

## Appendix 2.3 - Heavy Metal Exhaust Emissions From Mobile Sources

This appendix chapter provides additional information regarding the approaches applied for estimating exhaust heavy metal 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 heavy-metal exhaust emissions (other than lead from leaded gasoline), energy-related tier1 values have been derived from mass-related tier1 defaults provided in the 2023 EMEP/EEA Guidebook in chapter 1.A.3.b (Update 2024), page 99, table 3-82, taking into account not only the fuel heavy-metal content, but also the contribution of engine wear (*“These values have been calculated by encompassing the impact of engine wear to the heavy metal emissions. Therefore, by multiplying these apparent factors with fuel consumption, it is expected that the combined emissions of fuel and engine wear are estimated.”*)

**Table 3-82: Heavy metal emission factors for all vehicle categories in ppm/wt fuel**

| Category               | Pb     | Cd     | Cu     | Cr     | Ni     | Se     | Zn    | Hg     | As     |
|------------------------|--------|--------|--------|--------|--------|--------|-------|--------|--------|
| Passenger cars, petrol | 0.0016 | 0.0002 | 0.0045 | 0.0063 | 0.0023 | 0.0002 | 0.033 | 0.0087 | 0.0003 |
| Passenger cars, diesel | 0.0005 | 5 E-05 | 0.0057 | 0.0085 | 0.0002 | 0.0001 | 0.018 | 0.0053 | 0.0001 |
| LCVs, petrol           | 0.0016 | 0.0002 | 0.0045 | 0.0063 | 0.0023 | 0.0002 | 0.033 | 0.0087 | 0.0003 |
| LCVs, diesel           | 0.0005 | 5 E-05 | 0.0057 | 0.0085 | 0.0002 | 0.0001 | 0.018 | 0.0053 | 0.0001 |
| HDVs, petrol           | 0.0016 | 0.0002 | 0.0045 | 0.0063 | 0.0023 | 0.0002 | 0.033 | 0.0087 | 0.0003 |
| HDVs, diesel           | 0.0005 | 5 E-05 | 0.0057 | 0.0085 | 0.0002 | 0.0001 | 0.018 | 0.0053 | 0.0001 |
| L-category             | 0.0016 | 0.0002 | 0.0045 | 0.0063 | 0.0023 | 0.0002 | 0.033 | 0.0087 | 0.0003 |

From these default values, the following country-specific energy-related tier1 EF were derived via the average NCVs of the fuels used:

**Table 1: Tier1 emission factors derived from EMEP/EEA Guidebook 2023 defaults, in g/TJ**

|                                    | Pb     | Cd     | Hg     | As     | Cr     | Cu     | Ni     | Se     | Zn     | additional info:                          |
|------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------------------------------------------|
| <b>Diesel oil</b>                  | 0.0116 | 0.0012 | 0.1234 | 0.0023 | 0.1979 | 0.1327 | 0.0047 | 0.0023 | 0.4190 | derivation of tier1 EF<br>(MS Excel file) |
| <b>Biodiesel<sup>1</sup></b>       | 0.0134 | 0.0013 | 0.1423 | 0.0027 | 0.2282 | 0.1531 | 0.0054 | 0.0027 | 0.4833 |                                           |
| <b>Gasoline fuels</b>              | 0.0367 | 0.0046 | 0.1998 | 0.0069 | 0.1447 | 0.1033 | 0.0528 | 0.0046 | 0.7579 |                                           |
| <b>Natural gas (CNG &amp; LNG)</b> | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     |                                           |
| <b>LPG</b>                         | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     |                                           |
| <b>Biomethane</b>                  | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     | NE     |                                           |

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

Here, biodiesel has a slightly lower NCV compared to fossil diesel resulting in higher emissions per TJ, whereas for biogasoline the same NCV is applied as for fossil gasoline.

