Review of the consistency of PM, HM and POP emission factors – 6C Waste Incineration

Waste incineration encompasses five chapters in the GB:
- 6Ca Clinical waste incineration
- 6Cb Industrial waste incineration
- 6Cc Municipal waste incineration
- 6Cd Cremation
- 6Ce Small scale waste burning

Cross-cutting observations
In general the EFs provided are rather old and are based on different references for different pollutants, thereby potentially compromising the consistency of the EFs. Furthermore, many of the EFs refer to the previous version of the GB, which is a dead end meaning that the EFs are in fact not referenced.

Several of the EF tables for both tier 1 and tier 2 are missing relevant pollutants, and for several EF tables only the sum of PAH is available as EF and not EFs for the four PAHs for which there is a reporting requirement.

Clinical waste incineration
The GB chapter contains tier 1 EFs and five tier 2 EF tables. There are no PM10 and PM25 EFs available in neither the tier 1 nor the tier 2 tables. Only a total PAH EF is available.

The difference between the tier 1 and the different tier 2 EFs is limited to the EFs of some of the heavy metals and PCDD/F. It has not been possible to acquire a copy of Wenborn et al. (1998), which is the reference for the difference in EFs of cadmium, mercury and lead.

Since the vast majority of EFs are either missing or the same for all EF tables, it seems unnecessary to have so many EF table for this source category. Since it has not been possible to source some of the key current references, it is proposed to completely reshape the chapter based on available literature data. Depending on the available data, it could mean that the number of EF tables will be significantly reduced.

It has not been possible to complete the literature survey at this stage, so the main issue at the TFEIP meeting is whether it would be acceptable to the TFEIP to simplify the EFs provided taking into account the issues mentioned above.

Industrial waste incineration
The GB currently contains tier 1 EFs and tier 2 EFs for uncontrolled incineration of industrial waste and for incineration of sludge from wastewater treatment.

Industrial waste incineration
The GB currently contains tier 1 EFs, which is a mix of EFs taken from the BREF document, the previous GB and the ESPREME project and tier 2 EFs for unabated industrial waste incineration. Most of the tier 2 EFs are referenced to a previous version of the GB, which states that the same EFs as for medical waste incineration has been used for most pollutants. However, this is incorrect.
The text prefacing the tier 1 EFs states that only particle abatement is assumed. However, when analysing
the EFs for e.g. SO₂ and NOₓ, it seems evident that the EFs must be for plants with both desulphurisation
and NOₓ abatement installed. The tier 1 EFs as presented for the most part seems to be tier 2 EFs for a plant
using relatively modern flue gas cleaning devices. Therefore it should be considered to move the current
tier 1 EFs to a tier 2 table indicating flue gas cleaning (desulphurisation, NOₓ, abatement and particle
abatement). The unabated EFs could then be implemented as tier 1. Abatement efficiencies are included in
the GB, so it will be possible for countries to take into account the actual abatement technologies used in
the country.

**Sludge incineration**

The EFs currently in the GB refers to US EPA (1996) for main pollutants and PM, while other references are
used for HM, PAH and PCDD/F.

It is not clear why other references have been chosen for the heavy metals since factors are available in the
AP42 chapter on sewage sludge incineration (US EPA, 1995). For PAH EFs are available for single PAH from
the US EPA (US EPA, 1998). From US EPA (1995) only the uncontrolled EFs are complete regarding
pollutants. However, in US EPA (1998) the PAH EFs are provided for plants with wet scrubbers. The EFs
have a rating of E and the ranges of the reported EFs are significant, therefore it is considered reasonable
to include them in the EF table.

The HM EFs are rated B by the US EPA (C for mercury) and have been validated by an Australian study
(Sullivan & Woods, 2000). Therefore, the HM EFs from the US EPA are considered to be the best data
available.

For PCB and HCB the available data are also from North America.

