

## Appendix 2.4 - POP emissions from mobile combustion sources

This appendix chapter provides additional information regarding the approaches applied for estimating exhaust POP emissions from mobile sources in:

- Road Transport (1.A.3.b i - iv)
- Non-road Mobile Machinery in 1.A.2.g vii, 1.A.4.a ii/b ii/c ii, and 1.A.5.b
- Railways (1.A.3.c)
- Maritime Vessels and Ships in 1.A.3.d i, 1.A.3.d ii, 1.A.4.c iii and 1.A.5.b
- Aircraft in 1.A.3.a and 1.A.5.b

### Road Transport

For PAH exhaust emissions, the tier2 emission factors as provided in the 2023 EMEP/EEA Guidebook in chapter 1.A.3.b (Update 2024), pages 96-98, tables 3-79, 3-80, and 3-81 have been implemented with the current submission, upgrading the estimation from a tier1- to a tier2-approach.

**Table 3-79: PAHs and POPs bulk (hot + cold) emission factors**

| Species                | Bulk emission factors (µg/km) |             |                 |       |       |      |
|------------------------|-------------------------------|-------------|-----------------|-------|-------|------|
|                        | Petrol, E85, CNG PC & LCV     |             | Diesel PC & LCV |       | HDV   | LPG  |
|                        | Convent.                      | Euro I & on | DI              | IDI   | DI    |      |
| indeno(1,2,3-cd)pyrene | 1.03                          | 0.39        | 0.70            | 2.54  | 1.40  | 0.01 |
| benzo(k)fluoranthene   | 0.30                          | 0.26        | 0.19            | 2.87  | 6.09  | 0.01 |
| benzo(b)fluoranthene   | 0.88                          | 0.36        | 0.60            | 3.30  | 5.45  |      |
| benzo(ghi)perylene     | 2.90                          | 0.56        | 0.95            | 6.00  | 0.77  | 0.02 |
| Fluoranthene           | 18.22                         | 2.80        | 18.00           | 38.32 | 21.39 | 1.36 |
| benzo(a)pyrene         | 0.48                          | 0.32        | 0.63            | 2.85  | 0.90  | 0.01 |



Due to this improvement, the reported emissions especially for Benzo[a]Pyrene and, hence, the sum for PAH 1-4 increased rather strongly, by about % and % respectively, whereas the amounts of B[b]F, B[k]F, and I[123cd]P increased only slightly.

Regarding PCDD/F, a tier1 EF from (Rentz et al., 2008)<sup>1)</sup> is used instead.

Table 1: Tier1 default emission factors applied to road vehicles

|                               | B[a]P  | B[b]F | B[k]F | I[...] | PAHs 1-4 | PCDD/F    |
|-------------------------------|--------|-------|-------|--------|----------|-----------|
|                               | [mg/T] |       |       |        |          | [µg/km]   |
| <b>Diesel oil</b>             | 368    | 386   | 203   | 368    | 1,324    |           |
| <b>Biodiesel<sup>1)</sup></b> | 368    | 386   | 203   | 368    | 1,324    |           |
| <b>Gasoline fuels</b>         | 96     | 140   | 69    | 158    | 464      |           |
| <b>CNG</b>                    | NE     | NE    | NE    | NE     | NE       |           |
| <b>LPG</b>                    | 4.35   | 0.00  | 4.35  | 4.35   | 13.2     |           |
| <b>Biogas</b>                 | NE     | NE    | NE    | NE     | NE       |           |
| <b>all fuels</b>              |        |       |       |        |          | 0.0000056 |

<sup>1)</sup> values differ from EFs applied for fossil diesel oil to take into account the specific NCV of biodiesel

Here, the tier1 values for PAH exhaust emissions have been derived from the following tier1 default values provided in the July 2017 version of the 2016 EMEP/EEA Guidebook:

## Non-road Mobile Machinery in 1.A.2.g vii, 1.A.4.a.ii, 1.A.4.b.i, 1.A.4.c.ii and 1.A.5.b i

Table 3: Tier1 default emission factors applied to NRMM

|  | B[a]P  | B[b]F | B[k]F | I[...] <sup>1</sup> P | PAH 1-4 | PCDD/F            |
|--|--------|-------|-------|-----------------------|---------|-------------------|
|  | [mg/T] |       |       |                       |         | [µg/T]            |
| <b>Diesel oil</b>                            | 698    | 1.164 | 801   | 184                   | 2,847   | 1.62 <sup>3</sup> |
| <b>Biodiesel<sup>1</sup></b>                 | 806    | 1.343 | 924   | 212                   | 3,284   | 1.87              |
| <b>Gasoline fuels - 4-stroke</b>             | 919    | 919   | 90    | 204                   | 2,131   | 2.76 <sup>3</sup> |
| <b>Gasoline fuels - 2-stroke<sup>2</sup></b> | 919    | 919   | 90    | 204                   | 2,131   | 57.5 <sup>3</sup> |
| <b>LPG (1.A.4.a ii only)</b>                 | 4.35   | 0.00  | 4.35  | 4.35                  | 13.04   | NE                |

