3.B - Manure Management

Short description

NFR-Code	Name of Category	Method	AD	EF	State of reporting
3.B	**Manure Management**	**see sub-category details**			
consisting of / including source categories					
3.B.1.a & 3.B.1.b	Cattle	T3 (NH_3), T2 (NO_x , TSP, PM_{10} , $PM_{2.5}$, NMVOC)	NS, RS	CS (NH_3 , NO_x), D (TSP, PM_{10} , $PM_{2.5}$, NMVOC)	L: NH_3 (for 3.B.1.a)
3.B.2, 3.B.4.d, 3.B.4.e	Sheep, Goats, Horses	T2 (NH_3 , NO_x , TSP, PM_{10} , $PM_{2.5}$), T1 (NMVOC)	NS, RS	CS (NH_3 ,NO_x), D (TSP, PM_{10} , $PM_{2.5}$, NMVOC)	
3.B.3	Swine	T3 (NH_3), T2 (NO_x , TSP, PM_{10} , $PM_{2.5}$), T1 (NMVOC)	NS, RS	CS (NH_3 , NO_x), D (TSP, PM_{10} , $PM_{2.5}$, NMVOC)	
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_3 , NO_x , TSP, PM_{10} , $PM_{2.5}$), T1 (NMVOC)	NS, RS	CS (NH_3 , NO_x), D (TSP, PM_{10} , $PM_{2.5}$, NMVOC)	T: NH_3 (for 3.B.4.g iii)
3.B.4.h	Other animals				NE

Key Category	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
3.B.1.a	-/-	L/-	-	L/-	L/-	L/-	-/-	-	-	-	-	-	-	-	-
3.B.1.b	-/-	L/-	-	L/T	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.2	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.3	-/-	-/-	-	L/T	-/-	-/-	L/-	-	-	-	-	-	-	-	-
3.B.4.d	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.4.e	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.4.g.i	-/-	-/-	-	-/-	-/-	-/-	L/-	-	-	-	-	-	-	-	-
3.B.4.g.ii	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.4.g.iii	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.4.g.iv	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
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/EEA 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 (or surveys)
M	Model / Modelled
C	Confidential

EF - Emission Factors	
D	Default (EMEP Guidebook)

C	Confidential
CS	Country Specific
PS	Plant Specific data
M	Model / Modelled

Country specifics

In 2021, NH_3 emissions from category 3.B (manure management) were 43.2 % from total agricultural emissions, which is equal to ~ 208.5 kt NH_3. Within those emissions 49.1 % originate from cattle manure (~ 102.4 kt), 34.8 % from pig manure (ca. 72.5 kt), and 12.3 % from poultry manure (~ 25.6 kt). Calculations take into account the impact of anaerobic digestion of manure on the emissions.

NO_x emissions from category 3.B (manure management) contribute only 1.2 % (~ 1.3 kt) to the total agricultural NO_x emissions. They are calculated proportionally to N_2O emissions, see Rösemann et al. (2023) [1)].

NMVOC emissions from category 3.B (manure management) contributed 96.8 % (281.2 kt) from total agricultural NMVOC emissions (290.6 kt).

In 2021, manure management contributed, respectively, 65.4 % (39.6 kt), 37.0 % (12.3 kt) and 68.9 % (3.6 kt) to the total agricultural TSP, PM_{10} and $PM_{2.5}$ emissions (TSP: 60.6 kt, PM_{10}: 33.3 kt, $PM_{2.5}$: 5.3 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, 2023, Chapter 2.3.

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. (2023), Chapters 2.3. 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 2021, dairy cattle numbers are 60.3 % of 1990 numbers, while the total population of other cattle is at 54.9 % of 1990. Swine numbers decreased until 1995 and then increased slightly. Since 2014 a new decrease occurred which became significant between 2020 and 2021 (total pig numbers were reduced by almost 9 %). In 2021 swine numbers are 74.4 % of 1990 numbers. The 2021 numbers of horses, sheep and goats are, respectively, at 91.4 %, 55.0 % and 176.6 % of 1990.

Figures for broilers and turkeys are showing a massive increase since 1990. Since the year 2013, there have been only minor changes of total poultry numbers. In total, 2021 poultry population figures are at 152.8 % of 1990. A detailed description of the animal numbers used can be found in the National Inventory Report 2023 [2)], Chapter 5.1.3.2.3. Animal numbers of rabbits, ostrich and fur-bearing animals are available only for one year of the time series, see Rösemann et al. (2017). The animal numbers in these categories are low and the animals have limited impact on the total NH3 and NOx emissions. Nonetheless, following a recommendation from the NEC review 2022, Germany will obtain furtheris working on obtaining activity data for the entire time series and in order to report the emissions in a future submission.

