

## 3.B - Manure Management

### Short description

NFR-Code	Name of Category	Method	AD	EF	Key Category <sup>1</sup>	State of reporting
<b>3.B</b>	<b>Manure Management</b>	<b>see sub-category details</b>				
<b>consisting of / including source categories</b>						
3.B.1.a & 3.B.1.b	Cattle	T3 (NH <sub>3</sub> ), T2 (NO <sub>x</sub> , TSP, PM <sub>10</sub> , PM <sub>2.5</sub> , NMVOC)	NS, RS	CS (NH <sub>3</sub> , NO <sub>x</sub> ), D (TSP, PM <sub>10</sub> , PM <sub>2.5</sub> , NMVOC)	L & T: NH <sub>3</sub> (for 3.B.1.b), NMVOC	L: NH <sub>3</sub> (for 3.B.1.a)
3.B.2, 3.B.4.d, 3.B.4.e	Sheep, Goats, Horses	T2 (NH <sub>3</sub> , NO <sub>x</sub> , TSP, PM <sub>10</sub> , PM <sub>2.5</sub> ), T1 (NMVOC)	NS, RS	CS (NH <sub>3</sub> , NO <sub>x</sub> ), D (TSP, PM <sub>10</sub> , PM <sub>2.5</sub> , NMVOC)	no key category	
3.B.3	Swine	T3 (NH <sub>3</sub> ), T2 (NO <sub>x</sub> , TSP, PM <sub>10</sub> , PM <sub>2.5</sub> ), T1 (NMVOC)	NS, RS	CS (NH <sub>3</sub> , NO <sub>x</sub> ), D (TSP, PM <sub>10</sub> , PM <sub>2.5</sub> , NMVOC)	L & T: NH <sub>3</sub> , TSP	
3.B.4.a	Buffalo					NO, from 1990 until 1995, since 1996 IE, considered in 3.B.1.b
3.B.4.f	Mules and asses					IE, considered in 3.B.4.e
3.B.4.g i-iv	Poultry	T2 (NH <sub>3</sub> , NO <sub>x</sub> , TSP, PM <sub>10</sub> , PM <sub>2.5</sub> ), T1 (NMVOC)	NS, RS	CS (NH <sub>3</sub> , NO <sub>x</sub> ), D (TSP, PM <sub>10</sub> , PM <sub>2.5</sub> , NMVOC)	L: TSP (for 3.B.4.g i)	T: NH <sub>3</sub> (for 3.B.4.g iii)
3.B.4.h	Other animals					NE

Legend T = key source by Trend / L = key source by Level

*Methods* D: Default RA: Reference Approach T1: Tier 1 / Simple Methodology \* T2: Tier 2\* T3: Tier 3 / Detailed Methodology \* C: CORINAIR CS: Country Specific M: Model as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2019, in the group specific chapters.

*AD:- Data Source for Activity Data* NS: National Statistics RS: Regional Statistics IS: International

Statistics PS: Plant Specific data AS: Associations, business organisations Q: specific questionnaires, surveys

EF - Emission Factors D: Default (EMEP Guidebook) C: Confidential CS: Country Specific PS: Plant Specific data

## Country specifics



In 2019,  $\text{NH}_3$  emissions from category 3.B (manure management) derived up to 43.6 % from total agricultural emissions, which is equal to  $\sim 243.3$  kt  $\text{NH}_3$ . Within those emissions 47.2 % originate from cattle manure ( $\sim 114.9$  kt), 36.4 % from pig manure (ca. 88.5 kt), and 13.3 % from poultry manure ( $\sim 32.4$  kt). Calculations take into account the impact of anaerobic digestion of manure on the emissions.

$\text{NO}_x$  emissions from category 3.B (manure management) contribute only 1.2 % ( $\sim 1.4$  kt) to the total agricultural  $\text{NO}_x$  emissions. They are calculated proportionally to  $\text{N}_2\text{O}$  emissions, see Rösemann et al. (2021) <sup>1)</sup>.

NM VOC emissions from category 3.B (manure management) contributed 97.2 % (295.8 kt) from total agricultural NM VOC emissions (304.4 kt).

In 2019, manure management contributed, respectively, 71.1 % (42.9 kt), 42.7 % (13.0 kt) and 84.8 % (3.7 kt) to the total agricultural TSP,  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  emissions (TSP: 60.3 kt,  $\text{PM}_{10}$ : 30.4 kt,  $\text{PM}_{2.5}$ : 4.4 kt, respectively).

## Activity data for all pollutants

The Federal Statistical Agency and the Statistical Agencies of the federal states carry out surveys in order to collect, along with other data, the head counts of animals. The results of these surveys are

used for emission calculations, for details see Rösemann et al, 2021, Chapter 3.4.2.

The animal population figures used in the inventory are presented in Table 1. Buffaloes are included in the cattle population figures, mules and asses are included in the horse population figures (IE), see Rösemann et al. (2021), Chapters 4.1 and 7.1. In the first years after the German reunification in 1990 animal livestock decreased markedly. The head counts for cattle continued to decrease significantly until 2006/2007, followed by a more or less stable period until 2014. Since 2015 a slight decrease occurred. In 2019, dairy cattle numbers are 63.1 % of 1990 numbers, while the total population of other cattle is at 58.1 % of 1990. Swine numbers decreased until 1995 and then increased slightly. Since 2014 a slight decrease occurred (2019: 81.5 % of 1990). The 2019 numbers of horses, sheep and goats are, respectively, at 84.6 %, 55.5 % and 163.8 % of 1990.

Figures for broilers and turkeys are showing a massive increase since 1990. In total, 2019 poultry population figures are at 154.1 % of 1990. A detailed description of the animal figures used can be found in the National Inventory Report 2021 <sup>2)</sup>, Chapter 5.1.3.2.3.

