Category		Title
NFR:	2.A.5.a	Quarrying and mining of minerals other than coal
SNAP:	040616 040623	Extraction of mineral ores Quarrying
ISIC:	1410	Quarrying of stone, sand and clay
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Coordinator

Jeroen Kuenen

Contributing authors (including to earlier versions of this chapter)

Nathan Vandromme, Nadia Taïeb, Julien Vincent, Nadine Allemand

Contents

1 Overview

In its present state, this chapter covers dust and particulate matter emissions from non-coal quarrying and mining. While some of the description below applies equally, the mining of ore is not addressed explicitly. Depending on national circumstances, emissions from quarrying can be significant and contribute sizable amounts to the national total of TSP, PM_{10} and $PM_{2.5}$. Emissions of other pollutants are considered insignificant; however, this judgement could change in light of e.g. ore mining in some countries where heavy metals might be emitted.

The present version of the Guidebook does provide default emission factors for this source category, based on referenced or non-referenced literature values or, if no literature is available, expert judgement. Almost all details and numbers proposed here are adapted from the US EPA's AP 42 handbook (full details can be found in 6. References).

The present chapter provides a very simple process description, a Tier 1 worst case approach as well as a spreadsheet model developed for a Tier 2 approach to estimate emissions from this source category. While no separate Tier 3 method is presented, the use of facility data is an option and can be combined with results from the Tier 2 approach if properly verified.

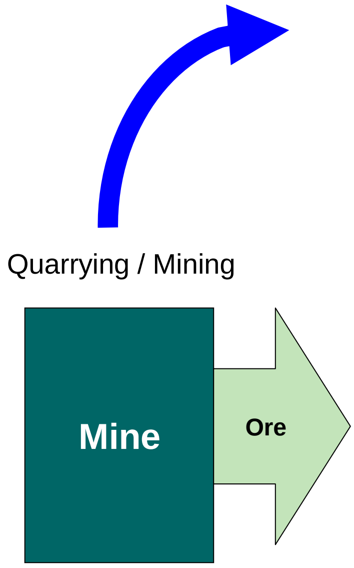
2 Description of sources

2.1 Process description

This chapter discusses the quarrying and mining of minerals other than coal, in particular of crushed rock, sand and gravel to produce aggregate as well as the production of recycled aggregate. While the mining of bauxite, copper ore, iron ore, manganese ore or zinc ore are covered by this sector, there is currently no method presented here.

This chapter does not include emissions from the combustion of fuels in the quarry and in the plant (drillers, mobile crushers, mobile screeners, electric generators etc.) or transport machinery(loaders, dumpers, cranes etc.).

Figure 2.1 A simple process scheme for source category 2.A.5.a Quarrying and mining of minerals other than coal



2.2 Techniques

Standard techniques are assumed for this source including blasting, transportation and crushing of materials. The Tier 2 method described below allows for the detailed consideration of abatement technology where applicable.

2.3 Emissions and controls

Quarrying and mining of minerals results in emissions of particulates. Controls will include wetting and covering of processes, depending on the materials.

3 Methods

3.1 Choice of method

This chapter presents a Tier 1 'worst case' default approach and a Tier 2 approach based on modelling the individual processing steps in the production of aggregate. More detailed information about the emissions from quarrying and mining may be found in AP-42 (US EPA, 2011a).

3.2 Tier 1 default approach

3.2.1 Algorithm

The Tier 1 approach uses the general equation:

$$E_{pollutant} = AR_{production} \times EF_{pollutant} \tag{1}$$

Where:

$E_{pollutant}$ = the emission of the specified pollutant

$AR_{production}$ = the activity rate for the quarrying/mining

$EF_{pollutant}$ = the emission factor for this pollutant

The Tier 1 emission factors assume worst-case, old technology and little to no abatement implementation in the country and integrate all sub-processes.

3.2.2 Default emission factors

Default emission factors for particulate emission from the quarrying and mining of minerals are given in Table 3-1. The emission factors are average factors taken from the Coordinated European Particulate Matter Emission Inventory Program (CEPMEIP) (Visschedijk et al., 2004). For Tier 1 the highest emission level has been chosen i.e. a worst case scenario.

Table 3-1 Tier 1 emission factors for source category 2.A.5.a Quarrying and mining of minerals other than coal.

Tier 1 default emission factors					
	Code	Name			
NFR source category	2.A.5.a	Quarrying and mining of minerals other than coal			
Fuel	NA				
Not applicable	NO_x, CO, NMVOC, SO_x, NH_3, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, HCH, PCBs, PCDD/F, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Not estimated					
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	102	g/Mg mineral	50	200	Visschedijk et al. (2004)
PM_{10}	50	g/Mg mineral	25	100	Visschedijk et al. (2004)
$PM_{2.5}$	5.0	g/Mg mineral	2.5	10	Visschedijk et al. (2004)

3.2.3 Activity data

Information on production statistics (for various source categories) is typically available from national statistics or United Nations statistical yearbooks. For some countries, the European Aggregates Association (UEPG) might offer detailed production data to be used for these estimates[1].

3.3 Tier 2 technology-specific approach

Dust emissions in quarries come from multiple point, surface and linear emissions sources distributed within a vast area and changing with time and with the operations of the quarry. They consist of coarse mineral particles (TSP), some of which are in the PM_{10} fraction and, to a smaller extent, also in the $PM_{2.5}$ fraction.

Emission sources are as follows:

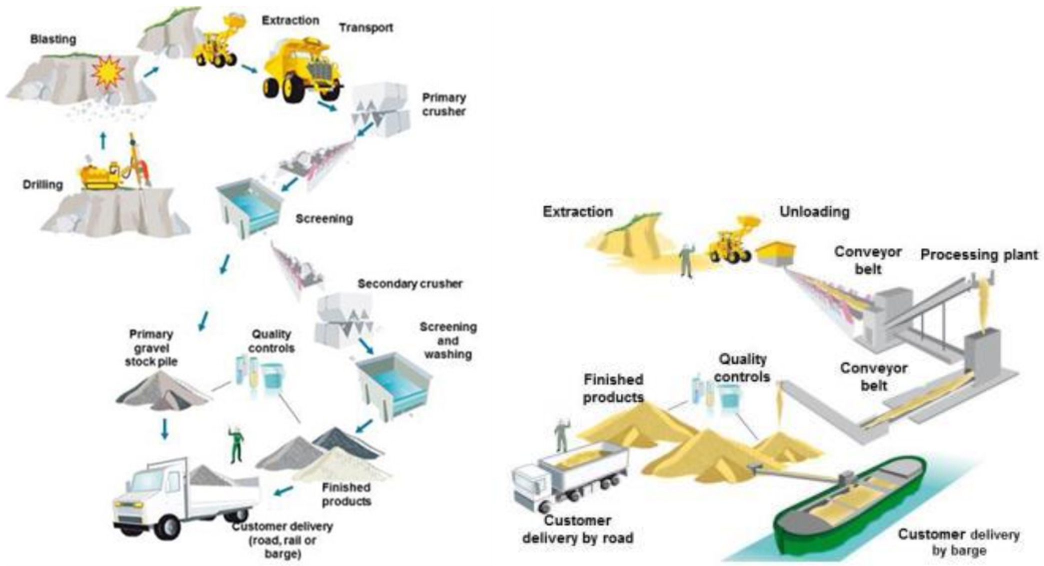
1. Drilling and blasting
2. Material processing: crushing, screening and transfer points

[1] Available online at http://www.uepg.eu/statistics/estimates-of-production-data (January 2019)

3. Internal transport
4. Material handling operations: loading and unloading
5. Wind erosion from stockpiles (the other dusty surfaces are not taken into account e.g. open fields, roads, open conveyor belts,...)

The operations encountered in a quarry are presented in Figure 3.2 for two types of quarries.

Figure 3.1: Operations encountered in two types of quarries



Lafarge Holcim (2018)

a) Crushed rock quarries (left) **b) Sand and gravel quarries (right)**

The method described in the following sections aims to calculate emission to produce aggregate. Other types of quarries, for instance to produce blocks of marble or granite, exist and apply different types of technologies to manufacture their products, such as stone cutting without screening. Those types of quarries are not considered by this approach and specific emission factors (or models) should be applied when calculating particles emitted during their productions.