Table 1: Population of animals

	Population of animals (in 1000)															
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
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	3,921.4	3,832.7
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	7,380.5	7,206.9
buffalo	NO	NO	IE	IE	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	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	444.9	447.8	450.7	453.7	456.6
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	1,780.3	1,794.8
goats	90.0	100.0	140.0	170.0	149.9	143.4	136.8	130.2	133.1	135.9	138.8	142.8	146.9	150.9	154.9	158.9
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	21,622.0	19,728.6
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	52,571.1	53,206.6	53,842.1	54,477.6	55,324.7
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	93,458.7	93,126.1	92,793.5	92,461.0	92,461.0
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	12,164.7	11,969.5	11,774.3	11,579.1	11,579.1
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	12,736.3	12,550.7	12,365.1	12,179.6	12,179.6
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	2,209.1	2,181.9	2,154.6	2,127.4	2,127.4
geese	781.5	617.0	404.8	329.5	278.1	366.8	455.5	544.2	472.5	400.8	329.0	327.7	326.3	324.9	323.5	323.5
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, [3)] 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. (2023), Chapter 2.

Most of the data mentioned above is not available from official statistics and was obtained from literature, from publications by agricultural associations, 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 UmweltInformationsystem 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) [4)]; a detailed description is provided in Henrichsmeyer et al. (1996) [5)].

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 2009, 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 (2009) were closed by linear interpolation on district level. For the year 2019 data from the 2020 official agricultural census (Landwirtschaftszählung 2020, LW20) are used for housing systems, storage systems and manure spreading systems. For 2010 to 2018 the housing and storage systems data was linearly interpolated between the censuses of 2010 and 2020. The data on manure spreading techniques was linearly interpolated between the census data from 2009 and 2015, and for 2016 to 2018 between the censuses conducted in 2016 and 2020. 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. (2023), Chapter 2.5. Time series of frequency distributions of housing systems, storage systems and application techniques as well as the corresponding emission factors are provided in NIR 2023, Chapter 19.3.2.

NH_3 and NO_x

Method

N in manure management

N excretion

In order to determine NH_3 and NO_x emissions from manure management of a specific animal category, the individual N excretion rate must be known as well as, for NH_3, 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[6]. However, the German agricultural emission inventory uses N mass balances to calculate the N excretions and the TAN contents of almost all reported animal categories. 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. (2023), Chapter 4.2 as well as Chapter 4.1.2.

