

Review of the consistency of PM, HM and POP emission factors – 4B Animal Husbandry and Manure Management

Chapter 4B contains tier 1 (Table 3.4) and tier 2 (Table 3.10) PM₁₀ and PM_{2.5} emission factors (EFs) for selected animal species. The main chapter does not contain TSP EFs. However, in the annex to the chapter the derivation of the EFs is described.

The tier 1 and tier 2 EFs as currently in the Guidebook (GB) are included below.

Table 3.4 Default Tier 1 estimates of EF for particle emissions from animal husbandry (housing),

Code	Livestock	EF for PM ₁₀ (kg AAP ⁻¹ . a ⁻¹)	EF for PM _{2.5} (kg AAP ⁻¹ . a ⁻¹)
100901	Dairy cows	0.36	0.23
100902	Other cattle (including young cattle, beef cattle and suckling cows)	0.24	0.16
100903	Fattening pigs	0.50	0.08
100904	Sows	0.58	0.09
100905 +100911	Sheep (and goats)	NA	NA
100906 +100912	Horses (and mules, asses)	0.18	0.12
100907	Laying hens (laying hens and parents). cages	0.017	0.002
	Laying hens (laying hens and parents), perchery	0.084	0.016
100908	Broilers (broilers and parents)	0.052	0.007
100909	Other poultry (ducks, geese, turkeys)	0.032	0.004
100910	Fur animals	NA	NA
100913	Camels	NA	NA
100914	Buffalo	NA	NA

Source: Schneider and Büscher, 2006; Hinz, 2005; Hinz and Tamoschat-Depolt, 2007

Table 3-10 Default Tier 2 EF for particle emissions from animal husbandry (housing),

Code	Livestock	Manure	EF for PM ₁₀ kg AAP ⁻¹ . a ⁻¹	EF for PM _{2.5} kg AAP ⁻¹ . a ⁻¹
100901	Dairy cows	slurry	0.70	0.45
		solid	0.36	0.23
100902	Other cattle (including young cattle, beef cattle and suckling cows)	slurry	0.32	0.21
		solid	0.24	0.16
100903	Fattening pigs	slurry	0.42	0.07
		solid	0.50	0.08
100904	Sows	slurry	0.45	0.07
		solid	0.58	0.09
100905	Sheep (and goats)	solid	NA	NA
+100911				
100906	Horses (and mules, asses)	solid	0.18	0.12
+100912				
100907	Laying hens (laying hens and parents)	cages	0.017	0.002
		perchery	0.084	0.016
100908	Broilers (broilers and parents)	solid	0.052	0.007
100909	Other poultry (ducks, geese, turkeys)	solid	0.032	0.004
100910	Fur animals	solid	NA	NA
100913	Camels	solid	NA	NA
100914	Buffalo	solid	NA	NA

Source: Schneider and Büscher, 2006; Hinz 2005; Hinz and Tamoschat-Depolt, 2007

1 As noted the tables do not contain TSP emission factors. Furthermore, there are no EFs (neither tier 1 nor tier 2)
 2 available for sheep, goats, fur animals, camels and buffalos.
 3 Tier 2 EFs are available for cattle, swine and laying hens. For cattle and swine the tier 1 EFs are based on the tier
 4 2 EFs for solid animal waste management systems. The tier 1 EFs for laying hens are identical to the tier 2 EFs
 5 and cannot be considered as tier 1.
 6 The references provided to both tables are incorrect. The EFs mainly refer to Takai et al. (1998) with additional
 7 information and assumptions from Seedorf and Hartung (2001).

8 Consistency of the current emission factors

9 The original basis for the PM EFs is Takai et al. (1998) for all animal species except horses, where the EFs refer
 10 to Seedorf and Hartung (2001). The original results are presented for inhalable dust (ID) and respiratory dust
 11 (RD). The EFs are shown below.

Table A3–1 Measured dust emissions (all data except horses: Takai et al. 1998; horses: Seedorf and Hartung, 2001)

Code	Livestock Category	Housing type	Emissions	
			ID mg LU ⁻¹ h ⁻¹	RD mg LU ⁻¹ h ⁻¹
100901	Dairy cattle	slurry	172.5	28.5
		solid	89.3	28.0
100902	Other cattle (including young cattle, beef cattle and suckling cows)	slurry	113.0	13.7
		solid	85.5	16.0
100902	Calves	slurry	127.5	19.5
		solid	132.0	27.3
100903	Fattening pigs	slurry	612.3	66.0
		solid	725.5	71.0
100903	Weaners	slurry	1 021.0	75.5
		solid	n.a.	n.a.
100904	Sows	slurry	345.8	47.8
		solid	448.5	47.5
100906	Horses	solid ¹⁾	55	n.a.
100907	Laying hens	cages	636.3	78.3
		perchery	3 080.7	595.3
		solid	3 965.8	517.5
	Broilers	solid	3 965.8	517.5

Notes:

1. n.a.: not available; ID: inhalable dust; RD: respirable dust.