*Table 1: Population of animals*

Population of animals (in 1000)														
	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
dairy cattle	6,354.6	5,229.4	4,569.8	4,236.4	4,183.1	4,190.1	4,190.5	4,267.6	4,295.7	4,284.6	4,217.7	4,199.0	4,100.9	4,011.7
other cattle	13,133.4	10,660.5	9,968.9	8,800.4	8,628.7	8,340.4	8,319.1	8,418.4	8,446.5	8,350.8	8,248.9	8,082.2	7,848.2	7,627.9
buffalo	NO	NO	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
mules and asses	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
horses	499.5	634.1	499.5	508.4	461.8	461.6	461.5	461.3	454.9	448.4	442.0	435.5	429.1	422.6
sheep	3,266.1	2,990.7	2,743.3	2,643.1	2,245.0	1,979.7	1,965.9	1,877.2	1,892.4	1,866.9	1,851.0	1,863.2	1,846.0	1,813.6
goats	90.0	100.0	140.0	170.0	149.9	143.4	136.8	130.2	133.1	135.9	138.8	141.7	144.6	147.4
swine	26,502.5	20,387.3	21,767.7	22,742.8	22,244.4	22,787.9	23,648.3	23,391.2	23,666.9	22,978.5	22,761.2	22,920.8	22,019.2	21,596.4
laying hens	53,450.5	45,317.3	44,225.6	38,203.6	35,279.0	39,514.9	43,750.8	47,986.7	49,303.0	50,619.3	51,935.5	52,524.4	53,561.4	53,901.4
broilers	35,393.0	42,025.8	50,359.9	56,762.5	67,531.1	77,402.6	87,274.1	97,145.6	96,027.5	94,909.4	93,791.3	93,791.3	93,791.3	93,791.3
turkeys	5,029.2	6,742.0	8,893.1	10,611.1	11,344.0	11,981.2	12,618.5	13,255.7	12,957.1	12,658.5	12,359.9	12,359.9	12,359.9	12,359.9
pullets	17,210.8	14,592.0	14,240.5	12,301.4	11,303.3	12,749.3	14,195.2	15,641.2	14,734.7	13,828.3	12,921.8	12,921.8	12,921.8	12,921.8
ducks	2,013.7	1,933.7	2,055.7	2,352.2	3,164.3	3,029.5	2,894.6	2,759.7	2,585.3	2,410.8	2,236.4	2,236.4	2,236.4	2,236.4
geese	781.5	617.0	404.8	329.5	278.1	366.8	455.5	544.2	472.5	400.8	329.0	329.0	329.0	329.0
other animals: no data available a)														

a) Animal numbers of other animals are not available. Emissions of other animals were approximated with estimated population figures for a single year (see Rösemann et. al., 2017, Chapter 9, <sup>3)</sup> and submitted to the TERT of the NECD-Review. The TERT confirmed that emissions are below the threshold of significance. For GHG emission reporting the UNFCCC has acknowledged that the emissions from Germany's other animals are negligible. To ensure consistency between UNFCCC and UNECE/NEC reporting, no air pollutants from other animals are reported.

## Additional data

Emission calculations in accordance with a Tier 2 or Tier 3 method require data on animal performance (animal weight, weight gain, milk yield, milk protein content, milk fat content, numbers of births, numbers of eggs and weights of eggs) and on the relevant feeding details (phase feeding, feed components, protein and energy content, digestibility and feed efficiency). To subdivide officially

recorded total numbers of turkeys into roosters and hens, the respective population percentages need to be known. Details on data requirements for the modelling of emissions from livestock husbandry in the German inventory can be found in Rösemann et al. (2021), Chapters 4 to 8.

Most of the data mentioned above is not available from official statistics and was obtained from literature, from publications by agricultural association, from regulations for agricultural consulting in Germany and from expert judgments. For 1991, 1995 and 1999, frequency distributions of feeding strategies, husbandry systems (shares of pasturing/stabling; shares of various housing methods), storage types as well as techniques of farm manure spreading were obtained with the help of the RAUMIS agricultural sector model (Regionalisiertes Agrar- und UmweltInformationssystem für Deutschland/ Regionalised agricultural and environmental information system for Germany). RAUMIS has been developed and is operated by the Institute of Rural Studies of the Thünen Institute (Federal Research Institute for Rural Areas, Forestry and Fisheries). For an introduction to RAUMIS see Weingarten (1995)<sup>4)</sup>; a detailed description is provided in Henrichsmeyer et al. (1996)<sup>5)</sup>.

RAUMIS did not model complete time series but only selected years. RAUMIS data for the years 1991, 1995, and 1999 are used in the inventory for years 1990 – 1993, 1994 – 1997, and 1998 – 1999, respectively. For the year 2010, respective data are used that were derived from the 2010 official agricultural census and the simultaneous survey of agricultural production methods (Landwirtschaftliche Zählung 2010, Statistisches Bundesamt/ Federal Statistical Office) as well as the 2011 survey on manure application practices (Erhebung über Wirtschaftsdüngerausbringung, Statistisches Bundesamt/ Federal Statistical Office).

For the year 2015, data on techniques of farm manure spreading from the 2016 official agricultural census (Agrarstrukturerhebung 2016, Statistisches Bundesamt / Federal Statistical Office) are used. The gaps between the latest RAUMIS model data (1999) and the first official data (2010) were closed by linear interpolation on district level. For 2011 to 2019 the 2010 data was kept, with the exception of data on techniques of farm manure spreading. For the latter the data was linearly interpolated between 2010 and 2015, and for 2016 to 2019 the 2015 data was kept. In addition it was taken into account that, as of 2012, slurry spread on bare soil has to be incorporated within four hours. For a description of the RAUMIS data, the data from official surveys and additional data from other sources see Rösemann et al. (2021), Chapter 3.4. Time series of frequency distributions of housing systems, storage systems and application techniques as well as the corresponding emission factors are provided in NIR 2021, Chapter 19.3.2.

