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# Overview of calculation methods for the quantity and composition of livestock manure in the Baltic Sea region

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# Overview of calculation methods for the quantity and composition of livestock manure in the Baltic Sea region

Report on current national manure calculation systems

*Produced in Manure Standards Work Package 3: Guidelines for calculated manure systems*

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# Introduction

There are existing manure calculation systems in Denmark, Estonia, Finland, Sweden, Germany, Russia and Poland. They are based on the mass-balance approach, i.e. they follow the fate of the organic matter and nutrients fed to the animals, excreted as faeces and urine and in the manure management chain. However, according to the collected information on their state-of-the-art (Luostarinen & Kaasinen 2016), there are differences in e.g. the level of detail, in the algorithms used and in the background data used in the national calculation tools. They are also variably used in practice, ranging from use as basis for manure fertilization to use in providing necessary data for manure-related legislation, e.g. manure storage capacity. Further, some systems are in the development phase (e.g. Finland), while others have been in use for years (e.g. Denmark).  To provide a strong background for developing the joint guidelines for manure calculation system in the Baltic Sea region, the current national calculation systems will be described and compared in detail, including:

- Animal categories
- Housing choices
- Background data used
- Algorithms of mass balance from feeding to excretion as urine and faeces
- Algorithms of mass balance in housing and storage
- Consideration of international guidelines (e.g. IPCC, EMEP/EEA, BREF)
- Development needs.

# Contents

# 1. Current national manure calculation systems

## 1.1. Ex-animal

### 1.1.1. Denmark

#### 1.1.1.1. Dairy cows

The calculations are principally based on balances for dry matter, nitrogen, phosphorus and potassium calculated from information on nutrient content in feed, gain, milk and foetus and on digestibility and turnover of individual nutrients. For N, P and K, the balances are expressed as in the example for N in the following equation:

$N_{Feed} = N_{Gain} + N_{Foetus} + N_{Milk} + N_{Faeces} + N_{Urine}$

Kg N excreted per cow per year = $N_{Faeces} + N_{Urine} = N_{Feed} – (N_{Milk} + N_{Gain} + N_{Foetus})$, where
$N_{Feed}$ = Kg feed dry matter per cow per year × kg crude protein per kg feed dry matter/6.25
$N_{Milk}$ = Kg milk per cow per year × g milk protein per kg milk/6.38/1000
$N_{Gain}$ = Kg gain per cow per year × 0.0256 kg N per kg gain
$N_{Foetus}$ = Kg foetus per cow per year × 0.0296 kg N per kg fetus

Dairy cows are separated into two groups: Heavy breed and Jersey. Crossbreeds are included in Heavy breed. That means, at all animals with less than 87.5% Jersey blood are characterised as Heavy breed. The table below shows the default values used to calculate energy requirement and nutrient balances in the most recent version of the Danish Normative System from 2017. In contradiction to data on milk yield and chemical composition of the diet, which are updated on a yearly basis, these numbers are seldom changed.

**Default values used to calculate energy requirement and nutrient balances**

| ***Heavy breed*** | ***Jersey*** |
|---|---|
| ***Weight and housing system:*** | |
| 600 kg average weight | 420 kg average weight |
| 92 % loose housing | 92 % loose housing |
| 640 kg mature weight | 440 kg mature weight |
| ***Gain:*** | |
| 40 kg gain per cow per year | 25 kg gain per cow per year |
| 333 g gain per day | 208 g gain per day |
| 120 days with gain | 120 days with gain |
| 25.6 g N pr. kg gain | 25.6 g N pr. kg gain |
| 6.1 g P pr. kg gain | 6.1 g P pr. kg gain |
| 1.8 g K pr. kg gain | 1.8 g K pr. kg gain |
| ***Foetus:*** | |
| 0.6 foetus per cow per year | 0.6 foetus per cow per year |
| 40 kg foetus weight<br>284 days pregnancy | 25 kg foetus weight<br>284 days pregnancy |
| 29.6 g N pr. kg foetus | 29.6 g N pr. kg foetus |

| | |
|---|---|
| 10.2 g P pr. kg foetus | 10.2 g P pr. kg foetus |
| 2.1 g K pr. kg foetus | 2.1 g K pr. kg foetus |
| ***Milk:*** | |
| 0.96 g P pr. kg milk | 1.08 g P pr. kg milk |
| 1.6 g K pr. kg milk | 1.6 g K pr. kg milk |
| ***Faeces:*** | |
| DM digestibility: 71 % | DM digestibility: 71 % |
| 13.5 % DM in faeces | 13.5 % DM in faeces |
| N in faeces (g per day) is calculated from DM intake (DM, kg per day) and N intake (N, g per day): $(0.04 \times N) + (1.8 \times DM^2/6.25) + (20 \times DM/6.25)$ | Partitioning of N excretion between faeces and urine follows the partitioning found for Heavy breed (in 2017/2018: 54.5 % in faeces) |
| P in faeces is calculated as a difference[a] | P in faeces is calculated as a difference |
| 3.0 g K per kg feed DM | 3.0 g K per kg feed DM |
| ***Urine:*** | |
| Kg urine= kg faeces/1.85 | Kg urine= kg faeces/1.85 |
| 5 % DM | 5 % DM |
| N in urine is calculated as a difference[b] | Partitioning of N excretion between faeces and urine follows the partitioning found for Heavy breed (in 2017/2018: 45.5 % in urine) |
| 3.0 mg P per kg animal weight per day | 3.0 mg P per kg animal weight per day |
| **K in urine is calculated as a difference[c]** | K in urine is calculated as a difference |

[a] $P_{Faeces} = P_{Feed} – (P_{Gain} + P_{Foetus} + P_{Milk} + P_{Urine})$
[b] $N_{Urine} = N_{Feed} – (N_{Gain} + N_{Foetus} + N_{Milk} + N_{Faeces})$
[c] $K_{Urine} = K_{Feed} – (K_{Gain} + K_{Foetus} + K_{Milk} + K_{Faeces})$

In contradiction to the default data above which only seldom are changed, new data on feed intake and chemical composition of the diet are collected from practice every year. These numbers are supplied by the advisory service (Kjeldsen & Aaes, 2017).

