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Ammonia emissions from animal manure and inorganic fertilisers in 2009

Calculated with the Dutch National Emissions Model for Ammonia (NEMA)

C. van Bruggen, C.M. Groenestein, B.J. de Haan, M.W. Hoogeveen, J.F.M. Huijsmans, S.M. van der Sluis & G.L. Velthof

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Wettelijke Onderzoekstaken Natuur & Milieu

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Ammonia emissions from animal manure and inorganic fertilisers in 2009

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C. van Bruggen

C.M. Groenestein

B.J. de Haan

M.W. Hoogeveen

J.F.M. Huijsmans

S.M. van der Sluis

G.L. Velthof

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Authors:
C. van Bruggen (CBS)
C.M. Groenestein (Wageningen UR Livestock Research)
B.J. de Haan (PBL)
M.W. Hoogeveen (LEI Wageningen UR)
J.F.M. Huijsmans (PRI Wageningen UR)
S.M. van der Sluis (PBL)
G.L. Velthof (Alterra Wageningen UR)

Centraal Bureau voor de Statistiek (CBS)
Postbus 24500, 2490 HA Den Haag
Tel: (070) 337 38 00; www.cbs.nl

Wageningen UR Livestock Research
Postbus 65, 8200 AB Lelystad
Tel: (0320) 238 238; e-mail: info.livestockresearch@wur.nl

Planbureau voor de Leefomgeving (PBL)
Postbus 303, 3720 AH Bilthoven
Tel: (030) 274 27 45; e-mail: info@pbl.nl

LEI Wageningen UR
Postbus 29703, 2502 LS Den Haag
Tel: (070) 335 83 30; e-mail: informatie.lei@wur.nl

Wageningen UR Plant Research International (PRI)
Postbus 16, 6700 AA Wageningen
Tel: (0317) 48 60 01; e-mail: info.pri@wur.nl

Alterra Wageningen UR
Postbus 47, 6700 AA Wageningen
Tel: (0317) 48 07 00; e-mail: info.alterra@wur.nl

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Statutory Research Tasks Unit for Nature & the Environment**,** P.O. Box 47, NL-6700 AA Wageningen, The Netherlands
Phone: +31 317 48 54 71; e-mail: info.wnm@wur.nl; Internet: www.wotnatuurenmilieu.wur.nl

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Contents

Summary

Table 1 presents data on a number of years of ammonia emissions from agriculture. The series have been calculated with the Dutch National Emissions Model for Ammonia (NEMA) (Velthof *et al.*, 2009; Van Bruggen *et al.,* 2011).

Ammonia emissions from agriculture have decreased by two thirds, since 1990. One of the main reasons for this decrease has been a reduction in nitrogen excretion by farm animals. In 1990 this excretion contained 690 million kilograms of nitrogen (N), an amount that was reduced to 484 million kilograms in 2009. Another reason for the decrease in ammonia emissions has been an increase in the distribution of animal manure outside the agricultural sector, including exports; from 20 million kilograms of nitrogen in 1990, to 64 million kilograms in 2009.

Of the total decline in NH_3 emissions nearly 80% was related to manure spreading. Reductions in the emissions from animal housing and manure storage were responsible for a further 13%. Grazing had a 7% share in the decline and inorganic fertiliser contributed a further 2%.

Table 1. Ammonia emissions from agriculture (million kg NH_3)

	1990	1995	2000	2005	2008	2009
Dairy cows						
Housing and storage	21.6	20.0	14.3	13.9	14.3	13.8
Pasture	9.0	8.0	2.2	1.5	1.1	0.6
Application	90.3	27.6	21.4	21.4	20.3	20.5
Total	120.9	55.6	37.9	36.7	35.7	34.8
Other cattle						
Housing and storage	12.8	13.0	10.1	7.8	8.2	8.3
Pasture	7.0	6.2	2.2	1.4	0.8	0.6
Application	43.2	16.9	13.2	10.0	8.9	8.8
Total	63.0	36.1	25.4	19.3	18.0	17.7
Other grazing livestock						
Housing and storage	1.0	1.2	1.3	1.2	1.2	1.1
Pasture	1.8	1.7	0.7	0.4	0.3	0.2
Application	1.1	1.4	1.6	1.4	1.2	1.2
Total	4.0	4.3	3.6	3.1	2.7	2.6
Pigs						
Housing and storage	34.7	33.8	24.5	17.8	18.9	19.1
Application	63.5	19.4	14.6	11.2	6.5	7.1
Total	98.3	53.3	39.1	29.0	25.4	26.2
Poultry, rabbits and fur-bearing animals						
Housing and storage	16.3	16.2	16.9	14.1	13.6	14.1
Application	16.6	7.9	8.6	5.7	3.4	2.4
Total	32.9	24.2	25.5	19.7	17.0	16.4
Total animal manure						
Housing and storage	86.5	84.3	67.1	54.7	56.2	56.3
Pasture	17.8	16.0	5.1	3.3	2.2	1.4
Application	214.8	73.3	59.2	49.7	40.4	40.0
Total	319.1	173.5	131.5	107.8	98.9	97.8
Inorganic fertiliser	13.9	14.0	12.0	13.0	10.1	10.1
Total	333.0	187.5	143.5	120.8	109.0	107.9

Figure 1 shows the development of NH_3 emissions from animal manure in housing and storage, in pastures, and from manure application. The decline in NH_3 emissions was greatest during the first half of the 1990s, due to implementation of low-emission application techniques. Annual ammonia emission levels are not always lower than those in their preceding year. In 1991, for example, nitrogen excretion levels were higher than in 1990, causing an increase in manure spreading. This included a larger amount of manure being applied to grassland with, on average, higher emission factors. This also occurred in 1993.