As for the sector "2.A.5.b Construction and demolition", the resuspension of soil dust by dumper traffic is an important contributor, but since resuspension by road transport as a whole may also be estimated elsewhere, there is a danger of double counting of emissions. However, the published literature suggests that resuspension on quarries sites is, by unit of activity and under the same meteorological conditions, usually several times higher than 'normal' traffic-induced resuspension. Vehicular resuspension from construction should therefore be estimated separately from resuspension by road transport and should be included in 2.A.5.b (EEA, 2016). The same approach has been used for the method presented here, road resuspension occurring inside the quarry is included.

In sections 3.3.1-3.3.5, equations to calculate emission factors are presented for each source. Section 3.3.6 presents a spreadsheet model using those equations to calculate particulate emissions from quarries at a national level.

3.3.1 Drilling and blasting

Introduction

Drilling and blasting are done in two steps: first, a hole is drilled, then explosives are placed in the hole, before being detonated to collapse the wall. This source includes the particulate emissions released during the drilling and blasting.

Required data to calculate particulate emissions

- Average area of the hole/blast (m²)
- Average height of the hole/blast (m)
- Material density
- Volume of production (m^3)

These 4 pieces of information may be used to deduce the 3 values below that are input to the methodology presented below:

- Number of holes per year (-)
- Number of blasts per year (-)
- Average area blasted (m²/blast)

Methodology used to calculate particulate emissions

The following equations are used to calculate particulate emissions related to drilling and blasting (U.S. EPA, 1998; Government of Canada, 2017):

$$E_{TSP} = k_{d-TSP} \times N_{hole} + k_b \times S^{1.5} \times N_{blast}$$

$$E_{PM10} = k_{d-PM10} \times N_{hole} + k_b \times k_{sf-PM10} \times S^{1.5} \times N_{blast}$$

$$E_{PM2.5} = k_{d-PM2.5} \times N_{hole} + k_b \times k_{sf-PM2.5} \times S^{1.5} \times N_{blast}$$

With:

- $E_{TSP/PM10/PM2.5}$: Emissions of TSP/PM10/PM2.5 (kg/year)
- N_{hole} : Number of holes /year
- S : Area blasted (m²/blast)
- N_{blast} : Number of blasts /year
- k_{d-TSP} : 0.59 (kg/hole)
- k_{d-PM10} : 0.31 (kg/hole)
- $k_{d-PM2.5}$: 0.31 (kg/hole)
- k_b : 0.00022 (kg/blast/m^3)
- $k_{sf-PM10}$: 0.52 (scaling factor, no unit)
- $k_{sf-PM2.5}$: 0.03 (scaling factor, no unit)

The coefficients used in those equations are based on wet drilling operations as this is the most commonly used technique (Government of Canada, 2017), assuming an abatement of 90% when using wet drilling. In the case of dry drilling with dedusting systems (cyclone) the abatement efficiency is likely to be lower.

3.3.2 Material processing

Introduction

Three levels of processing are considered, each level producing increasingly finer grains: primary, secondary and tertiary level. Emission factors for each level are considered to be equal (see Table 3-2), therefore a total flow per type of equipment can be used. Three types of equipment emit particles: screeners, crushers and transfer points (which are fall points on/from conveyor belts used to transfer material toward equipment, between equipment and toward storage).

Required data to calculate particulate emissions

- Abatement techniques implemented – rate of use and efficiency (for each type of equipment)
- Percentage of wet and dry processing
- Flow of material going through each type and level of equipment

Methodology used to calculate particulate emissions

The following equations are used to calculate particulate emissions related to material processing (US EPA, 2004; Government of Canada, 2017):

$$E_{\substack{TSP\\PM10\\PM2.5}} = P \times \left(k_{Dry} \times \left(EF_{\substack{TSP\\PM10\\PM2.5}}\Big|_{Dry_{cru}} \times Flow_{cru} \times (1 - ER_{cru}) + EF_{\substack{TSP\\PM10\\PM2.5}}\Big|_{Dry_{sc}} \times Flow_{sc} \times (1 - ER_{sc}) + EF_{\substack{TSP\\PM10\\PM2.5}}\Big|_{Dry_{TP}} \times Flow_{TP} \times (1 - ER_{TP}) \right) + k_{Wet} \times \left(EF_{\substack{TSP\\PM10\\PM2.5}}\Big|_{Wet_{cru}} \times Flow_{cru} + EF_{\substack{TSP\\PM10\\PM2.5}}\Big|_{Wet_{sc}} \times Flow_{sc} + EF_{\substack{TSP\\PM10\\PM2.5}}\Big|_{Wet_{TP}} \times Flow_{TP} \right) \right)$$

Where:

- $E_{TSP/PM10/PM2.5}$: Emissions of TSP/PM_{10}/$PM_{2.5}$ (kg/year)
- $EF_{TSP/PM10/PM2.5 \mid Dry}$: Emission factors for crushers (cru), screeners (sc) and transfer points (TP) for dry material (kg/t)
- $EF_{TSP/PM10/PM2.5 \mid Wet}$: Emission factors for crushers (cru), screeners (sc) and transfer points (TP) for wet material (kg/t)
- $Flow_{cru/sc/TP}$: Total flow of material going through crushers (cru), screeners (sc) and transfer points (TP) (% of production)
- $ER_{cru/sc/TP}$: Abatement factor (%), depending on the reduction technology implemented on the crushers (cru), screeners (sc) and transfer points (TP)
- k_{Dry} : Percentage of the material extracted from the deposit with a moisture content below or equal to 1.3% (%)
- k_{Wet} : Percentage of the material extracted from the deposit with a moisture content above 1.3% (%)
- P : Production (t/year)

Emissions are divided into emissions from processing of wet material (moisture content above 1.3%) and processing of dry material (moisture content below or equal to 1.3%). No abatement technology is considered to be used when wet material is processed because emissions are already significantly reduced (by 78 to 96%). The emission factors (EF) associated with each equipment are presented in Table 3-2.

Table 3-2: Emission factors per processing step and particles size

Processing step	EF_{Dry} (kg/t)			EF_{Wet} (kg/t)		
	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Crushing	0.0027	0.0012	0.0006	0.0006	0.00027	0.00005
Screening	0.0125	0.0043	0.00028	0.0011	0.00037	0.000025
Transfer point	0.0015	0.00055	0.00014	0.00007	0.000023	0.0000065

The emission factors should increase with the level of unit (as the grain gets finer), but only emission factors for tertiary units are available. Therefore, those factors are used for every unit as a conservative approach. The abatement factors can be calculated using the abatement technology efficiency and the abatement technology use, with the following equation:

$$1 - ER = ((1 - Eff) \times Use + (1 - Use))$$

Where:

- ER : Abatement factor (%)
- Eff : Efficiency of the abatement technology (%)
- Use : Use of the abatement technology (%)

The abatement efficiency for each processing step and for various abatement technologies are presented in Table 3-3.

Table 3-3: Abatement efficiency per processing step and per abatement technology

Processing step	Abatement technology	Eff (abatement efficiency)
Crusher	Water Spray	50%
	Water Spray and Surfactant	75%
	Partial Enclosure	85%
	Full Enclosure	90%
	Central Baghouse	95%
Screener	Covered Screener	50%
	Covered Screener with Water Spray	75%
	Covered Screener with Water Spray and Surfactant	90%
	Covered Screener with Control Fabric Filter	95%
	Wet screening	100%
Transfer points	Wet suppression method*	95%

* No information available for other transfer point methods.

When several abatement technologies can be applied, a total abatement factor can be calculated using the following equation:

$$1 - ER_{Total} = (1 - ER_1) \times (1 - ER_2) \times (1 - ER_3)$$

3.3.3 Internal transport

Introduction

This step includes the emissions related to the transport (by vehicles) of materials inside the quarry. Transport of materials emits particles due to the contact between the tyres of the trucks and the road. A distinction is made between unpaved and paved roads due to the significant difference in particulate emissions between the two surfaces. Particulate emissions related to tyres and brakes abrasion are not included in this section, but emissions due to resuspension are included which can explain high emission factors for this section.