Feed intake has been calculated based on theoretical energy requirement for maintenance, gain and foetus, theoretical energy requirement for milk yield from controlled cows, calculated feed efficiency and energy density in the diet. Total DM intake is 7851 and 6466 kg DM per cow per year for Heavy breed and Jersey, respectively.

Contents of N, P and K in the diet are calculated based on the chemical composition of diets from practice in the last 4 years, where data from each year is weighted with 10 %, 20 %, 30 % og 40 %, respectively

Feed DM digestibility is as default 71 % (Poulsen & Kristensen, 1997), and faeces DM excretion can subsequently be calculated based on intake and digestibility. Total faecal excretion is then calculated using a default faecal DM content of 13.5 %. Amount of urine is by default amount of faeces divided by 1.85, and urine DM content is 5 %.

Faecal N excretion is calculated for Heavy breed based on DM intake (kg/day) and N intake (g/day) (Poulsen & Kristensen, 1997).

$N_{Fæces}$ (kg/cow/year) = $0,001 \times 365 \times [(0.04 \times N) + (1,8 \times DM^2/6.25) + (20 \times DM/6.25)]$

Partitioning of N excretion between faeces and urine follows the partitioning found for Heavy breed (in 2017/2018: 54.5 % in faeces). N in urine is the calculated as a difference ($N_{Urine} = N_{Feed} – (N_{Gain} + N_{Foetus} + N_{Milk} + N_{Faeces})$).

**N-balance (kg/cow/year)**

| | Heavy breed | | Jersey | |
|---|---|---|---|---|
| | **Kg** | **%** | **Kg** | **%** |
| Feed | 208.5 | 100 | 173.8 | 100 |
| Milk | 56.1 | 27 | 47.6 | 27 |
| Gain | 1.0 | 0 | 0.6 | 0 |
| Foetus | 0.7 | 0 | 0.4 | 0 |
| Faeces | 82.1 | 39 | 68.2 | 39 |
| Urine | 68.6 | 33 | 56.9 | 33 |
| Faeces+urine | 150.7 | 72 | 125.1 | 72 |
| g N/kg ECM | 14.2 | | 13.2 | |

Partitioning of P excretion between urine and faeces is done based on calculating P excretion in urine as 3.0 mg P per kg weight per day, where after P excretion in faeces in calculated as a difference ($P_{Faeces} = P_{Feed} - (P_{Gain} + P_{Foetus} + P_{Milk} + P_{Urine})$).

**P-balance (kg/cow/year)**

| | Heavy breed | | Jersey | |
|---|---|---|---|---|
| | **Kg** | **%** | **Kg** | **%** |
| Feed | 31,7 | 100 | 27,4 | 100 |
| Milk | 10,0 | 32 | 7,9 | 29 |
| Gain | 0,2 | 1 | 0,2 | 1 |
| Foetus | 0,2 | 1 | 0,2 | 1 |
| Faeces | 20,6 | 65 | 18,7 | 68 |
| Urine | 0,7 | 2 | 0,5 | 2 |
| Faeces+urine | 21,2 | 67 | 19,2 | 70 |
| g P/kg ECM | 2,00 | | 2,02 | |

K excretion in faeces is calculated as 3.0 g K per kg feed DM and excretion in urine is subsequently calculated as a difference

**K-balance (kg/cow/year)**

| | Heavy breed | | Jersey | |
|---|---|---|---|---|
| | **Kg** | **%** | **Kg** | **%** |
| Feed | 117,0 | 100 | 86,6 | 100 |
| Milk | 16,7 | 14 | 11,7 | 13 |
| Gain | 0,1 | 0 | 0,0 | 0 |
| Foetus | 0,1 | 0 | 0,0 | 0 |
| Faeces | 23,6 | 20 | 19,4 | 22 |
| Urine | 76,6 | 66 | 55,5 | 64 |
| Faeces+urine | 100,2 | 86 | 74,9 | 86 |
| g K/kg ECM | 9,45 | | 7,91 | |

In the table below is the excretion of N, P and K in 2017/2018 summarised.

**Excretion of N, P and K in 2017/2018 for dairy cows**

| | Heavy breed | | | | | Jersey | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ton | | Kg | | | Ton | | Kg | | |
| | manure | Pct. | | | | manure | Pct. | | | |
| | | DM | N | P | K | | DM | N | P | K |
| Faeces | 16.9 | 13.5 | 82.1 | 20.6 | 23.6 | 13.9 | 13.5 | 68.2 | 18.7 | 19.4 |
| Urine | 9.1 | 5.0 | 68.6 | 0.7 | 76.6 | 7.5 | 5.0 | 56.9 | 0.5 | 55.5 |
| Total | 26.0 | 10.5 | 150.7 | 21.2 | 100.2 | 21.4 | 10.5 | 125.1 | 19.2 | 74.9 |

#### 1.1.1.2. Slaughter pigs

The calculations include balances on nitrogen, phosphorus, potassium and volume (dry matter). The basic data originates from farm production statistics (feed intake as FEs, body weight (initial and final), growth, mortality etc.; updated annually), dietary nutrient content per FEs and nutrient digestibility (combined information from feed controlling authorities, general feed composition and scientific reports; updated annually), and nutrient retention in the body (scientific reports and papers; updated when new data is available). FEs (Feed unit for pigs = FUp) is currently used in Denmark but FEs (FUp) can be replaced by kg throughout the equation.