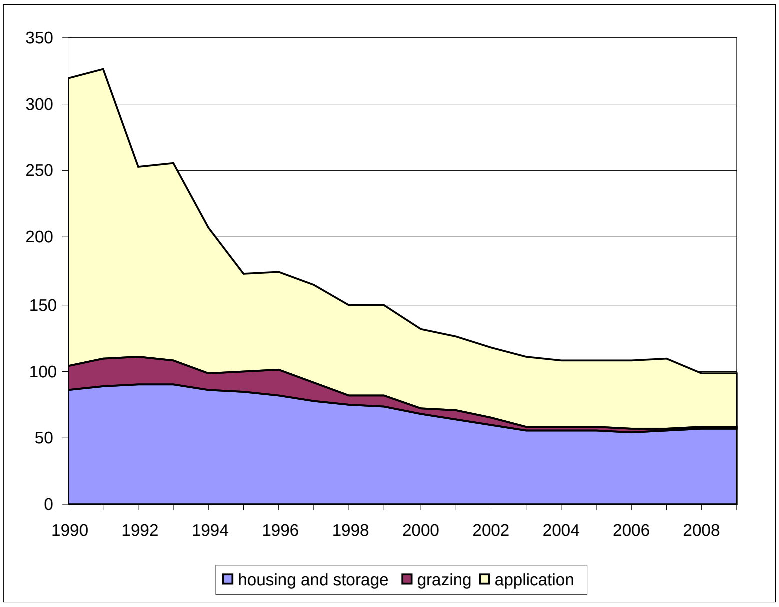

Figure 1. Ammonia emissions from animal manure in agriculture (million kg NH_3)

Figure 2 shows the development of NH_3 emissions in agriculture, per animal category.

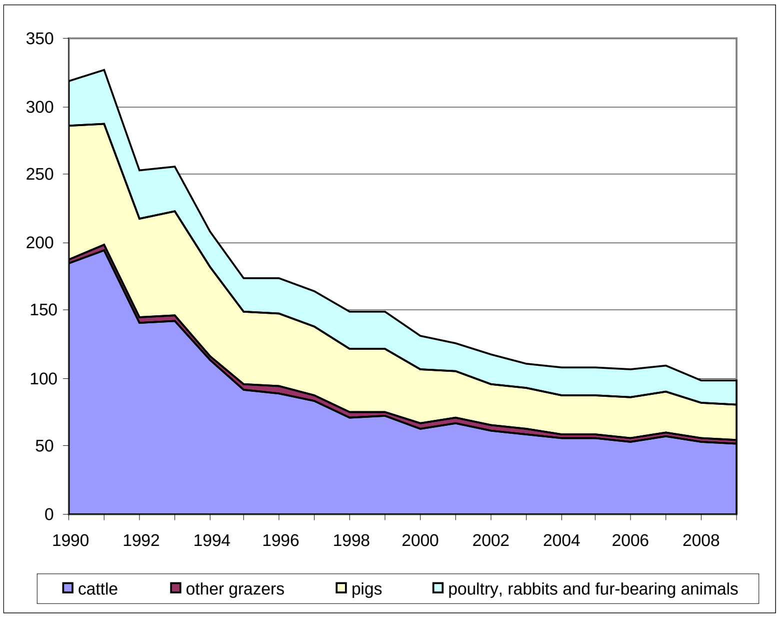

Figure 2. Ammonia emissions from agriculture, per animal category (million kg NH_3)

Ammonia emission levels in 2009 were similar to those in 2008. There was, however, a decrease in emissions in pastures because of the low N content in dairy-cow rations during grazing seasons (Section 2.10) and a shift in manure production from pastures to animal housing (CBS, 2011).

Chapter 4 presents a table with elaborate data on NH_3 emissions from agriculture.

Some animal manure is being produced outside the agricultural sector, such as by horses and ponies that are not included in the agricultural census. In addition, a share of manure is being applied outside the agricultural sector; for example, in nature areas and on hobby farms and private properties. Table 2 presents a summary of ammonia emissions from animal manure and inorganic fertilisers outside the agricultural sector.

Table 2. Ammonia emissions outside the agricultural sector (million kg NH_3)

	1990	**1995**	**2000**	**2005**	**2008**	**2009**
Total animal manure						
Housing and storage	1.3	1.3	1.3	1.3	1.2	1.2
Pasture	0.7	0.7	0.3	0.3	0.6	0.4
Application	6.9	4.0	2.7	4.2	2.9	3.0
Total	8.9	6.0	4.3	5.8	4.7	4.6
Inorganic fertiliser	0.6	0.6	0.7	0.9	0.8	0.8
Total	9.5	6.7	4.9	6.7	5.5	5.4

In animal housing and manure storage, in addition to ammonia emissions, other N compounds are also emitted (Table 3). However, indirect emissions of other N compounds formed after manure application on soils are outside the scope of this report.

Table 3. Emission levels of other gaseous nitrogen losses from manure in animal housing and from manure stored outside animal housing (million kg N)

	1990	**1995**	**2000**	**2005**	**2008**	**2009**
Agriculture						
N_2O	2.2	2.2	1.9	1.7	1.9	1.9
NO	2.2	2.2	1.9	1.7	1.9	1.9
N_2	13.7	13.3	11.3	10.2	11.0	11.1
Outside agriculture						
N_2O	0.2	0.2	0.2	0.2	0.1	0.1
NO	0.2	0.2	0.2	0.2	0.1	0.1
N_2	0.8	0.8	0.8	0.8	0.7	0.7
Total						
N_2O	2.4	2.4	2.1	1.9	2.0	2.0
NO	2.4	2.4	2.1	1.9	2.0	2.0
N_2	14.5	14.1	12.1	11.0	11.7	11.9

1 Introduction

This working document is a translation of WOt-working document 251 (in Dutch).