Table 2: National means of N excretions and TAN contents

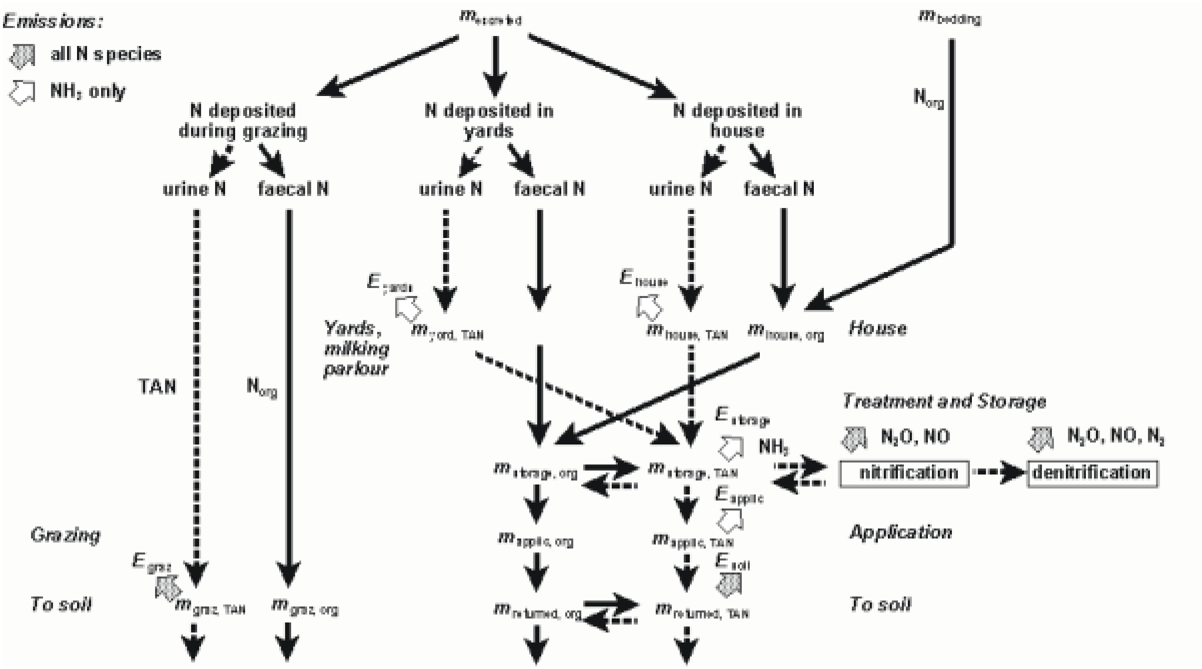
	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
mean N excretions in kg per animal place																
dairy cattle	92.0	97.9	103.8	108.9	110.2	110.9	111.2	110.7	111.6	112.8	114.1	113.8	116.1	119.1	121.4	121.9
other cattle	37.9	39.9	41.3	41.2	42.1	42.0	42.0	42.2	42.2	42.5	42.5	42.7	42.9	43.4	43.7	43.8
horses	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	48.8	48.9
sheep	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	7.8	7.8
goats	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	11.0	11.0
swine	13.0	13.4	13.2	13.0	12.8	12.7	12.7	12.6	12.6	12.7	12.7	12.6	12.6	12.5	12.4	12.6
laying hens	0.81	0.78	0.76	0.79	0.87	0.87	0.88	0.88	0.88	0.89	0.89	0.89	0.90	0.90	0.90	0.90
broilers	0.48	0.41	0.45	0.49	0.51	0.48	0.42	0.38	0.40	0.40	0.40	0.40	0.41	0.40	0.39	0.39
turkeys	2.0	2.0	2.0	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.1	2.1
pullets	0.32	0.29	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.29
ducks	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	0.61	0.61
geese	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	0.70	0.70	0.70
mean TAN contents in %																
dairy cattle	58.0	55.0	53.0	51.3	49.9	49.5	49.2	49.2	48.6	48.5	48.2	48.0	47.3	46.9	46.5	46.5
other cattle	65.5	65.7	65.7	65.7	66.0	66.1	66.2	66.2	66.3	66.3	66.4	66.4	66.4	66.4	66.4	66.3
horses	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	60.0	60.0
sheep	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	50.0	50.0
goats	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	50.0	50.0
swine	72.0	71.7	71.1	71.8	72.3	72.0	71.8	71.7	71.5	71.6	71.4	71.2	71.1	71.0	70.8	70.9
laying hens	70.2	69.6	69.0	69.3	70.0	70.0	70.0	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2
broilers	60.8	58.9	56.4	53.5	50.0	49.4	48.8	48.2	47.6	46.9	46.5	46.1	45.7	45.2	44.8	44.8
turkeys	64.7	64.7	63.0	63.9	63.0	63.1	63.8	63.5	63.5	63.5	63.5	63.3	63.0	63.0	62.1	62.1
pullets	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	67.8	67.8
ducks	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	49.9	49.9

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
geese	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	70.0	70.0

N mass flow and emission assessment

The calculation of the emissions of NH_3, N_2O, NO_x and N_2 from German animal husbandry is based on the so-called N mass flow approach (e. g. Dämmgen and Hutchings, 2008 [7]). 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 NH_3 emissions (EMEP, 2019), and the IPCC guidelines for greenhouse gas emissions (IPCC (2006)[8]. Reidy et al. (2008),[9], 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 model 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 represented. During storage Norg can be transformed into TAN and vice versa. Both, the way and the magnitude of such transformations may be influenced by manure treatment processes like, e. g., anaerobic digestion where a considerable fraction of Norg is mineralized to TAN. For details see Rösemann et al. (2023), Chapter 4.2. Wherever NH_3 is emitted, its formation is related to the amount of the TAN present. N_2O emissions are related to the total amount of N available (Norg + 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 N2 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 model 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) supplemented by data from the 2020 agricultural census. The average removal efficiency of NH_3 is 80 % for swine and 70 % for poultry, while for TSP and PM_{10} the rates are set to 90 % and for $PM_{2.5}$ to 70 % for both animal categories. For swine two types of air scrubbers are distinguished: systems of “first class” that remove both NH_3 and particles, and ”second class” systems that remove only particles reliably and have a NH_3 removal efficiency of 20%.

According to the KTBL data, 6.6 % of all pig places were equipped with ”first class” systems in 2021, another 11.2 % were equipped with “second class” systems. For poultry 8 % of all laying hen places and 2.1 % of all broiler places were equipped with air scrubbers that remove both NH_3 and particles. The amounts of NH_3-N removed by air scrubbing are completely added to the pools of total N and TAN for landspreading. For details see Rösemann et al. (2023), Chapter 4.2.2.

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. (2023), Chapters 2.6 and 4.2.5. The resulting digestates are considered as liquid. Two different types of digestates storage systems are considered: gastight storage and open tank. For open tanks formation of a natural crust because of co-fermentation with 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.

NH_3 and NO emissions occur from pre-storage of solid manure, from non-gastight storage of digestates and from land-spreading of digestates (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 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 NH_3, N_2O, NO_x and N_2 describing the emissions from the various housing and storage systems.