Required data to calculate particulate emissions

- Abatement techniques implemented – use and efficiency
- Total distance travelled by dumpers on unpaved and paved roads (km)
- Annual number of rainy days + daily precipitation (mm)
- Silt content (< 75 µm) of road surface material
- Dumper weight (on average)

Methodology used to calculate particulate emissions for unpaved road

The following equations are used to calculate particulate emissions related to internal transport on unpaved road (US EPA (2006a)):

$$E_{TSP} = k_{TSP} \times \left(\frac{s}{k_s}\right)^{0.7} \times \left(\frac{W_{dumper}}{k_W}\right)^{0.45} \times d_{unpaved} \times \left(1 - \frac{p}{k_{day}}\right) \times (1 - ER)$$

$$E_{PM10} = k_{PM10} \times \left(\frac{s}{k_s}\right)^{0.9} \times \left(\frac{W_{dumper}}{k_W}\right)^{0.45} \times d_{unpaved} \times \left(1 - \frac{p}{k_{day}}\right) \times (1 - ER)$$

$$E_{PM2.5} = k_{PM2.5} \times \left(\frac{s}{k_s}\right)^{0.9} \times \left(\frac{W_{dumper}}{k_W}\right)^{0.45} \times d_{unpaved} \times \left(1 - \frac{p}{k_{day}}\right) \times (1 - ER)$$

Where:

- $E_{TSP/PM10/PM2.5}$: Emissions of TSP/PM10/PM2.5 (kg/year)
- s : Silt content (< 75 µm) of road surface material (%)
  Default values proposed (Table 13.2.2-1 of US EPA 2006a):
  - 4.8 for sand and gravel processing
  - 9.15 (average of 8.3 and 10) for crushed rock quarries
- W_{dumper} : Dumper weight (on average) (t)
- $d_{unpaved}$: Total distance travelled by dumpers on unpaved road (km/year)
- ER : Abatement factor (%)

- p : Number of days per year with at least 0.254 (0.01 inch) mm natural precipitation[2]
- k_{TSP} : 1.381 (kg/km)
- k_{PM10} : 0.422 (kg/km)
- $k_{PM2.5}$: 0.042 (kg/km)
- k_W : 2.72 (t)
- k_s : 12 (-)
- k_{day} : 365 (-)

Methodology used to calculate particulate emissions for paved road

The following equations are used to calculate particulate emissions related to internal transport on paved road (US EPA, 2011b). It should be noted that in this equation, a reduction measure like washing is reflected in a lower silt load rather than an abatement factor.

$$E_{TSP} = k_{TSP} \times (sL \times k_{sL})^{0.91} \times \left(W_{dumper} \times k_W\right)^{1.02} \times d_{paved} \times \left(1 - \frac{p}{k_{day}}\right)$$

$$E_{PM10} = k_{PM10} \times (sL \times k_{sL})^{0.91} \times \left(W_{dumper} \times k_W\right)^{1.02} \times d_{paved} \times \left(1 - \frac{p}{k_{day}}\right)$$

$$E_{PM2.5} = k_{PM2.5} \times (sL \times k_{sL})^{0.91} \times \left(W_{dumper} \times k_W\right)^{1.02} \times d_{paved} \times \left(1 - \frac{p}{k_{day}}\right)$$

Where:

- $E_{TSP/PM10/PM2.5}$: Emissions of TSP/PM10/PM2.5 (kg/year)
- *sL* : Silt load of the paved road (g/m^2)
- W_{dumper} : Dumper weight (on average) (t)
- d_{paved} : Total distance travelled by dumpers on paved (km/year)
- p : Number of days per year with at least 0.254 mm natural precipitation[3]
- k_{TSP} : 3.23 x 10^{-3} (kg/km)
- k_{PM10} : 0.62 x 10^{-3} (kg/km)
- $k_{PM2.5}$: 0.15 x 10^{-3} (kg/km)
- k_{sL} : 1 (m^2/g)
- k_W : 1.1 (t^{-1})
- k_{day} : 4 x 365 (-)

Considering average numbers for quarries (sL = 5 ; Wdumper= 40 ; p = 150) the emissions factors of TSP per km on paved road is 572 g/km, which is 7500 times the emissions factor for road abrasion reported in the EMEP Guidebook (EEA, 2016). This difference can be explained by two parameters: firstly, emissions due to resuspension are included in the emission factors calculated above but not in those from the EMEP Guidebook [cf Discussion at the start of chapter 3.3]. Secondly, paved roads in quarries are dusty which result in high silt loads and therefore high emission factors.

[2] See end of section 3.3.5 to change this threshold.

[3] The threshold can be increased to 1 mm by changing k_{day} from 4x365 to 3x365. The adapted equation should provide very similar results.

No abatement factor is considered for emissions from paved road because this type of abatement technology typically impacts the silt load (also wetting the surface is considered not be an efficient method since the road surface dries faster compared to unpaved roads), e.g. by periodically scrubbing of the road's surface. Therefore, if abatement technologies are used it should be considered by applying a lower silt load.

It should be noted that the speed of dumpers/trucks is not taken into account in this formula despite its influence on particulate emissions. The VDI 3790 indicates that the factors used in this equation seems to suggest a speed of 30 km/h. The VDI also indicates that a possible solution to reduce emissions could be to reduce vehicles' speed and they suggest a factor of 0.2 for the effectiveness when reducing vehicle velocity by 10 km/h. This could be an additional reduction for this source of emission (VDI 3790 Part 4 2018).

3.3.4 Material handling operation (stockpiles)

Introduction

This step includes particulate emissions related to dumpers unloading directly material in the stockpiles and to loaders loading material from the stockpiles into dumpers/trucks. The number of times the material is handled should also reflect the use of intermediate stockpiles. If the material is unloaded in a first stockpile than moved to a second stockpile the number of times the material is handled should be 4.

The equation presented below are not specific to dumpers/truck but have been developed to estimate the quantity of particulate emissions generated by either type of drop operation.

Required data to calculate particulate emissions

- Number of times the material is handled
- Moister content of the material (%)
- Average yearly wind speed (m/s)

Methodology used to calculate particulate emissions

The following equations are used to calculate particulate emissions related to the material handling operations (US EPA, 2006b):

$$E_{TSP} = k_{pms-TSP} \times k_{mat.hand} \times \frac{\left(\frac{U}{k_U}\right)^{1.3}}{\left(\frac{M}{k_M}\right)^{1.4}} \times Q_{mat.\ handled}$$

$$E_{PM10} = k_{pms-PM10} \times k_{mat.hand} \times \frac{\left(\frac{U}{k_U}\right)^{1.3}}{\left(\frac{M}{k_M}\right)^{1.4}} \times Q_{mat.\ handled}$$

$$E_{PM2.5} = k_{pms-PM2.5} \times k_{mat.hand} \times \frac{\left(\frac{U}{k_U}\right)^{1.3}}{\left(\frac{M}{k_M}\right)^{1.4}} \times Q_{mat.\ handled}$$

Where:

- $E_{TSP/PM10/PM2.5}$: Emissions of TSP/PM10/PM2.5 (kg/year)
- U : Average yearly wind speed (m/s)
- M : Moisture content of the stockpile material (in %)
- $Q_{mat.\ handled}$: Quantity of stockpile material handled (t/year)
- k_U : 2.2 (s/m)
- k_M : 2 (-)
- $k_{mat.hand}$: 0.0016 (kg/t)
- $k_{pms-TSP}$: 0.74 (particle size multiplier, no unit)
- $k_{pms-PM10}$: 0.35 (particle size multiplier, no unit)
- $k_{pms-PM2.5}$: 0.053 (particle size multiplier, no unit)

3.3.5 Wind erosion from stockpiles

Introduction

This step includes particles emitted when the wind blows on uncovered stockpiles. The stockpiles are considered to be conical.