**Recommendations**

It is proposed to use the available data in chapter 2.2 of AP42 from the US EPA and to supplement these
with data from other sources for PAHs, PCBs and HCB. Based on this the EF table would be as presented
below.

<table>
<thead>
<tr>
<th>Tier 2 emission factors</th>
<th>Code</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFR source category</td>
<td>6.C.b</td>
<td>Industrial waste incineration</td>
</tr>
<tr>
<td>Fuel</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>SNAP [if applicable]</td>
<td>090205</td>
<td>Incineration of sludge from waste water treatment</td>
</tr>
<tr>
<td>Technologies/Practices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region or regional conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abatement technologies</td>
<td>Uncontrolled</td>
<td></td>
</tr>
<tr>
<td>Not applicable</td>
<td>HCH</td>
<td></td>
</tr>
<tr>
<td>Not estimated</td>
<td>NH3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Value</th>
<th>Unit</th>
<th>95 % confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOₓ</td>
<td>2.5</td>
<td>kg/Mg</td>
<td>US EPA, 1995</td>
</tr>
<tr>
<td>CO</td>
<td>15.5</td>
<td>kg/Mg</td>
<td>US EPA, 1995</td>
</tr>
<tr>
<td>NMVOC</td>
<td>0.84</td>
<td>kg/Mg</td>
<td>US EPA, 1995</td>
</tr>
<tr>
<td>SO₂</td>
<td>14</td>
<td>kg/Mg</td>
<td>US EPA, 1995</td>
</tr>
<tr>
<td>TSP</td>
<td>52</td>
<td>kg/Mg</td>
<td>US EPA, 1995</td>
</tr>
<tr>
<td>PM10</td>
<td>4.1</td>
<td>kg/Mg</td>
<td>US EPA, 1995</td>
</tr>
<tr>
<td>PM2.5</td>
<td>1.1</td>
<td>kg/Mg</td>
<td>US EPA, 1995</td>
</tr>
<tr>
<td>Pb</td>
<td>50</td>
<td>g/Mg</td>
<td>US EPA, 1995</td>
</tr>
<tr>
<td>Cd</td>
<td>16</td>
<td>g/Mg</td>
<td>US EPA, 1995</td>
</tr>
<tr>
<td>Hg</td>
<td>2.3</td>
<td>g/Mg</td>
<td>US EPA, 1995</td>
</tr>
<tr>
<td>As</td>
<td>4.7</td>
<td>g/Mg</td>
<td>US EPA, 1995</td>
</tr>
<tr>
<td>Cr</td>
<td>14</td>
<td>g/Mg</td>
<td>US EPA, 1995</td>
</tr>
</tbody>
</table>
Municipal waste incineration

The chapter in the GB currently contains tier 1 and tier 2 EFs. The tier 2 EFs are reported as uncontrolled while the tier 1 EFs according to the text are based on plants with “acid gas abatement and particle abatement”. The abatement efficiency for acid gas abatement is only listed as 76 %, which is very low compared to present day standards.