The detailed 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 NH_3 emission factors are country-specific but some are taken from EMEP (2019). No specific NH_3 emission factors are known for the application of digested manure. However, due to co-fermentation with 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. (2023), Chapter 4.3.

Table 3 provides, by animal category, the implied NH_3 emission factors for manure management (housing and storage). The overall German NH_3 IEF for manure application is reported in section 3.D.a.2.a.

The the detailed emission factors for N_2O, NO_x and 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_2O emission factors are taken from IPCC (2006). The emission factors for NO_x and N_2 are approximated as being proportional to the N_2O emission factors, i.e. the NO-N and N_2 emission factors are, respectively, one-tenth and three times the value of the N_2O-N emission factor, see Rösemann et al. (2023), chapter 4.2.4. This proportionality is also applied to anaerobic digestion of manure, where N_2O 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 NOx. The conversion of NO emissions into NO_x emissions is achieved by multiplying the NO emissions with the NO_2/ NO molar weight ratio of 46/30. This relationship also holds for NO and NO_x emission factors.

Table 3 shows the implied emission factors of NH_3 and NO_x 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_3 & NO_x from manure management

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
IEF in kg NH_3 per animal place																

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
dairy cattle	9.8	10.3	11.1	12.2	12.7	12.8	12.8	12.8	12.9	13.1	13.3	13.3	13.5	13.9	14.0	14.0
other cattle	6.2	6.3	6.4	6.7	7.2	7.1	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.7	6.7	6.7
horses	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	13.7	13.7
sheep	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	0.83	0.82
goats	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	1.62	1.62
swine	4.53	4.45	4.33	4.25	4.08	4.01	3.94	3.89	3.84	3.86	3.81	3.77	3.73	3.67	3.63	3.67
laying hens	0.214	0.206	0.211	0.209	0.137	0.138	0.136	0.135	0.133	0.132	0.130	0.129	0.128	0.126	0.125	0.125
broilers	0.143	0.120	0.128	0.131	0.128	0.118	0.103	0.092	0.094	0.094	0.094	0.093	0.094	0.092	0.089	0.088
turkeys	0.793	0.793	0.797	0.874	0.836	0.839	0.892	0.862	0.860	0.859	0.859	0.860	0.835	0.835	0.783	0.783
pullets	0.103	0.095	0.087	0.087	0.084	0.083	0.083	0.082	0.082	0.082	0.083	0.083	0.084	0.084	0.083	0.083
ducks	0.193	0.193	0.193	0.192	0.189	0.188	0.188	0.186	0.186	0.185	0.185	0.185	0.186	0.186	0.185	0.185
geese	0.384	0.384	0.384	0.383	0.380	0.380	0.380	0.379	0.379	0.378	0.378	0.378	0.378	0.378	0.378	0.378
IEF in kg NO_x per animal place																
dairy cattle	0.106	0.114	0.125	0.130	0.126	0.124	0.120	0.117	0.118	0.119	0.120	0.120	0.123	0.126	0.128	0.128
other cattle	0.053	0.057	0.059	0.063	0.064	0.064	0.064	0.064	0.064	0.065	0.065	0.066	0.067	0.068	0.068	0.069
horses	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	0.086	0.086
sheep	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	0.006	0.006
goats	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	0.013	0.013
swine	0.011	0.013	0.012	0.014	0.014	0.014	0.013	0.013	0.013	0.012	0.012	0.012	0.012	0.011	0.011	0.011
laying hens	0.00027	0.00026	0.00025	0.00029	0.00035	0.00035	0.00033	0.00033	0.00033	0.00033	0.00033	0.00033	0.00033	0.00033	0.00033	0.00033
broilers	0.00016	0.00014	0.00015	0.00018	0.00020	0.00019	0.00016	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015
turkeys	0.00067	0.00067	0.00070	0.00084	0.00090	0.00091	0.00092	0.00090	0.00089	0.00089	0.00089	0.00089	0.00086	0.00085	0.00081	0.00081
pullets	0.00011	0.00010	0.00009	0.00010	0.00012	0.00012	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011
ducks	0.00024	0.00024	0.00024	0.00025	0.00027	0.00027	0.00026	0.00027	0.00027	0.00027	0.00027	0.00027	0.00027	0.00026	0.00026	0.00026
geese	0.00024	0.00024	0.00025	0.00027	0.00030	0.00030	0.00028	0.00029	0.00028	0.00029	0.00029	0.00029	0.00028	0.00028	0.00028	0.00028

Trend discussion for Key Sources

Dairy cattle, other cattle and swine are key sources of NH_3 emissions from manure management. The time series of the total NH_3 emissions from all three categories are predominantly driven by the development of the animal numbers, see Table 1. 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. Increasing dairy cattle emissions since 2010 are also due to a sharp decline of tied housing systems, which have a lower NH_3 emission factor than loose housing systems. For swine the IEF is decreasing over time due to lower raw protein contents in feed and the use of air scrubbing systems that, to a high degree, remove NH_3 from the housings.