Ammonia emissions from animal manure and inorganic fertiliser in 2009 was calculated using the Dutch National Emissions Model for Ammonia (NEMA). The methodology is described by Velthof *et al*. (2009).

Van Bruggen *et al.* (2011) present the basic assumptions used in calculations of ammonia emissions over the 1990–2008 period.

The current report describes the basic assumptions used in calculations of ammonia emissions of 2009.

2 Basic assumptions animal manure

2.1 Animal numbers

Table 2.1 provides an overview of animal numbers. The numbers for 2009 were obtained from the agricultural census as described in Van Bruggen *et al.* (2011), as are those for the 1990–2008 period.

Table 2.1. Number of animals (x 1,000)

Animal category	**2008**	**2009**
Dairy and breeding cattle		
Female young stock, 12 months and under	532	577
Male young stock, 12 months and under	34	33
Female young stock, 12 months and over	589	613
Male young stock, 12 months and over, including stud bulls	23	22
Dairy cows	1,466	1,489
Beef cattle		
Fattening calves, in white-meat production	627	625
Fattening calves, in pink-meat production	272	269
Female young stock, 12 months and under	43	41
Male young stock (incl. oxen), 12 months and under	54	53
Female young stock, 12 months and over	63	65
Male young stock (incl. oxen), 12 months and over	61	57
Suckler cows, feedlot cows and grazing cows, 24 months and over	127	123
Ewes	583	538
Dairy goats	208	231
Horses	93	94
Ponies	51	51
Fattening pigs	5,839	5,872
Gilts and young boars	236	253
Sows	978	985
Boars	8	8
Broilers, parent animals of 18 weeks and under	2,386	2,646
Broilers, parent animals of 18 weeks and over	4,863	4,288
Laying hens, 18 weeks and under	11,508	11,347
Laying hens, 18 weeks and over	33,586	35,294
Broilers	44,358	43,285
Meat ducks, including parent animals	1,064	1,157
Turkeys	1,044	1,060
Rabbits (does)	41	41
Mink (female parents)	849	870

Source: Agricultural census (Landbouwtelling, CBS, 2011)

NB Not included in the table are animal categories for which the excretion data was incorporated in that on female parents (piglets, male animals, and the young in breeding systems of sheep, goats, rabbits and fur-bearing animals).

2.2 Excretion of N, TAN and P

The working group for uniformity of calculations on manure and nutrient data (*Werkgroep Uniformering berekening Mest- en mineralencijfers* (WUM)) each year calculates N excretions per animal, including the apportionment to housing and grazing seasons. For the calculation of excretion factors per animal, certain animal categories have been combined in order to match the available index numbers on feed use and animal production (WUM, 2010).

In addition to N excretion data, the share in TAN (total ammonia nitrogen) also was determined. Here, TAN has been defined as urine N and mainly consists of urea. In order to determine the TAN excretion, information on N digestibility of animal rations was required. Table 2.2 shows the N digestibility that was used in calculating TAN excretion for 2009. Hardly any changes occurred, compared to the data for 2008. The methodology for determining N digestibility is described in Van Bruggen et al. (2011).

Table 2.2. Faecal nitrogen digestibility of feed (%) in 2009

	N digestion coefficient
	%
Grass silage	74.6
Grass silage from extensively managed grassland	72.1
Maize silage	46.6
Meadow grass	81.8
Meadow grass of extensively managed grassland	77.8
Dairy cattle	
standard compound feed	76.7
protein-rich compound feed	83.5
Beef cattle	
Starting feed for beef bulls	83.3
Finishing feed for beef bulls	78.8
Starting feed for fattening calves for pink-meat production	80.0
Finishing feed for fattening calves for pink-meat production	79.9
Compound feed for pigs	
Fattening pigs	79.4
Gilts	79.6
Sows, including piglets up to 25 kilograms	78.3
Boars	75.1
Compound feed for poultry	
Laying hens of 18 weeks and under	82.0
Laying hens of 18 weeks and over	84.3
Broilers, parent animals of 18 weeks and under	80.0
Broilers, parent animals of 18 weeks and over	81.9
Broilers	85.3
Meat ducks	84.6
Meat turkeys	86.7

Sources: Bikker et al. 2011 and WUM

TAN was calculated on the basis of N excretion and N digestibility of rations. Amounts of N and P excretions and shares of TAN for housing and pasture are indicated in Table 2.3. Apportionment of dairy cow excretions to housing and pasture during grazing seasons is described in the following paragraph. For elaboration on changes in data between 2008 and 2009, see CBS (2011).