All calculations follows the same basic equation, where N is used as example:

$N_{Excretion} = N_{Intake} – N_{Retention}$, where

$N_{Intake}$ = FEs feed/kg body weight gain × (Final body weight – initial body weight), kg × kg crude protein per FEs/6.25
$N_{Retention}$ = (Kg final body weight – kg initial body weight) × 0.0296 kg N/kg body weight gain
$N_{Excretion}$ = Total urinary and fecal excretion of N

The segregation of the total excretion into the urinary and fecal excretion is calculated by use of this equation:

$N_{Excretion} = N_{Faeces} + N_{Urine}$, where

$N_{Excretion}$ is the total excretion
$N_{Faeces}$ is the faecal excretion
$N_{Urine}$ is the urinary excretion.

$N_{Faeces} = N_{Intake} (100 – N_{Digestibility})$
$N_{Urine} = N_{Intake} – N_{Retention} – N_{Faeces}$, or by $N_{Urine} = N_{Excretion} – N_{Faeces}$

**The recent updating of the Danish Normative System (2017) used the following default values for slaughter pigs:**

| | |
|---|---|
| Initial body weight, kg | 31 |
| Final body weight, kg | 110 |
| Feed intake, FEs*)/kg gain | 2.82 |
| Dry matter (feed), % | 87 |
| Crude protein content, g/FEs | 145.9 |
| Phosphorus content, g/FEs | 4.8 |

| | |
|---|---|
| Potassium content, g/FEs | 7.0 |
| Dry matter (faeces), % | 25 |
| Dry matter (urine), % | 2 |
| N retention, g/kg gain | 29.6 |
| P retention, g/kg gain | 5.5 |
| K retention, g/kg gain | 2.2 |
| N digestibility ($N_{Digestibility}$), % | 81 |
| P digestibility ($P_{Digestibility}$), % | 55 |
| K digestibility ($K_{Digestibility}$), % | 70 |

*) FEs = FUp (**F**eed **U**nit for **p**igs)

**Calculated nutrient balances for Danish slaughter pigs *ex animal* (2017)**

| | Nitrogen | | Phosphorus | | Potassium | |
|---|---|---|---|---|---|---|
| | Kg | % | Kg | % | Kg | % |
| Intake | 5.20 | 100 | 1.07 | 100 | 1.60 | 100 |
| Retention | 2.34 | 45 | 0.44 | 41 | 0.17 | 12 |
| Excretion: | | | | | | |
| Faeces | 0.99 | 19 | 0.48 | 45 | 0.47 | 30 |
| Urine | 1.86 | 36 | 0.15 | 14 | 0.92 | 58 |
| Total | 2.86 | 55 | 0.63 | 59 | 1.39 | 88 |

**Calculated excretion of N, P and K content for one slaughter pig (31 to 110 kg) according to the Danish Normative System (2017)**

| | Nitrogen, kg | Phosphorus, kg | Potassium, kg | Volume, tonnes | DM, % |
|---|---|---|---|---|---|
| Faeces | 0.99 | 0.48 | 0.47 | 0.12 | 25 |
| Urine | 1.86 | 0.15 | 0.92 | 0.37 | 2 |
| Total | 2.86 | 0.63 | 1.39 | 0.49 | 7.8 |

#### 1.1.1.3. Broilers

The calculations include balances on nitrogen, phosphorus, potassium and volume (dry matter). The basic data originates from farm production statistics (feed intake, body weight gain (final), growth, mortality etc.; updated annually), dietary nutrient content (combined information from feed controlling authorities, general feed composition and scientific reports; updated annually), and nutrient retention in the body (scientific reports and papers; updated when new data is available).

All calculations follows the same basic equation as slaughter pigs. N is used as example:

$N_{Excretion} = N_{Intake} – N_{Retention}$, where

$N_{Intake}$ = Kg feed intake per broiler × kg crude protein per kg/6.25
$N_{Retention}$ = Kg final body weight × 0.0290 kg N/kg body weight
$N_{Excretion}$ = Total excretion of N (no segregation into urine and faeces)

**The recent updating of the Danish Normative System from 2017 used the following values for broilers (per broiler slaughtered at 35 days of age):**

| | |
|---|---|
| Final body weight, kg | 2.13 |
| Feed intake, kg | 3.39 |

| | |
|---|---|
| Dry matter (feed), % | 88 |
| Crude protein content, g/kg diet | 204 |
| Phosphorus content, g/kg diet | 5.4 |
| Potassium content, g/kg diet | 8.8 |
| Dry matter (faeces), % | 25 |
| N retention, g/kg gain | 29.0 |
| P retention, g/kg gain | 3.3 |
| K retention, g/kg gain | 2.5 |

**Calculated nutrient balances for 1.000 Danish broilers 35 days of age *ex animal* (2017)**

| | Nitrogen | | Phosphorus | | Potassium | |
|---|---|---|---|---|---|---|
| | Kg | % | Kg | % | Kg | % |
| Intake | 109.6 | 100 | 18.3 | 100 | 29.8 | 100 |
| Retention | 61.8 | 56 | 7.0 | 38 | 5.3 | 18 |
| Excretion | 47.8 | 44 | 11.3 | 62 | 24.5 | 82 |

**Calculated excretion of N, P and K content for *1.000* broilers (age 35 days) according to the Danish Normative System (2017)**

| | Nitrogen, kg | Phosphorus, kg | Potassium, kg | Volume, tonnes | DM, % |
|---|---|---|---|---|---|
| Total | 31.5 | 7.30 | 17.6 | 3.46 | 25 |

### 1.1.2. Estonia

The Estonian formulae for calculating the quantity and quality of manure (ex-animal, ex-housing, ex- storage) for all animal species are similar to the Danish normative manure system. The Estonian default values presented in the regulation "Calculated values of nutrient content of different types of manure, methodology for calculating manure storage capacity and coefficients for the calculation of animal units" (https://www.riigiteataja.ee/akt/116072014008). The last update of the regulation was done 2014.