2. ¹⁾ Wood shavings.

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 14 The EFs are provided in terms of livestock units corresponding to 500 kg live weight.

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 16 The original EFs are converted using transformation factors based on Seedorf and Hartung (2001) and personal
 17 communication.

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Table A3–3 Transformation factors for the conversion of inhalable dust (ID) into PM₁₀ and PM_{2.5}

Code	Livestock type	Transformation factor for PM ₁₀ kg PM ₁₀ (kg ID) ⁻¹	Transformation factor for PM _{2.5} kg PM _{2.5} (kg ID) ⁻¹
101001	Dairy cows	¹ 0.46	² 0.30
101002	Other cattle	¹ 0.46	² 0.30
101003	Fattening pigs (including weaners)	0.45	0.08
101004	Sows	0.45	0.08
101006	Horses ³	¹ 0.46	² 0.30
100907, 100908, 100909	Poultry	1.0	1.0

Note:

1. ¹Seedorf and Hartung (2001), the same conversion factor for horses is assumed as for cattle
2. ²Seedorf (personal communication).

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3 The transformation factors for poultry are not correct considering the column headers used since the factor of 1 for
4 PM_{2.5} relates to RD and not ID. Therefore a footnote should be added for poultry stating that “The transformation
5 factor for PM_{2.5} relates to respiratory dust and not inhalable dust”.

6

7 When trying to reproduce the EFs currently in the GB (Table A3-4), there are small deviations for fattening pigs,
8 weaners and sows for PM₁₀. This is highlighted in Table 1 below.

Table A3–4 EFs for inhalable dust, respirable dust, PM₁₀ and PM_{2.5}

Code	Animal category	Housing type	Animal weight kg animal ⁻¹	Conversion factor LU animal ⁻¹	Emission factors EF			
					ID kg AAP ⁻¹ . a ⁻¹	RD kg AAP ⁻¹ . a ⁻¹	PM ₁₀ kg AAP ⁻¹ . a ⁻¹	PM _{2.5} kg AAP ⁻¹ . a ⁻¹
100901	Dairy cattle	slurry	500	1.0	1.51	0.25	0.70	0.45
		solid	500	1.0	0.78	0.25	0.36	0.23
100902	Beef cattle	slurry	350	0.7	0.69	0.08	0.32	0.21
		solid	350	0.7	0.52	0.10	0.24	0.16
100902	Calves	slurry	150	0.3	0.34	0.05	0.15	0.10
		solid	150	0.3	0.35	0.07	0.16	0.10
100903	Fattening pigs	slurry	80	0.12	0.86	0.09	0.42	0.07
		solid	80	0.12	1.02	0.10	0.50	0.08
100903	Weaners	slurry	20	0.04	0.36	0.026	0.18	0.029
		solid	20	0.04	n.a.	n.a.	n.a.	n.a.
100904	Sows	slurry	150	0.3	0.91	0.13	0.45	0.073
		solid	150	0.3	1.18	0.12	0.58	0.094
100906	Horses	solid ¹⁾	400	0.8	0.39	n.a.	0.18	0.12
100907	Laying hens	cages	1.55	0.0031	0.017	0.0021	0.017	0.0021
		perchery	1.55	0.0031	0.084	0.0162	0.084	0.0162
100908	Broilers	solid	0.75	0.0015	0.052	0.0068	0.052	0.0068

Notes:

1. n.a. not available.
2. ¹⁾ wood shavings.

