Application of Emission Factors for pollution load calculation[1]

Case study 1: Cement industry

Case study 2: Petroleum refineries

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[1] As required by the NBB Guidelines and H2020 Indicator factsheets

Preamble

The use of Emission Factors (EF) for the calculation of pollution loads from industrial operations is applicable in cases where direct measurements are not in place. There are several possibilities to obtain these EF from the literature, national permits or by conducting mass balances of the relevant industrial unit operations.

To assist those Mediterranean countries which are seeking a summary of internationally reliable EF UNEP/MAP has prepared some tools for consideration i.e. the Methodology for setting national EF and the Regional Template in which all available EF are categorised according to the various sectors/ sub-sectors according to the NBB and the E-PRTR classification.

These case studies will also facilitate/complement the "calculation/estimation methods" described in the H2020 Indicator Factsheets and corresponding Data Dictionaries.

How the relevant pollution loads will be calculated is shown by two case studies: 1) the cement industry and 2) the petroleum refineries: in the 1st case there are only **air emissions** to be calculated whereas for petroleum refineries **air** and **water emissions** (effluents) are present.

Case study 1 – Cement industry

Basic assumption: the production capacity of a cement factory is 1,000 tonnes/day (average) = 365,000 tonnes/year (non-stop operation).

Step 1 – Find the cement sector according to NBB/E-PRTR categorisation

1. Open the Regional Template and go to Sheet titled "Emission Factors (I)".
2. Scroll down till rows 301 - 302 where the cement industry is listed according to NBB (cell A) and E-PRTR (cell B).

Step 2 – PCDD/PCDF Emissions

1. On row 2 all parameters for air emissions for all industrial processes are listed (cells D till AS). PCDD/PCDF is listed in cell H. The units of each parameter are listed in cell AT.
2. Go to row 301 and cell H where the EF (0.15) is given. Then go to cell AT where the PCDD/PCDF unit is given (µg I-TEQ/ 10^3 kg of product); that means that **0.15 µg I-TEQ/ 10^3 kg** of produced cement are emitted.
3. Calculate the total load of PCDD/PCDF emitted: 0.15 X 365,000 tonnes = 54,750 µg I-TEQ are emitted per year = **0.05475 g/year**.

If fabric filters are installed:

Step 3 - PCDD emissions

1. Go to row 302 and cell F (EF = 1.4 X 10^{-9}), then go to cell AT where the PCDD unit is given (kg pollutant/10^3 kg of product); that means that **1.4 X 10^{-9} kg/10^3 kg** of cement are emitted.
2. Calculate the total load of PCDD emitted: 1.4 X 10^{-9} X 365,000 tonnes are emitted per year = **0.0000511 kg/year.**

Step 4 - PCDF emissions

1. Go to row 302 and cell G (EF = 1.4 X 10^{-10}), then go to cell AT where the PCDF unit is given (kg pollutant/10^3 kg of product); that means that 1.4 X 10^{-10} kg/10^3 kg of cement are emitted.
2. Calculate the total load of PCDF emitted: 1.4 X 10^{-10} X 365,000 tonnes are emitted per year = **0.00000511 kg/year.**

Step 5 - Benzene emissions

1. Go to row 302 and cell J (EF = 0.008), then go to cell AT where the benzene unit is given (kg pollutant/10^3 kg of product); that means that 0.008 kg/10^3 kg of cement are emitted.
2. Calculate the total load of benzene emitted: 0.008 X 365,000 tonnes are emitted per year = **2,920 kg/year.**

If electrostatic precipitators are installed:

1. Go to row 303 and cell J (EF = 0.0016)
2. 0.0016 X 365,000 = **584 kg/year.**

Step 6 -- Arsenic emissions

1. Go to row 302 and cell O (EF = 6.5 X 10^{-6}), then go to cell AT where the arsenic unit is given (kg pollutant/10^3 kg of product); that means that 6.5 X 10^{-6} kg/10^3 kg of cement are emitted.
2. Calculate the total load of arsenic emitted: 6.5 X 10^{-6} X 365,000 tonnes are emitted per year = **2.37 kg/year.**