Required data to calculate particulate emissions

- Number of stockpiles
- Stockpiles height
- Angle of repose (angle made by the material with the ground when it is in a conical stockpile)
- Quantity of material stored (can be expressed in weeks of production)
- Bulk density of the material
- Silt loading of stockpiles (%) (where silt <75 µm)
- Abatement techniques implemented – use and efficiency

Methodology used to calculate particulate emissions

The following equations are used to calculate particulate emissions related to the wind erosion from stockpiles (MDAQMD, AVAPCD, 2000):

$$E_{TSP} = k_{wind.erosion} \times AD_{TSP} \times \left(\frac{s}{k_s}\right) \times \left(\frac{(1-p)}{k_{working.days}}\right) \times \left(\frac{I}{k_I}\right) \times A \times (1-ER)$$

$$E_{PM10} = k_{wind.erosion} \times AD_{PM10} \times \left(\frac{s}{k_s}\right) \times \left(\frac{(1-p)}{k_{working.days}}\right) \times \left(\frac{I}{k_I}\right) \times A \times (1-ER)$$

$$E_{PM2.5} = k_{wind.erosion} \times AD_{PM2.5} \times \left(\frac{s}{k_s}\right) \times \left(\frac{(1-p)}{k_{working.days}}\right) \times \left(\frac{I}{k_I}\right) \times A \times (1-ER)$$

Where:

- $E_{TSP/PM10/PM2.5}$: Emissions of TSP/PM_{10}/$PM_{2.5}$ (kg/year)
- ER : Abatement factor (%) (not used in the model, if watering is used it should increase the moisture content and therefore it is already included)
- p : Average percentage of days during the year with at least 0.254 mm of precipitation (%)[4]
- s : Average silt loading of stockpiles in percent[5] (%), default values that may be used are:
    - limestone: 0.5%
    - crushed limestone: 1.5%
    - sand and gravel: 8%
    - overburden: 10%
    - inorganic minerals: 30%
- I : Percentage of time with unobstructed wind speed >19.3 km/h (5.36 m/s) (instantaneous speed if available) in percent (%)
- A : Exposed surface area of stockpiles (m^2)
- AD : Aerodynamic factor (1 for TSP, 0.5 for PM_{10} and 0.2 for $PM_{2.5}$)
- $k_{wind.erosion}$: 1.12 x 10^{-4} x 1,7 x 365 (kg/m^2)
- k_s : 1.5 (-)
- $k_{working.days}$: 235 x 365^{-1} (%)
- k_I : 15 (-)

Knowing that stockpiles are conical, with their number and the weight of material stored, it is possible to calculate the exposed surface area using the following equations:

$$A = nb_{stockpile} \times r \times \sqrt{(r^2 + h^2)} = nb_{stockpile} \times r^2 \times \sqrt{(1 + tan(\theta)^2)}$$

$$r = \sqrt[3]{\left(\frac{\frac{W}{\rho} \times 3}{\pi \times tan(\theta)}\right)}$$

Where:

- A : Exposed surface area of stockpiles (m^2)
- $nb_{stockpile}$: Number of stockpiles

[4] See end of section 3.3.5 to change the threshold.

[5] The value of “s” and “I” must be entered in percent, therefore if the silt load is 2% the input value is 2 (and not 0.02).

- r : Stockpiles radii (m)
- h : Stockpiles height (m)
- w : Weight of material stored (t)
- ρ : Bulk material density (t/m^3)
- Θ : Angle of repose (°)

Precipitation threshold

A threshold of 0.254 mm (0.01 inch)) precipitation is applied in the equations used to estimate particulate emissions from paved and unpaved road and from stockpiles wind erosion. The hypothesis behind this threshold is that on a day with that amount of precipitation, there is no dust from unpaved roads and stockpiles (there is a reduction on paved roads, but it is smaller). The threshold seems to have been chosen based on the precision of US weather stations. The threshold could be increase to 1 mm for a more conservative approach that simplifies the data requirement.

3.3.6 Tier 2 spreadsheet model development

A spreadsheet model was developed and is available to calculate particulate emissions at the country level using the equations presented in chapter 3.3.1 to 3.3.5. Detailed step-by-step instructions on how to adapt the model and calculate country specific emissions for this sector are not covered here, but are presented in the spreadsheet file.

As a bottom-up Tier 3 approach is not feasible at this scale for large countries, average parameters for quarries of various categories are used instead of data for individual quarries. To do so, quarries have been divided into 9 categories depending on their size and the nature of the deposit. Those categories are:

Size:

- Large quarries (Production ≥ 500 kt)
- Medium quarries (100 kt ≤ Production < 500 kt)
- Small quarries (Production < 100 kt)

The size of the quarries does not impact the method applied to calculate particulate emissions but influences the input parameters. Indeed, large quarries are usually more efficient in terms of transport, use abatement technologies to reduce dust emissions more often and often produce a larger range of grain sizes aggregate which requires additional crushers and screeners. Those differences are considered in the parameters described in the following sections, thus allowing to take into account the variability in the operations between the three size categories. Those categories are based on the production. When classifying quarries, however, where possible the production capacity should be used instead of the current annual production. Indeed, some quarries may have a low annual production because they produce aggregate for a short period of time then sell the production over the rest of the year. However, operations in this type of quarries are similar to those in larger quarries and should not be assimilated to smaller quarries with constant productions all over the year.

Nature of the deposit:

- Crushed rock
- Sand and Gravel
- Recycled aggregates

In crushed rock quarries, the deposit is composed of compact and solid rock, requiring mine blasting and drilling to be extracted. On the contrary, deposits of sand and gravel quarries are soft and the material can be directly extracted with an excavator. Additionally, the process to transform the deposit into aggregates varies depending on the nature of the deposit. Crushed rock quarries require significant crushing steps, where some sand and gravel quarries only require collecting and sorting by size of the material extracted directly from the deposit. Finally, recycled aggregates are produced from construction and demolition residues, therefore blasting and drilling are not required and usually transport inside the quarry is minimal because the processing equipment is mobile and can be placed close to the deposit. Table 3-4 summarizes the steps (sources of emissions) required for each type of deposits.

Table 3-4: Steps considered depending on the nature of the deposit

Steps (source of emissions)	**Crushed rock**	**Sand and Gravel**	**Recycled aggregates**
1 – Drilling and Blasting	X		
2 – Material processing	X	X	X
3 – Internal transport in the quarry	X	X	
4 – Material handling operation	X	X	X
5 – Wind erosion from stockpiles	X	X	X

In the following sections, methodologies to calculate emission factors are presented for each category of quarries and for each source of emissions. For additional technical information, please refer to the spreadsheet model file that came as part of this Guidebook chapter.

Overview

Based on the input parameters, emission factors are calculated for each category of quarries and for each step. Then, using the production of each category, the particulate emissions can be calculated for each category and the sum of those emissions provides the total quantity of particles emitted by quarries. Figure 3.3 summarises those steps.

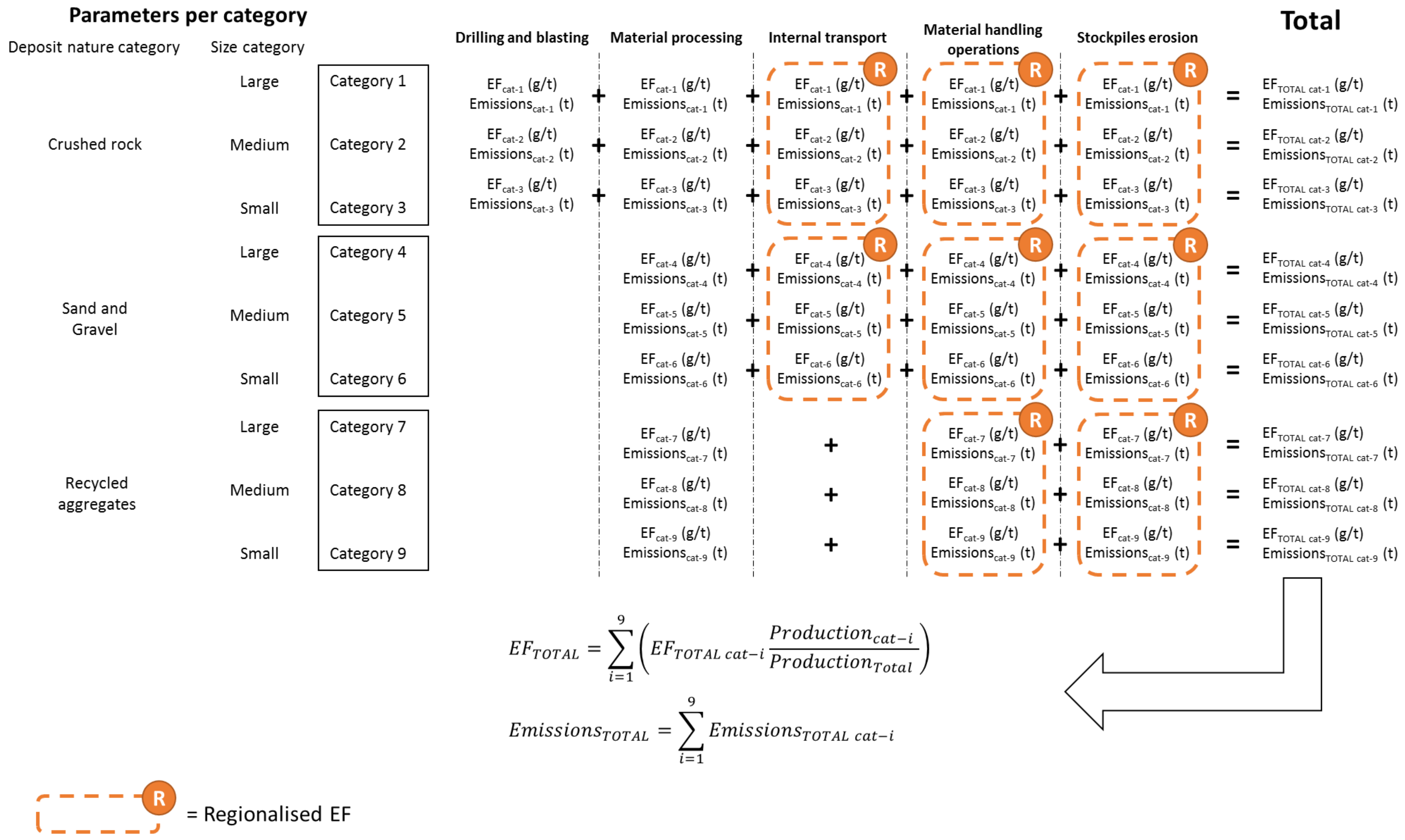
The result of the model consists of 9 emission factors, one for each category. Each emission factor can be decomposed into 5 sub-emission factors, one for each source. Usually the crushed rock quarries have the largest emission factors and the internal transport and the material processing account for most of the emissions.