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Table 1 Table A3-4 recalculated based on the information provided in annex 3

Code	Animal category	Housing type	Animal weight kg animal ⁻¹	Conversion factor LU animal ⁻¹	Emission factors EF			
					ID kg AAP ⁻¹ . a ⁻¹	RD kg AAP ⁻¹ . a ⁻¹	PM ₁₀ kg AAP ⁻¹ . a ⁻¹	PM _{2.5} kg AAP ⁻¹ . a ⁻¹
100901	Dairy cattle	slurry	500	1	1,51	0,25	0,70	0,45
		solid	500	1	0,78	0,25	0,36	0,23
100902	Beef cattle	slurry	350	0,7	0,69	0,08	0,32	0,21
		solid	350	0,7	0,52	0,10	0,24	0,16
100902	Calves	slurry	150	0,3	0,34	0,05	0,15	0,10
		solid	150	0,3	0,35	0,07	0,16	0,10
100903	Fattening pigs	slurry	80	0,16	0,86	0,09	0,39	0,07
		solid	80	0,16	1,02	0,10	0,46	0,08
100903	Weaners	slurry	20	0,04	0,36	0,03	0,16	0,029
		solid	20	0,04				
100904	Sows	slurry	150	0,3	0,91	0,13	0,41	0,073
		solid	150	0,3	1,18	0,12	0,53	0,094

100906	Horses	solid	400	0,8	0,39		0,18	0,12
100907	Laying hens	cages	1,55	0,0031	0,017	0,0021	0,017	0,0021
		perchery	1,55	0,0031	0,084	0,0162	0,084	0,0162
100908	Broilers	solid	0,75	0,0015	0,052	0,0068	0,052	0,0068

1 Furthermore, table A3-4 list the conversion factor for fattening pigs as 0.12, while the correct factor is 0.16, which
2 also appears to have been used in the calculations.

3 Some of the animal weights used to convert the EFs seem low, and for many animal species there is no connection
4 between the animal weights listed in table A3-2 and table A3-4. Since the assumed weight directly impacts the
5 emission factors, it is essential that the animal weights are representative.

6 Table 2 below contains the animal weights currently used to convert the PM EFs, the animal weights listed in
7 table A3-2 and the proposed new animal weights to be used.

8 **Table 2 Animal weights currently used in the calculation of PM EFs, the typical animal weights used in the NH₃**
9 **calculations and the proposed revised animal weights.**

Code	Animal category	Housing type	Animal weight kg animal ⁻¹ Table A3-4	Animal weight kg animal ⁻¹ Table A3-2	Animal weight kg animal ⁻¹ Proposed value
100901	Dairy cattle	Slurry	500	600	600
		Solid	500	600	600
100902	Beef cattle	Slurry	350	340	340
		Solid	350	340	340
100902	Calves	Slurry	150		150
		Solid	150		150
100514	Buffalo	Solid		700	700
100903	Fattening pigs	Slurry	80	65	65
		Solid	80	65	65
100903	Weaners	Slurry	20		20
		Solid	20		20
100904	Sows	Slurry	150	225	225
		Solid	150	225	225
100906	Horses	Solid	400	500	500
100512	Mules and asses	Solid			350
100907	Laying hens	Cages	1.55	2.2	2.2
		Perchery	1.55	2.2	2.2
100908	Broilers	Solid	0.75	0.9	1
		Ducks			2
		Geese			3.5
		Turkey			7.5

10 It is not clear why calves and weaners are included in the annex but not in the main chapter of the GB.

11 For cattle and swine the tier 1 EFs are based on solid animal waste management systems (AWMS). For swine the
12 AWMS distribution for solid/liquid in EU27 is 42/58 according to the EU reporting in 2011 to the UNFCCC. For
13 dairy cattle the distribution is 49/51 and for non-dairy cattle 59/41. In that respect it should be reconsidered
14 whether it is a reasonable choice to select the EFs for solid AWMS as the tier 1 EFs or if instead weighted EFs
15 should be implemented.

1 Based on the information in the annex it is not clear how the EFs for other poultry have been derived. One
2 possibility could be to scale the EFs for broilers according to animal weights (for ducks, geese and turkey).

3 **Implementation of TSP emission factors**

4 Based on Philips et al. (1998) and Mark & Vincent (1986), it would be reasonable to consider the ID EFs as TSP
5 EFs in the Guidebook.

6 **Evaluation of missing emission factors**

7 Currently EFs are not available for sheep, goats, mules & asses, buffalos and fur animals. Mules and asses are
8 mentioned with horses in the EF tables. However, since horses and mules differ in weight it has been considered
9 as a missing EF and therefore countries reporting has been analysed. EFs for camels are not believed to be
10 relevant and have therefore not been considered further. When analysing the reporting of Parties to CLRTAP, it
11 becomes clear that some countries are reporting PM emissions for some of these animal species.

12 **Table 3 Countries reporting PM from animal species not currently included in the GB**

Sheep	Goats	Mules and Asses	Buffalos	Fur animals
Czech Republic	Czech Republic	France	Italy	No reporting
Denmark	Denmark	Germany		
France	France	Italy		
Switzerland	Netherlands	Romania		
	Switzerland	Spain		
		Switzerland		

13 The information in the sections below is extracted from the Informative Inventory Reports (IIRs) of the different
14 countries.