## **NH<sub>3</sub> and NO<sub>x</sub>**

### **Method**

#### **N in manure management**

##### **N excretion**

In order to determine NH<sub>3</sub> and NO<sub>x</sub> emissions from manure management of a specific animal category, the individual N excretion rate must be known as well as, for NH<sub>3</sub>, the TAN content of the N excretions. Default excretion rates are provided by IPCC Guidelines and default TAN contents can be found in the EMEP Guidebook, 2019<sup>6)</sup>. However, the German agricultural emission inventory uses N

mass balances to calculate the N excretions and the TAN contents of almost all animal categories to be reported. N mass balance calculations (see below) consider N intake with feed, N retention due to growth, N contained in milk and eggs, and N in offspring. Table 2 presents national means of N excretions and TAN contents. For methodological details and mass balance input data see Rösemann et al. (2021), Chapter 3.3.4.3 as well as Chapters 4 to 8.

Table 2: National means of N excretions and TAN contents

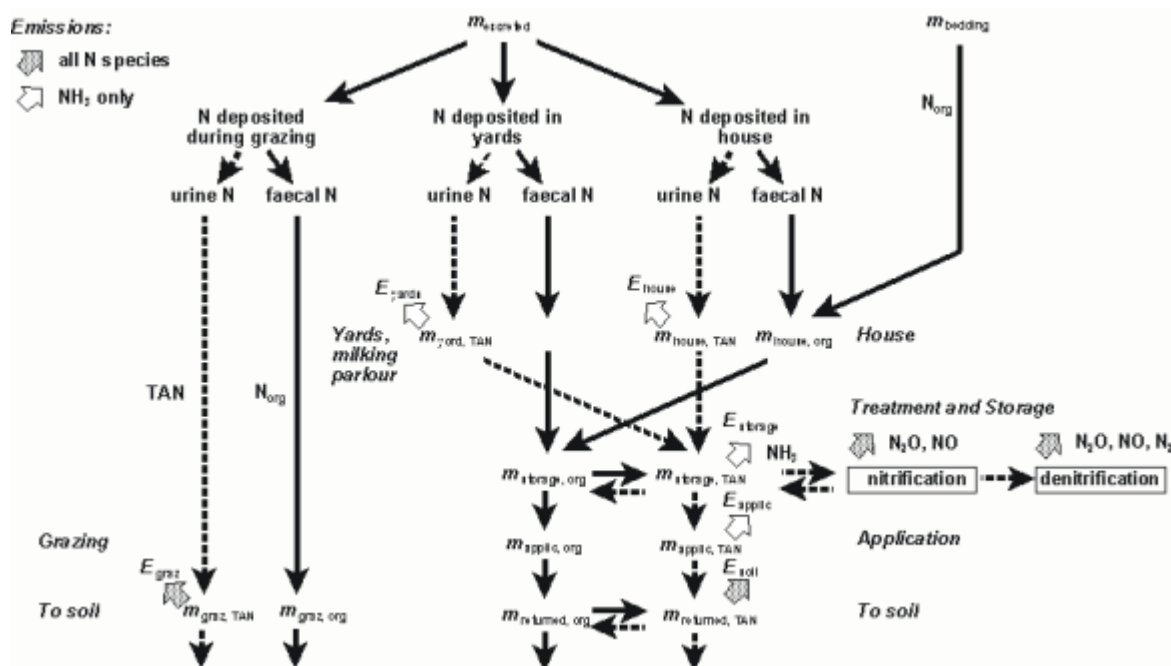
	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
<b>mean N excretions in kg per animal place</b>														
<b>dairy cattle</b>	92.0	97.9	103.8	108.9	110.3	111.0	111.3	110.7	111.8	113.1	114.5	114.3	116.8	120.0
<b>other cattle</b>	38.1	40.4	41.9	41.8	42.6	42.4	42.4	42.5	42.5	42.8	42.7	42.9	43.1	43.5
<b>horses</b>	48.2	48.1	49.0	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8
<b>sheep</b>	7.7	7.7	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
<b>goats</b>	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
<b>swine</b>	12.1	12.6	12.7	12.8	12.9	12.9	12.9	13.0	13.0	13.0	13.1	13.2	13.3	13.3
<b>laying hens</b>	0.82	0.79	0.78	0.80	0.87	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.89	0.89
<b>broilers</b>	0.48	0.44	0.49	0.52	0.57	0.54	0.49	0.45	0.48	0.50	0.50	0.51	0.52	0.51
<b>turkeys</b>	2.0	2.0	2.0	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
<b>pullets</b>	0.33	0.29	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
<b>ducks</b>	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
<b>geese</b>	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
<b>mean TAN contents in %</b>														
<b>dairy cattle</b>	58.0	55.0	52.9	51.3	49.9	49.6	49.3	49.2	48.7	48.6	48.3	48.2	47.6	47.2
<b>other cattle</b>	65.0	64.7	64.5	64.5	64.8	64.8	64.9	64.9	65.0	65.0	64.9	64.9	64.9	64.9
<b>horses</b>	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
<b>sheep</b>	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
<b>goats</b>	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
<b>swine</b>	74.3	74.1	73.8	73.7	73.3	73.2	73.0	73.0	72.9	72.9	72.8	72.7	72.7	72.7
<b>laying hens</b>	70.3	69.6	69.1	69.4	70.0	70.0	70.0	70.1	70.2	70.1	70.1	70.1	70.1	70.1
<b>broilers</b>	60.8	60.1	58.0	55.1	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8
<b>turkeys</b>	63.9	63.9	62.2	63.0	62.1	62.3	62.9	62.6	62.6	62.6	62.6	62.6	62.6	62.6
<b>pullets</b>	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8
<b>ducks</b>	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9
<b>geese</b>	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0