**Calculated (default) manure quantity and chemical composition for dairy cows, slaughter pigs and broilers**

| No | Species, age or production group | Manure quantity and chemical composition | | | | | | | | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Amount t/year | Dry matter content % | N kg | P kg | K kg | N kg/t | P kg/t | K kg/t | |
| 1 | Dairy cows | 22,9 | 15,3 | 134,0 | 30,1 | 101,0 | 5,9 | 1,3 | 4,4 | 8725 kg milk and 270.4 kg milk protein per year |
| 7 | Slaughter pigs | 0,5 | 7,2 | 3,3 | 0,6 | 1,3 | 7,0 | 1,2 | 2,8 | 30-110 kg, weight gain 80 kg |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 12 | Broilers (1000 birds) | 3,7 | 12,0 | 64,8 | 16,2 | 28,0 | 17,5 | 4,4 | 7,6 | Growing period 40 days |

### 1.1.3. Finland

In Finland, Natural Resources Institute Finland (Luke) has been responsible for manure excretion values used e.g. in emission inventories, nutrient balances and other such regulatory needs. While creating the Finnish Normative Manure System during 2014-2017, the parameters and animal categories calculated increased. Due to this situation, Finland do not have proper documentation and detailed algorithms of our excretion calculations at the moment.

#### 1.1.3.1. Dairy cows

Major databases for background information are annually updated:

- Total milk production from databases of Luke statistics (http://stat.luke.fi/en).
  - Milk yield (kg per cow per year), concentration of protein, fat and lactose in milk
  - Data originally collected from dairies and farms
- Registry of animal ID's of the Finnish Food Safety Authority EVIRA (https://www.evira.fi/en):
  - Slaughter age and weight for dairy cows
- ProAgria (advisory organization) database of annual milk recording and feed use on farms
  - The composition of ration for dairy cows, ME-value, proportion of concentrates in ration, crude protein content of whole ration, D-value for silage

Nutrient requirements of dairy cows are taken from Luke Feed Tables and feeding recommendations (www.luke.fi/feedtables) and are used to calculate the requirements of energy (ME) from milk production and composition.

Using equations from literature and Luke's own experimental database the concentration of crude protein and organic matter in ration is calculated. Equation of the corrected ME intake is used in calculation of dry matter (DM) intake. Then, intake of digestible organic matter and digestibility of DM are calculated.

DM content of excreted faeces is calculated according to equations from literature and faeces quantity as Faeces, kg = feed DM intake X (1-DM digestibility) / faeces DM content.

Calculation of the excretion of N, P and K is based on literature equations.
N for urine = N intake – N milk – N for growing – N for calf – N faeces.
Feed values of P and K are based on the Feed Tables.

#### 1.1.3.2 Slaughter pigs

In the excretion calculations, the live weight of slaughter pigs 119 kg is used.

The net energy requirement is calculated according the feeding recommendations, as an average of all 8 genotype-sex-combinations. The missing values (maximum weight less than 119 kg) were extrapolated.

The net energy requirement was converted to dry matter intake by dividing them with the net energy content values of the feeding recommendations.

Feed nitrogen, phosphorus, potassium and organic matter contents were estimated based on example diets fulfilling the protein and mineral requirements presented in feeding recommendations.

The nitrogen, phosphorus and potassium contents of fattening pigs were obtained from the literature. Average values (g/kg): N: 24.6, P: 5.3, K: 1.9. These values should be updated and connected to the lean meat percentage of the slaughtered pig.

Organic matter, dry matter and crude protein digestibility and faecal dry matter content were calculated according to literature. Faecal output: Undigested dry matter (kg) /faecal dry matter (kg/kg).

Faecal nitrogen is equal to the undigested nitrogen. Urinary nitrogen is calculated as follows: Nitrogen intake – faecal nitrogen – retained nitrogen.

Excretion division of potassium and phosphorus can be calculated likewise.

#### 1.1.3.3. Broilers

The background data used is partly of national origin and partly from international literature. All data is checked annually and updated where possible.

Feed data (the chemical composition of feed and the feed ingredients used) is taken directly from Finnish feed producers. Growth and feed intake are from management guides for bird hybrids (Broiler: Ross & Aviagen). All data is taken from Finnish farm practices, if only available.

Deposition of N and P in body will most likely be taken from Danish data (29 g N/kg and 3.3-3.7 g P/kg deposited in gain).

Nitrogen and Phosphorus excretions are calculated as intake in feed – deposited in the body = excreted; organic matter is calculated as intake in feed – undigested = excreted; dry matter = undigested dry matter from feed.

### 1.1.4. Germany

National standards for nutrient excretion of animal farms are usually derived by farmers from the German Fertilization Ordinance (BMELV, 2007). However, the calculation does not proceed further to consider the manure management and the changes in manure during housing and storage. Now, the Fertilizer Ordinance contains default values for housing and storage losses of N. Furthermore, the KTBL published related calculations, which I added to this document.

The nutrient excretion is calculated on the basis of a mass balance approach. The exported N in animal products (nutrient retention by animal or in animal products) is subtracted from the nutrient intake by feed. The exact methodology is described in `Arbeiten der DLG, Band 199´ (DLG, 2005; 2014).