For NO_x 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_3 and NO_x from 3B with the respective data of last year's submission.The total emissions of NH_3 are considerably lower than those of submission 2022. The main reason for this is recalculation No. 2 (deep bedding), which lowers especially the manure management emissions of other cattle (correspondingly this increases the emissions from manure spreading (3.D.a.2.a), albeit to a lesser extent).

The NH_3 and NO_x emissions from swine and poultry are lower than in the 2022 submission mainly due to the use of new data on raw protein content in fattening pig feed from the survey "Protein use in pig fattening" (recalculation No. 8). The main reason for lower poultry emissions are the changes made for the laying hens category concerning grazing and emission factors (recalculation No. 10). See main page of the agricultural sector (Chapter 5 - NFR 3 - Agriculture (OVERVIEW)), list of **recalculation reasons, No. 2, 8, 10**.

Further details on recalculations are described in Rösemann et al. (2023), Chapter 1.3.

Tables REC-1 and REC-2: Comparison of the NH_3 and NO_x emissions of the submissions (SUB) 2022 and 2023

NH$_3$ emissions from manure management, in Gg																
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Total	**2023**	296.08	244.15	242.78	243.08	238.82	238.18	241.00	240.92	240.96	237.93	234.15	232.03	225.13	220.63	216.65	208.39
	2022	307.85	257.56	256.39	256.42	251.11	252.27	257.23	259.54	262.08	261.24	259.61	259.48	254.22	251.43	249.17	
Dairy cattle	**2023**	62.10	53.93	50.70	51.58	53.23	53.55	53.55	54.58	55.25	56.01	55.90	55.84	55.41	55.63	54.85	53.81
	2022	62.19	54.13	50.82	51.39	52.87	53.48	53.79	55.15	56.27	57.48	57.79	58.21	58.22	58.88	59.09	
Other cattle	**2023**	81.36	66.68	63.90	59.07	61.71	58.81	58.07	58.48	58.16	57.19	55.93	54.46	52.53	51.02	49.64	48.55
	2022	91.43	78.85	76.86	71.97	73.10	71.17	71.64	73.40	74.47	74.55	74.32	73.70	72.46	71.69	70.41	
Swine	**2023**	120.10	90.66	94.17	96.65	90.80	91.28	93.14	90.97	90.92	88.61	86.73	86.30	82.18	79.34	78.56	72.41
	2022	121.81	91.84	95.23	97.70	91.92	92.81	95.19	93.59	94.09	92.36	91.07	91.20	87.44	85.01	84.75	
poultry	**2023**	22.94	21.72	24.64	26.35	24.64	26.36	28.10	28.83	28.63	28.23	27.79	27.58	27.13	26.73	25.68	25.64
	2022	22.84	21.58	24.10	25.93	24.79	26.62	28.46	29.33	29.25	28.95	28.64	28.52	28.22	27.95	27.00	
Other animals	**2023**	9.59	11.16	9.37	9.43	8.43	8.18	8.16	8.07	8.00	7.89	7.79	7.85	7.88	7.90	7.93	7.98
	2022	9.59	11.16	9.37	9.43	8.43	8.18	8.16	8.07	8.00	7.89	7.79	7.85	7.88	7.90	7.93	

NO$_x$ emissions from manure management, in Gg																
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Total	**2023**	1.731	1.554	1.517	1.509	1.489	1.461	1.439	1.436	1.441	1.432	1.421	1.408	1.383	1.368	1.346	1.307
	2022	1.731	1.554	1.516	1.505	1.487	1.460	1.439	1.437	1.444	1.436	1.427	1.416	1.393	1.379	1.365	
Dairy cattle	**2023**	0.671	0.597	0.570	0.551	0.525	0.519	0.502	0.501	0.505	0.508	0.508	0.504	0.504	0.507	0.502	0.492
	2022	0.671	0.597	0.570	0.553	0.524	0.517	0.501	0.499	0.503	0.507	0.506	0.503	0.503	0.507	0.506	
Other cattle	**2023**	0.690	0.604	0.587	0.551	0.553	0.533	0.530	0.539	0.544	0.543	0.540	0.535	0.526	0.520	0.505	0.494
	2022	0.690	0.604	0.587	0.550	0.548	0.529	0.525	0.534	0.539	0.538	0.535	0.530	0.521	0.515	0.506	
Swine	**2023**	0.281	0.256	0.270	0.313	0.317	0.314	0.311	0.299	0.296	0.285	0.277	0.273	0.258	0.246	0.244	0.226
	2022	0.281	0.256	0.270	0.309	0.320	0.318	0.317	0.307	0.305	0.295	0.289	0.287	0.273	0.262	0.258	
poultry	**2023**	0.026	0.024	0.027	0.032	0.038	0.042	0.042	0.045	0.045	0.045	0.045	0.045	0.044	0.044	0.043	0.043
	2022	0.026	0.024	0.027	0.032	0.039	0.042	0.043	0.045	0.045	0.045	0.045	0.045	0.045	0.044	0.044	
Other animals	**2023**	0.063	0.073	0.062	0.062	0.055	0.053	0.053	0.053	0.052	0.051	0.051	0.051	0.051	0.052	0.052	0.052
	2022	0.063	0.073	0.062	0.062	0.055	0.053	0.053	0.053	0.052	0.051	0.051	0.051	0.051	0.052	0.052	