In addition, the EMEP/EEA Guidebook provides separate values for heavy metals from the unintended co-incineration of lube oil. The latter are reported in [NFR sub-category 2.G.4](#) as emissions from product use. (*Note: This country-specific approach has been discussed and accepted at both the 2018 TFEIP meeting and the 2018 NEC review.*)

**Table 3-83: Heavy metal emission factors for all vehicle categories in ppm/wt lubricant**

| Category               | Pb     | Cd   | Cu  | Cr   | Ni    | Se   | Zn    | Hg | As |
|------------------------|--------|------|-----|------|-------|------|-------|----|----|
| Passenger cars, petrol | 0.0332 | 4.56 | 778 | 19.2 | 31.89 | 4.54 | 450.2 | 0  | 0  |
| Passenger cars, diesel | 0.0332 | 4.56 | 778 | 19.2 | 31.89 | 4.54 | 450.2 | 0  | 0  |
| LCVs, petrol           | 0.0332 | 4.56 | 778 | 19.2 | 31.89 | 4.54 | 450.2 | 0  | 0  |
| LCVs, diesel           | 0.0332 | 4.56 | 778 | 19.2 | 31.89 | 4.54 | 450.2 | 0  | 0  |
| HDVs, petrol           | 0.0332 | 4.56 | 778 | 19.2 | 31.89 | 4.54 | 450.2 | 0  | 0  |
| HDVs, diesel           | 0.0332 | 4.56 | 778 | 19.2 | 31.89 | 4.54 | 450.2 | 0  | 0  |
| L-category             | 0.0332 | 4.56 | 778 | 19.2 | 31.89 | 4.54 | 450.2 | 0  | 0  |

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

Without country-specific information, tier1 values are applied.

However, instead of using the emission factors provided in (EMEP/EEA, 2023) <sup>1)</sup>, Table 3-1 Tier 1 emission factors for off-road machinery,...

**Table 3-1 Tier 1 emission factors for off-road machinery**

| Tier 1 emission factors |                                                    |           |             |                 |
|-------------------------|----------------------------------------------------|-----------|-------------|-----------------|
| Fuel                    | NFR sector                                         | Pollutant | Units       | Emission factor |
| Diesel                  | 1.A.2.g.vii, 1.A.4.a.ii, 1.A.4.b.ii and 1.A.4.c.ii |           |             |                 |
|                         |                                                    | Cadmium   | mg/kg fuel  | 0.010           |
|                         |                                                    | Copper    | mg/ kg fuel | 1.70            |
|                         |                                                    | Chromium  | mg/ kg fuel | 0.050           |
|                         |                                                    | Nickel    | mg/ kg fuel | 0.07            |
|                         |                                                    | Selenium  | mg/ kg fuel | 0.01            |
|                         |                                                    | Zinc      | mg/ kg fuel | 1.00            |
| Gasoline                | 1.A.2.g.vii, 1.A.4.a.ii, 1.A.4.b.ii and 1.A.4.c.ii |           |             |                 |
|                         |                                                    | Cadmium   | mg/kg fuel  | 0.01            |
|                         |                                                    | Copper    | mg/kg fuel  | 1.70            |
|                         |                                                    | Chromium  | mg/kg fuel  | 0.05            |
|                         |                                                    | Nickel    | mg/kg fuel  | 0.07            |
|                         |                                                    | Selenium  | mg/kg fuel  | 0.01            |
|                         |                                                    | Zinc      | mg/kg fuel  | 1.00            |

...the EF for exhaust HMs from NFR 1.A.3.b.i-iv (see above) are applied in order to assure the separate reporting of emissions from fuel and engine wear and the unintended co-incineration of lube oil:

Table 2: Tier1 emission factors derived from EMEPEEA Guidebook 2023 defaults for NFRs 1.A.3.b i-iv, in g/TJ

|                                  | Pb     | Cd     | Hg     | As     | Cr     | Cu     | Ni     | Se     | Zn     |
|----------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| <b>Diesel oil</b>                | 0.0116 | 0.0012 | 0.1234 | 0.0023 | 0.1979 | 0.1327 | 0.0047 | 0.0023 | 0.4190 |
| <b>Biodiesel<sup>1</sup></b>     | 0.0134 | 0.0013 | 0.1423 | 0.0027 | 0.2282 | 0.1531 | 0.0054 | 0.0027 | 0.4833 |
| <b>Gasoline fuels - 4-stroke</b> | 0.0367 | 0.0046 | 0.1998 | 0.0069 | 0.1447 | 0.1033 | 0.0528 | 0.0046 | 0.7579 |