### N mass flow and emission assessment

The calculation of the emissions of  $\text{NH}_3$ ,  $\text{N}_2\text{O}$ ,  $\text{NO}_x$  and  $\text{N}_2$  from German animal husbandry is based on the so-called N mass flow approach (e. g. Dämmgen and Hutchings, 2008<sup>7)</sup>). This approach differentiates between N excreted with faeces (organic nitrogen Norg, i. e. undigested feed N) and urine (total ammoniacal nitrogen TAN, i. e. fraction of feed N metabolized). The N flow within the manure management system is treated as depicted in the figure below. This method reconciles the requirements of both the Atmospheric Emission Inventory Guidebook for  $\text{NH}_3$  emissions (EMEP, 2019), and the IPCC guidelines for greenhouse gas emissions (IPCC (2006)<sup>8)</sup>. Reidy et al. (2008),<sup>9)</sup>, showed for several European countries (Germany, the Netherlands, Switzerland, United Kingdom) that their N-flow based inventory models yielded, in spite of national peculiarities, comparable results as long as standardised data sets for the input variables were used.



Not explicitly shown in the N mass flow scheme is air scrubbing in housing and anaerobic digestion of manure. These issues are separately described further below. Note that emissions from grazing and application are reported in sector 3.D.



General scheme of N flows in animal husbandry

$m$ : mass from which emissions may occur. Narrow broken arrows: TAN (total ammoniacal nitrogen); narrow continuous arrows: organic N. The horizontal arrows denote the process of immobilisation in systems with bedding occurring in the house, and the process of mineralisation during storage, which occurs in any case. Broad arrows denote N-emissions assigned to manure management ( $E_{yard}$   $NH_3$  emissions from yards;  $E_{house}$   $NH_3$  emissions from house;  $E_{storage}$   $NH_3$ ,  $N_2O$ ,  $NO_x$  and  $N_2$  emissions from storage;  $E_{applic}$   $NH_3$  emissions during and after spreading;  $E_{graz}$   $NH_3$ ,  $N_2O$ ,  $NO_x$  and  $N_2$  emissions during and after grazing;  $E_{soil}$   $N_2O$ ,  $NO_x$  and  $N_2$  emissions from soil resulting from manure input).

The figure allows tracing of the pathways of the two N fractions after excretion. The various locations where excretion may take place are considered. The partial mass flows down to the input to soil are depicted. During storage  $N_{org}$  can be transformed into TAN and vice versa. Both, the way and the amount of such transformations may be influenced by manure treatment processes like, e. g., anaerobic digestion where a considerable fraction of  $N_{org}$  is mineralized to TAN. For details see Rösemann et al. (2021), Chapters 3.3.4.3 and 3.3.4.4. Wherever  $NH_3$  is emitted, its formation is related to the amount of the TAN present. For poultry the excretion of uric acid nitrogen (UAN) should be used instead of TAN (see Dämmgen and Erisman, 2005<sup>10</sup>). In line with EMEP (2019), it is assumed that UAN excreted can be considered TAN.  $N_2O$  emissions are related to the total amount of N available ( $N_{org} + TAN$ ).  $NO_x$  emissions (i. e. NO emissions) are calculated proportionally to the  $N_2O$  emissions, see section 'Emission factors'. Note that the  $N_2O$ ,  $NO_x$  and  $N_2$  emissions from the various storage systems include the respective emissions from the related housing systems.

### Air scrubber systems in swine and poultry housings

For pig and poultry production the inventory considers the effect of air scrubbing. Data on frequencies of air scrubbing facilities and the removal efficiency are provided by KTBL (Kuratorium für Technik und Bauwesen in der Landwirtschaft / Association for Technology and Structures in Agriculture). The

average removal efficiency of  $\text{NH}_3$  is 80 % for swine and 70 % for poultry, while for TSP and  $\text{PM}_{10}$  the rates are set to 90 % and for  $\text{PM}_{2.5}$  to 70 % for both animal categories. For swine two types of air scrubbers are distinguished: certified systems that remove both  $\text{NH}_3$  and particles, and non-certified systems that remove only particles.

According to the KTBL data, 7.3 % of all pig places were equipped with certified systems in 2019, another 0.7 % were equipped with non-certified systems. For poultry 0.6 % of all laying hen places and 1.5 % of all broiler places were equipped with air scrubbers that remove both  $\text{NH}_3$  and particles. The amounts of  $\text{NH}_3\text{-N}$  removed by air scrubbing are completely added to the pools of total N and TAN for landspreading. For details see Rösemann et al. (2021), Chapter 3.3.4.3.3.

### **Anaerobic digestion of manure**

According to IPCC (2006), anaerobic digestion of manure is treated like a particular storage type that, however, comprises three sub-compartments (pre-storage, fermenter and storage of digestates). For details see Rösemann et al. (2021), Chapters 3.3.4.4 and 3.4.4.2. The resulting digestates are considered as liquid. Two different types of digestates storage systems are considered: gastight storage and open tank. For the open tank formation of a natural crust because of the usual co-fermentation of energy crops is taken into account. Furthermore, the modelling of anaerobic digestion and spreading of the digestates takes into account that the amount of TAN in the digestates is higher than in untreated slurry and that the frequencies of spreading techniques differ from those for untreated slurry.