The EFs presented below are based on measurements carried out in Denmark (Nielsen et al., 2010) after the implementation of the EU waste incineration directive. The original EFs are based on energy input. The EFs have been converted using a NCV of 10.5 GJ per tonnes.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Code</th>
<th>Value</th>
<th>Unit</th>
<th>95 % confidence interval</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td></td>
<td>1071 g/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>CO</td>
<td></td>
<td>41 g/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>NMVOC</td>
<td></td>
<td>5,9 g/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>SO2</td>
<td></td>
<td>87 g/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>NH3</td>
<td></td>
<td>3,0 g/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>TSP</td>
<td></td>
<td>3,0 g/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>PM10</td>
<td></td>
<td>g/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>PM2.5</td>
<td></td>
<td>g/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>Pb</td>
<td></td>
<td>58,0 mg/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>Cd</td>
<td></td>
<td>4,5 mg/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>Hg</td>
<td></td>
<td>18,8 mg/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>As</td>
<td></td>
<td>6,2 mg/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>Cr</td>
<td></td>
<td>16,4 mg/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>Cu</td>
<td></td>
<td>13,7 mg/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>Ni</td>
<td></td>
<td>21,6 mg/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>Se</td>
<td></td>
<td>11,7 mg/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>Zn</td>
<td></td>
<td>24,5 mg/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>PCBs</td>
<td></td>
<td>3,4 ng/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>PCDD/F</td>
<td></td>
<td>52,5 ng/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>Benzo(a)pyrene</td>
<td></td>
<td>8,4 mikrog/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>Benzo(b)fluoranthene</td>
<td></td>
<td>17,9 mikrog/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>Indeno(1,2,3-cd)pyrene</td>
<td></td>
<td>9,5 mikrog/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>Benzo(k)fluoranthene</td>
<td></td>
<td>11,6 mikrog/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
<tr>
<td>HCB</td>
<td></td>
<td>45,2 mikrog/Mg</td>
<td></td>
<td></td>
<td>Nielsen et al., 2010</td>
</tr>
</tbody>
</table>
These EFs can be assumed to be representative for modern waste incineration plants. The waste incineration plants in Denmark combusts a mix of municipal and commercial/industrial waste.

**Recommendations**

It is recommended to replace the current tier 1 EFs with the EFs presented above. Furthermore, it is recommended to keep the table with unabated EFs, and the table on abatement efficiencies for the time being. It is reasonable to revise these data in the future.

**Cremation**

The chapter on cremation contains tier 1 EFs for human cremations as presented below. Furthermore, there are tier 2PM EFs available for burning of cows and sheep.

**Incineration of corpses**

The current tier 1 EFs in the GB are shown below.

### Table 3.1 Tier 1 emission factors for source category 6.C.d Cremation, cremation of human bodies

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Value</th>
<th>Unit</th>
<th>95% confidence interval</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>0.309</td>
<td>kg/body</td>
<td>0.0309</td>
<td>0.0309</td>
</tr>
<tr>
<td>CO</td>
<td>0.141</td>
<td>kg/body</td>
<td>0.0141</td>
<td>0.0141</td>
</tr>
<tr>
<td>NMVOC</td>
<td>0.013</td>
<td>kg/body</td>
<td>0.0013</td>
<td>0.0013</td>
</tr>
<tr>
<td>SOx</td>
<td>0.544</td>
<td>kg/body</td>
<td>0.0544</td>
<td>0.0544</td>
</tr>
<tr>
<td>TSP</td>
<td>14.6</td>
<td>g/body</td>
<td>9.63</td>
<td>9.63</td>
</tr>
<tr>
<td>Pb</td>
<td>0.0186</td>
<td>mg/body</td>
<td>0.00186</td>
<td>0.00186</td>
</tr>
<tr>
<td>Cd</td>
<td>0.00311</td>
<td>mg/body</td>
<td>0.000311</td>
<td>0.000311</td>
</tr>
<tr>
<td>Hg</td>
<td>0.934</td>
<td>mg/body</td>
<td>0.0934</td>
<td>0.0934</td>
</tr>
<tr>
<td>As</td>
<td>0.011</td>
<td>mg/body</td>
<td>0.0011</td>
<td>0.0011</td>
</tr>
<tr>
<td>Cr</td>
<td>0.00844</td>
<td>mg/body</td>
<td>0.000844</td>
<td>0.000844</td>
</tr>
<tr>
<td>Cu</td>
<td>0.00771</td>
<td>mg/body</td>
<td>0.000771</td>
<td>0.000771</td>
</tr>
<tr>
<td>Ni</td>
<td>0.0107</td>
<td>mg/body</td>
<td>0.00107</td>
<td>0.00107</td>
</tr>
<tr>
<td>PCDD/F</td>
<td>0.0168</td>
<td>µg/body</td>
<td>0.00037</td>
<td>0.00037</td>
</tr>
<tr>
<td>Benzo(a)pyrene</td>
<td>0.0103</td>
<td>µg/body</td>
<td>0.00103</td>
<td>0.00103</td>
</tr>
</tbody>
</table>

It can be seen that EFs are not estimated for a large number of pollutants. Furthermore, most of the EFs are referenced to the previous version of the GB.