|                                               | <b>Pb</b> | <b>Cd</b> | <b>Hg</b> | <b>As</b> | <b>Cr</b> | <b>Cu</b> | <b>Ni</b> | <b>Se</b> | <b>Zn</b> |
|-----------------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| <b>Gasoline fuels - 2-stroke</b> <sup>2</sup> | 0.0522    | 2.29      | 0.1958    | 0.0068    | 9.78      | 391       | 16.1      | 2.28      | 227       |
| <b>LPG (1.A.4.a ii only)</b>                  | NE        | NE        | NE        | NE        | NE        | NE        | NE        | NE        | 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> including the HM of 1:50 lube oil mixed to the gasoline



*Until submission 2017, the EMEP/EEA default EFs provided for NRMM were used in the German inventory. As these EFs do not differentiate between fuel combustion and lubricant co-incineration, the inventory compiler decided to apply the more specific EFs from road transport to NRMM in 1.A.2.g vii, 1.A.4.a ii, b ii and c ii and 1.A.5.b, too. This country-specific approach has been discussed and accepted at both the 2018 TFEIP meeting and the 2018 NEC review.*

Furthermore, as stated in the 2023 EMEP/EEA Guidebook, similar EF are applied for land based military vehicles and mobile machinery as part of NFR 1.A.5.b:

### Notes:

For land based military emissions, use emission factors for 1.A.2.g.vii as no other data are available.

Heavy-metal emissions from lubricants (as far as not used in 2-stroke mix) are reported under [NFR sub-category 2.G.4](#) as emissions from product use.

## Railways

Tier1 default EF as provided in the corresponding chapter of the EMEP/EEA Guidebook 2023:

**Table 3-1 Tier 1 emission factors for railways**

| Tier 1 emission factor |                                                                       |               |                         |       |                          |
|------------------------|-----------------------------------------------------------------------|---------------|-------------------------|-------|--------------------------|
|                        | Code                                                                  | Name          |                         |       |                          |
| NFR Source Category    | 1.A.3.c                                                               | Railways      |                         |       |                          |
| Fuel                   | Gas Oil/Diesel                                                        |               |                         |       |                          |
| Not applicable         | HCH, PCB, HCB                                                         |               |                         |       |                          |
| Not estimated          | SOx, Pb, Hg, As, PCDD/F, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene |               |                         |       |                          |
| Pollutant              | Value                                                                 | Unit          | 95% confidence interval |       | Reference                |
|                        |                                                                       |               | Lower                   | Upper |                          |
| NOx                    | 52.4                                                                  | kg/tonne fuel | 25                      | 93    | Aggregated Tier 2 method |
| CO                     | 10.7                                                                  | kg/tonne fuel | 6                       | 19    | Guidebook (2006)         |
| NMVOC                  | 4.65                                                                  | kg/tonne fuel | 2                       | 8     | Guidebook (2006)         |
| NH <sub>3</sub>        | 0.007                                                                 | kg/tonne fuel | 0.004                   | 0.012 | Guidebook (2006)         |
| TSP                    | 1.52                                                                  | kg/tonne fuel | 3                       | 23    | Aggregated Tier 2 method |
| PM10                   | 1.44                                                                  | kg/tonne fuel | 2                       | 16    | Aggregated Tier 2 method |
| PM2.5                  | 1.37                                                                  | kg/tonne fuel | 2                       | 14    | Aggregated Tier 2 method |
| Cd                     | 0.01                                                                  | g/tonne fuel  | 0.003                   | 0.025 | Guidebook (2006)         |
| Cr                     | 0.05                                                                  | g/tonne fuel  | 0.02                    | 0.2   | Guidebook (2006)         |
| Cu                     | 1.7                                                                   | g/tonne fuel  | 0.5                     | 4.9   | Guidebook (2006)         |
| Ni                     | 0.07                                                                  | g/tonne fuel  | 0.02                    | 0.2   | Guidebook (2006)         |
| Se                     | 0.01                                                                  | g/tonne fuel  | 0.003                   | 0.025 | Guidebook (2006)         |
| Zn                     | 1                                                                     | g/tonne fuel  | 0.3                     | 2.5   | Guidebook (2006)         |
| Benzo(a)pyrene         | 0.03                                                                  | g/tonne fuel  | 0.01                    | 0.1   | Guidebook (2006)         |
| Benzo(b)fluoranthene   | 0.05                                                                  | g/tonne fuel  | 0.02                    | 0.2   | Guidebook (2006)         |
| Benz(a)anthracene      | 0.08                                                                  | g/tonne fuel  | 0.03                    | 0.2   | Guidebook (2006)         |
| CO <sub>2</sub>        | 3140                                                                  | kg/tonne fuel | 3120                    | 3160  | Guidebook (2006)         |
| Dibenzo(a,h)anthracene | 0.01                                                                  | g/tonne fuel  | 0.004                   | 0.03  | Guidebook (2006)         |