Table 2.3. N and P excretion (in kg/animal.year) and share of TAN (%), 2009

	Excretion in animal housing			Excretion in pasture[1)]		
	N	TAN	P_2O_5	N	TAN	P_2O_5
Dairy and breeding cattle						
Female young stock, 12 months and under	28.8	66	8.1	7.1	78	1.7
Male young stock, 12 months and under	33.2	62	8.3			
Female young stock, 12–24 months	45.0	68	13.8	28.2	76	8.4
Male young stock, 12–24 months	84.4	70	27.1			
Female young stock, 24 months and over	45.0	68	13.9	28.2	76	8.4
Dairy cows - housing period	66.0	59	21.3			
Dairy cows - grazing season	38.2	62	11.9	22.8	62	7.0
Stud bulls, 24 months and over	84.4	70	27.1			
Beef cattle						
Fattening calves, in white-meat production	10.6	65	4.4			
Fattening calves, in pink-meat production	28.0	58	8.9			
Female young stock, 12 months and under	28.4	65	8.0	7	79	1.7
Male young stock, incl. oxen, 12 months and under	26.9	54	7.9			
Female young stock, 12–24 months	44.1	68	13.6	28.6	76	8.6
Male young stock, incl.oxen, 12–24 months	54.9	60	19.0			
Female young stock, 24 months and over	44.1	68	13.6	28.6	76	8.5
Male young stock, incl. oxen, 24 months and over	54.9	60	19.0			
Suckler cows, feedlot cows and grazing cows	37.9	65	13.0	44.9	75	14.0
Ewes	1.4	66	0.5	12.5	74	3.9
Dairy goats	16.1	58	6.3			
Horses	30.3	73	12.0	28.2	75	10.6
Ponies	13.2	74	5.1	18.9	78	6.7
Fattening pigs	12.7	68	5.1			
Gilts and young boars of 50 kg and under	13.6	70	6.4			
Sows	30.3	65	15.1			
Young boars 50 kg and over	13.6	70	6.4			
Boars	23.2	72	12.2			
Broilers, parent animals of 18 weeks and under	0.3	69	0.2			
Bropilers, parent animals of 18 weeks and over	1.1	77	0.6			
Laying hens, 18 weeks and under	0.3	75	0.2			
Laying hens, 18 weeks and over	0.8	78	0.4			
Broilers	0.5	71	0.2			
Meat ducks	0.8	70	0.4			
Turkeys	2.0	77	1.0			
Rabbits (does)	7.7	70	3.8			
Mink (female parents)	1.9	70	1.0			

[1)] Only applicable to categories of animals with grazing seasons.

Apportionment of dairy cow excretions to housing and pasture

Apportionment of excretions to housing and pasture for 2009 was based on data from the agricultural census 2010, which included data on grazing from 2009. This resulted in information on duration of housing and grazing seasons, and distribution of dairy cows over grazing systems. The grazing systems applied and the duration of daytime grazing together determine the amounts of excretion in animal housing during grazing seasons for dairy cows. Excretion amounts in animal housing for day and night grazing and for daytime grazing were assumed to be proportional to the number of barn hours (WUM, 2010).

As emission factors are calculated per housing system, the amount of nitrogen excreted within animal housing must be determined for each grazing system applied (unlimited grazing, limited grazing, or full-time housing). It is assumed that tie stalls and compost barns are only used in combination with unlimited grazing (Oenema *et al.,* 2000). This would mean that, during grazing seasons, 15% of excretions by dairy cows ends up inside their housing systems. To determine excretion levels in cubicle housing systems for dairy cows during grazing seasons, the apportionment to grazing systems was corrected for the numbers of tie stalls and compost barns. Subsequently, shares of the excretions within animal housing per grazing system were used for determining the contribution in nitrogen excretion, for cubicle housing, including other housing types not studied (Table 2.4).

Table 2.4. Contribution of grazing systems to N excretions within animal housing during grazing seasons of dairy cows, housed in cubicle housing systems

Grazing systems	**Number of dairy cows (lbt2010)**	**Share of tie stalls and compost barns (lbt2008)**	**Share of dairy cows, excl. tie stalls and compost barns**	**Excretions in housing systems during grazing seasons, per grazing system**	**Share per grazing system in N excretions within cubicle housing**
	%	%	%	%	
Unlimited grazing	22	5.8	17	15	4
Limited grazing	54		58	67	58
Full-time housing	24		28	100	38
Total	100		100		100

Sources: Agricultural census 2010 (Landbouwtelling, (lbt2010)) and 2008 (lbt2008).

2.3 Mineralisation and immobilisation

In calculations of TAN excretion, 10% net mineralisation of organic N excretion was taken into account for liquid cattle and pig manure. It was assumed that such mineralisation takes place immediately following excretion within animal housing. TAN levels and emissions from animal housing may have been slightly overestimated for housing systems that are mucked out regularly.

For solid manure from grazing livestock and pigs, a 25% immobilisation of TAN immediately following excretion was assumed (Van Bruggen *et al.,* 2011).

2.4 Housing of farm animals

For 2009 no new information was available on the housing of farm animals. Therefore, information on animal places related to liquid manure and those related to solid manure was based on data from the agricultural census of 2008. The same is true for degrees of implementation of housing systems and derived emission factors (Van Bruggen et al., 2011).

2.5 Emission factors of N_2O, NO and N_2

Calculations of other gaseous N losses from indoor-produced manure were based on calculations of N_2O emissions according to IPCC guidelines (IPCC, 1996; GPG, 2001) and Oenema et al. (2000). Emission factors per type of manure are elaborated in Van Bruggen et al. (2011).

2.6 Manure storage outside animal housing

Shares of manure stored outside housing systems have not changed from those of 2008, with the exception of poultry litter of broilers and ducks. Shares of exports and incineration were taken into account in the determination of storage of poultry litter outside housing systems. The share of broiler litter stored outside housing systems decreased from 40% in 2008 to 35% in 2009. Storage of duck litter increased from 85% to 90%. Emission factors for manure storage have not been adjusted (Van Bruggen et al., 2011).

2.7 Manure distribution outside agriculture

2.7.1 Introduction

Emissions from manure production or from distribution outside agriculture have been addressed separately in calculations for environmental assessments and apportioned to consumers and consumer services. Examples are emissions from manure from horses not included in the agricultural census, and from manure application on hobby farms, private properties and nature areas.

Manure distribution outside agriculture includes:
- Distribution to hobby farms;
- Distribution to nature areas;
- Distribution to private properties;
- Manure treatment;
- Net export.

Data on manure distribution outside agriculture was based on assumptions and results from the project 'Monitoring the manure market' and from CBS research into manure treatment. For a description of these basic assumptions see Van Bruggen *et al.* (2011). To determine the distribution of phosphate in untreated solid manure, manure distribution volumes were assumed based on transport documentation and phosphate content according to the WUM. Table 2.5 presents an overview of phosphate contents.