The recommended EFs are shown below.
Cd  5.03  mg/body  WebFIRE
Hg  1492.32  mg/body  WebFIRE
As  13.61  mg/body  WebFIRE
Cr  13.56  mg/body  WebFIRE
Cu  12.43  mg/body  WebFIRE
Ni  17.33  mg/body  WebFIRE
Se  19.78  mg/body  WebFIRE
Zn  120.12  mg/body  WebFIRE
PCBs  0.41  mg/body  Toda, 2006
Hg  1492.32  mg/body  WebFIRE
As  13.61  mg/body  WebFIRE
Cr  13.56  mg/body  WebFIRE
Cu  12.43  mg/body  WebFIRE
Ni  17.33  mg/body  WebFIRE
Se  19.78  mg/body  WebFIRE
Zn  160.12  mg/body  WebFIRE
PCBs  0.41  mg/body  Toda, 2006
PCDD/F  0.027  µg/body  WebFIRE
Benzo(a)pyrene  13.20  µg/body  WebFIRE
Benzo(b)fluoranthene  7.21  µg/body  WebFIRE
Benzo(k)fluoranthene  6.44  µg/body  WebFIRE
Indeno(1,2,3-cd)pyrene  6.99  µg/body  WebFIRE
Total 4 PAHs  33.84  µg/body  WebFIRE
HCB  0.15  mg/body  Toda, 2006

SO$_2$, NO$_x$, NMVOC, CO

The following table provides an overview of the different sources to the emission factors for SO$_2$, NO$_x$, NMVOC and CO for human cremation. There is good agreement between the different sources, providing that the emission factors selected for the previous GB is a reasonable estimate. It is recommended that these four emission factors are not changed.

However, it should be noted that the emission factor for SO$_2$ has increased with a factor 10 from, GB2007 to GB2009. It has not been possible to find the original source to verify which factor is correct.

<table>
<thead>
<tr>
<th>SO$_2$, NO$_x$, NMVOC, CO emission factors, kg/cremated body</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO$_2$</td>
</tr>
<tr>
<td>NO$_x$</td>
</tr>
<tr>
<td>NMVOC</td>
</tr>
<tr>
<td>CO</td>
</tr>
</tbody>
</table>

*Sources provided by The Guidebook 2007

Particulate matter, heavy metals (except mercury)

The following table provides an overview of the different sources of the emission factors for particulate matter and heavy metals for human cremation.

When comparing to other sources, the GB values for the individual metals appears to be under estimated. It is recommended to use US EPA WebFIRE, which will also provide some of the previously not included compounds. By using WebFIRE as the source for both particles, individual heavy metals, PAHs and PCDD/F, a higher degree of consistency is achieved.

Data given by WebFIRE includes an average body weight of incinerated corpses of 141 lb (64 kg); wrapping material adds another 4 lb (1.8 kg) cardboard and 2 lb (0.9 kg) wood. The only calculation performed on the provided data is the conversion from pounds to kilograms; 1 lb, lbs = 0.453 592 kg. Data provided by WebFIRE refers to “Emissions Testing of a Propane Fired Incinerator at a Crematorium. October 29, 1992. (Confidential Report No. ERC-39)”
### Particulate matter and heavy metals emission factors, kg/cremated body