**Notes**

B(k)f & Indeno (1,2,3-cd) pyrene and dioxins emission factor values are not available for railway emissions. It is therefore recommended to use values corresponding to old technology heavy duty vehicles from the Exhaust Emissions from Road Transport chapter (1.A.3.b.iii).

BC fraction of PM (f-BC): 0.65. Source: for further information see Appendix A

**Table 3: Tier1 default emission factors applied to railway vehicles, in g/TJ**

|                              | Pb                 | Cd                | Hg                 | As                 | Cr                | Cu                 | Ni                | Se                | Zn                 |
|------------------------------|--------------------|-------------------|--------------------|--------------------|-------------------|--------------------|-------------------|-------------------|--------------------|
| <b>Diesel oil</b>            | 0.012 <sup>1</sup> | 0.23 <sup>2</sup> | 0.123 <sup>1</sup> | 0.002 <sup>1</sup> | 1.16 <sup>2</sup> | 39.57 <sup>2</sup> | 1.63 <sup>2</sup> | 0.23 <sup>2</sup> | 23.28 <sup>2</sup> |
| <b>Biodiesel<sup>3</sup></b> | 0.013              | 0.001             | 0.142              | 0.003              | 0.23              | 0.15               | 0.01              | 0.003             | 0.48               |
| <b>Lignite Briquettes</b>    | NE                 |                   |                    |                    |                   |                    |                   |                   |                    |
| <b>Raw Lignite</b>           | NE                 |                   |                    |                    |                   |                    |                   |                   |                    |
| <b>Hard Coal</b>             | NE                 |                   |                    |                    |                   |                    |                   |                   |                    |
| <b>Hard Coal Coke</b>        | NE                 |                   |                    |                    |                   |                    |                   |                   |                    |

<sup>1</sup> tier1 default from <sup>2)</sup>, chapter: 1.A.3.b i-iv - Road transport: exhaust emissions: tier1 value for diesel vehicles

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

<sup>3</sup> values differ from EFs applied for fossil diesel oil to take into account the specific NCV of biodiesel

(NOTE: Assuming that biodiesel contains far less HMs than fossil diesel oil, similar values are applied to all mobile sources using this biogenic fuel.)

As the EMEP/EEA GB 2023 does not provide specific defaults for **Pb, Hg and As**, the EF applied here has been derived from chapter: 1.A.3.b i-iv - Road transport: exhaust emissions: tier1 value for diesel vehicles.

Besides these emissions from fuel combustion and engine wear, the German inventory also covers **abrasive emissions from brakes, wheels on rail and contact line**. Here, a country-specific approach is applied with emissions of (i) chromium and nickel being estimated as part of the particle emissions from brake wear whereas emissions of copper (ii) copper are estimated as part of the PM emissions from the contact line.