$\text{NH}_3$  and NO emissions occur from pre-storage of solid manure, from non-gastight storage of digestates and from landspreading of digestates ( $\text{NH}_3$  emissions and NO emissions from landspreading of digested manure are reported in 3.Da.2.a). There are no such emissions from pre-storage of slurry, from the fermenter and from gastight storage of digestates. Note that  $\text{NH}_3$  and NO emissions calculated with respect to the digestion of animal manures do not comprise the contributions by co-digested energy crops. The latter are dealt with separately in 3.D.a.2.c and 3.I.

### **Emission Factors**

Application of the N mass flow approach requires detailed emission factors for  $\text{NH}_3$ ,  $\text{N}_2\text{O}$ ,  $\text{NO}_x$  and  $\text{N}_2$  describing the emissions from the various housing and storage systems.

The detailed  $\text{NH}_3$  emission factors are, in general, related to the amount of TAN available at the various stages of the N flow chain. The emission factors for laying hens, broilers, pullets, ducks and turkeys are related to N. Most  $\text{NH}_3$  emission factors are country specific but some are taken from EMEP (2019). No specific  $\text{NH}_3$  emission factors are known for the application of digested manure. However, due to co-fermentation of energy crops, the viscosity of digested manure resembles that of untreated cattle slurry. Hence, the emission factors for untreated cattle slurry are adopted for the application of digested manure. For the detailed emission factors of livestock husbandry see Rösemann et al. (2021), Chapters 4 to 8; for emission factors of digested manure see Rösemann et al. (2021), Chapter 3.4.4.2.4. Table 3 provides, by animal category, the implied  $\text{NH}_3$  emission factors for manure management (housing and storage). The overall German  $\text{NH}_3$  IEF for manure application is reported in section 3.D.a.2.a.

The detailed emission factors for  $\text{N}_2\text{O}$ ,  $\text{NO}_x$  and  $\text{N}_2$  relate to the amount of N available which is N

excreted plus, in case of solid manure systems, N input with bedding material. The N<sub>2</sub>O emission factors are taken from IPCC (2006). The emission factors for NO<sub>x</sub> and N<sub>2</sub> are approximated as being proportional to the N<sub>2</sub>O emission factors, i. e. the NO-N and N<sub>2</sub> emission factors are, respectively, one-tenth and three times the value of the N<sub>2</sub>O-N emission factor, see Rösemann et al. (2021), chapter 3.3.4.3.5. This proportionality is also applied to anaerobic digestion of manure, where N<sub>2</sub>O emissions occur from pre-storage of solid manure and non-gastight storage of digestates with the emission factors being those used for normal storage of solid manure and the storage of untreated slurry with natural crust provided by IPCC (2006). Note that the inventory model calculates NO rather than NO<sub>x</sub>. The conversion of NO emissions into NO<sub>x</sub> emissions is achieved by multiplying the NO emissions with the NO<sub>x</sub>/NO molar weight ratio of 46/30. This relationship also holds for NO and NO<sub>x</sub> emission factors.

All NO<sub>x</sub> emissions from the agricultural sector are excluded from emission accounting by [adjustment](#) as they are not considered in the NEC and Gothenburg commitments.

Table 3 shows the implied emission factors of NH<sub>3</sub> and NO<sub>x</sub> for the various animal categories. These emission factors normalize emissions from an animal category as the ratio of the total emission to the respective number of animals.

Table 3: IEF for NH<sub>3</sub> & NO<sub>x</sub> from manure management

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
<b>IEF in kg NH<sub>3</sub> per animal place</b>														
<b>dairy cattle</b>	9.8	10.4	11.1	12.1	12.6	12.5	12.4	12.3	12.2	12.3	12.4	12.3	12.4	12.6
<b>other cattle</b>	7.0	7.4	7.7	8.2	8.4	8.4	8.3	8.3	8.3	8.4	8.4	8.4	8.4	8.5
<b>horses</b>	13.5	13.5	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
<b>sheep</b>	0.83	0.82	0.84	0.83	0.84	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.82	0.83
<b>goats</b>	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62
<b>swine</b>	4.42	4.41	4.37	4.32	4.19	4.15	4.12	4.12	4.11	4.09	4.10	4.10	4.11	4.10
<b>laying hens</b>	0.214	0.203	0.203	0.200	0.142	0.144	0.144	0.145	0.145	0.145	0.146	0.146	0.147	0.147
<b>broilers</b>	0.143	0.131	0.141	0.144	0.148	0.140	0.126	0.116	0.122	0.126	0.128	0.130	0.133	0.131
<b>turkeys</b>	0.788	0.788	0.792	0.869	0.831	0.835	0.888	0.858	0.857	0.856	0.857	0.857	0.859	0.859
<b>pullets</b>	0.108	0.096	0.088	0.087	0.082	0.081	0.081	0.079	0.079	0.079	0.079	0.080	0.080	0.080
<b>ducks</b>	0.193	0.193	0.193	0.192	0.190	0.189	0.188	0.187	0.186	0.186	0.186	0.186	0.186	0.186
<b>geese</b>	0.301	0.301	0.301	0.300	0.298	0.298	0.298	0.297	0.297	0.297	0.297	0.297	0.297	0.297
<b>IEF in kg NO<sub>x</sub> per animal place</b>														
<b>dairy cattle</b>	0.106	0.114	0.125	0.130	0.125	0.122	0.118	0.115	0.115	0.116	0.117	0.117	0.119	0.122
<b>other cattle</b>	0.053	0.058	0.060	0.064	0.065	0.064	0.064	0.063	0.063	0.063	0.063	0.063	0.063	0.064
<b>horses</b>	0.084	0.084	0.086	0.086	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.086	0.086	0.086
<b>sheep</b>	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
<b>goats</b>	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
<b>swine</b>	0.010	0.012	0.012	0.014	0.016	0.016	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
<b>laying hens</b>	0.00027	0.00026	0.00026	0.00029	0.00035	0.00035	0.00034	0.00034	0.00033	0.00034	0.00034	0.00033	0.00033	0.00033
<b>broilers</b>	0.00016	0.00015	0.00016	0.00019	0.00022	0.00021	0.00018	0.00017	0.00018	0.00019	0.00019	0.00019	0.00019	0.00019
<b>turkeys</b>	0.00067	0.00067	0.00070	0.00083	0.00090	0.00090	0.00091	0.00089	0.00089	0.00089	0.00088	0.00088	0.00087	0.00087
<b>pullets</b>	0.00011	0.00010	0.00009	0.00010	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011
<b>ducks</b>	0.00024	0.00024	0.00024	0.00025	0.00027	0.00027	0.00026	0.00027	0.00026	0.00027	0.00027	0.00026	0.00026	0.00026
<b>geese</b>	0.00018	0.00018	0.00019	0.00021	0.00023	0.00023	0.00021	0.00022	0.00021	0.00022	0.00022	0.00021	0.00021	0.00021