Planned improvements

No improvements are planned at present.

NMVOC

In 2021, NMVOC emissions from manure management amount to 281.2 kt which is 96.8 % of total NMVOC emissions from the agricultural sector. 84.6 % originate from cattle, 4.5 % from pigs, and 9.7 % from poultry.

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. The use of the Tier 2 methodology deliversyields NMVOC emissions which formally could be reported in the sectors 3.D.a.2.a (application of manure to soils) and 3.D.a.3 (grazing emissions). However, to be congruent with the NMVOC emissions for other animal categories, Germany reports these emissions in the NMVOC emissions reported from manure management (3.B). For the NFR codes 3.D.a.2.a and 3.D.a.3 the key note IE is used for NMVOC emissions.

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:

- gross feed intake in MJ per year, country specific data from the annual reporting of greenhouse gas emissions, see NIR 2023, Chapter 5.1.3.3,
- proportion x_{house} of the year the animals spend in the livestock building: country specific data, being equal to 1 – x_{graz} with x_{graz} the proportion of the year spent on pasture, see NIR 2023, Chapter 19.3.2,
- $FRAC_{silage}$: 1 as proposed by EMEP (2019)-3B-29, since silage feeding for cattle is considered dominant in Germany
- $FRAC_{silage\ store}$: 0.25 as proposed by EMEP (2019)-3B-30 for European conditions
- $EF_{NMVOC,\ silage\_feeding}$, $EF_{NMVOC,\ house}$, $EF_{NMVOC,\ graz}$ are taken from EMEP (2019)-3B-32, table 3.11 as 0.0002002, 0.0000353 and 0.0000069 kg NMVOC/MJ feed intake, respectively,
- $EF_{NH_3,storage}$, $EF_{NH_3,building}$ and $EF_{NH_3,application}$ are taken from the NH_3 reporting (see above and 3.D).

For all other animal categories the Tier 1 emission factors for NMVOC were used as provided in EMEP (2019)-3B-18, Table 3.4. For horses the emission factors for feeding with silage was chosen, for all other animals the emission factors for feeding without silage. Due to missing country-specific emission factors or emission factors that do not correspond to the inventory’s animal categories, the emission factors provided in EMEP (2019)-3B-18, Table 3.4, were used to define specific emission factors for weaners, boars, lambs, ponies/light horses and pullets, see Rösemann et al. (2023), Chapter 4.3.3. The implied emission factors given in Table 4 relate the overall NMVOC emissions to the number of animals in each animal category. The IEFs for dairy cattle and other cattle are much higher than the EMEP Tier 1 EF, which are 17.937 kg NMVOC for dairy cattle and 8.902 kg NMVOC for other cattle. The only possible explanation for those huge differences is that the EMEP Tier 2 and Tier 1 methods are not consistent.

The IEFs for the other categories provided in Table 4 correspond to the EMEP Tier 1 emission factors, except for horses, sheep, swine and other poultry. These categories comprise subcategories with different emission factors so that their overall IEFs in Table 4 represent subpopulation-weighted national mean values. Note that other poultry in Germany includes not only geese and ducks but also pullets. For pullets no default EF is given in the EMEP guidebook (EMEP, 2019), hence the EF of broilers has been adopted (because of similar housing). This assumption significantly lowers the overall IEF of other poultry in Table 4 the IEFs are listed separately for each poultry category). The IEF of the sheep category is significantly lower than the EMEP Tier 1 emission factor, because for lambs the EF is assumed to be 40% lower compared to an adult sheep in accordance with the difference in N excretion between lambs and adult sheep.