Table 4: Country-specific emission factors for abrasive emissions, in g/km

|                                       | PM <sub>2.5</sub> | PM <sub>10</sub> | TSP     | BC | Pb | Cd | Hg | As | Cr      | Cu      | Ni      | Se | Zn |
|---------------------------------------|-------------------|------------------|---------|----|----|----|----|----|---------|---------|---------|----|----|
| <b>Contact line</b> <sup>1</sup>      | 0.00016           | 0.00032          | 0.00032 | NA | NA | NA | NA | NA | NA      | 0.00033 | NA      | NA | NA |
| <b>Tyres on rails</b> <sup>2</sup>    | 0.009             | 0.018            | 0.018   | NA | NA |    |    |    |         |         |         |    |    |
| <b>Braking system</b> <sup>3</sup>    | 0.004             | 0.008            | 0.008   | NA | NA | NA | NA | NA | 0.00008 | NA      | 0.00016 | NA | NA |
| <b>Current collector</b> <sup>4</sup> | NE                | NE               | NE      | NE | NA |    |    |    |         |         |         |    |    |

<sup>1</sup> assumption: 100 per cent copper

<sup>2</sup> assumption: 100 per cent steel

<sup>3</sup> assumption: steel alloy containing Chromium and Nickel

<sup>4</sup> typically: aluminium alloy + coal contacts; no particulate matter emissions calculated yet

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

Table 5: Tier1 default emission factors applied to inland ships and vessels, in g/TJ

|                               | Pb    | Cd    | Hg    | As    | Cr   | Cu   | Ni    | Se    | Zn   |
|-------------------------------|-------|-------|-------|-------|------|------|-------|-------|------|
| <b>Diesel oil</b>             | 1.21  | 0.233 | 0.123 | 0.002 | 1.16 | 39.6 | 1.63  | 0.233 | 23.3 |
| <b>Biodiesel</b> <sup>1</sup> | 0.013 | 0.001 | 0.142 | 0.003 | 0.23 | 0.15 | 0.005 | 0.003 | 0.48 |

<sup>1</sup> similar EF for biodiesel applied for all mobile sources

## 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

Tier1 default EF as provided in the corresponding chapter of the EMEP/EEA Guidebook 2023:

**Table 3-1 Tier 1 emission factors for ships using bunker fuel oil**

| Tier 1 default emission factors |                 |                                                                       |                         |       |                                 |
|---------------------------------|-----------------|-----------------------------------------------------------------------|-------------------------|-------|---------------------------------|
|                                 | Code            | Name                                                                  |                         |       |                                 |
| NFR Source Category             | 1.A.3.d.i       | International navigation                                              |                         |       |                                 |
|                                 | 1.A.3.d.ii      | National navigation                                                   |                         |       |                                 |
|                                 | 1.A.4.c.iii     | Agriculture / forestry / fishing: National fishing                    |                         |       |                                 |
|                                 | 1.A.5.b         | Other, mobile (including military, land based and recreational boats) |                         |       |                                 |
| Fuel                            | Bunker Fuel Oil |                                                                       |                         |       |                                 |
| Not applicable                  |                 |                                                                       |                         |       |                                 |
| Not estimated                   | NH <sub>3</sub> |                                                                       |                         |       |                                 |
| Pollutant                       | Value           | Unit                                                                  | 95% confidence interval |       | Reference                       |
|                                 |                 |                                                                       | Lower                   | Upper |                                 |
| NO <sub>x</sub>                 | 69.1            | kg/tonne fuel                                                         | 0                       | 0     | Scipper (2021)                  |
| CO                              | 3.67            | kg/tonne fuel                                                         | 0                       | 0     | Scipper (2021)                  |
| NM VOC                          | 1.67            | kg/tonne fuel                                                         | 0                       | 0     | Scipper (2021)                  |
| SO <sub>2</sub>                 | 19.2            | kg/tonne fuel                                                         | 0                       | 0     | Scipper (2021)See also note (1) |
| PM <sub>10</sub>                | 5.2             | kg/tonne fuel                                                         | 0                       | 0     | Scipper (2021)                  |
| BC                              | 0.0903          | kg/tonne fuel                                                         | 0                       | 0     | Scipper (2021)                  |
| Benzo(b)fluoranthene            | 0.03            | g/tonne fuel                                                          |                         |       | average value                   |
| Benzo(k)fluoranthene            | 0.02            | g/tonne fuel                                                          |                         |       | average value                   |
| Benzo(a)pyrene                  | 0.005           | g/tonne fuel                                                          |                         |       | average value                   |
| Indeno(1,2,3- cd)pyrene         | 0.009           | g/tonne fuel                                                          |                         |       | average value                   |
| Pb                              | 0.18            | g/tonne fuel                                                          | 0                       | 0     | average value                   |
| Cd                              | 0.02            | g/tonne fuel                                                          | 0                       | 0     | average value                   |
| Hg                              | 0.02            | g/tonne fuel                                                          | 0                       | 0     | average value                   |
| As                              | 0.68            | g/tonne fuel                                                          | 0                       | 0     | average value                   |
| Cr                              | 0.72            | g/tonne fuel                                                          | 0                       | 0     | average value                   |
| Cu                              | 1.25            | g/tonne fuel                                                          | 0                       | 0     | average value                   |
| Ni                              | 32              | g/tonne fuel                                                          | 0                       | 0     | average value                   |
| Se                              | 0.21            | g/tonne fuel                                                          | 0                       | 0     | average value                   |
| Zn                              | 1.2             | g/tonne fuel                                                          | 0                       | 0     | average value                   |
| PCB                             | 0.57            | mg/tonne fuel                                                         | 0                       | 0     | Cooper (2005)                   |
| PCDD/F                          | 0.47            | ug I-TEQ /tonne fuel                                                  | 0                       | 0     | Cooper (2005)                   |
| HCB                             | 0.14            | mg/tonne fuel                                                         | 0                       | 0     | Cooper (2005)                   |