<sup>1</sup> values differ from EFs applied for fossil diesel oil to take into account the specific NCV of biodiesel

<sup>2</sup> no separate values available for 2-stroke-mix including 1:50 lube oil.

<sup>3</sup> tier1 values derived from <sup>2)</sup>

## Railways

Table 3: Tier1 default emission factors applied to railway vehicles

|                           | B[a]P            | B[b]F              | B[k]F            | I[...] <sup>1</sup> p | PAH 1-4 <sup>3</sup> | PCDD/F |
|---------------------------|------------------|--------------------|------------------|-----------------------|----------------------|--------|
|                           | [mg/T]           |                    |                  |                       |                      | [µg/T] |
| <b>Diesel oil</b>         | 698 <sup>2</sup> | 1,164 <sup>2</sup> | 801 <sup>1</sup> | 184 <sup>1</sup>      | 2,847 <sup>3</sup>   | 2.09   |
| <b>Biodiesel</b>          | 806              | 1,343              | 924              | 212                   | 3,284                | 2.41   |
| <b>Lignite Briquettes</b> | 34,500           | NE                 | NE               | NE                    | 90,000               | 29.80  |
| <b>Raw Lignite</b>        | NE               |                    |                  |                       |                      | NE     |
| <b>Hard Coal</b>          | NE               |                    |                  |                       |                      | NE     |
| <b>Hard Coal Coke</b>     | NE               |                    |                  |                       |                      | NE     |

<sup>1</sup> tier1 default from <sup>3)</sup>, chapter: 1.A.3.b i-iv - Road transport: exhaust emissions: tier1 value for diesel vehicles

<sup>2</sup> tier1 default from <sup>4)</sup>, chapter: 1.A.3.c - Railways

<sup>3</sup> sum of tier1 default value applied for B[a]P, B[b]F, B[k]F, and I[...]<sup>1</sup>P

As the EMEP/EEA GB 2019 does not provide a tier1 value for **PCDD/F**, the EF applied here has been derived from a study carried out by Rentz et al. (2008) <sup>5)</sup> for the German Federal Environment Agency. Furthermore, both **HCB** and **PCBs** emissions are stated as *not applicable* in <sup>6)</sup>, chapter 1.A.3.c Railways, Table 3-1 Tier 1 emission factors for railways.

## Inland Vessels and Ships in 1.A.3.d ii

Table 4: Tier1 default emission factors applied to inland ships and vessels

|                              | B[a]P            | B[b]F              | B[k]F            | I[...] <sup>1</sup> p | PAH 1-4 <sup>2</sup> | HCB               | PCBs              | PCDD/F            |
|------------------------------|------------------|--------------------|------------------|-----------------------|----------------------|-------------------|-------------------|-------------------|
|                              | [mg/T]           |                    |                  |                       |                      |                   |                   | [µg/T]            |
| <b>Diesel oil</b>            | 698 <sup>4</sup> | 1,164 <sup>4</sup> | 801 <sup>5</sup> | 184 <sup>5</sup>      | 2,847                | 1.86 <sup>3</sup> | 0.88 <sup>3</sup> | 93.0 <sup>7</sup> |
| <b>Biodiesel<sup>1</sup></b> | 806              | 1,343              | 924              | 212                   | 3,284                | 1.02              | 2.15              | 107               |

<sup>1</sup> similar EF for biodiesel applied for all mobile sources; due to lack of better information EF values are derived from conventional diesel oil but taking into account the specific NCV of biodiesel

<sup>2</sup> sum of tier1 default values applied for B[a]P, B[b]F, B[k]F, and I[1,2,3-c,d]P

<sup>3</sup> tier1 defaults from <sup>7)</sup>, Chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation: Tables 3-1 and 3-2

<sup>4</sup> tier1 defaults from <sup>8)</sup>, Chapter: 1.A.3.c Railways: Diesel, Table 3-1

<sup>5</sup> tier1 defaults from <sup>9)</sup>, Chapter: 1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv - Road transport, Table 3-8: HDV, Diesel

## Maritime Vessels and Ships in 1.A.3.d i, 1.A.3.d ii, 1.A.4.c iii and 1.A.5.b iii

The following table provides the tier1 EF applied for POPs from ships and vessels in both civil and military operation in NFR categories 1.A.3.d i -International Maritime Navigation, 1.A.3.d ii - National Navigation (Shipping), 1.A.4.c iii -Fishery and 1.A.5.b iii - Other: Military Navigation.