15 **Sheep**

16 France is using a TSP EF for sheep 153 g/animal and considers 40 % PM₁₀ and 12 % PM_{2.5}. Denmark is using the
17 emission factors from France. The IIR of the Czech Republic does not contain detailed information on the
18 emission factors used. Switzerland reports PM₁₀ and PM_{2.5} EFs of 39 g/animal and 6 g/animal and assumes that
19 TSP = PM₁₀. There is no reference for the values provided in the Swiss IIR. It is also not clear whether the EFs
20 refer to AAP.

21 The assumption that TSP = PM₁₀ does not seem plausible considering the current data in the GB as well as e.g. the
22 information from the French IIR and Takai et al. (1998).

23 **Goats**

24 The PM EFs used by Denmark, France and Switzerland are identical for the EFs for sheep. The Netherlands refer
25 to a recent scientific study (Mosquera & Hol, 2011). Based on the study PM₁₀ EFs are derived for mature goats
26 (19 g/animal) and young goats (10 g/animal). The PM_{2.5} EFs are 5.3 g/animal and 2.8 g/animal. There is no
27 information on TSP EFs.

28 **Mules and Asses**

29 France is using the same EFs for mules as for sheep (also identical to horses and goats) and Switzerland does the
30 same. Germany assumes the same EFs as for horses and refers to the GB. Italy uses EFs from the GB corrected
31 for country specific animal weights. While not explicitly stated, it seems that the same basic EFs are assumed for
32 mules and asses as for horses. In the Romanian IIR there is no information on the EFs applied. Spain refers to the
33 GB and assumes the same PM EFs as for horses.

1 **Buffalos**

2 Only Italy reports emissions from buffalos. According to Condor et al. (2008) the EFs are derived from the EFs
3 for cows and other cattle and scaled according to animal weight.

4 **Fur animals**

5 No countries reported PM emissions from fur animal in the 2011 reporting to CLRTAP. However, a recent Dutch
6 study provided PM₁₀ and PM_{2.5} EFs for mink (Mosquera et al., 2011).

7 The EFs has been reported as

- 8 • PM₁₀ emission: 8.1 ± 3.6 g/breeding mink place per year
- 9 • PM_{2.5} emission: 4.2 ± 2.1 g/breeding mink place per year

10 There is no TSP EF available. The transformation factors currently available in the GB suggest factors between
11 0.45 and 1. As a first option a transformation factor of 0.45 could be considered similar to that for swine.

12 **Recommendations**

13 The tier 1 EFs for cattle and swine should be based on a weighted average of solid and liquid AWMS based on
14 EU27 reporting of N amounts to UNFCCC in 2011, For swine the rounded distribution is 40/60 (solid/liquid), for
15 dairy cattle the distribution is 50/50 and for non-dairy cattle 60/40.

16

17 Weaners and calves should be implemented in the EF tables. This has been done in the revised tables below
18 (Table 4 and 5).

19 For other poultry it is proposed to scale separately for duck, geese and turkeys according to weight. The EF for
20 broilers is used.

21

22 The choice of animal weights as indicated in Table 2 and Table 5 is made based on the following assumptions.
23 For animals with a lifetime of more than 1 year, e.g. dairy cattle the grown animal weight has been used. For
24 animals with a short lifetime, e.g. broilers, the median weight during the production cycle has been used. When
25 feasible the same weights have been chosen for the PM calculation as have been reported in the GB for the NH₃
26 calculation.

27

28 For the tier 1 EF for laying hens, the EF for perchery from tier 2 has been chosen. This is based on the fact that
29 traditional cages are banned in the EU from 2012 and therefore this is considered the most representative housing
30 type.

31

32 For sheep and goats, data are available from the French and Swiss inventories. However, both sets of EFs are not
33 well documented in the IIRs. For illustrative purposes the values from the French IIR have been inserted in Table
34 4 and 5 below. It will be up to further discussion whether EFs for sheep and goats can be implemented based on
35 the data from France and Switzerland or if there is knowledge of other data available.

36

37 Table 4 below shows the updated version of table A3-4 of the GB taking into account the correction of errors, the
38 new animal weights and the EFs for animals not previously covered.