Step 7 - Benzo(a)anthracene emissions

1. Go to row 302 and cell P (EF = 2.1 X 10^{-8}), then go to cell AT where the benzo(a)anthracene unit is given (kg pollutant/10^3 kg of product); that means that 2.1 X 10^{-8} kg/10^3 kg of cement are emitted.
2. Calculate the total load of benzo(a)anthracene emitted: 2.1 X 10^{-8} X 365,000 tonnes are emitted per year = **0.0077 kg/year.**

Step 8 – Cadmium emissions

1. Go to row 302 and cell Q (EF = 1.1 X 10^{-6}), then go to cell AT where the Cadmium unit is given (kg pollutant/10^3 kg of product); that means that 1.1 X 10^{-6} kg/10^3 kg of cement are emitted.
2. Calculate the total load of cadmium emitted: 1.1 X 10^{-6} X 365,000 tonnes are emitted per year = **0.4015 kg/year.**

If electrostatic precipitators are installed:

1. Go to row 303 and cell Q (EF = 4.2 X 10^{-6})
2. 4.2 X 10^{-6} X 365,000 = **1.533 kg/year.**

Step 9 – Benzo(b)fluoranthene emissions

1. Go to row 302 and cell S (EF = 2.8 X 10^{-8}), then go to cell AT where the benzo(b)fluoranthene unit is given (kg pollutant/10^3 kg of product); that means that 2.8 X 10^{-8} kg/10^3 kg of cement are emitted.
2. Calculate the total load of benzo(b)fluoranthene emitted: 2.8 X 10^{-8} X 365,000 tonnes are emitted per year = **0.01 kg/year.**

Step 10 – Benzo(g,h,i)perylene emissions

1. Go to row 302 and cell T (EF = 3.9 X 10^{-8}), then go to cell AT where the benzo(g,h,i)perylene unit is given (kg pollutant/10^3 kg of product); that means that 3.9 X 10^{-8} kg/10^3 kg of cement are emitted.
2. Calculate the total load of benzo(g,h,i)perylene emitted: 3.9 X 10^{-8} X 365,000 tonnes are emitted per year = **0.014 kg/year.**

Step 11 – Copper emissions

1. Go to row 302 and cell AA (EF = 0.0026), then go to cell AT where the copper unit is given (kg pollutant/10^3 kg of product); that means that 0.0026 kg/10^3 kg of cement are emitted.
2. Calculate the total load of copper emitted: 0.0026 X 365,000 tonnes are emitted per year = **949 kg/year.**

Step 12 – Mercury emissions

1. Go to row 302 and cell AB (EF = 1.2 X 10^{-5}), then go to cell AT where the mercury unit is given (kg pollutant/10^3 kg of product); that means that 1.2 X 10^{-5} kg/10^3 kg of cement are emitted.
2. Calculate the total load of mercury emitted: 1.2 X 10^{-5} X 365,000 tonnes are emitted per year = **4.38 kg/year.**

If electrostatic precipitators are installed:

1. Go to row 303 and cell AB (EF = 0.00011)
2. 0.00011 X 365,000 = **40.15 kg/year.**

Step 13 – Chromium emissions

1. Go to row 302 and cell AC (EF = 7.0 X 10^{-5}), then go to cell AT where the chromium unit is given (kg pollutant/10^3 kg of product); that means that 7.0 X 10^{-5} kg/10^3 kg of cement are emitted.
2. Calculate the total load of chromium emitted: 7.0 X 10^{-5} X 365,000 tonnes are emitted per year = **25.5 kg/year.**

If electrostatic precipitators are installed:

1. Go to row 303 and cell AC (EF = 3.9 X 10^{-6}).
2. 3.9 X 10^{-6} X 365,000 = **1.42 kg/year.**

Step 14 – Lead emissions

1. Go to row 302 and cell AD (EF = 3.8 X 10^{-5}), then go to cell AT where the lead unit is given (kg pollutant/10^3 kg of product); that means that 3.8 X 10^{-5} kg/10^3 kg of cement are emitted.