#### 1.1.4.1. Dairy cows

**Feeding regime and animal nutrient excretions for dairy cows (grass based diet with pasture, heavy breed, 8.000 kg ECM/year)**

| **Feeding (dt DM/cow and year)** | |
|---|---|
| Grass | 14 |
| Grass silage | 23 |
| Corn silage | 8 |
| Straw | 2,5 |

| | | | |
|---|---|---|---|
| Soybean/ rapeseed cake | 1,5 | | |
| Wheat/barley | 3 | | |
| Dairy concentrates (18[1]/3[2]) | 16 | | |
| Mineral feed | 0,15 | | |
| **Balance (kg/cow and year)** | | | |
| Nutrient | N | P | K |
| Excretions | 128,9 | 18,7 | 118,1 |

[1]crude protein content in %;
[2]energy level

**Information about the animal categories**

| **Feature** | **Value** | **Unit** |
|---|---|---|
| Body weight dairy cow (heavy breed) | 675 | kg |
| Body weight dairy cow (Jersey) | 450 | kg |
| Average body weight gain per year (heavy breed) | | kg |
| Average body weight gain per year (light breed) | | kg |
| Average calf body weight at birth (heavy breed) | 45 | kg |
| Average calf body weight at birth (light breed) | 30 | kg |
| Calves per cow per year | 0,9 | Number |

**N, P and K content in milk, body weight gain and embryo**

| | **N** | **P** | **K** |
|---|---|---|---|
| Milk | g crude protein/6,38 | 1,0 g/kg | 1,5 g/kg |
| Body weight gain[1] | Breeds for dairy: 25 g/kg | 6,0 g/kg | 1,9 g/kg |
| | Breeds for meat: 27 g/kg | 6,5 g/kg | |
| Embryo | No extra value | No extra value | No extra value |

[1]New research results indicate the need to differentiate between breeds for dairy and meat with regard to the N and P content in body weight gain.

**Main algorithms for the calculation**

Formula for calculation of faeces quantity

Faeces (kg/cow and year) = kg DM of Feed * (100 – % Digestibility) / % Faeces DM/100

Formula for calculation of urine quantity

Urine (kg/cow and year) = (kg DM of Feed * % Digestibility/100 – kg retention by animal for body weight gain, milk and embryo)/ % urine DM/100

For both (faeces and urine), grazing days are considered pro rata.

Nutrient content of manure (N, P, K)

Feed N,P,K – (milk N,P,K + body weight gain N,P,K + embryo N,P,K) (see mass balance approach in the general information section) (for slurry ≙ N,P,K faeces + N,P,K urine)

**DM contents of faeces and urine dependent on animal category**

| **Animal category** | **Faeces** | **Urine[1]** |
|---|---|---|
| | **g DM/kg FM** | |
| Heifers | 180 | 20 |
| Dairy cows | 200 | 20 |

| | | |
|---|---|---|
| Beef cattle | 200 | 20 |
| Calf fattening | 150 | 5 |
| Suckler cows | 200 | 20 |

[1]DM in urine is related to the content of ash

### 1.1.4.2. Slaughter pigs

The German system differentiates according to different production levels (daily body weight gain: 750, 850 or 950 g in the period "28 - 118 kg live weight" -> results in total body weight gain of 223, 244 and 267 kg per place and year respectively). Within these production levels, the system differentiates according to the feeding regime (standard, N-/P- reduced & N-/P-strongly reduced).

**Feeding regime and animal nutrient excretions for slaughter pigs (28-118 kg live weight, 850 g body weight gain per day, standard feeding regime, N-/P-reduced and strongly N-/P-reduced)**

| Production level (weight gain in g/day) | | 850 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Energy input (MJ ME/kg weight gain) | | 36,5 | | | | | | | | |
| Feeding regime* | | **Standard** | | **2-phase-fattening** | | | **3-phase-fattening** | | | |
| As of ... kg live weight | | 28 | 40 | 28 | 40 | 70 | 28 | 40 | 65 | 90 |
| **Feed amount** | kg/phase | 24,3 | 225 | 24,3 | 72,8 | 154 | 24,3 | 59,9 | 69,7 | 97,5 |
| | kg/pig | 248 | | 251 | | | 251 | | | |
| **N** | kg/pig | 4,48 | | 4,30 | | | 3,87 | | | |
| | kg/place** | 12,2 | | 11,7 | | | 10,6 | | | |
| | g/kg weight gain | 50,0 | | 47,8 | | | 43,0 | | | |
| **P** | kg/pig | 0,79 | | 0,68 | | | 0,63 | | | |
| | kg/place** | 2,17 | | 1,87 | | | 1,71 | | | |
| | g/kg weight gain | 8,80 | | 7,59 | | | 7,00 | | | |
| **K** | kg/pig | 1,81 | | 1,75 | | | 1,70 | | | |
| | kg/place** | 4,95 | | 4,78 | | | 4,64 | | | |
| | g/kg weight gain | 20,0 | | 19,5 | | | 18,8 | | | |

*pre-fattening from 28 to 40 kg live weight considered in all feeding regimes;
**2,73 batches per year

**N, P and K content in body weight gain**

| | **N** | **P** | **K** |
|---|---|---|---|
| | g/kg body weight | | |
| Body weight gain | 25,6 | 5,1 | 2,0 |

**Main algorithms for the calculation**

<u>Formula for calculation of faeces quantity</u>

Faeces (kg/pig and period) = kg DM of Feed * (100 – % Digestibility) / % Faeces DM/100

<u>Formula for calculation of urine quantity</u>

Urine (kg/pig and period) = (kg DM of Feed * % Digestibility/100 – kg retention by animal for body weight gain)/ % urine DM/100

Nutrient content of manure (N, P, K)

Feed N,P,K – body weight gain N,P,K (see mass balance approach in the general information section) (for slurry ≙ N,P,K faeces + N,P,K urine)

**DM contents of faeces and urine**

| Animal category | Faeces | Urine |
|---|---|---|
| | g DM/kg FM | |
| Slaughter pigs | 250 | 20 |

### 1.1.4.3. Broilers

**Information about the general structure**

For poultry, analyses of the whole body have currently been conducted and data from the Netherlands are taken into account to consider the changes of the nutrient content in the weight gain due to breeding progress and further development of the production technology.

The German system differentiates according to final weight or fattening period respectively, and to the feeding regime (standard feeding regime and N-/P-reduced).