Table 4: IEF for NMVOC from manure management

	IEF in kg NMVOC per animal place															
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
dairy cattle	30.939	32.691	35.437	36.558	37.249	37.614	37.628	37.468	37.885	38.142	38.501	38.438	39.196	39.968	40.525	40.637
other cattle	11.714	11.672	11.782	11.638	11.652	11.565	11.496	11.462	11.371	11.350	11.280	11.252	11.235	11.265	11.330	11.382
horses	6.497	6.491	6.688	6.660	6.644	6.643	6.642	6.641	6.644	6.646	6.648	6.651	6.654	6.657	6.660	6.663
sheep	0.131	0.131	0.132	0.132	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.132
goats	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542
swine	0.695	0.698	0.690	0.682	0.669	0.663	0.656	0.654	0.652	0.651	0.649	0.648	0.648	0.648	0.642	0.645
laying hens	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165
broilers	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	0.108	0.108
turkeys	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	0.489	0.489
pullets	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	0.108	0.108
ducks	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	0.489	0.489
geese	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	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: $R^2 = 0.867$; other cattle: $R^2 = 0.993$).

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 slightly lower for dairy cattle and other cattle. This is mostly due to **recalculation reason No. 2**(deep bedding), see main page of the agricultural sector). This changes the NH_3 emissions which have impact on the Tier 2 methodology which is applied for cattle NMVOC emissions. For other animals there are no differences. Further details on recalculations are described in Rösemann et al. (2023), Chapter 1.3.

Table REC-3: Comparison of NMVOC emissions of the submissions (SUB) 2021 and 2022

NMVOC emissions from manure management, in Gg																	
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Total	**2023**	390.91	332.32	318.01	296.90	296.25	296.36	298.20	303.25	305.49	304.13	300.85	297.81	293.76	290.79	286.92	281.15
	2022	391.24	332.95	318.87	298.26	297.23	297.42	299.37	304.56	306.95	305.72	302.74	299.98	296.20	293.49	289.79	
Dairy cattle	**2023**	196.60	170.95	161.94	154.87	155.82	157.61	157.68	159.90	162.74	163.42	162.39	161.40	160.74	160.34	158.92	155.75
	2022	196.61	170.97	162.10	155.51	155.79	157.59	157.67	159.89	162.77	163.48	162.60	161.76	161.25	161.00	159.99	
Other cattle	**2023**	153.85	124.43	117.46	102.42	100.54	96.46	95.63	96.49	96.04	94.78	93.05	90.94	88.18	85.93	83.62	82.03
	2022	154.16	125.04	118.15	103.14	101.55	97.54	96.82	97.80	97.48	96.31	94.72	92.75	90.10	87.97	85.42	
Other animals	**2023**	40.46	36.94	38.62	39.61	39.89	42.29	44.89	46.87	46.70	45.93	45.42	45.47	44.85	44.52	44.38	43.37
	2022	40.46	36.94	38.62	39.61	39.89	42.29	44.89	46.87	46.70	45.93	45.42	45.47	44.85	44.52	44.38	

Planned improvements

No improvements are planned at present.

TSP, PM10 and PM2.5

In 2020, TSP emissions from manure management amount to 71.3 % of total emissions from the agricultural sector. Within the emissions from manure management 22.5 % originate from cattle, 39.5 % from pigs, and 37.4 % from poultry. 42.8 % of the PM_{10} emissions from the agricultural sector are caused by manure management, where 34.4 % originate from cattle, 19.1 % from pigs, and 45.6 % from poultry. $PM_{2.5}$ emissions from the agricultural sector mostly originate from manure management (84.9 %), of which are 78.0 % from cattle, 3.0 % from pigs, and 17.5 % from poultry.

Method

EMEP (2013-3B-26) provided a Tier 2 methodology. In the current Guidebook (EMEP, 2019), this methodology has been replaced by a Tier 1 methodology. However, EF for cattle derived with the EMEP 2013 Tier 2 methodology remained unchanged. Therfore, the EMEP 2013[10)] methodology was kept for cattle. For swine the EMEP 2013 methodology was formally kept but the EMEP 2019 Tier 1 EF was used both for slurry and solid based manure management systems. The same was done with the EMEP 2016 EFs for laying hens (used for cages and perchery). In case the EMEP 2019 EFs are simply rounded EMEP 2013 EFs, the unrounded EMEP 2013 EFs were kept. The inventory considers air scrubber systems in swine and poultry husbandry. For animal places equipped with air scrubbing the emission factors are reduced according to the removal efficiency of the air scrubber systems (90 % for TSP and PM_{10}, 70 % for $PM_{2.5}$). For details see Vos et al. (2022), Chapter 3.3.4.3.3.

Activity data

Animal numbers serve as activity data, see Table 1.