**Table 3-2 Tier 1 emission factors for ships using marine diesel oil/marine gas oil**

| Tier 1 emission factor  |                                            |                                                                       |                         |       |                                  |
|-------------------------|--------------------------------------------|-----------------------------------------------------------------------|-------------------------|-------|----------------------------------|
|                         | Code                                       | Name                                                                  |                         |       |                                  |
| NFR Source Category     | 1.A.3.d.i                                  | International navigation                                              |                         |       |                                  |
|                         | 1.A.3.d.ii                                 | National navigation                                                   |                         |       |                                  |
|                         | 1.A.4.c.iii                                | Agriculture / forestry / fishing: National fishing                    |                         |       |                                  |
|                         | 1.A.5.b                                    | Other, mobile (including military, land based and recreational boats) |                         |       |                                  |
| Fuel                    | Marine diesel oil/marine gas oil (MDO/MGO) |                                                                       |                         |       |                                  |
| Not applicable          | HCH                                        |                                                                       |                         |       |                                  |
| Not estimated           | NH <sub>3</sub>                            |                                                                       |                         |       |                                  |
| Pollutant               | Value                                      | Unit                                                                  | 95% confidence interval |       | Reference                        |
|                         |                                            |                                                                       | Lower                   | Upper |                                  |
| NOx                     | 72.2                                       | kg/tonne fuel                                                         | 0                       | 0     | Scipper (2021)                   |
| CO                      | 3.84                                       | kg/tonne fuel                                                         | 0                       | 0     | Scipper (2021)                   |
| NM VOC                  | 1.75                                       | kg/tonne fuel                                                         | 0                       | 0     | Scipper (2021)                   |
| SO <sub>2</sub>         | 1.82                                       | kg/tonne fuel                                                         | 0                       | 0     | Scipper (2021) See also note (1) |
| PM <sub>10</sub>        | 1.07                                       | kg/tonne fuel                                                         | 0                       | 0     | Scipper (2021)                   |
| BC                      | 0.0483                                     | kg/tonne fuel                                                         | 0                       | 0     | Scipper (2021)                   |
| Benzo(b)fluoranthene    | 0.01                                       | g/tonne fuel                                                          |                         |       | average value                    |
| Benzo(k)fluoranthene    | 0.01                                       | g/tonne fuel                                                          |                         |       | average value                    |
| Benzo(a)pyrene          | 0.002                                      | g/tonne fuel                                                          |                         |       | average value                    |
| Indeno(1,2,3- cd)pyrene | 0.001                                      | g/tonne fuel                                                          |                         |       | average value                    |
| Pb                      | 0.13                                       | g/tonne fuel                                                          | 0                       | 0     | average value                    |
| Cd                      | 0.01                                       | g/tonne fuel                                                          | 0                       | 0     | average value                    |
| Hg                      | 0.03                                       | g/tonne fuel                                                          | 0                       | 0     | average value                    |
| As                      | 0.04                                       | g/tonne fuel                                                          | 0                       | 0     | average value                    |
| Cr                      | 0.05                                       | g/tonne fuel                                                          | 0                       | 0     | average value                    |
| Cu                      | 0.88                                       | g/tonne fuel                                                          | 0                       | 0     | average value                    |
| Ni                      | 1                                          | g/tonne fuel                                                          | 0                       | 0     | average value                    |
| Se                      | 0.1                                        | g/tonne fuel                                                          | 0                       | 0     | average value                    |
| Zn                      | 1.2                                        | g/tonne fuel                                                          | 0                       | 0     | average value                    |
| PCB                     | 0.038                                      | mg/tonne fuel                                                         | 0                       | 0     | Cooper (2005)                    |
| PCDD/F                  | 0.13                                       | ug I-TEQ/tonne                                                        | 0                       | 0     | Cooper (2005)                    |
| HCB                     | 0.08                                       | mg/tonne fuel                                                         | 0                       | 0     | Cooper (2005)                    |