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TSP</td>
<td>1.46E-02</td>
<td>2.54E-05</td>
<td>2.24E-01</td>
<td>1.55</td>
<td>6.60E-02</td>
<td>3.86E-02</td>
<td>1.59E-01</td>
</tr>
<tr>
<td>PM10</td>
<td>1.40</td>
<td>5.90E-02</td>
<td>3.47E-02</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM2.5</td>
<td>1.24</td>
<td>5.90E-02</td>
<td>3.47E-02</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>As</td>
<td>1.10E-08</td>
<td>1.10E-08</td>
<td></td>
<td>1.36E-05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cd</td>
<td>3.11E-09</td>
<td>3.11E-09</td>
<td>5.03E-06</td>
<td>1.97E-05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td>8.44E-09</td>
<td>8.44E-09</td>
<td></td>
<td>1.36E-05</td>
<td>1.73E-05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>7.71E-09</td>
<td>7.71E-09</td>
<td>1.24E-05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>1.07E-08</td>
<td>1.08E-08</td>
<td></td>
<td>1.73E-05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>1.86E-08</td>
<td>1.86E-08</td>
<td>2.00E-04</td>
<td>3.00E-05</td>
<td>1.14E-03</td>
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<tr>
<td>Se</td>
<td></td>
<td></td>
<td>1.98E-05</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Zn</td>
<td></td>
<td></td>
<td>1.60E-04</td>
<td>1.13E-02</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Sources provided by The Guidebook 2007*
1 **Mercury**

2 The following table provides an overview of the different sources to the emission factors for mercury for human cremation. With the exception of EB2009/GB2007 there is good compliance between the different sources. To support consistency, WebFIRE is recommended as the source for a mercury emission factor.

3 **Mercury emission factors, kg/cremated body**

4

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Netherland IIR 2012</td>
<td>9.34E-7</td>
<td>9.34E-7</td>
<td>5.00E-3</td>
<td>2.08E-3</td>
<td>1.43E-3</td>
<td>8.00E-4</td>
<td>3.87E-3</td>
<td>1.49E-3</td>
<td>1.12E-3</td>
<td>5.43E-4</td>
</tr>
<tr>
<td>Schleicher and Gram, 2008</td>
<td>2.08E-3</td>
<td>2.08E-3</td>
<td>5.00E-3</td>
<td>2.08E-3</td>
<td>1.43E-3</td>
<td>8.00E-4</td>
<td>3.87E-3</td>
<td>1.49E-3</td>
<td>1.12E-3</td>
<td>5.43E-4</td>
</tr>
<tr>
<td>Defra 2004</td>
<td>2.08E-3</td>
<td>2.08E-3</td>
<td>5.00E-3</td>
<td>2.08E-3</td>
<td>1.43E-3</td>
<td>8.00E-4</td>
<td>3.87E-3</td>
<td>1.49E-3</td>
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<td>Norway researcher, 2001 **</td>
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<td>Tetra, 2007</td>
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<td>5.13E-3</td>
<td>4.90E-3</td>
<td>3.20E-3</td>
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</table>

5 *It has not been possible to obtain this source, data is provided by The Guidebook 2007*.

6 **Calculated from 0.8 mg Hg/Nm$^3$ and the average of 3500 Nm$^3$/hr in 2 hrs and 3880 Nm$^3$/hr in 1.5 hrs.
PAHs, PCDD/F, PCBs, HCB

The following table provides an overview of the different sources to the emission factors for PAHs, PCDD/F, PCBs and HCB for human cremation. It has not been possible to find any sources to verify the emission factors for benzo(b)flouranthene, benzo(k)flouranthene, benzo(g,h,i)perylen and indeno(1,2,3-c,d)pyrene) given by WebFIRE. There is no clear compliance between the different sources of emissions factors for this group of compounds; it is recommended that WebFIRE is used as the source for PAHs and PCDD/F and that Toda (2006) is used as the source for PCBs and HCB.