1 **Table 4 Revised version of Table A3-4 of the GB**

Code	Animal category	Housing type	Animal weight	Conversion factor LU animal-1	Emission factors EF			
					TSP - ID kg AAP-1. a-1	RD kg AAP-1. a-1	PM10 kg AAP-1. a-1	PM2.5 kg AAP-1. a-1
100901	Dairy cattle	Slurry	600	1.2	1.81	0.30	0.83	0.54
		Solid	600	1.2	0.94	0.29	0.43	0.28
100902	Beef cattle	Slurry	350	0.7	0.69	0.08	0.32	0.21
		Solid	350	0.7	0.52	0.10	0.24	0.16
100902	Calves	Slurry	150	0.3	0.34	0.05	0.15	0.10
		Solid	150	0.3	0.35	0.07	0.16	0.10
100903	Fattening pigs	Slurry	65	0.13	0.70	0.08	0.31	0.06
		Solid	65	0.13	0.83	0.08	0.37	0.07
100903	Weaners	Slurry	20	0.04	0.36	0.03	0.16	0.03
		Solid	20	0.04				
100904	Sows	Slurry	225	0.5	1.36	0.19	0.61	0.11
		Solid	225	0.5	1.77	0.19	0.80	0.14
100906	Horses	Solid	500	1.0	0.48		0.22	0.14
100907	Laying hens	Cages	2.2	0.0044	0.025	0.0030	0.025	0.0030
		Perchery	2.2	0.0044	0.119	0.0229	0.119	0.0229
100908	Broilers	Solid	1	0.0020	0.069	0.0091	0.069	0.0091
100912	Mules and asses	Solid	350	0.7	0.34		0.16	0.10
100914	Buffalos	Slurry	700	1.4	2.12	0.35	0.97	0.63
		Solid	700	1.4	1.10	0.34	0.50	0.33
100909	Ducks	Solid	2	0.004	0.14	0.018	0.14	0.018
100909	Geese	Solid	3.5	0.007	0.24	0.032	0.24	0.032
100909	Turkeys	Solid	7.5	0.015	0.52	0.068	0.52	0.068

1 **Table 5 Revised tier 1 EFs (New Table 3-4 in the GB)**

Code	Livestock	EF for TSP (kg AAP ⁻¹ . a ⁻¹)	EF for PM ₁₀ (kg AAP ⁻¹ . a ⁻¹)	EF for PM _{2.5} (kg AAP ⁻¹ . a ⁻¹)
100901	Dairy cows	1.38	0.63	0.41
100902	Other cattle (including young cattle, beef cattle and suckling cows)	0.59	0.27	0.18
100902	Calves	0.34	0.16	0.10
100903	Fattening pigs	0.75	0.34	0.06
	Weaners	0.21	0.10	0.02
100904	Sows	1.53	0.69	0.12
100905	Sheep	0.139	0.0556	0.0167
100911	Goats	0.139	0.0556	0.0167
100906	Horses	0.48	0.22	0.14
100912	Mules and asses	0.34	0.16	0.10
100907	Laying hens (laying hens and parents)	0.119	0.119	0.023
100908	Broilers (broilers and parents)	0.069	0.069	0.009
100909	Ducks	0.14	0.14	0.02
100909	Geese	0.24	0.24	0.03
100909	Turkeys	0.52	0.52	0.07
100910	Fur animals	0.018	0.0081	0.0042
100914	Buffalo	1.45	0.67	0.44

2

3 **Table 6 Revised tier 2 EFs (New Table 3-10 in the GB)**

Code	Livestock	Manure	EF for TSP kg AAP ⁻¹ . a ⁻¹	EF for PM ₁₀ kg AAP ⁻¹ . a ⁻¹	EF for PM _{2.5} kg AAP ⁻¹ . a ⁻¹
100901	Dairy cows	Slurry	1.81	0.83	0.54
		Solid	0.94	0.43	0.28
100902	Other cattle (including young cattle, beef cattle and suckling cows)	Slurry	0.69	0.32	0.21
		Solid	0.52	0.24	0.16
100902	Calves	Slurry	0.34	0.15	0.10
		Solid	0.35	0.16	0.10
100514	Buffalos	Slurry	2.12	0.97	0.63
		Solid	1.10	0.50	0.33
100902	Weaners	Slurry	0.70	0.31	0.06
		Solid	0.83	0.37	0.07
100903	Fattening pigs	Slurry	0.36	0.16	0.03
		Solid	0.00	0.00	0.00
100904	Sows	Slurry	1.36	0.61	0.11
		Solid	1.77	0.80	0.14
100907	Laying hens (laying hens and parents)	Cages	0.025	0.025	0.003
		Perchery	0.119	0.119	0.023

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