Emission factors

Tier 1 emission factors for TSP, PM_{10} and $PM_{2.5}$ from livestock husbandry are provided in EMEP (2019-3B-19), Table 3.5 and

55, Table A1.7. For cattle the Tier 2 emission factors provided in EMEP (2013-3B-29), Table 3-11 were used, because they differentiate between slurry and solid manure systems and were also used to develop the EMEP 2019 Tier 1 emissions factors.

The implied emission factors given in Table 5 relate the overall TSP and PM emissions to the number of animals in each animal category. The Guidebook does not indicate whether EFs have considered the condensable component (with or without).

Table 5: IEF for TSP, PM_{10} & $PM_{2.5}$ from manure management

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
IEF in kg TSP per animal place															
dairy cattle	1.2124	1.4016	1.4544	1.4738	1.4882	1.4953	1.5028	1.5101	1.5189	1.5270	1.5365	1.5451	1.5540	1.5631	1.5721
other cattle	0.5194	0.5107	0.5017	0.4916	0.4804	0.4790	0.4788	0.4788	0.4775	0.4766	0.4763	0.4760	0.4758	0.4751	0.4746
horses	0.3514	0.3512	0.3558	0.3552	0.3548	0.3548	0.3548	0.3548	0.3548	0.3549	0.3549	0.3550	0.3551	0.3551	0.3552
sheep	0.0484	0.0478	0.0489	0.0486	0.0489	0.0485	0.0485	0.0485	0.0483	0.0482	0.0482	0.0482	0.0480	0.0482	0.0482
goats	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914
swine	0.8260	0.8366	0.8320	0.8247	0.8104	0.8043	0.8086	0.8037	0.8002	0.7910	0.7918	0.7891	0.7865	0.7813	0.7858
laying hens	0.1900	0.1900	0.1900	0.1900	0.1900	0.1900	0.1900	0.1900	0.1900	0.1899	0.1898	0.1897	0.1894	0.1890	0.1889
broilers	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0399	0.0399	0.0397	0.0396	0.0395	0.0394	0.0394
turkeys	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	0.1100
pullets	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400
ducks	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	0.1400
geese	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	0.2400
IEF in kg PM_{10} per animal place															
dairy cattle	0.5557	0.6426	0.6668	0.6757	0.6823	0.6855	0.6890	0.6923	0.6964	0.7001	0.7044	0.7084	0.7125	0.7166	0.7208
other cattle	0.2403	0.2363	0.2320	0.2273	0.2221	0.2214	0.2213	0.2213	0.2207	0.2203	0.2202	0.2200	0.2200	0.2196	0.2194
horses	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	0.1636
sheep	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	0.0193
goats	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	0.0368
swine	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	0.1141
laying hens	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	0.0398
broilers	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	0.0197
turkeys	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	0.1100
pullets	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	0.0200
ducks	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	0.1400
geese	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	0.2400
IEF in kg $PM_{2.5}$ per animal place															
dairy cattle	0.3616	0.4181	0.4338	0.4396	0.4439	0.4460	0.4483	0.4505	0.4531	0.4555	0.4583	0.4609	0.4636	0.4663	0.4690
other cattle	0.1574	0.1548	0.1520	0.1490	0.1457	0.1453	0.1452	0.1452	0.1448	0.1445	0.1445	0.1444	0.1443	0.1441	0.1439
horses	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	0.1038
sheep	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	0.0059
goats	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	0.0112
swine	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	0.0051
laying hens	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	0.0030
broilers	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	0.0020
turkeys	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	0.0200
pullets	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	0.0020
ducks	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	0.0180
geese	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	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 (0.78). 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 2000 through 2019 are a consequence of the use of the data of the official agricultural census 2020 as well as new animal population figures for the years 2017-2019 (**recalculation reason 1**, see main page of the agricultural sector). Further details on recalculations are described in Vos et al. (2022), Chapter 3.5.2.

Table REC-4: Comparison of particle emissions (TSP, PM_{10} & $PM_{2.5}$) of the submissions (SUB) 2021 and 2022

TSP, PM10, PM2.5 emissions from manure management, in Gg																
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
TSP	**2022**	50.04	42.24	42.43	41.25	40.30	41.80	43.95	45.14	45.45	44.74	44.54	44.59	43.65	43.04	42.99
TSP	**2021**	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	
PM_{10}	**2022**	14.34	12.71	12.63	12.29	12.31	12.76	13.33	13.84	13.82	13.63	13.48	13.43	13.20	13.02	12.91
PM_{10}	**2021**	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	
$PM_{2.5}$	**2022**	5.01	4.47	4.18	3.89	3.85	3.87	3.93	4.03	4.04	4.02	3.97	3.94	3.86	3.79	3.72
$PM_{2.5}$	**2021**	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	

For **pollutant-specific information on recalculated emission estimates for Base Year and 2019**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

No improvements are planned at present.

Uncertainty

Details will be described in chapter 1.7.

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