The “internal transport”, “material handling operations” and “stockpiles erosion” have regionalized emission factors to take into account the regional variability of weather (wind and rain). This regionalisation is important because weather parameters have thresholds and non-linear impacts on the emissions. The equation to calculate total emission factors and emissions from regionalised ones is presented below.

$$EF_{cat-i} = \sum_{Region=0}^{n} \left(EF_{cat-i_{Region}} \frac{Production_{cat-i_{Region}}}{Production_{cat-i_{TOTAL}}} \right)$$

$$E_{cat-i} = \sum_{Region=0}^{n} E_{cat-i_{Region}}$$

Figure 3.2: Model overview



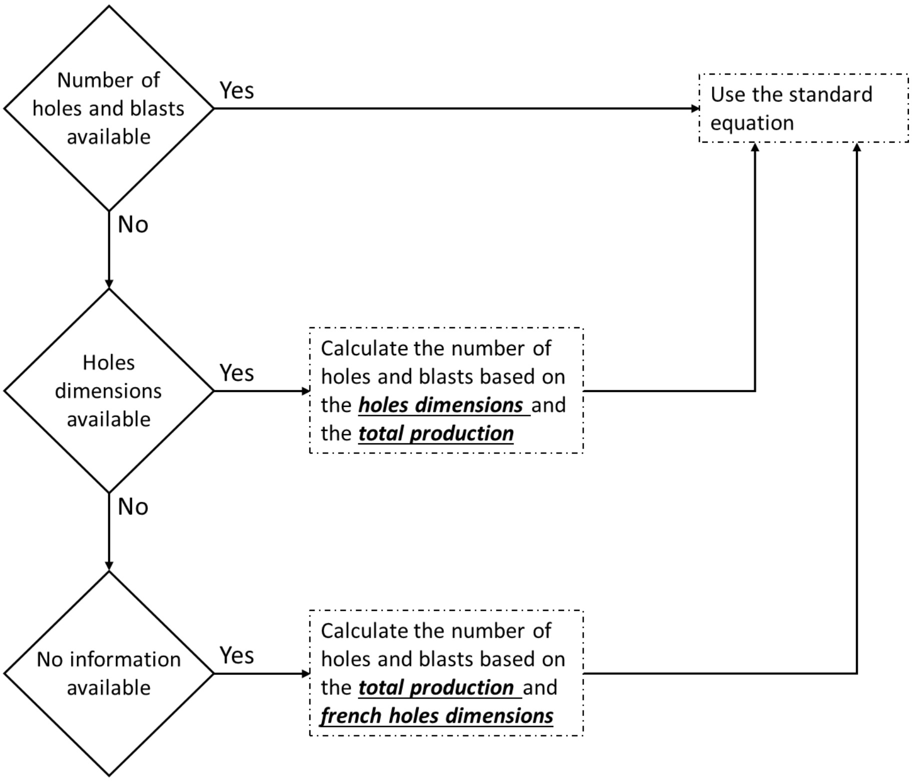
$$EF_{TOTAL} = \sum_{i=1}^{9}\left(EF_{TOTAL\ cat-i}\frac{Production_{cat-i}}{Production_{Total}}\right)$$

$$Emissions_{TOTAL} = \sum_{i=1}^{9} Emissions_{TOTAL\ cat-i}$$

Drilling and blasting

Drilling and blasting are only used for crushed rock quarries. The data required to calculate the particles emitted by this step are the number of blasts and drilling holes and the surface of the blasts. Those data are not easy to obtain, especially at a national level, therefore an option to circumvent the lack of data is to calculate those numbers based on the average drilling holes size (the blasts surface is assumed to be the same as the drilling holes surface). French drilling holes dimensions can be used when national data are not available. Those data have been validated by the French and German industry (UNICEM and MIRO, respectively). Figure 3.3 summarises the approach to apply depending on the available data.

Figure 3.3: Choice of the approach to calculate emissions from drilling and blasting depending on the available data



Sample values for the parameters are presented at the end of chapter 3.3.6.

Material processing

Three levels of processing are considered, each level producing increasingly finer grains: primary, secondary and tertiary level. Each level is composed of one unit modelled by a crusher, a screener and several transfer points. The emissions factors applied are presented in Table 3-3.2 in section 3.3.2. Emission factors should increase with the level of unit (as the grain gets finer), but only emission factors for tertiary units are available. Therefore, those factors are used for every unit as a conservative approach.

Material processing is modelled in two layers: the flows and the units.

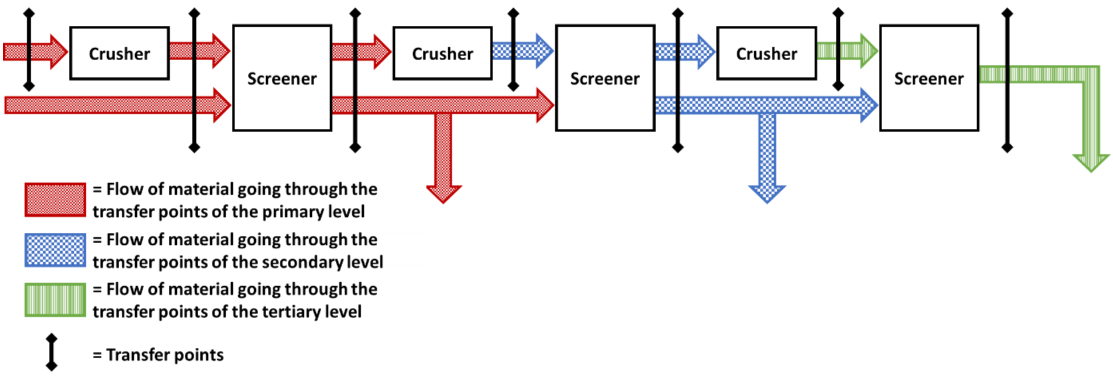
The flows

The first layer models the flows for each piece of equipment for each level. The flows vary with the nature of the deposit but are independent from the size of the quarries. Therefore, 27 flows are required:
3 types of deposit × 3 levels of unit × 3 pieces of equipment = 27 flows (%).

Flows going through crushers and screeners can usually be provided by the industry using average values from flowsheets of typical quarries. Only quarries having that level of equipment should be considered. Therefore, if for instance 10 flowsheets are provided but 3 do not have a tertiary unit, these 3 flowsheets should not be considered when calculating flows for tertiary units.