From these mass-related default emission factors, energy-related tier1 EF were derived via average NCVs for the fuels used:

Table 6: Tier1 emission factors derived from EMEP/EEA Guidebook 2023 defaults, in g/TJ

|                                   | Pb   | Cd   | Hg   | As   | Cr   | Cu   | Ni   | Se   | Zn   |
|-----------------------------------|------|------|------|------|------|------|------|------|------|
| <b>Heavy Fuel oil<sup>1</sup></b> | 4.46 | 0.50 | 0.50 | 16.9 | 17.8 | 31.0 | 793  | 5.20 | 29.7 |
| <b>Diesel oil<sup>2</sup></b>     | 3.03 | 0.23 | 0.70 | 0.93 | 1.16 | 20.5 | 23.3 | 2.33 | 27.9 |
| <b>LNG</b>                        | NE   |      |      |      |      |      |      |      |      |

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

<sup>2</sup> tier1 defaults from <sup>5)</sup>, Chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation: Table 3-2

These “country-specific” values are similarly applied for exhaust HMs from ships and vessels in NFR categories 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

The EMEP/EEA Guidebook 2023 does not provide specific default values for heavy metal 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 adopt the tier1 EF from gasoline fuel used in non-road mobile machinery as a proxy. Although the Party assumes that HM emissions are also likely to occur from the combustion of jet kerosene, no gap-filling is carried out for this fuel. Instead, all heavy metal emission from jet kerosene are reported as *not estimated* (NE).

Table 7: Tier1 default emisison factors applied to aircraft, in g/TJ

|                   | Pb                 | Cd    | Hg    | As    | Cr    | Cu    | Ni    | Se    | Zn    |
|-------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Kerosene          | NE                 |       |       |       |       |       |       |       |       |
| Aviation gasoline | 9,481 <sup>1</sup> | 0.005 | 0.200 | 0.007 | 0.145 | 0.103 | 0.053 | 0.005 | 0.758 |

<sup>1</sup> estimated from average lead content of AvGas 100 LL (see also: 1.A.3.a ii (i) and FAQs) of 0.56 g Pb/liter

1), 2), 3), 4), 5) EMEP/EEA, 2023: EMEP/EEA air pollutant emission inventory guidebook 2023; Chapter 1.A - Combustion; URL: <https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion>, Copenhagen, 2023 & 2024 (road transport).