2. Calculate the total load of lead emitted: 3.8 X 10^{-5} X 365,000 tonnes are emitted per year = **13.87 kg/year.**

If electrostatic precipitators are installed:

1. Go to row 303 and cell AD (EF = 0.00036).
2. 0.00036 X 365,000 = **131.4 kg/year.**

Step 15 – HCl emissions

1. Go to row 302 and cell AF (EF = 0.073), then go to cell AT where the HCl unit is given (kg pollutant/10^3 kg of product); that means that 0.073 kg/10^3 kg of cement are emitted.
2. Calculate the total load of HCl emitted: 0.073 X 365,000 tonnes are emitted per year = **26.6 kg/year.**

Step 16 – Formaldehyde emissions

1. Go to row 302 and cell AG (EF = 0.00023), then go to cell AT where the formaldehyde unit is given (kg pollutant/10^3 kg of product); that means that 0.00023 kg/10^3 kg of cement are emitted.
2. Calculate the total load of formaldehyde emitted: 0.00023 X 365,000 tonnes are emitted per year = **83.95 kg/year.**

Step 17 – Ammonia emissions

1. Go to row 302 and cell AR (EF = 0.0051), then go to cell AT where the ammonia unit is given (kg pollutant/10^3 kg of product); that means that 0.0051 kg/10^3 kg of cement are emitted.
2. Calculate the total load of ammonia emitted: 0.0051 X 365,000 tonnes are emitted per year = **1,861.5 kg/year.**

If electrostatic precipitators are installed:

Step 18 – Chlorobenzene emissions

1. Go to row 303 and cell AJ (EF = 8.0 X 10^{-6}), cell AT (unit).
2. 8.0 X 10^{-6} X 365,000 = **2.92 kg/year.**

Step 19 – Toluene emissions

1. Go to row 303 and cell AK (EF = 0.0001), cell AT (unit).
2. 0.0001 X 365,000 = **36.5 kg/year.**

Step 20 – Fluor emissions

1. Go to row 303 and cell AN (EF = 0.00045), cell AT (unit).
2. 0.00045 X 365,000 = **164.25 kg/year.**

Step 21 – Phenol emissions

1. Go to row 303 and cell AQ (EF = 5.5 X 10^{-5}), cell AT (unit).
2. 5.5 X 10^{-5} X 365,000 = **20.0 kg/year.**

Case study 2: Petroleum refineries

Basic assumption: the production capacity of a refinery is 10,000 tonnes/day (average) = 3,650,000 tonnes/year (non-stop operation) by assumed density of 1,000 kg/m^3 of oil (= 3,650,000 litres).

Step 1 - Find the refinery sector according to NBB/E-PRTR categorisation

1. Open the Regional Template and go to Sheet titled "Emission Factors (I)".
2. Scroll down till rows 3 - 15 where the various types of petroleum refineries are listed according to NBB (cell A) and E-PRTR (cell B).

Step 2 – VOC Emissions (air)

For fluid catalytic cracking units (uncontrolled):

1. On row 2 all parameters for air emissions for all industrial processes are listed (cells D till AS). VOC is listed in cell D. The units of each parameter are listed in cell AT.
2. Go to row 3 and cell D (EF = 0.63), then go to cell AT where the VOC unit is given (Kg/10^3 L fresh feed); that means that 0.63 kg/10^3 L of oil are emitted.
3. Calculate the total load of VOC emitted: 0.63 X 3,650,000 tonnes (litres) are emitted per year = **2,299,500 kg/year.**

For moving-bed catalytic cracking units:

1. Go to row 4 and cell D (EF = 0.25), then go to cell AT where the VOC unit is given (Kg/10^3 L fresh feed); that means that 0.25 kg/10^3 L of oil are emitted.
2. Calculate the total load of VOC emitted: 0.25 X 3,650,000 tonnes (litres) are emitted per year = **912,500 kg/year.**

For compressor engines/reciprocating engines:

1. Go to row 5 and cell D (EF = 21.8), then go to cell AT where the VOC unit is given (Kg/10^3 L fresh feed); that means that 21.8 kg/10^3 L of oil are emitted.
2. Calculate the total load of VOC emitted: 21.8 X 3,650,000 tonnes (litres) are emitted per year = **79,570,000 kg/year.**

For compressor engines/gas turbines:

1. Go to row 6 and cell D (EF = 0.28), then go to cell AT where the VOC unit is given (Kg/10^3 L fresh feed); that means that 0.28 kg/10^3 L of oil are emitted.
2. Calculate the total load of VOC emitted: 0.28 X 3,650,000 tonnes (litres) are emitted per year = **1,022,000 kg/year.**

For blowdown systems (uncontrolled):

1. Go to row 7 and cell D (EF = 1.662), then go to cell AT where the VOC unit is given (Kg/10^3 L fresh feed); that means that 1.662 kg/10^3 L of oil are emitted.
2. Calculate the total load of VOC emitted: 1.662 X 3,650,000 tonnes (litres) are emitted per year = **6,066,300 kg/year.**

For blowdown systems (vapour recovery system and flaring):

1. Go to row 8 and cell D (EF = 0.002), then go to cell AT where the VOC unit is given (Kg/10_3 L fresh feed); that means that 0.002 kg/10_3 L of oil are emitted.
2. Calculate the total load of VOC emitted: 0.002 X 3,650,000 tonnes (litres) are emitted per year = **7,300 kg/year.**

For vacuum distillation column condensers (uncontrolled):

1. Go to row 9 and cell D (EF = 0.14), then go to cell AT where the VOC unit is given (Kg/10_3 L fresh feed); that means that 0.14 kg/10_3 L of oil are emitted.
2. Calculate the total load of VOC emitted: 0.14 X 3,650,000 tonnes (litres) are emitted per year = **511,000 kg/year.**

Fugitive emissions (total):

1. Go to row 10 and cell D (EF = 0.39), then go to cell AT where the VOC unit is given (Kg/10_3 L fresh feed); that means that 0.39 kg/10_3 L of oil are emitted.
2. Calculate the total load of VOC emitted: 0.39 X 3,650,000 tonnes (litres) are emitted per year = **1,423,500 kg/year.**

Step 3 – Petroleum hydrocarbon Discharges (water)

For topping refineries:

1. On row 2 all parameters for water discharges for all industrial processes are listed (cells AU till BT). Petroleum hydrocarbon is listed in cell AU. The units of each parameter are listed in cell BU.
2. Go to row 11 and cell AU (EF = 8.3), then go to cell BU where the petroleum hydrocarbon unit is given (Kg/10_3m_3 crude oil); that means that 8.3 kg/10_3m_3 crude oil are emitted.
3. Calculate the total load of petroleum hydrocarbon emitted: 8.3 X 3,650,000 tonnes (litres) are emitted per year = **30,295,000 kg/year.**

For cracking refineries:

1. Go to row 12 and cell AU (EF = 31.2), then go to cell BU where the petroleum hydrocarbon unit is given (Kg/10_3m_3 crude oil); that means that 31.2 kg/10_3m_3 crude oil are emitted.
2. Calculate the total load of petroleum hydrocarbon emitted: 31.2 X 3,650,000 tonnes (litres) are emitted per year = **113,880,000 kg/year.**

For petrochemical refinery (no lub oil):