**Feeding regime and animal nutrient excretions for broilers (fattening up to 29 days and fattening as of 39 days; standard feeding regime and N-/P-reduced respectively)**

| | **Broiler fattening up to 29 days** | | | | | | **Broiler fattening as of 39 days** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production level | 1,55 kg weight gain/animal 13,8 kg weight gain/place and year* | | | | | | 2,6 kg weight gain/animal 18,2 kg weight gain/place and year** | | | | | |
| Feeding regime | Standard feeding | | | N-/P-reduced | | | Standard feeding | | | N-/P-reduced | | |
| **Feed input** | | | | | | | | | | | | |
| Starter | 0,25 kg/animal | | | | | | 0,25 kg/animal | | | | | |
| Phase 1 | 0,80 kg/animal | | | | | | 0,80 kg/animal | | | | | |
| Phase 2 | 0,85 kg/animal | | | | | | 1,20 kg/animal | | | | | |
| Final phase | 0,47 kg/animal | | | | | | 2,04 kg/animal | | | | | |
| **Balance** | | | | | | | | | | | | |
| | N | P | K | N | P | K | N | P | K | N | P | K |
| g/animal | 30 | 7 | 15 | 28 | 6 | 15 | 59 | 13 | 27 | 55 | 11 | 27 |
| g/place and year | 267 | 62 | 134 | 249 | 53 | 134 | 413 | 91 | 189 | 385 | 77 | 189 |

*8,9 batches per year;

**7 batches per year

## 1.1.5. Latvia

Officially calculations according to national regulation (Republic of Latvia Cabinet Regulation No. 834 “Regulation Regarding Protection of Water and Soil from Pollution with Nitrates Caused by Agricultural Activity” Annex 2 “Amount of Acquisition of Livestock Manure and Composition Thereof”).

The values are based on 2007 – 2009 project. They have not been recalculated or changed since. Additionally regulations give values for P and K expressed as $P_2O_5$ and $K_2O$.

Calculations and formulas used:

$$\text{Faeces, kg} = \text{DM, kg} \times (100\,\% - \text{DM digestion, \%}) \times \frac{100}{15}\%$$

$$\text{Urine, kg} = \text{Faeces, kg} \times \frac{45}{100}\%$$

$$\text{N ex} - \text{animal, kg} = \text{N feed, kg} - \text{N in gain, kg} - \text{N in embryo, kg} - \text{N in milk, kg}$$

$$\text{P ex} - \text{animal, kg} = \text{P feed, kg} - \text{P in gain, kg} - \text{P in embryo, kg} - \text{P in milk, kg}$$

$$\text{K ex} - \text{animal, kg} = \text{K feed, kg} - \text{K in gain, kg} - \text{K in embryo, kg} - \text{K in milk, kg}$$

#### 1.1.5.1. Dairy cows

Experimental data from surveys and laboratory analyses for cows with milk production 6200 kg. Similar data for cows with milk production with 6421 kg, 7000 kg, 7350 kg, 10250 kg, 11000 kg, and 11700 kg were gathered.

**Feed consumption per one milking cow (milk production 6200 kg) per year**

| Feed | Consumption, kg | Composition, natural moisture content, % | | | | Consumption, kg | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | DM | N | P | K | DM | N | P | K |
| Pasture grass | 11250 | 18 | 0,54 | 0,09 | 0,60 | 2025 | 60,8 | 10,1 | 67,5 |
| Hay | 537 | 78 | 2,08 | 0,47 | 1,69 | 418,86 | 11,2 | 2,2 | 9,1 |
| Silage | 7993 | 30,2 | 0,40 | 0,16 | 0,28 | 2413,886 | 31,6 | 12,8 | 22,1 |
| Rolled grain (barley + oats) | 2190 | 83 | 1,78 | 0,57 | 0,59 | 1817,7 | 39,0 | 12,5 | 12,9 |
| Brewer’s grain | 3650 | 23 | 1,21 | 0,22 | 0,01 | 839,5 | 44,2 | 8,0 | 0,4 |
| Rape sprouts | 292 | 86 | 4,93 | 2,54 | 1,75 | 251,12 | 14,4 | 7,4 | 5,1 |
| Total | | | | | | **7766,066** | **201,1** | **53,4** | **117,1** |

**Example of calculation per one milking cow (milk production 6200 kg) per year**

| No. | Variables, comments | Calculation, result |
|---|---|---|
| 1.1. | DM consumed, kg (total per year) | **7766** |
| 1.2. | DM digestion rate, % (literature data Standard values (1998), average per grazing and in-barn period) | 71 |
| 1.3. | DM in faeces, kg (per year) | 1.1. × (100 - 1.2.)/100 = 2252 |
| 1.4. | Amount of faeces, kg (faeces, natural moist per year, 15 % dry matter) | 1.3. × 100 / 15 = **15014** |
| 1.5. | Amount of urine, kg | 1.4. × 45 / 100 = **6825** |

| | | |
|---|---|---|
| | (literature data Standard values (1998), assuming urine makes up 45 % of faeces) | |
| 2.1. | N in feed, kg<br>(total per year) | **201,1** |
| 2.2. | N in gain, kg<br>(average data from the literature Standard values (1998)) | 1,0 |
| 2.3. | N in embryo, kg<br>(average data from the literature Standard values (1998)) | 0,7 |
| 2.5. | Protein yield, kg<br>(total amount per year) | 396 |
| 2.6. | N in protein, kg<br>(assuming protein contains 6,25 N) | 2.5. / 6,25 = 63,3 |
| 2.7. | N ex-animal, kg<br>(faeces + urine, N excreted) | 2.1. - 2.2. - 2.3. - 2.6. = **136,1** |
| 3.1. | P in feed, kg<br>(total per year) | **53,4** |
| 3.2. | P in gain, kg<br>(average data from the literature Standard values (1998)) | 0,3 |
| 3.3. | P in embryo, kg<br>(average data from the literature Standard values (1998)) | 0,2 |
| 3.5. | P in milk, kg<br>(total amount per year) | 14,3 |
| 3.6. | P ex-animal, kg<br>(faeces + urine, N excreted) | 3.1. - 3.2. - 3.3. - 3.5. = **38,6** |
| 4.1. | K in feed, kg<br>(total per year) | **117** |
| 4.2. | K in gain, kg<br>(average data from the literature Standard values (1998)) | 0,25 |
| 4.3. | K in embryo, kg<br>(average data from the literature Standard values (1998)) | 0,24 |
| 4.5. | K in milk, kg<br>(total amount per year) | 9,9 |
| 4.6. | K ex-animal, kg<br>(faeces + urine, N excreted) | 4.1. - 4.2. - 4.3. - 4.5. = **106,6** |