### Trend discussion for Key Sources



Dairy cattle, other cattle and swine are key sources of NH<sub>3</sub> emissions from manure management. The time series of the total NH<sub>3</sub> emissions from all three categories are predominantly driven by the development of the animal numbers, see Table 1. This also holds for the negative trend of total emissions in the last few years. However, the effect of decreasing animal numbers is partly compensated by the continuously increasing animal performance. This leads to increasing N excretions per animal, see Table 2, which, in principle, is reflected by increasing implied emission factors, see Table 3. For swine, as of 2012, the IEF is almost constant over time due to the use of air scrubbing systems that, to a high degree, remove NH<sub>3</sub> from the housings.

For NO<sub>x</sub> there are no key categories.

### Recalculations

All time series of the emission inventory have completely been recalculated since 1990. Tables REC-1 and REC-2 compare the recalculated time series for NH<sub>3</sub> and NO<sub>x</sub> from 3B with the respective data of last year's submission. The total emissions of NH<sub>3</sub> and NO<sub>x</sub> are significantly lower than those of submission 2020. This is predominantly due to the update of the models of dairy cows, calves, heifers and male beef cattle, see main page of the agricultural sector ([Chapter 5 - NFR 3 - Agriculture \(OVERVIEW\)](#)), list of **recalculation reasons, No. 1 through 4, and 12**.

The NH<sub>3</sub> and NO<sub>x</sub> emissions from pig changed only slightly; the reasons are given in the list of **recalculation reasons (No. 6 through 8, and 12)**.

The NH<sub>3</sub> emissions from poultry are higher than those reported in submission 2020 for all years of the time series, while NO<sub>x</sub> emissions differ only slightly. The underlying changes in poultry emission calculations are provided in the **recalculation reasons, No. 9 through 11, and 12**.

The overall NH<sub>3</sub> emissions of other animals increased for all years of the time series due to the update of the NH<sub>3</sub> emission factor for sheep manure storage, see **recalculations reasons No. 9 Chapter 5 - NFR 3 - Agriculture (OVERVIEW)**. Further details on recalculations are described in Rösemann et al. (2021), Chapter 3.5.2..

*Tables REC-1 and REC-2: Comparison of the NH<sub>3</sub> and NO<sub>x</sub> emissions of the submissions (SUB) 2020 and 2021*

NH <sub>3</sub> emissions from manure management, in Gg															
	SUB	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
<b>Total</b>	<b>2021</b>	303.26	256.08	256.91	257.32	252.88	253.17	257.21	258.42	260.03	256.36	253.73	252.85	247.20	243.31
	<b>2020</b>	325.60	275.30	276.21	276.48	271.11	271.43	275.70	277.31	279.59	276.30	273.98	272.83	267.01	
<b>Dairy cattle</b>	<b>2021</b>	62.19	54.13	50.81	51.28	52.71	52.44	51.86	52.30	52.48	52.72	52.10	51.64	50.74	50.40
	<b>2020</b>	75.05	65.57	61.87	62.48	64.19	64.22	63.79	64.44	65.29	65.88	65.43	64.96	64.24	
<b>Other cattle</b>	<b>2021</b>	91.39	78.88	76.79	71.73	72.48	69.75	69.39	70.26	70.48	69.85	68.90	67.62	65.85	64.47
	<b>2020</b>	101.28	87.37	86.15	81.09	80.84	77.90	77.51	78.51	78.74	78.14	77.24	75.69	73.74	
<b>Swine</b>	<b>2021</b>	117.12	89.92	95.08	98.23	93.21	94.56	97.47	96.29	97.28	94.06	93.26	93.92	90.54	88.50
	<b>2020</b>	117.12	89.92	95.08	98.23	93.21	94.58	97.51	96.36	97.37	94.17	93.40	94.09	90.63	
<b>poultry</b>	<b>2021</b>	22.96	21.99	24.87	26.65	26.06	28.23	30.34	31.50	31.80	31.84	31.68	31.95	32.45	32.43
	<b>2020</b>	22.71	21.41	23.86	25.36	24.55	26.63	28.81	30.02	30.27	30.31	30.21	30.46	30.87	
<b>Other animals</b>	<b>2021</b>	9.59	11.16	9.37	9.43	8.43	8.18	8.16	8.07	8.00	7.89	7.79	7.72	7.62	7.51
	<b>2020</b>	9.44	11.02	9.25	9.31	8.33	8.09	8.07	7.98	7.91	7.80	7.71	7.64	7.53	