Table 1: PAHs, PCDD/F, PCBs and HCB emission factors, kg/cremated body

<table>
<thead>
<tr>
<th>Source</th>
<th>benzo(b)flouranthene</th>
<th>benzo(k)flouranthene</th>
<th>benzo(g,h,i)perylen</th>
<th>indeno(1,2,3-c,d)pyrene</th>
<th>benzo(a)pyrene flouranthene</th>
<th>benzo(a)pyrene fluoranthene</th>
<th>benzo(a)pyrene PCDD/F</th>
<th>benzo(a)pyrene PCBs</th>
<th>benzo(a)pyrene HCB</th>
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<tr>
<td>GB2009</td>
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<td>5.90E-11</td>
<td>1.68E-11</td>
<td>5.00E-07</td>
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<tr>
<td>US-EPA 1996</td>
<td>7.21E-09</td>
<td>6.44E-09</td>
<td>1.32E-08</td>
<td>6.99E-09</td>
<td>1.32E-08</td>
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<td>1.32E-08</td>
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<td>Wang et al., 2003</td>
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<td>1.03E-11</td>
<td>1.03E-11</td>
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<td>5.90E-11</td>
<td>1.68E-11</td>
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<td>NAEI, 2012</td>
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<td>Finland IIR 2012</td>
<td>1.4E-08</td>
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<td>Hansen and Hansen 2002</td>
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<td>Irland IIR 2011</td>
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<td>Hansen, 2000</td>
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<td>1.32E-08</td>
<td>2.67E-11</td>
<td>2.83E-10</td>
</tr>
</tbody>
</table>

Sources provided by The Guidebook 2007
Incineration of carcasses
Comparing the recommended TSP EF for human cremation given by WebFiRE with the tier 2 EFs for open burning of sheep and cows, emissions are 0.59 kg/Mg, 2.18 kg/Mg and 0.897 kg/Mg for human, sheep and cows respectively. It seems reasonable at human cremation causes less particle emission than open burning of animal carcasses. The difference between sheep and cows appears large, but no other data has been found to suggest that the current data are unreasonable.

Small scale waste burning
Small-scale waste burning as in the current GB consists of a tier 1 EF table, and tier 2 EFs for leaf burning, forest residues, orchard crops, weeds, vine crops, backfire burning and headfire burning.

In the current GB chapter there is EFs for NMVOC, NH₃, TSP, PM₁₀, PM₂.₅, PCDD/F and total PAH. However, when reviewing the EFs, the following observations are made: the EFs provided for NMVOC, NH₃, PCDD/F and total PAH are identical for tier 1 and all available tier 2 tables.

The TSP EFs are from a previous version of the GB and are not referenced. The calculation of PM₁₀ and PM₂.₅ is based on particle size distribution from crude oil plumes!

Furthermore, the tier 1 TSP EF is lower than all of the tier 2 TSP EF.

It is difficult to defend the current level of disaggregation considering that the only EFs that vary across the different tier 2 EF tables are PM and that these factors are not referenced.

Recommendation
It is proposed to use data by Jenkins et al. (1996) to develop EFs for forest residues (Douglas fir slash & Ponderosa pine slash) and orchard crops (Almond prunings & Walnut prunings). The detailed data by Jenkins et al. will also increase the completeness of the EF tables since it covers more pollutants, e.g. it will be possible to include EFs of heavy metals and the four PAH compounds.

Based on the two tier 2 data sets the tier 1 EFs can be developed as the average value.

References


Schleicher and Gram, 2008: Analyse af omkostningerne for rensering for kviksølv på krematorier i Danmark, Ole Schleicher og Lars K. Gram, FORCEx Technology, Miljøprojekt Nr. 1191 2008, Danish Environmental Protection Agency, Danish Ministry of Environment. Available at: http://www.mst.dk/Publikationer/Publikationer/2008/02/978-87-7052-594-7.htm (Danish)


WebFIRE: United States Environmental Protection Agency, Technology Transfer Network Clearinghouse for Inventories & Emissions Factors, WebFIRE. Available at: http://cfpub.epa.gov/WebFIRE/