Table 4: Tier1 default emission factors applied to maritime ships and vessels

|                                   | B[a]P            | B[b]F              | B[k]F            | I[...] <sub>p</sub> | PAH 1-4 <sup>2</sup> | HCB               | PCBs              | PCDD/F            |
|-----------------------------------|------------------|--------------------|------------------|---------------------|----------------------|-------------------|-------------------|-------------------|
|                                   | [mg/T]           |                    |                  |                     |                      |                   |                   | [µg/T]            |
| <b>Diesel oil</b>                 | 698 <sup>4</sup> | 1,164 <sup>4</sup> | 801 <sup>5</sup> | 184 <sup>5</sup>    | 2,847                | 1.86 <sup>3</sup> | 0.88 <sup>3</sup> | 93.0 <sup>7</sup> |
| <b>Biodiesel<sup>1</sup></b>      | 806              | 1,343              | 924              | 212                 | 3,284                | 2.15              | 1.02              | 107               |
| <b>Heavy Fuel oil<sup>6</sup></b> | 741              | 1,235              | 849              | 195                 | 3,020                | 3.46              | 14.1              | 98.7              |

<sup>1</sup> similar EF for biodiesel applied for all mobile sources; due to lack of better information EF values are derived from conventional diesel oil but taking into account the specific NCV of biodiesel

<sup>2</sup> sum of tier1 default values applied for B[a]P, B[b]F, B[k]F, and I[1,2,3-c,d]P

<sup>3</sup> tier1 defaults from <sup>10)</sup>, Chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation: Tables 3-1 and 3-2

<sup>4</sup> tier1 defaults from <sup>11)</sup>, Chapter: 1.A.3.c Railways: Diesel, Table 3-1

<sup>5</sup> tier1 defaults from <sup>12)</sup>, Chapter: 1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv - Road transport, Table 3-8: HDV, Diesel

<sup>6</sup> derived from default for fossil diesel oil, but adapted to specific NCV of heavy fuel oil

<sup>7</sup> tier1 value derived from <sup>13)</sup>

## Aircraft in 1.A.3.a and 1.A.5.b ii

The EMEP/EEA GB 2016 (July 2017) does not provide specific defaults for POP emissions from the combustion of jet kerosene and aviation gasoline, stating that for aviation gasoline these emissions are *not estimated* (NE):

Therefore, the inventory compiler decided to apply the tier1 EF for **PAHs** from gasoline fuel used in non-road mobile machinery here, too. Furthermore, both **HCB** and **PCBs** emissions are stated as *not applicable* in <sup>14)</sup>, chapter 1.A.3.a, 1.A.5.b Aviation, Table 3.3 Tier 1 emission factors for NFR 1.A.3.a.ii.(i): Civil aviation (domestic, LTO).

As the Party assumes that POP emissions from the combustion of jet kerosene are unlikely to occur, these emissions are reported as *not applicable* (NA).

Table 5: Tier1 default emission factors applied to aircraft, in mg/T

|                          | B[a]P | B[b]F | B[k]F | I[...] <sub>p</sub> | PAH 1-4 | PCDD/F |
|--------------------------|-------|-------|-------|---------------------|---------|--------|
| <b>Kerosene</b>          | NA    | NA    | NA    | NA                  | NA      | NA     |
| <b>Aviation gasoline</b> | 126   | 182   | 90    | 205                 | 602     | NE     |

<sup>1), 2), 5), 13)</sup> Rentz et al., 2008: Nationaler Durchführungsplan unter dem Stockholmer Abkommen zu persistenten organischen Schadstoffen (POPs), im Auftrag des Umweltbundesamtes, FKZ 205 67 444, UBA Texte | 01/2008, January 2008 - URL:

<https://www.umweltbundesamt.de/en/publikationen/nationaler-durchfuehrungsplan-unter-stockholmer>

<sup>3), 4), 6), 7), 8), 9), 10), 11), 12), 14)</sup> EMEP/EEA (2019): EMEP/EEA air pollutant emission inventory guidebook 2019, Copenhagen, 2019.