1. Go to row 13 and cell AU (EF = 52.9), then go to cell BU where the petroleum hydrocarbon unit is given (Kg/10_3m_3 crude oil); that means that 52.9 kg/10_3m_3 crude oil are emitted.
2. Calculate the total load of petroleum hydrocarbon emitted: 52.9 X 3,650,000 tonnes (litres) are emitted per year = **193,085,000 kg/year.**

For lub oil refinery:

1. Go to row 14 and cell AU (EF = 120), then go to cell BU where the petroleum hydrocarbon unit is given (Kg/10_3m_3 crude oil); that means that 120 kg/10_3m_3 crude oil are emitted.
2. Calculate the total load of petroleum hydrocarbon emitted: 120 X 3,650,000 tonnes (litres) are emitted per year = **438,000,000 kg/year.**

For integrated refinery (cracking, lub oil, petrochemicals):

1. Go to row 15 and cell AU (EF = 74.9), then go to cell BU where the petroleum hydrocarbon unit is given (Kg/10_3m_3 crude oil); that means that 74.9 kg/10_3m_3 crude oil are emitted.
2. Calculate the total load of petroleum hydrocarbon emitted: 74.9 X 3,650,000 tonnes (litres) are emitted per year = **273,385,000 kg/year.**

Step 4 – Phenols Discharges (water)

For topping refineries:

1. Go to row 11 and cell AV (EF = 0.034), cell BU (unit).
2. 0.034 X 3,605,000 = **343,100 kg/year.**

For cracking refineries:

1. Go to row 12 and cell AV (EF = 4), cell BU (unit).
2. 4 X 3,605,000 = **14,600,000 kg/year.**

For petrochemical refinery (no lub oil):

1. Go to row 13 and cell AV (EF = 7.7), cell BU (unit).
2. 7.7 X 3,605,000 = **28,105,000 kg/year.**

For lub oil refinery:

1. Go to row 14 and cell AV (EF = 8.3), cell BU (unit).
2. 8.3 X 3,605,000 = **30,295,000 kg/year.**

For integrated refinery (cracking, lub oil, petrochemicals):

1. Go to row 15 and cell AV (EF = 3.8), cell BU (unit).
2. 3.8 X 3,605,000 = **13,870,000 kg/year.**

Step 5 – Chromium Discharges (water)

For topping refineries:

1. Go to row 11 and cell AX (EF = 0.007), cell BU (unit).
2. 0.007 X 3,605,000 = **25,550 kg/year.**

For cracking refineries:

1. Go to row 12 and cell AX (EF = 0.25), cell BU (unit).
2. 0.25 X 3,605,000 = **912,500 kg/year.**

For petrochemical refinery (no lub oil):

1. Go to row 13 and cell AX (EF = 0.234), cell BU (unit).
2. 0.234 X 3,605,000 = **854,100 kg/year.**

For lub oil refinery:

1. Go to row 14 and cell AX (EF = 0.046), cell BU (unit).
2. 0.046 X 3,605,000 = **167,900 kg/year.**

For integrated refinery (cracking, lub oil, petrochemicals):

1. Go to row 15 and cell AX (EF = 0.49), cell BU (unit).
2. 0.49 X 3,605,000 = **1,788,500 kg/year.**

Step 6 – BOD_5 Discharges (water)

For topping refineries:

1. Go to row 11 and cell BB (EF = 3.4), cell BU (unit).
2. 3.4 X 3,605,000 = **12,410,000 kg/year.**

For petrochemical refinery (no lub oil):

1. Go to row 13 and cell BB (EF = 172), cell BU (unit).
2. 172 X 3,605,000 = **627,800,000 kg/year.**

For lub oil refinery:

1. Go to row 14 and cell BB (EF = 217), cell BU (unit).
2. 0.046 X 3,605,000 = **792,050,000 kg/year.**

For integrated refinery (cracking, lub oil, petrochemicals):

1. Go to row 15 and cell BB (EF = 197), cell BU (unit).
2. 197 X 3,605,000 = **719,050,000 kg/year.**