Compilation of Air Pollutant Emission Factors*

**13.2.1 Paved Roads**

\[3\] United States Environmental Protection Agency, AP 42, *Compilation of Air Pollutant Emission Factors*

**13.2.2 Unpaved Roads**

\[4\] United States Environmental Protection Agency, AP 42, *Compilation of Air Pollutant Emission Factors*

**13.2.5 Industrial Wind Erosion**
US EPA methodology (AP42)

Predictive emission factor equations for open dust sources applies to a single dust-generating activity, such as vehicle traffic on haul roads. The predictive equation explains much of the observed variance in emission factors by relating emissions to three sets of source parameters:

- measures of source activity or energy expended (e.g., speed and weight of a vehicle traveling on an unpaved road, number of holes, bulldozing hours, etc.)
- properties of the material being disturbed (e.g., suspendable fines in the surface material of an unpaved road, coal moisture %, coal silt %, etc.)
- climate (wind speed, precipitations)
Coal mine EFs [USEPA AP42] (1)

Drilling

\[ \text{EF}_{\text{PST}} = 0.59 \text{ kg/hole overburden, } \text{EF}_{\text{PST}} = 0.10 \text{ kg/hole coal} \]
Coal mine EFs [USEPA AP42] (2)

Blasting (coal or overburden)

\[ EF_{PST} = 0.00022 \times A^{1.5}, \quad EF_{PM10} = 0.52 \times EF_{PST}, \quad EF_{PM2.5} = 0.03 \times E_{PST} \text{ kg/blast} \]

[A=horizontal area in m², with blasting depth < 21 m]
Coal mine EFs [USEPA AP42] (3)

**Bulldozing (coal)**

\[ \text{EF}_{\text{PST}} = 35.6 \times S^{1.2}/M^{1.3}, \quad \text{EF}_{\text{PM10}} = 0.18 \times \text{EF}_{\text{PST}}, \quad \text{EF}_{\text{PM2.5}} = 0.005 \times \text{EF}_{\text{PST}} \text{ kg/hours} \]

[M= material moisture content (%), S= material silt content (%)]

**Bulldozing (overburden)**

\[ \text{EF}_{\text{PST}} = 2.6 \times S^{1.2}/M^{1.3}, \quad \text{EF}_{\text{PM10}} = 0.13 \times \text{EF}_{\text{PST}}, \quad \text{EF}_{\text{PM2.5}} = 0.02 \times \text{EF}_{\text{PST}} \text{ kg/hours} \]

[M= material moisture content (%), S= material silt content (%)]
Coal mine EFs [USEPA AP42] (4)

Dragline (overburden)

\[
\text{EF}_{\text{PST}} = 0.0046 \times d^{1.1} / M^{0.3}, \quad \text{EF}_{\text{PM10}} = 0.47 \times \text{EF}_{\text{PST}}, \quad \text{EF}_{\text{PM2.5}} = 0.01 \times \text{EF}_{\text{PST}} \quad \text{kg/m}^3
\]

\([M= \text{material moisture content (\%), } d= \text{drop height (m)}]\)
Coal mine EFs [USEPA AP42] (5)

**Truck loading (coal)**

\[
EF_{\text{PST}} = 0.58/M^{1.2}, \quad EF_{\text{PM10}} = 0.077 \cdot EF_{\text{PST}}, \quad EF_{\text{PM2.5}} = 0.002 \cdot EF_{\text{PST}} \quad \text{kg/Mg}
\]

\[M= \text{material moisture content (\%)}\]
Coal mine EFs [USEPA AP42] (6)

Vehicles traffic on paved road

\[
EF_{PST} = [3.23 \, (sL)^{0.91} \times W^{1.02}] \times (1 - 1.2 \times P/N) \, g/vkt
\]

\[
EF_{PM10} = [0.62 \, (sL)^{0.91} \times W^{1.02}] \times (1 - 1.2 \times P/N) \, g/vkt
\]

\[
EF_{PM2.5} = [0.15 \, (sL)^{0.91} \times W^{1.02}] \times (1 - 1.2 \times P/N) \, g/vkt
\]

\[sL = \text{road surface silt loading (g/m}^2\), \text{ default value 0.6 for average daily traffic ADT}<500, 0.2 for 500<ADT<5000, 0.06 for 5000<ADT<10000, 0.03 for ADT>10000]\]

\[W = \text{average weight (Mg) of vehicles traveling the road}\]

\[P = \text{number of hours with at least 0.254 mm of precipitation during the averaging period}\]

\[N = \text{number of hours in the averaging period}\]

\[vkt = \text{vehicle kilometer traveled}\]

The term silt loading refers to the mass of silt-size material (equal to or less than 75 micrometers [μm] in physical diameter) per unit area of the travel surface. The total road surface dust loading consists of loose material that can be collected by broom sweeping and vacuuming of the traveled portion of the paved road. Silt loading is the product of the silt fraction and the total loading.
Coal mine EFs [USEPA AP42] (7)