When flows for transfer points are not available, the simplified model presented in Figure 3.4, can be used to calculate them. As part of the material does not have to be crushed, some material goes directly in the screeners, as is shown in Figure 3.4. Please note that the width of the arrows in this schematic figure does not represent the amount of material but just the path it takes.

Figure 3.4: Simplified model used to calculate flow through transfer points



In Figure 3.4 the transfer points associated to each level are presented in different colours, which illustrates the following equations:

$$Flow_{TP_{primary}} = Flow_{cru_{primary}} + 2 \times Flow_{sc_{primary}}$$

$$Flow_{TP_{secondary}} = Flow_{cru_{secondary}} + Flow_{sc_{secondary}}$$

$$Flow_{TP_{tertiary}} = Flow_{cru_{tertiary}} + Flow_{sc_{tertiary}}$$

Where:

- $Flow_{cru/sc/TP}$: Total flow of material going through crushers (cru), screeners (sc) and transfer points (TP) (% of production)

An example of results, for French quarries, is presented in Table 3-5.

Table 3-5 Example – Model of flows – French results

Equipment for each unit	Crushed rock	Sand and Gravel	Recycled aggregates
Primary Unit			
Primary Crusher (% of total production)	90%	15%	100%
Primary Screener (% of total production)	100%	100%	100%
Primary Transfer Point (% of total production)[a]	290%	215%	300%
Secondary Unit			
Secondary Crusher (% of total production)	70%	60%	70%
Secondary Screener (% of total production)	90%	60%	100%
Secondary Transfer Point (% of total production) [a]	160%	120%	170%
Tertiary Unit			
Tertiary Crusher (% of total production)	50%	60%	0%
Tertiary Screener (% of total production)	90%	60%	0%
Tertiary Transfer Point (% of total production) [a]	140%	120%	0%
[a] Calculated based on the model presented in Figure 3.4			

<u>The production units</u>

The second layer models the percentage of quarries equipped with each level of unit. A quarry can only have one unit per level, therefore the percentage of quarries having, for instance, a primary unit should be between “0 %” and “100 %”. “0 %” indicates that no quarry has a primary unit; “100 %” indicates that every quarry is equipped with a primary unit.

The number and level of units in a quarry depends on the size and the nature of the deposit. Therefore, 27 percentages are required: 3 types of deposits ×3 sizes of quarries×3 levels of unit=27 percentages (%)

An example of results, for French quarries, is presented in Table 3-6.

Table 3-6: Example – Model of production units – French results

Unit per size of quarries	Crushed rock	Sand and Gravel	Recycled aggregates
Large quarries			
Large quarries – Primary Unit	100%	100%	100%
Large quarries – Secondary Unit	100%	100%	100%
Large quarries – Tertiary Unit	75%	100%	0%
Medium quarries			
Medium quarries – Primary Unit	100%	100%	100%
Medium quarries – Secondary Unit	100%	100%	100%
Medium quarries – Tertiary Unit	75%	100%	0%
Small quarries			
Small quarries – Primary Unit	100%	100%	100%
Small quarries – Secondary Unit	50%	50%	0%
Small quarries – Tertiary Unit	0%	0%	0%

Combination of flows and units

The total flow of material going through each piece of equipment can be calculated based on the value presented in **Error! Reference source not found.** and Table 3-6 using the following equation:

$$Total\ Flow_{equipement_{quarry\ size_{nature\ of\ deposit}}} = \sum_{level=1}^{3} \left(Unit_{level_{nature\ of\ deposit_{quarry\ size}}} \times Flow_{equipement_{level_{nature\ of\ deposit}}} \right)$$

Where:

- Equipment: Piece of equipment, can be crushers (cru), screeners (sc) or transfer points (TP)
- Level: Level of unit, can be primary (1), secondary (2) or tertiary (3)
- Nature of deposit: Nature of the deposit, can be crushed rock, sand and gravel or recycled aggregate
- Unit: Percentage of quarry with a primary, secondary or tertiary unit for each category of quarries (%) (e.g. Table 3-6)
- Flow: flow of material going through a specific piece of equipment of a specific unit level for each type of deposits (% of production) (e.g. Table 3-5)
- Total flow: Total flow of material going through a specific piece of equipment for each category

Based on those total flows, the emission factors and emissions can be calculated using the equations presented in chapter 3.3.2.

Sample values for the parameters are presented at the end of chapter 3.3.6.

Internal transport

As indicated in Table 3.6 there is no transport in recycled aggregate quarries. The processing equipment for this type of deposits is mobile and can be placed close to the material deposit instead of transporting the material from the deposit to the processing equipment by dumper. This reduces significantly the required internal transport. Therefore, this step is considered negligible for this type of deposits.

As mentioned in chapter 3.2, a regionalisation is required to calculate the particles emitted by internal transport. The parameters required to calculate the emission factors and emissions of internal transport are those presented in chapter 3.3.2 for each category of quarry and for each region. However, the abatement techniques implemented (use and efficiency), the total distance travelled by dumpers on unpaved and paved roads and dumper weight (on average) vary with the categories of quarries but can be considered independent from the region. On the contrary, the annual number of rainy days is independent from the quarries categories but varies with the region. Finally, the silt content of the surface material can be assumed constant for each region for each category of quarries. Table 3.7 summarises the pieces of information required and their dependency.

Table 3-7: Quantity of data required for internal transport and their dependency

Data name	Dependency	Pieces of information to collect
Abatement techniques implemented – use	Category of quarries	6[a] x Y[b]
Abatement techniques implemented – efficiency	Nature of the deposit	2[a] x Y[b]
Total distance travelled by dumpers on unpaved roads	Category of quarries	6[a]
Total distance travelled by dumpers on paved roads	Category of quarries	6[a]
Dumper weight	Category of quarries	6[a]
Annual number of days with at least 1 mm natural precipitation	Regions	X[c]
Silt content	None	1

a. only 6 categories and 2 types of deposits, because there is no internal transport for the recycled aggregates quarries
b. Y is the number of abatement techniques implemented
c. X is the number of regions

Based on those data it is possible to calculate the emission factors and emissions for each region and for each category of quarries. National results can be calculated using the equations presented at the end of the sub-chapter Overview.

Sample values for the parameters are presented at the end of chapter 3.3.6.

Material handling operations (to/from stockpiles)

As for the internal transport the particles emitted during the material handling operations vary with the weather conditions and must be regionalised. Only the moisture content of the material varies with the nature of the deposit (sand and gravel quarries tend to have more humid material). All other parameters required to calculate the emission factors and emissions of this step can be considered independent from the category of quarries. Table 3.8 summarises the pieces of information required and their dependency.

Table 3-8: Quantity of data required for material handling operations and their dependency

Data name	Dependency	Pieces of information to collect
Average yearly wind speed	Regions	X[a]
Moisture content of the material (in %)	Nature of the deposit	3
Quantity of material handled (t)	None	1

a. X is the number of regions

To estimate the quantity of material handled, a hypothesis can be made on the number of times the material is handled before leaving the quarry, then the quantity can be calculated by multiplying the production by this number.

Based on those data it is possible to calculate the emission factors and emissions for each region and for each category of quarries. National results can be calculated using the equations presented at the end of the sub-chapter Overview.

Sample values for the parameters are presented at the end of chapter 3.3.6.

Wind erosion from stockpiles

Emissions from wind erosion of stockpiles depend on the weather and must be regionalised. As mentioned in chapter 3.3.5 the exposed area of stockpiles can be calculated based on the hypothesis that stockpiles are cones. Therefore, the data required are the number of stockpiles and their geometry. Usually the industry cannot provide the number of stockpiles but based on the average quantity of material stored at all time for each category of quarries (and based on the geometry of the stockpiles) it is possible to calculate the number of stockpiles. The stockpiles geometry can be considered the same for all categories of quarries because the material is very similar, and the height of the stockpiles is dictated by the piece of equipment used, which is usually very similar between categories of quarries. The quantity of material stored is usually proportional to the production, therefore if the regional production per category of quarries is provided with the ratio of this production being stored, it is possible to calculate an average number of stockpiles for each category of quarries for each region.