Table 2.5. Phosphate content of solid manure (kg P_2O_5/t)

Type of manure	2008	2009
Horse and pony manure	2.3	2.3
Sheep manure	2.8	3.6
Goat manure	4.9	4.8
Laying poultry manure	21.6	22.1
Broiler manure	17.4	17.4
Duck manure	5.1	5.4
Turkey manure	19.3	19.3
Rabbit manure	9.5	10.1
Mink manure	11.5	9.6

NB For distribution outside the agricultural sector, mink manure is regarded as solid manure. Source: WUM

2.7.2 Hobby farms

Distribution to hobby farms, as presented in Table 2.6, was based on MAMBO model calculations for the project 'Monitoring the manure market 2009' (Luesink *et al.,* 2010).

Table 2.6. Distribution of animal manure from agriculture to hobby farms (million kg P_2O_5)

	2008	**2009**
Dairy cows - liquid manure	0.728	0.873
Dairy cows - solid manure	0.000	0.070
Young stock, including stud bulls - liquid manure	0.302	0.321
Young stock, including stud bulls - solid manure	0.083	0.087
Beef cattle, excluding fattening calves - liquid manure	0.063	0.202
Beef cattle, excluding fattening calves - solid manure	0.005	0.005
Sheep	0.000	0.027
Fattening calves	0.303	0.137
Fattening pig manure	0.392	0.381
Breeding pigs, liquid manure	1.625	1.526
Laying hens, liquid manure, untreated	0.000	0.000
Rabbits	0.053	0.045
Total	3.554	3.674

Source: MAMBO, Monitoring manure market

2.7.3 Nature areas

Total distribution to nature areas has not changed, compared to that in preceding years (Van Bruggen *et al.,* 2011). Apportionment to the animal categories in Table 2.7 was based on phosphate production in manure on pastures.

Table 2.7. Distribution of animal manure from agriculture to nature areas (million kg P_2O_5)

	2008	**2009**
Dairy cattle		
Female young stock, 12 months and under	0.132	0.154
Female young stock, 12–24 months	0.606	0.694
Female young stock, 24 months and over	0.095	0.112
Dairy cows	1.859	1.633
Beef cattle		
Female young stock, 12 months and under	0.011	0.011
Female young stock, 11–24 months	0.053	0.061
Female young stock, 11–24 months and over	0.023	0.027
Suckler cows, feedlot cows and grazing cows	0.251	0.270
Sheep	0.297	0.329
Horses	0.129	0.156
Ponies	0.045	0.054
Total	3.500	3.500

Source: MAMBO, Monitoring manure market

2.7.4 Private properties

Distribution to private properties (Table 2.8) was derived from transport documentation on animal manure. Distribution data includes manure pellets and spent mushroom compost (SMC). The relative small distribution of manure pellets to private properties is regarded to have been poultry manure.

Distribution of SMC was apportioned to horse manure and poultry manure based on the shares of these manure types in the production of substrate for mushroom cultivation. The share of horse manure was corrected for the share of companies that are not registered as agricultural businesses, and was estimated at two thirds of the total. Distribution of poultry manure in the form of SMC was apportioned to laying poultry and meat poultry, in proportion to the share of these manure types in the production of mushroom substrate, according to CBS research on manure treatment 2009.

Table 2.8. Distribution of animal manure from agriculture to private properties (million kg P_2O_5)

	2008	**2009**
Dairy cows - liquid manure	0.399	0.427
Sheep	0.005	0.005
Goats	0.015	0.012
Horses and ponies (untreated manure)	0.010	0.020
Horse and pony manure in SMC	0.015	0.016
Fattening calves	0.081	0.103
Fattening pig manure	0.589	0.704
Breeding pig manure	0.372	0.392
Poultry manure, including manure pellets		
Laying poultry liquid untreated manure	0.000	0.000
Laying poultry solid untreated manure	0.033	0.014
Broilers (untreated manure)	0.016	0.002
Ducks (untreated manure)	0.002	0.001
Turkeys (untreated manure)	0.000	0.000
Laying poultry manure in SMC	0.014	0.016
Broiler manure in SMC	0.020	0.019
Manure pellets	0.020	0.034
Rabbits	0.003	0.002
Mink	0.008	0.005
Total	1.602	1.772

Sources: Transportation documentation animal manure (National Service for the Implementation of Regulations (Dienst Regelingen)) and CBS research into manure treatment.

2.7.5 Manure treatment

Manure is removed from the agricultural sector by certain manure treatment processes, such as liquid calve-manure treatment systems and manure incineration. However, certain manure treatment methods may also add to the amount of ‘animal manure’. For instance, in the case of manure fermentation; its end-product (digestate) also contains N and P_2O_5 from co-substrates that were added to animal manure to increase the output of the fermentation process. Other products may also be added in the composting of manure. In the determination of manure distribution, both within and outside the agricultural sector, no account was taken of possible increases or decreases in the amounts of animal manure caused by certain forms of manure treatment, such as fermentation. Also, on balance, no removal of nitrogen or phosphate occurs during other manure treatment methods, such as manure separation combined with ultrafiltration.

Manure treatment products that are being distributed abroad have been included under exports.

Although, based on sampled data from liquid calve-manure treatment, an increase or decrease in the amount of phosphate may occur, the overall amount of phosphate in the treatment process stays the same. The balance, therefore, was set to zero. Data on liquid calve-manure treatment were obtained from the CBS research into manure treatment. In 2009, 1.35 million kilograms of nitrogen was removed in liquid calve-manure treatment.

The DEP power station in Moerdijk, in 2009, processed 3.2 million kilograms of phosphate in manure from broilers and turkeys, and 4.5 kilograms of phosphate in manure from laying hens, according to transport documentation on animal manure.