<b>NO<sub>x</sub> emissions from manure management, in Gg</b>															
	<b>SUB</b>	<b>1990</b>	<b>1995</b>	<b>2000</b>	<b>2005</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>2015</b>	<b>2016</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>
<b>Total</b>	<b>2021</b>	1.720	1.551	1.523	1.534	1.529	1.502	1.480	1.475	1.482	1.465	1.455	1.444	1.418	1.401
	<b>2020</b>	1.863	1.674	1.639	1.644	1.632	1.604	1.582	1.579	1.588	1.572	1.562	1.548	1.519	
<b>Dairy cattle</b>	<b>2021</b>	0.671	0.597	0.570	0.552	0.521	0.513	0.495	0.491	0.493	0.495	0.494	0.489	0.488	0.489
	<b>2020</b>	0.722	0.640	0.601	0.580	0.549	0.541	0.523	0.521	0.525	0.528	0.527	0.522	0.520	
<b>Other cattle</b>	<b>2021</b>	0.696	0.614	0.600	0.566	0.562	0.538	0.529	0.532	0.532	0.526	0.519	0.509	0.497	0.487
	<b>2020</b>	0.788	0.695	0.685	0.649	0.637	0.611	0.602	0.606	0.606	0.601	0.593	0.581	0.566	
<b>Swine</b>	<b>2021</b>	0.264	0.242	0.263	0.322	0.351	0.355	0.359	0.353	0.357	0.344	0.343	0.346	0.335	0.328
	<b>2020</b>	0.264	0.242	0.263	0.322	0.351	0.355	0.359	0.353	0.357	0.344	0.343	0.346	0.334	
<b>poultry</b>	<b>2021</b>	0.026	0.024	0.028	0.033	0.040	0.043	0.045	0.047	0.048	0.048	0.048	0.048	0.049	0.049
	<b>2020</b>	0.026	0.024	0.028	0.033	0.040	0.043	0.045	0.047	0.048	0.048	0.048	0.048	0.049	
<b>Other animals</b>	<b>2021</b>	0.063	0.073	0.062	0.062	0.055	0.053	0.053	0.053	0.052	0.051	0.051	0.050	0.050	0.049
	<b>2020</b>	0.063	0.073	0.062	0.062	0.055	0.053	0.053	0.053	0.052	0.051	0.051	0.050	0.050	

#### Planned improvements

No improvements are planned at present.

## NMVOC

In 2019, NMVOC emissions from manure management amount to 295.8 which is 97.2 % of total NMVOC emissions from the agricultural sector. 84.8 % originate from cattle, 4.7 % from pigs, and 9.4 % from poultry. All NMVOC emissions from the agricultural sector are excluded from emission accounting by adjustment as they are not considered in the NEC and Gothenburg commitments (see Chapter 11 - [Adjustments and Emissions Reduction Commitments](#)).

## Method

The Tier 2 methodology provided by EMEP (2019)-3B-28 was used to assess the NMVOC emissions from manure management for dairy cattle and other cattle. For all other animals the Tier 1 methodology (EMEP (2019)-3B-17) was used.

#### Activity data

Animal numbers serve as activity data, see Table 1.

#### Emission factors

For the Tier 2 methodology applied to dairy cattle and other cattle the following data was used:



<b>pullets</b>	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
<b>ducks</b>	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489
<b>geese</b>	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489

### Trend discussion for Key Sources

Dairy cattle and other cattle are key sources of NMVOC emissions from manure management. The total NMVOC emissions from both animal categories strongly correlate with the animal numbers given in Table 1 (dairy cattle:  $R^2 = 0.895$ ; other cattle:  $R^2 = 0.995$ ).

### Recalculations

All time series of the emission inventory have completely been recalculated since 1990. Table REC-3 compares the recalculated time series of the NMVOC emissions from 3.B with the respective data of last year's submission. The recalculated total emissions are lower by 4 to 11 %. This is due to improved methodology for the cattle sector (**recalculation reasons 1 through 4**, see [main page of the agricultural sector](#)). Emissions of other animals remained unchanged. Further details on recalculations are described in Rösemann et al. (2021), Chapter 3.5.2.

Table REC-3: Comparison of NMVOC emissions of the submissions (SUB) 2020 and 2021

NMVOC emissions from manure management, in Gg															
	SUB	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
<b>Total</b>	<b>2021</b>	390.80	332.18	318.01	297.65	296.79	297.13	299.17	304.38	306.74	305.38	303.07	300.94	297.86	295.83
	<b>2020</b>	439.44	365.76	344.98	320.23	317.25	317.26	318.95	324.80	326.92	325.45	322.84	320.20	316.49	
<b>Dairy cattle</b>	<b>2021</b>	196.61	170.97	162.10	155.50	155.75	157.45	157.39	159.40	162.04	162.45	161.82	161.15	160.81	160.84
	<b>2020</b>	231.88	194.00	177.13	167.50	166.57	168.13	167.69	170.01	172.37	172.58	171.57	170.89	169.97	
<b>Other cattle</b>	<b>2021</b>	153.72	124.27	117.29	102.54	101.14	97.38	96.89	98.11	98.00	97.00	95.83	94.23	91.95	90.15
	<b>2020</b>	167.09	134.83	129.24	113.12	110.78	106.84	106.37	107.92	107.84	106.95	105.84	103.75	101.42	
<b>Other animals</b>	<b>2021</b>	40.46	36.94	38.62	39.61	39.89	42.29	44.89	46.87	46.70	45.93	45.42	45.56	45.11	44.84
	<b>2020</b>	40.46	36.94	38.62	39.61	39.89	42.29	44.89	46.87	46.70	45.93	45.42	45.56	45.11	

### Planned improvements

No improvements are planned at present.