#### 1.1.5.2. Slaughter pigs

Values from national regulations. Again, values given in regulations have not been changed. Values are based on same project and calculated similarly as for dairy cows given above.

Calculations and formulas used:

$$\mathrm{Faeces, kg} = \mathrm{DM, kg} \times (100\,\% - \mathrm{DM\ digestion, \%}) \times 3{,}27$$

$$\mathrm{Urine, kg} = \mathrm{Faeces, kg} \times 2$$

$$\mathrm{NPK_{ex-animal}, kg} = \mathrm{NPK_{feed}, kg} - \mathrm{NPK_{per\ gain\ kg}}, \frac{\mathrm{kg}}{\mathrm{kg}} \times \mathrm{body\ gain, kg}$$

**Feed consumption per one slaughter pig per feeding period**

| Feed | Consumpiton, kg | Composition, natural moisture content, % | | | | Consumption, kg | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | DM | N | P | K | DM | N | P | K |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Feed "Porker 1" | 81 | 83,5 | 2,68 | 1,28 | 0,76 | 67,64 | 2,2 | 1,0 | 0,6 |
| Feed "Porker 2" | 158 | 87,1 | 2,64 | 1,26 | 0,78 | 137,62 | 4,2 | 2,0 | 1,2 |
| Total | 239 | | | | | **205,25** | **6,3** | **3,0** | **1,8** |

**Example of calculation per one slaughter pig per feeding period**

| No. | Variables, comments | Calculation, result |
|---|---|---|
| A | Body weight start, kg | 30 |
| B | Body weight end, kg | 98 |
| C | Body gain, kg | B – A = 68 |
| 1.1. | DM consumed, kg | 205,15 |
| 1.2. | DM digestion rate, % | 79 |
| 1.3. | DM in faeces, kg | 1.1. × (100 - 1.2.)/100 = 43,05 |
| 1.4. | Amount of faeces, kg | 1.3. × 3,27 = 140,40 |
| 1.5. | Amount of urine, kg | 1.4. × 2 = 280,80 |
| 2.1. | N in feed, kg | 6,3 |
| 2.2. | N in gain, kg/kg (per gain kg) | 0,028 |
| 2.3. | N in gain, kg (per pig) | C × 2.2. = 1,90 |
| 2.4. | N ex-animal, kg | 2.1. - 2.3. = 4,4 |
| 3.1. | P in feed, kg | 3,00 |
| 3.2. | P in gain, kg/kg (per gain kg) | 0,013 |
| 3.3. | P in gain, kg (per pig) | C × 3.2. = 0,88 |
| 3.4. | P ex-animal, kg | 3.1. - 3.3. = 38,6 |
| 4.1. | K in feed, kg | 1,8 |
| 4.2. | K in gain, kg/kg (per gain kg) | 0,0026 |
| 4.3. | K in gain, kg (per pig) | C × 4.2. = 0,18 |
| 4.4. | K ex-animal, kg | 4.1. - 4.3. = 1,62 |

### 1.1.5.3. Broilers

Values from national regulations. Again values given in regulations have not been changed. Values are based on same project and calculated similarly as for dairy cows given above.

Calculations and formulas used:

$$\text{Faeces, kg} = \text{DFeedM, kg} \times \frac{\text{DM}_{\text{feed}},\%}{100} \times \frac{100 - \text{DM digestion},\%}{100}$$

$$\text{NPK}_{\text{ex-animal}}, \text{kg} = \text{Feed, kg} \times \frac{\text{NPK}_{\text{feed}},\%}{100} - \text{Body gain, kg} \times \frac{\text{NPK}_{\text{in gain}},\%}{100}$$

**Example of calculation per one broiler per period**

| No. | Variables, comments | Calculation, result |
|---|---|---|
| 3. | Body weight end, kg | 1,985 |
| 4. | Body gain, kg | 1,945 |
| 5. | Feed consumed, kg (per animal) | 3,243 |
| 6. | Feed consumed, kg/kg (per kg) | 1,67 |
| 22. | DM in feed, % | 87,65 |
| 23. | DM digestion rate, % | 80 |
| 24. | DM faeces, kg | 5. × 22. × (100 - 23. / 100) = 0,65 |

| | | |
|---|---|---|
| 25. | DM faeces, % | 22 |
| 26. | Faeces, kg | 24 × (100 / 25.) = 2,95 |
| 7. | N in feed, % | 3,63 |
| 8. | N in feed, kg | 5. × (7. / 100) = 0,118 |
| 9. | N in gain, % | 3 |
| 10 | N in gain, kg | 4. × (9. / 100) = 0,058 |
| 11. | N ex-animal, kg | 8. - 10. = 0,059 |
| 12. | P in feed, % | 1,45 |
| 13. | P in feed, kg | 5. × (12. / 100) = 0,047 |
| 14. | P in gain, % | 1,43 |
| 15. | P in gain, kg | 4. × (14. / 100) = 0,028 |
| 16. | P ex-animal, kg | 13. - 14. = 0,019 |
| 17. | K in feed, % | 0,96 |
| 18. | K in feed, kg | 5. × (17. / 100) = 0,031 |
| 19. | K in gain, % | 0,34 |
| 20. | K in gain, kg | 4. × (19. / 100) = 0,007 |
| 21. | K ex-animal, kg | 18. - 20. = 0,024 |

### 1.1.6. Poland

Standard values were established experimentally for all main species of livestock. These analyses were conducted in National Research Institute for Animal Production. The research covered population of: 1080 dairy cows, 1800 slaughter pigs and 7000 broilers. The results of quantity and chemical composition analysis were statistically elaborated for different animal housing systems: deep, shallow and straw less barn. Analysis were performed between 2004 – 2011. The next monitoring program is planned for 20019-2021.