The following equations summarise the method used to calculate the total exposed area of stockpiles for each category of quarries and each region based on the regional production and the average quantity of material stored at all time.

$$Q.stored_{region_{category}} = \frac{P_{region_{category}}}{Nbq_{region_{category}}} \times Ratio\ \ Stored_{category}$$

$$V = \frac{1}{3} \times \pi \times \frac{h^3}{(\tan\theta)^2}$$

$$r = \frac{h}{\tan\theta}$$

$$Area = \pi \times r^2 \times \sqrt{(r^2 + h^2)}$$

$$NbspQ_{region_{category}} = \frac{Q.stored\ per\ quarry_{region_{category}}}{V \times \rho}$$

$$Total\ Area_{\ region_{category}} = Nb\ stockpiles\ per\ quarry_{region_{category}} \times Area$$

Where:

- Q. Stored : the average quantity of material stored at all time per quarry (t)
- P : the production of material (t)
- Nbq : the number of quarries
- Ratio Stored : the percentage of the production being stored at all time (%)
- V : the volume of one stockpile (m^3)
- ρ : the bulk density of the material (t/m^3)
- h : the stockpiles height (m)
- θ : the repose angle of stockpiles (°)
- r : the stockpiles radii (m)
- Area : the exposed area of one stockpile (m^2)
- NbspQ : the number of stockpiles per quarry
- Total Area : the total exposed area of all stockpiles (m^2)

Table 3-9 summarises the pieces of information required and their dependency.

Table 3-9: Quantity of data required for wind erosion of stockpiles and their dependency

Data name	Dependency	Pieces of information to collect
Abatement techniques implemented – use	Category of quarries	9 x Y[a]
Abatement techniques implemented – efficiency	Nature of the deposit	3 x Y[a]
Average number of days during the year with at least 0.254 mm of precipitation	Regions	X[b]
Average silt loading of stockpiles in percent (%)	Nature of the deposit	3
Percentage of time with unobstructed wind speed >19.3 km/h	Regions	X
Height of stockpiles	None	1
Repose angle	None	1
Bulk density of the material	None	1
Regional production per category of quarries	Regions and Category of quarries	9 x X[b]
Percentage of the production being stored at all time (%)	Category of quarries	9

a. Y is the number of abatement techniques implemented
b. X is the number of regions

Based on those data, it is possible to calculate the emission factors and emissions for each region and for each category of quarries. National results can be calculated using the equations presented throughout this chapter.

Sample values for the parameters are presented below.

Sample parameters

The following table presents all the input parameters in the case of France, which should be changed when applying the method to a new context (e.g. another country). Those parameters are based on the French context and have been validated by the UNICEM ("Union nationale des industries de carrières et matériaux de construction"), representing the French aggregates industry. Most are based on surveys of various quarries in France, other on discussion with expert in the field. When applying the model to another context, if context-specific parameters cannot be obtained the French value can be used as default parameter. However, it is recommended to discuss the input parameters with national expert in the field.

Weather parameters are not presented because they are too specific.

Table 3-10: Sample parameters (French context)

Parameters	**Crushed rock**	**Sand and Gravel**	**Recycled aggregates**	**Reference**
DRILLING AND BLASTING				
Average surface of a hole/blast (m^2)	13	-	-	[1] FR data, 2012
Average height of a hole (m)	15	-	-	[1] FR data, 2012
Density (t/m^3)	2.5	-	-	[1] FR data, 2012
Volume of production (m^3)	80 400 000	-	-	
Volume per hole (m^3)	195	-	-	
Calculated number of holes/blasts	412 308	-	-	
Number of holes	-	-	-	
Number of blasts	-	-	-	
MATERIAL PROCESSING				
Flow per equipment				
Primary Unit				
Primary Crusher (% of total production)	90%	15%	100%	[2] FR data, 2018
Primary Screener (% of total production)	100%	100%	100%	[2] FR data, 2018
Primary Transfer Point (% of total production)	290%	215%	300%	[2] FR data, 2018
Secondary Unit				
Secondary Crusher (% of total production)	70%	60%	70%	[2] FR data, 2018
Secondary Screener (% of total production)	90%	60%	100%	[2] FR data, 2018
Secondary Transfer Point (% of total production)	160%	120%	170%	[2] FR data, 2018
Tertiary Unit				
Tertiary Crusher (% of total production)	50%	60%	0%	[2] FR data, 2018
Tertiary Screener (% of total production)	90%	60%	0%	[2] FR data, 2018
Tertiary Transfer Point (% of total production)	140%	120%	0%	[2] FR data, 2018
Number of Unit				
Large quarries				
Large quarries – Primary Unit	100%	100%	100%	[2] FR data, 2018
Large quarries – Secondary Unit	100%	100%	100%	[2] FR data, 2018
Large quarries – Tertiary Unit	75%	100%	0%	[2] FR data, 2018
Medium quarries				
Medium quarries – Primary Unit	100%	100%	100%	[2] FR data, 2018
Medium quarries – Secondary Unit	100%	100%	100%	[2] FR data, 2018
Medium quarries – Tertiary Unit	75%	100%	0%	[2] FR data, 2018
Small quarries				

Small quarries – Primary Unit	100%	100%	100%	[2] FR data, 2018
Small quarries – Secondary Unit	50%	50%	0%	[2] FR data, 2018
Small quarries – Tertiary Unit	0%	0%	0%	[2] FR data, 2018
Wet processing				
Percentage of wet processing (%) – Large quarries	0%	0%	0%	
Percentage of wet processing (%) – Medium quarries	0%	0%	0%	
Percentage of wet processing (%) – Small quarries	0%	0%	0%	
Crushing – abatement technology – Dry Processing				
Crushing – Partial Enclosure – Efficiency	85%	85%	85%	[3] Canada – Guide, 2017
Crushing – Water Spray – Efficiency	50%	50%	50%	[3] Canada – Guide, 2017
Crushing – Abatement technology 3 – Efficiency	0%	0%	0%	
Large quarries				
Crushing – Partial Enclosure – Use	79%	79%	79%	[4] FR data, 2012
Crushing – Water Spray – Use	24%	24%	24%	[5] FR data, 2013
Crushing – Abatement technology 3 – Use	0%	0%	0%	
Crushing – Total abatement – Large quarries	71%	71%	71%	
Medium quarries				
Crushing – Partial Enclosure – Use	61%	61%	61%	[4] FR data, 2012
Crushing – Water Spray – Use	22%	22%	22%	[5] FR data, 2013
Crushing – Abatement technology 3 – Use	0%	0%	0%	
Crushing – Total abatement – Medium quarries	57%	57%	57%	
Small quarries				
Crushing – Partial Enclosure – Use	0%	0%	0%	[4] FR data, 2012
Crushing – Water Spray – Use	0%	0%	0%	[5] FR data, 2013
Crushing – Abatement technology 3 – Use	0%	0%	0%	
Crushing – Total abatement – Small quarries	0%	0%	0%	
Screening – abatement technology – Dry Processing				
Screening – Covered Screen – Efficiency	50%	50%	50%	[3] Canada – Guide, 2017
Screening – Wet Screening – Efficiency	100%	100%	100%	[2] FR data, 2018
Screening – Abatement technology 3 – Efficiency	0%	0%	0%	
Large quarries				

Screening – Covered Screen – Use	39%	39%	39%	[5] FR data, 2013
Screening – Wet Screening – Use	0%	70%	0%	[2] FR data, 2018
Screening – Abatement technology 3 – Use	0%	0%	0%	
Screening – Total abatement – Large quarries	20%	76%	20%	
Medium quarries				
Screening – Covered Screen – Use	26%	26%	26%	[5] FR data, 2013
Screening – Wet Screening – Use	0%	70%	0%	[2] FR data, 2018
Screening – Abatement technology 3 – Use	0%	0%	0%	
Screening – Total abatement – Medium quarries	13%	74%	13%	
Small quarries				
Screening – Covered Screen – Use	0%	0%	0%	[5] FR data, 2013
Screening – Wet Screening – Use	0%	70%	0%	[2] FR data, 2018
Screening – Abatement technology 3 – Use	0%	0%	0%	
Screening – Total abatement – Small quarries	0%	70%	0%	
Transfer point – abatement technology – Dry Processing				
Transfer point – Abatement technology 1 – Efficiency	95%	95%	95%	[3] Canada – Guide, 2017
Transfer point – Abatement technology 2 – Efficiency	0%	0%	0%	
Transfer point – Abatement technology 3 – Efficiency	0%	0%	0%	
Large quarries				
Transfer point – Abatement technology 1 – Use	0%	0%	0%	
Transfer point – Abatement technology 2 – Use	0%	0%	0%	
Transfer point – Abatement technology 3 – Use	0%	0%	0%	
Transfer point – Total abatement – Large quarries	0%	0%	0%	
Medium quarries				
Transfer point – Abatement technology 1 – Use	0%	0%	0%	
Transfer point – Abatement technology 2 – Use	0%	0%	0%	
Transfer point – Abatement technology 3 – Use	0%	0%	0%	