2.7.6 Net exports

Export data was based on transport documentation. All of the exported cattle manure was considered to be liquid manure from dairy cows, including cakes and filtrate after manure separation, and solid cattle manure (manure codes 10 to 14). Nitrogen export was calculated by multiplying exported phosphates with the average $N:P_2O_5$ ratio.

Export of spent mushroom compost (SMC) consisted mainly of poultry manure and that of horses and ponies. Total production of SMC was considered equal to the amount of this compost removed from agricultural businesses, hobby farms and other businesses, on the basis of transport documentation. The share of exported SMC, which is around 76%, could also be deduced from this documentation. Information on the amounts of poultry manure and horse manure that have been processed into substrate for mushroom cultivation was obtained from the CBS research into manure treatment. The shares of chicken and broiler manure in processed poultry manure are known. Their export in the form of SMC could be calculated by multiplying the processed amounts of phosphate (based on transport information) with the export share.

Export of horse-manure-related SMC was corrected for the amount of manure that would have come from horses not included in the agricultural census. This involves imported horse manure and nationally produced horse manure that does not originate from agricultural businesses. It was estimated that around one third of Dutch horse manure originated from agricultural businesses (Hoogeveen et al., 2010, Appendix 5). Export of agriculture-related horse manure in the form of SMC (phosphate), therefore, was calculated thus: (total processed horse manure minus imports) * 1/3 * export share * WUM content.

In addition to the export of agriculture-related horse manure in the form of SMC, there is also the export of untreated horse manure. It was assumed that, for the export of this manure, also one third originated from agricultural businesses. All imported horse manure was assumed subsequently to be exported in the form of SMC. The share of animal manure in the export of other compost and sewage treatment sludge was considered negligible.

All export of mink manure was calculated as being solid manure. Data on exported liquid mink manure was converted into data on solid manure by halving manure volumes (Hoogeveen et al., 2010 p.109).

Export of manure pellets in packages up to 25 kilograms is not included in transport documentation, as such documentation is not required for packages of this size. Distribution levels of manure pellets in small packages were derived from the supply of animal manure to treatment facilities and the registered output in manure pellets. Inquiries at a number of manure treatment facilities have shown that close to all manure pellets are exported. The distribution of these pellets was apportioned to laying poultry, meat poultry and cattle, on the basis of results from CBS research on manure treatment.

Export of treated and untreated manure is presented in Table 2.9.

Table 2.9. Net export of treated and untreated animal manure from the agricultural sector (million kg P_2O_5)

	2008	**2009**
Dairy cows - liquid manure	0.454	0.551
Goats	0.003	0.005
Horses and ponies (untreated manure)	0.033	0.044
Horse and pony manure in SMC	0.454	0.392
Fattening calves	0.035	0.031
Fattening pig manure	1.977	3.757
Breeding pig manure, liquid	2.300	1.489
Poultry manure, including manure pellets		
Laying poultry, liquid manure, untreated	0.000	0.000
Laying poultry, solid manure, untreated	9.368	9.823
Broilers (untreated manure)	4.035	2.937
Ducks (untreated manure)	0.049	0.037
Turkeys (untreated manure)	0.604	0.493
Laying poultry manure in SMC	0.520	0.497
Meat poultry manure in SMC	0.728	0.593
Manure pellets/dried	2.572	2.882
Rabbits	0.043	0.053
Mink and foxes	0.277	0.289
Total	23.453	23.873

Sources: Transportation documentation animal manure (National Service for the Implementation of Regulations (Dienst Regelingen)) and CBS research into manure treatment.

2.8 Manure application

2.8.1 Apportionment to grassland and arable land

The amount of nitrogen and phosphate applied to soils was calculated from data on manure production, gaseous losses from housing and storage, stock mutations and distribution outside the agricultural sector. Apportionment of manure from housing and storage to grassland and arable land in 2009, presented in Table 2.10, was based on that in the Monitoring of the manure market 2009.

Table 2.10. Application on grassland and arable land of animal manure from manure storage (%)

	2008		**2009**	
	Grassland	**Arable land**	**Grassland**	**Arable land**
Manure shares	47.5	52.5	48.7	51.3
Share per type of manure				

	2008		2009	
	Grassland	**Arable land**	**Grassland**	**Arable land**
Cattle				
Dairy cows	68.8	16.0	68.9	17.2
Young stock	11.2	8.0	10.2	10.6
Other cattle	4.6	3.1	4.4	2.9
Fattening calves	3.1	5.2	1.7	7.0
Other grazing livestock	2.9	2.6	2.8	3.1
Fattening pigs	2.7	39.7	5.2	37.5
Breeding pigs	6.2	15.3	6.5	16.5
Poultry				
Laying poultry	0.1	3.3	0.1	1.1
Meat poultry	0.0	5.3	0.0	2.4
Other confined animals	0.4	1.4	0.3	1.7
Total	100	100	100	100

Source: MAMBO, Monitoring manure market

2.8.2 Implementation of application techniques

In the agricultural census 2010, participants were queried about manure application of 2009. Results have been included in Van Bruggen *et al.* (2011). Table 2.11 presents data on the application techniques used in 2009. These data were also used for 2008.

For the calculation of application emissions, the various types of manure were first apportioned to grassland and arable land, based on results from Monitoring of the manure market (Section 2.8.1). A description of the method used for apportioning the application of liquid and solid manure to grassland and arable land to the various techniques, can be found in Van Bruggen *et al.* (2011).

Table 2.11. Share of application techniques (%)

	2009		
	average	**liquid manure**	**solid manure**
Grassland			
Shallow injection	56	60	-
Partly injection, partly narrow band	12	13	-
Trailing shoe and hose	23	25	-
Surface spreading	9	3	100
Total	100	100	100
Arable land			
Deep placement	61	68	-
Shallow injection	8	9	-
Trailing shoe and hose	6	7	-
Partly injection, partly narrow band	7	8	-
Surface incorporation in one track	3	3	-
Surface incorporation in two tracks	11	5	62
Surface spreading	4	-	38
Total	100	100	100

Source: Agricultural census of 2010.