## TSP, PM10 and PM2.5

In 2019, TSP emissions from manure management amount to 71.1 % of total emissions from the agricultural sector. Within the emissions from manure management 22.4 % originate from cattle, 39.3 % from pigs, and 37.7 % from poultry. 42.7 % of the PM<sub>10</sub> emissions from the agricultural sector are caused by manure management, where 34.0 % originate from cattle, 18.9 % from pigs, and 46.2 % from poultry. PM<sub>2.5</sub> emissions from the agricultural sector mostly originate from manure management (84.8 %), of which are 77.5 % from cattle, 3.0 % from pigs, and 18.0 % from poultry.



	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
<b>dairy cattle</b>	0.5557	0.6426	0.6668	0.6759	0.6827	0.6819	0.6813	0.6804	0.6803	0.6798	0.6801	0.6798	0.6797	0.6797
<b>other cattle</b>	0.2403	0.2363	0.2321	0.2278	0.2230	0.2226	0.2227	0.2229	0.2225	0.2222	0.2222	0.2222	0.2223	0.2222
<b>horses</b>	0.1619	0.1619	0.1639	0.1636	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1635	0.1635	0.1635	0.1635
<b>sheep</b>	0.0194	0.0192	0.0196	0.0195	0.0196	0.0195	0.0194	0.0194	0.0194	0.0193	0.0193	0.0193	0.0192	0.0193
<b>goats</b>	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368
<b>swine</b>	0.1241	0.1255	0.1244	0.1230	0.1199	0.1187	0.1185	0.1177	0.1170	0.1158	0.1156	0.1151	0.1147	0.1139
<b>laying hens</b>	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0399	0.0399	0.0398
<b>broilers</b>	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0199	0.0198	0.0198	0.0198	0.0197
<b>turkeys</b>	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100
<b>pullets</b>	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200
<b>ducks</b>	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400
<b>geese</b>	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400
<b>IEF in kg PM<sub>2.5</sub> per animal place</b>														
<b>dairy cattle</b>	0.3616	0.4181	0.4339	0.4398	0.4442	0.4437	0.4433	0.4427	0.4427	0.4423	0.4425	0.4423	0.4422	0.4422
<b>other cattle</b>	0.1574	0.1548	0.1521	0.1493	0.1463	0.1460	0.1461	0.1462	0.1460	0.1458	0.1458	0.1458	0.1459	0.1458
<b>horses</b>	0.1027	0.1026	0.1039	0.1038	0.1036	0.1036	0.1036	0.1036	0.1036	0.1037	0.1037	0.1037	0.1037	0.1037
<b>sheep</b>	0.0059	0.0059	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059
<b>goats</b>	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112
<b>swine</b>	0.0056	0.0057	0.0056	0.0056	0.0054	0.0054	0.0053	0.0053	0.0053	0.0052	0.0052	0.0052	0.0052	0.0052
<b>laying hens</b>	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030
<b>broilers</b>	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
<b>turkeys</b>	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200
<b>pullets</b>	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
<b>ducks</b>	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180
<b>geese</b>	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320

## Trend discussion for Key Sources

Swine and laying hens are key sources of TSP emissions from manure management. The total TSP emissions from swine mainly follow the animal numbers given in Table 1. However, due to air scrubbing and different emission factors of the different housing systems of the four swine subcategories (sows with piglets, weaners, fattening pigs, boars) and the varying population shares in those housing systems the  $R^2$  of the linear regression is lower than 1 (0.79). For laying hens and broilers, due to the low prevalence of air scrubbing systems. TSP emissions almost perfectly correlate with the animal numbers provided in Table 1 ( $R^2 = 1$ ).

## Recalculations

Table REC-4 shows the effects of recalculations on emissions of particulate matter. Changes in the years 1990 through 1999 are a consequence of the update of the dairy cow model (**recalculation reason 1**, see [main page of the agricultural sector](#)). This update includes a modified calculation of the share of year spent on pasture, resulting in longer grazing periods and therefore lower emissions of particulate matter from manure management in the years 1990 through 1999. Differences of TSP and PM emissions in the years as of 2005 are due to updated activity data of air scrubbing systems



for sows, weaners, fattening pigs and broilers, see **recalculation reasons 8 and 10** on [the main page of the agricultural sector](#). Further details on recalculations are described in Rösemann et al. (2021), Chapter 3.5.2.

*Table REC-4: Comparison of particle emissions (TSP, PM<sub>10</sub> & PM<sub>2.5</sub>) of the submissions (SUB) 2020 and 2021*

<b>TSP, PM10, PM2.5 emissions from manure management, in Gg</b>															
	<b>SUB</b>	<b>1990</b>	<b>1995</b>	<b>2000</b>	<b>2005</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>2015</b>	<b>2016</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>
<b>TSP</b>	<b>2021</b>	50.04	42.24	42.44	41.26	40.32	41.79	43.90	45.06	45.33	44.58	44.35	44.40	43.55	42.90
<b>TSP</b>	<b>2020</b>	50.26	42.41	42.44	41.26	40.32	41.79	43.91	45.07	45.36	44.61	44.39	44.44	43.62	
<b>PM<sub>10</sub></b>	<b>2021</b>	14.34	12.71	12.63	12.29	12.32	12.75	13.31	13.80	13.77	13.56	13.39	13.36	13.17	13.00
<b>PM<sub>10</sub></b>	<b>2020</b>	14.44	12.78	12.63	12.29	12.32	12.75	13.31	13.80	13.78	13.57	13.40	13.38	13.19	
<b>PM<sub>2.5</sub></b>	<b>2021</b>	5.01	4.47	4.18	3.89	3.86	3.86	3.91	4.01	4.01	3.97	3.91	3.88	3.80	3.72
<b>PM<sub>2.5</sub></b>	<b>2020</b>	5.08	4.52	4.18	3.89	3.86	3.86	3.91	4.01	4.01	3.97	3.91	3.88	3.80	

## Planned improvements

No improvements are planned at present.

## Uncertainty

Details will be described in [chapter 1.7](#).

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