Vehicles traffic on unpaved road

\[
EF_{\text{PST}} = [4.9 \, (sL/12)^{0.9} \times (W/3)^{0.45}] \times (1 - P/N) \, g/vkt \\
EF_{\text{PM10}} = [1.15 \, (sL/12)^{0.9} \times (W/3)^{0.45}] \times (1 - P/N) \, g/vkt \\
EF_{\text{PM2.5}} = [0.15 \, (sL/12)^{0.9} \times (W/3)^{0.45}] \times (1 - P/N) \, g/vkt
\]

\[sL = \text{road surface silt loading (g/m}^2\): \text{haul road to/from pit 8.4, plant road 5.1, scraper route 17, haul road freshly graded 24}\]
\[W = \text{average weight (Mg) of vehicles traveling the road}\]
\[P = \text{number of hours with at least 0.254 mm of precipitation during the averaging period}\]
\[N = \text{number of hours in the averaging period}\]
\[vkt = \text{vehicle kilometer traveled}\]

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Coal mine EFs [USEPA AP42] (8)

Wind erosion of storage piles (1)

- dust emissions may be generated by wind erosion of open aggregate storage piles
- these sources typically are characterized by nonhomogeneous surfaces impregnated with non erodible elements (particles larger than approximately 1 centimeter [cm] in diameter)
- particulate emissions occur when wind speed is greater than threshold wind speeds

<table>
<thead>
<tr>
<th>Material</th>
<th>Threshold Friction Velocity (m/s)</th>
<th>Threshold Wind Velocity At 10 m (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overburdena</td>
<td>1.02</td>
<td>21</td>
</tr>
<tr>
<td>Scoria (roadbed material)a</td>
<td>1.33</td>
<td>27</td>
</tr>
<tr>
<td>Ground coal (surrounding coal pile)</td>
<td>0.55</td>
<td>16</td>
</tr>
<tr>
<td>Uncrusted coal pilea</td>
<td>1.12</td>
<td>23</td>
</tr>
<tr>
<td>Scraper tracks on coal pile (Lightly crusted)</td>
<td>0.62</td>
<td>15</td>
</tr>
<tr>
<td>Fine coal dust on concrete pad</td>
<td>0.54</td>
<td>11</td>
</tr>
</tbody>
</table>

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Coal mine EFs [USEPA AP42] (9)

Wind erosion of storage piles (2)

• rates tend to decay rapidly (half-life of a few minutes) during an erosion event
• aggregate material surfaces are characterized by finite availability of erodible material (mass/area) referred to as the erosion potential
• any natural crusting of the surface binds the erodible material, thereby reducing the erosion potential
• emissions generated by wind erosion are dependent on the frequency of disturbance of the erodible surface because each time that a surface is disturbed, its erosion potential is restored.
• a disturbance is defined as an action that results in the exposure of fresh surface material
• on a storage pile, this would occur whenever aggregate material is either added to or removed from the old surface
Coal mine EFs [USEPA AP42] (10)

Wind erosion of storage piles (3)

\[
E_{PST} = \sum_{t=1}^{N} [58 (u^* - u_{t}^*)^2 + 25 (u^* - u_{t}^*)]
\]
\[
E_{PM10} = 0.5 \sum_{t=1}^{N} [58 (u^* - u_{t}^*)^2 + 25 (u^* - u_{t}^*)]
\]
\[
E_{PM2.5} = 0.075 \sum_{t=1}^{N} [58 (u^* - u_{t}^*)^2 + 25 (u^* - u_{t}^*)]
\]

\[u^* = \text{friction velocity (m/s) = 0.053 } u_{10}\]

\[u_{t}^* = \text{threshold friction velocity (m/s); default value used: 0.7}\]

\[N \text{ number of disturbances} \]
\[(\text{for a surface disturbed daily } N = 365 \text{ per year})\]

The wind speed profile in the surface boundary layer is found to follow a logarithmic distribution; the friction velocity \(u^*\) is a measure of wind shear stress on the erodible surface, as determined from the slope of the logarithmic velocity profile.
Case study – operational data

Coal and overburden moisture content (%) = 30, silt content (%) = 20

Number of coal hole = 4,616
Number of overburden hole = 12,800
Number of coal blasts = 23
Number of coal blasts = 54

Horizontal area in m², with blasting depth < 21 m = 10,065

Mg coal loaded = 1,250,000
Hours of coal buldozing = 3,600
Hours of overburden buldozing = 4,050

Average weight (Mg) of vehicles traveling paved road = 30
Length of paved road = 13 km (coal on paved road)

Average weight (Mg) of vehicles traveling unpaved road = 100
Length of unpaved road = 4.75 km (overburden on non paved road)

Meteorological hourly data
Case study – emissions for materials (Mg)

![Bar chart showing emissions for PM10 and PM2.5 from overburden and coal](image)

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*Results from a quarrying and mining case study*
Case study – emissions for type of operation and material

![Graph showing emissions for PM10 and PM2.5 for different types of transport and other sources.]

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Results from a quarrying and mining case study
Case study – emissions for sources other transport

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Results from a quarrying and mining case study
## Reduction measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Measure description</th>
<th>Reduction potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road paving</td>
<td>Paving of the surface of roads covered by trucks transporting coal</td>
<td>&gt;90%</td>
</tr>
<tr>
<td>Speed reduction</td>
<td>Reducing truck speed from 65k/h to 30k/h (it can be strengthened by increasing distances between trucks)</td>
<td></td>
</tr>
<tr>
<td>Watering</td>
<td>Watering (standard procedure)</td>
<td>50% (conservative estimation)</td>
</tr>
<tr>
<td>Reduce operations in windy days</td>
<td>Reduction or suspension of operations during dry, windy conditions</td>
<td></td>
</tr>
</tbody>
</table>

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