2.9 Emission factors of manure application

For information on the methods used for determining the emission factors in Table 2.12, see Velthof *et al.* (2009) (Appendix 14) and Van Bruggen *et al.* (2011).

Table 2.12. Emission factors of manure application (% of TAN)

Emission factor	**2009**
Shallow injection	19
Partly injection, partly narrow band	22.5
Trailing shoe and -hose	26
Surface spreading (grassland)	74
Surface spreading (arable land)	69
Deep placement (arable land)	2
Surface incorporation in one track	22
Surface incorporation in two tracks	46

2.10 Ammonia emissions during grazing

Calculation of ammonia emissions during grazing is described in Velthof et al. (2009, Section 4.6 and p.151). The emission factor is dependent on the average nitrogen content of dairy cow rations during grazing seasons. The calculated emission factor for TAN excretion from dairy cows during grazing was applied to all grazing livestock categories. Because of the large amount of maize silage in 2009 rations, the emission factor related to grazing was set at 2.7%. Over the 2006–2008 period, the emission factor was around 3.5% (Van Bruggen *et al.,* 2011).

3 Inorganic fertiliser

The calculation of the average emission factor for inorganic fertiliser was based on distribution data (LEI inorganic fertiliser statistics) and emission factors for ammonia per type of inorganic fertiliser (Velthof *et al.,* 2009; Appendix 16). Figures on total distribution were subsequently corrected for non-agricultural destinations, such as hobby farms and private properties.

The study by Luesink *et al.* (2011) is the first to have taken into account the inorganic fertiliser distribution with non-agricultural destinations, such as private properties, departments of public parks and gardens, and garden centres. Annual distribution was estimated at five million kilograms of nitrogen.

Annual distribution of inorganic fertiliser to hobby farms was estimated at 12.4 million kilograms of nitrogen, calculated for an area size of 150,000 hectares and inorganic fertiliser application of half the amount used on grassland in the late 1990s (Luesink *et al.,* 2011).

At the time of calculation of the ammonia emissions for 2009, distribution data on inorganic fertiliser for that year were not yet available. Therefore, the provisional figure on its distribution for 2009 was set to that of 2008.

Table 3.1. Inorganic fertiliser use (1,000 kg N) and average emission factor (% of N)

	2009*
Ammonium nitrate	0
Ammonium sulphate	12,804
Ammonium sulphate nitrate	4,684
Sodium nitrate	0
Ammonium bisulphate	0
Mixed nitrogen compound fertiliser	5,854
Potassium nitrate	0
Calcium ammonium nitrate	156,802
Calcium nitrate	0
Monoammonium phosphate	0
Other NPK, NP and NK-compound fertiliser	42,767
Nitrogen phosphate potassium magnesium compound fertiliser	7,054
Nitromagnesite	1,416
Urea	6,731
Liquid ammonia	0
Sulphur-coated urea	0
Non-specified products	0
Total distribution	238,112
specified into:	
Agriculture and horticulture	220,712
Hobby farms	12,400
Private property owners and others	5,000
Average emission factor (%)	3.8%

**provisional figure, equal to the distribution in 2008.*

4 Results

Table 4.1 presents average emission factors for NH3-N from liquid and solid manure in animal housing, per animal category. The influence of grazing systems applied (for dairy cattle) and low-emission application techniques has been taken into account in the calculation of emission factors. The emission factor for grazing are provided in Section 2.10.

Table 4.2 presents ammonia emission data on a number of years.

Table 4.1. Emission factors for NH3-N from animal housing (% of TAN excretion)

	Liquid manure	Solid manure
Dairy cows - housing period	10.2	10.5
Dairy cows - housing during grazing season	12.4	33.2
Female young stock, up to 24 months (including beef cattle)	11.2	11.7
Male young stock and stud bulls	11.7	11.7
Fattening calves in white-meat production	25.8	
Fattening calves in pink-meat production	11.9	
Beef bulls	18.5	18.5
Suckler cows, feedlot cows and grazing cows	15.1	15.1
Sheep		27.8
Goats		17.1
Horses		19.5
Ponies		29.0
Fattening pigs	20.5	
Gilts and young boars	22.5	
Sows	19.7	19.7
Boars	25.4	25.4
Broilers, parent animals of 18 weeks and under		80.3
Broilers, parent animals of 18 weeks and over		45.9
Laying hens, 18 weeks and under	8.98	22.5
Laying hens, 18 weeks and over	13.6	16.0
Broilers		19.5
Young meat ducks		29.7
Turkeys		35.6
Rabbits		54.3
Mink	8.01	

Table 4.2. Ammonia emissions from agriculture (million kg NH3)