Transfer point – Total abatement – Medium quarries	0%	0%	0%	
Small quarries				
Transfer point – Abatement technology 1 – Use	0%	0%	0%	
Transfer point – Abatement technology 2 – Use	0%	0%	0%	
Transfer point – Abatement technology 3 – Use	0%	0%	0%	
Transfer point – Total abatement – Small quarries	0%	0%	0%	
INTERNAL TRANSPORT				
Distance travelled on unpaved road				
Distance travelled on unpaved road – LQ (km)	31 725	0	0	[6] FR data, 2012
Distance travelled on unpaved road – MQ (km)	23 500	3 200	0	[6] FR data, 2012
Distance travelled on unpaved road – SQ (km)	18 800	2 400	0	[6] FR data, 2012
Distance travelled on paved road				
Distance travelled on paved road – LQ (km)	10 575	0	0	[6] FR data, 2012
Distance travelled on paved road – MQ (km)	0	0	0	[6] FR data, 2012
Distance travelled on paved road – SQ (km)	0	0	0	[6] FR data, 2012
Road transport – abatement technology				
Road watering – Efficiency (unpaved road)	55%	70%	0%	[7] Canada – Guide, 2008
Road watering – Use – LQ (unpaved road)	95%	95%	0%	[4] FR data, 2012
Road watering – Use – MQ (unpaved road)	91%	91%	0%	[4] FR data, 2012
Road watering – Use – SQ (unpaved road)	50%	50%	0%	[4] FR data, 2012
Vehicles weight on average				
Vehicles weight on average – LQ (t)	71	74	0	[6] FR data, 2012
Vehicles weight on average – MQ (t)	51	45	0	[6] FR data, 2012
Vehicles weight on average – SQ (t)	30	30	0	[6] FR data, 2012
Surface material silt content				
Surface material silt content – Unpaved road (%)	1.6%	0.8%	1.6%	[8] FR data, 2018
Surface material silt content – Paved road (g/m^2)	8.3	8.3	8.3	
MATERIAL HANDLING OPERATION				

Average moisture content of material handled (%)	2%	6%	2%	[1] FR data, 2012
Average number of times the material is handled	2	2	2	[9] FR data, 2013
WIND EROSION FROM STOCKPILES				
Angle of repose (°)	30	30	30	[2] FR data, 2018
Bulk density of material in stockpiles (t/m^3)	1.6	1.6	1.6	[10] University Course, 2015
Silt content of stockpiles (%)	1.6%	0.8%	1.6%	[1] FR data, 2012
Quantity of material stored in stockpiles				
Quantity stored in stockpiles – LQ (week of production)	4	4	4	[2] FR data, 2018
Quantity stored in stockpiles – MQ (week of production)	8	8	8	[2] FR data, 2018
Quantity stored in stockpiles – SQ (week of production)	26	26	26	[2] FR data, 2018
Stockpile height				
Standard stockpile height – LQ (m)	10	10	10	[2] FR data, 2018
Standard stockpile height – MQ (m)	10	10	10	[2] FR data, 2018
Standard stockpile height – SQ (m)	10	10	10	[2] FR data, 2018

Table 3-11 presents the references used in Table 3-10.

Table 3-11: Reference of default parameters

Reference	Details
[1] FR data, 2012	UNICEM, « Réunion de travail sur la détermination du Facteur d'Emission des Carrières », Meeting minutes, 2012
[2] FR data, 2018	UNICEM – « Minutes : Actualisation de la méthodologie d'estimation des émissions des carrières – 20-09-2018 », 2018
[3] Canada – Guide, 2017	Government of Canada, "Pits and quarries reporting guide", 2017, https://www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory/report/pits-quarries-guide.html
[4] FR data, 2012	UNICEM, "Questionnaire to quarries operators", Survey 2012
[5] FR data, 2013	UNICEM, « Bilan des systèmes de réduction des émissions de poussières mis en place », Survey 2013
[6] FR data, 2012	UNICEM, "Hypothesis validation", email, 2012
[7] Canada – Guide, 2008	Environment Canada, « Tableur pour les poussières des routes industrielles non asphaltées », 2008, https://www.ec.gc.ca/inrp-npri/6DE7F8BC-5E38-4FD3-B678-FAB93A0D8DF3/RoadDustCalculator_f_Nov_19__2008.xls
[8] FR data, 2018	UNICEM – Oral communication, 2018

[9] FR data, 2013	UNICEM, UNPG, “Meeting minutes – 25/11/2013”, 2013
[10] University Course, 2015	CM 425, “Aggregates for concrete”, University of Washington, 2015, http://courses.washington.edu/cm425/aggregate.pdf

3.4 Tier 3 emission modelling and use of facility data

The methods outlined by the US EPA’s AP42 and the deduction presented above can be used to estimate emissions of individual quarries. Given sufficient resources, each quarry in a country could be addressed specifically and the results could be summed to use as this sectors total. Additionally, some large quarries might also provide useful facility data for either direct use or verification, e.g. under the EU’s E-PRTR scheme. For some emission inventories a hybrid approach might be the best option, using facility data for the larger extraction sites while still applying the Tier 2 method for small and medium quarries.

4 Data quality

No specific issues for this source category.

5 Glossary

A	the exposed surface area of stockpiles
$AD_{pollutant}$	the aerodynamic factor of the specified pollutant
$AR_{production}$	the activity rate for the quarrying/mining
Area	the exposed area of one stockpile
d_{paved}	the total distance travelled by dumpers on paved road (km)
$d_{unpaved}$	the total distance travelled by dumpers on unpaved road (km)
$E_{pollutant}$	the emission of the specified pollutant
$EF_{pollutant}$	the emission factor for this pollutant
$Eff_{tech.}$	The abatement efficiency of the specified technology
$ER_{tech.}$	The abatement factor of this technology
equipment	the piece of equipment, can be crushers (cru), screeners (sc) or transfer points (TP)
$Flow_{equipment}$	the total flow of material going through the specified equipment
h	the stockpiles height
I	the percentage of time with unobstructed wind speed >19.3 km/h in percent
$k_{Dry/Wet}$	the percentage of the material extracted from the deposit with a moisture content below or equal to 1.3% (Dry) or above 1.3% (Wet)
level	the level of unit, can be primary (1), secondary (2) or tertiary (3)

M	the moisture content of the material (in %)
N_{hole}	the number of holes
N_{blast}	the number of blasts
nature of deposit	the nature of the deposit, can be crushed rock, sand and gravel or recycled aggregate
Nbq	the number of quarries
NbspQ	the number of stockpiles per quarry
$nb_{stockpiles}$	the number of stockpiles
p	the number of days per year with at least 0.245 mm of natural precipitation
P	the production of aggregate
$Q_{mat. handled}$	the quantity of material handled
Q_{stored}	the average quantity of material stored at all time per quarry
r	the stockpiles radii
Ratio stored	the percentage of the production being stored at all time (%)
s	the silt content (< 75 µm) of surface material or stockpiles (%)
S	the area blasted
sL	the silt load of the paved road (g/m^2)
Total Area	the total exposed area of all stockpiles
Transfer point	Fall point on/from conveyor belt
U	the average yearly wind speed
Unit	The percentage of quarry with a primary, secondary or tertiary unit for each category of quarries (%)
Use_{tech}	the use of the specified abatement technology
V	the volume of one stockpile
w	the weight of material stored
W_{dumper}	the dumper weight (on average)
ρ	the bulk material density
Θ	the angle of repose

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7 Point of enquiry

Enquiries concerning this chapter should be directed to the relevant leader(s) of the Task Force on Emission Inventories and Projection's expert panel on combustion and industry. Please refer to the TFEIP website (www.tfeip-secretariat.org/) for the contact details of the current expert panel leaders.