	1990	1995	2000	2005	2008	2009
Cattle	183.9	91.8	63.4	56.0	53.7	52.6
Housing and storage	34.4	33.0	24.4	21.7	22.6	22.0
Housing	30.8	30.6	23.3	20.8	21.7	21.2
Storage	3.5	2.4	1.1	0.8	0.8	0.8
Pasture	16.0	14.2	4.4	2.9	2.0	1.2
Application	133.5	44.6	34.5	31.4	29.2	29.3
Dairy cows	120.9	55.6	37.9	36.7	35.7	34.8
Housing and storage	21.6	20.0	14.3	13.9	14.3	13.8
Housing	19.4	18.7	13.8	13.4	13.9	13.3
Storage	2.2	1.3	0.5	0.5	0.5	0.5
Pasture	9.0	8.0	2.2	1.5	1.1	0.6
Application	90.3	27.6	21.4	21.4	20.3	20.5
Young stock incl. stud bulls	41.2	22.8	16.2	11.6	11.1	11.1
Housing and storage	6.8	6.9	5.5	4.0	4.5	4.6
Housing	5.9	6.3	5.1	3.8	4.2	4.3
Storage	0.9	0.7	0.4	0.2	0.3	0.3
Pasture	5.6	4.7	1.7	1.1	0.6	0.5
Application	28.8	11.1	9.1	6.5	6.0	6.1
Meat calves	4.1	2.7	3.5	3.2	3.1	3.0
Housing and storage	1.5	1.8	2.2	2.0	2.1	2.1
Housing	1.5	1.8	2.2	2.0	2.1	2.1
Storage	0.0	0.0	0.0	0.0	0.0	0.0
Pasture	0.0	0.0	0.0	0.0	0.0	0.0
Application	2.6	0.9	1.3	1.3	1.0	0.9
Suckler cows, feedlot cows and grazing cows	3.6	3.1	2.4	2.0	1.5	1.4
Housing and storage	0.7	0.9	0.9	0.7	0.6	0.6
Housing	0.6	0.9	0.8	0.7	0.6	0.5
Storage	0.1	0.1	0.1	0.0	0.0	0.0
Pasture	0.8	0.9	0.4	0.3	0.2	0.1
Application	2.1	1.2	1.2	1.0	0.7	0.7
Other beef cattle	14.1	7.5	3.2	2.5	2.3	2.2
Housing and storage	3.8	3.3	1.5	1.1	1.0	1.0
Housing	3.4	3.0	1.4	1.0	1.0	0.9
Storage	0.4	0.3	0.1	0.1	0.1	0.1
Pasture	0.6	0.6	0.1	0.1	0.1	0.0
Application	9.7	3.7	1.6	1.3	1.2	1.1
Sheep and goats	3.0	3.0	2.2	1.7	1.6	1.4
Housing and storage	0.7	0.7	0.8	0.6	0.6	0.5
Housing	0.6	0.6	0.7	0.6	0.5	0.5
Storage	0.1	0.1	0.1	0.1	0.1	0.1
Pasture	1.7	1.5	0.6	0.3	0.2	0.1
Application	0.7	0.8	0.9	0.7	0.8	0.7
Horses and ponies	0.9	1.3	1.3	1.4	1.1	1.2
Housing and storage	0.3	0.4	0.5	0.6	0.6	0.6
Housing	0.3	0.4	0.4	0.5	0.5	0.5
Storage	0.0	0.1	0.1	0.1	0.1	0.1
Pasture	0.2	0.2	0.1	0.1	0.1	0.1
Application	0.4	0.6	0.7	0.7	0.5	0.5

	1990	1995	2000	2005	2008	2009
Pigs	98.3	53.3	39.1	29.0	25.4	26.2
Housing and storage	34.7	33.8	24.5	17.8	18.9	19.1
Housing	34.2	33.4	24.3	17.5	18.6	18.8
Storage	0.6	0.5	0.2	0.3	0.3	0.3
Application	63.5	19.4	14.6	11.2	6.5	7.1
Fattening pigs	66.3	35.6	25.6	19.6	17.8	18.1
Housing and storage	22.8	22.8	16.0	12.1	13.4	13.5
Housing	22.4	22.5	15.9	11.9	13.2	13.2
Storage	0.4	0.3	0.1	0.2	0.2	0.2
Application	43.5	12.8	9.6	7.5	4.4	4.7
Breeding pigs	32.0	17.7	13.5	9.4	7.7	8.1
Housing and storage	12.0	11.1	8.5	5.7	5.5	5.7
Housing	11.7	10.9	8.4	5.6	5.4	5.5
Storage	0.2	0.2	0.1	0.1	0.1	0.1
Application	20.0	6.6	5.0	3.8	2.1	2.4
Poultry	32.3	23.5	24.9	19.1	16.6	16.1
Housing and storage	15.8	15.9	16.6	13.8	13.3	13.8
Housing	14.7	14.5	15.3	12.3	12.0	12.4
Storage	1.1	1.3	1.3	1.4	1.3	1.4
Application	16.5	7.6	8.3	5.3	3.3	2.3
Laying poultry	21.3	15.5	14.3	8.9	9.6	9.2
Housing and storage	9.4	8.9	9.8	8.1	8.4	8.8
Housing	8.9	8.3	9.1	7.2	7.3	7.6
Storage	0.5	0.6	0.6	0.9	1.1	1.2
Application	12.0	6.6	4.5	0.8	1.2	0.4
Meat poultry	11.0	8.0	10.6	10.2	7.0	6.9
Housing and storage	6.4	7.0	6.8	5.7	4.9	5.1
Housing	5.8	6.3	6.1	5.2	4.7	4.9
Storage	0.6	0.7	0.7	0.5	0.2	0.2
Application	4.6	1.1	3.8	4.5	2.1	1.8
Rabbits and fur-bearing animals	0.6	0.6	0.6	0.6	0.4	0.4
Housing and storage	0.5	0.4	0.3	0.3	0.3	0.2
Housing	0.5	0.3	0.3	0.3	0.3	0.2
Storage	0.0	0.0	0.0	0.0	0.0	0.0
Application	0.1	0.3	0.2	0.3	0.1	0.1
Total animal manure	319.1	173.5	131.5	107.8	98.9	97.8
Housing and storage	86.5	84.3	67.1	54.7	56.2	56.3
Housing	81.0	79.9	64.3	52.0	53.6	53.6
Storage	5.4	4.4	2.8	2.7	2.7	2.7
Pasture	17.8	16.0	5.1	3.3	2.2	1.4
Application	214.8	73.3	59.2	49.7	40.4	40.0
Inorganic fertiliser	13.9	14.0	12.0	13.0	10.1	10.1
Total	333.0	187.5	143.5	120.8	109.0	107.9

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