For fertilization advisory purposes, the quantity and composition of manure is calculated according to the scheme presented below:

Calculation of quantity of urine and faeces:

*Faeces = dry matter of forage x (1-%utilization d.m./100) x 100/ % dry matter of faeces*

*Urine = dry matter of forage (kg) x urine (kg) per dry matter of forage (kg)*

*Cow- 0.96 kg of urine per 1 kg dry matter of forage*
*Pig – 2 kg of urine per 1 kg dry matter of forage*

**Calculation of N, P and K content in excrement**

| | N | P | K | Forage (dry matter) per year |
|---|---|---|---|---|
| ***Cow in summer*** | 521 | 72 | 321 | 6420 |
| ***In winter (daily)*** | 369 | 77 | 271 | |
| ***Pig (daily)*** | 66 | 16 | 18 | 117 |
| ***Broiler (56 days)*** | 144 | 18 | 25 | 4 |

| | Forage dry matter per year |
|---|---|
| ***Cow (per year)*** | 6420 |
| ***Pig (1 animal)*** | 117 |
| ***Broiler (1 animal )*** | 4 |

**N utilization (percentage of total uptake)**

| | Animal body | faeces | Urine |
|---|---|---|---|

| | | | |
|---|---|---|---|
| ***Cow*** | 22 -26 | 32-34 | 42-44 |
| ***Pig*** | 30 | 21 | 49 |
| ***Broiler*** | 49,5 | 50,5 | |

**P utilization (percentage of total uptake)**

| | Animal body | faeces | Urine |
|---|---|---|---|
| ***Cow*** | 30,1 | 68,2 | 1,7 |
| ***Pig*** | 30 | 49 | 21 |
| ***Broiler*** | 52,2 | 47,8 | - |

**K utilization (percentage of total uptake)**

| | Animal body | faeces | Urine |
|---|---|---|---|
| ***Cow in summer*** | 10 | 1,8 | 88,2 |
| ***Pig*** | 7,6 | 37 | 55,4 |
| ***Broiler*** | 17,9 | 82,1 | |

**Quantity of excrement (kg)**

| | faeces | Urine |
|---|---|---|
| ***Cow (per year)*** | 12778 | 6163 |
| ***Pig (1 animal )*** | 94 | 234 |
| ***Broiler (1 animal)*** | 4,6 | |

## 1.1.7. Russia

The manure output is calculated on the basis of the mass of animal/poultry excrements. The values of excrement mass (faeces and urine) as well as their moisture content for each animal category are specified in the guidance documents. The basic document is Management Directive for Agro-Industrial Complex “Recommended Practice for Engineering Designing of Systems for Animal and Poultry Manure Removal and Pre-application Treatment”. This document also specifies NPK content in the excrements and the bedding material as well as correction factors, which take into account the animal housing system and milking system.

### 1.1.7.1. Dairy cows

Mass and moisture content of dairy cows’ excrements per one head is shown in next table.

**Total mass and moisture content of excrements**

| Animal category | Indicator | Excrements | | |
|---|---|---|---|---|
| | | Total | Including | |
| | | | Faeces | Urine |
| Dairy cows | mass, kg/day | 55 | 35 | 20 |
| | moisture content, % | 88.4 | 85.2 | 94.1 |

The regulatory documents of the Russian Federation specify the nutrient content in cattle excrements in general as shown in next table (dairy cows are not regarded separately).

**Nutrient content in cattle excrements**

| Content in the dry matter of cattle excrements, % | |
|---|---|
| Total nitrogen (N) | 3.2 |
| Phosphorous ($P_2O_5$) | 1.8 |
| Potassium, ($K_2O$) | 5.0 |

#### 1.1.7.2. Slaughter pigs

In the Russian regulatory document, the category “fattening pigs” (under 70 kg) is specified. For this animal category, the values of excrements mass and moisture content per one head are set in the next table.

**Manure mass and moisture content of excrements for fattening pigs**

| Animal category (gender and age group) | Indicator | Excrements | | |
|---|---|---|---|---|
| | | Total | Including | |
| | | | Faeces | Urine |
| Fattening pigs (under 70 kg) | mass, kg/day | 6.5 | 2.7 | 3.8 |
| | moisture content, % | 87.5 | 74.7 | 96.9 |

#### 1.1.7.3. Broilers

The Russian regulatory documents specify the following animal categories:

- Broiler (1 - 8 weeks old), cage housing;
- Broiler (1 - 9 weeks old), floor housing.

Table shows the values of excrement mass and moisture content for categories per one head per day.

**Mass and moisture content of excrements**

| Animal category | Excrements, g/head/day | Moisture content, % |
|---|---|---|
| Broilers (1 - 9 weeks old), floor housing | 158 | 66-74 |
| Broiler (1 - 8 weeks old), cage housing | 135 | 66-74 |

### 1.1.8. Sweden

Last update of standard feeding was made 2011, before that 2002. Update from 2011 was made by feed advisors from five different regions in Sweden and they used the tool NorFor (Nordic Feed Evaluation System) to calculate rations.

#### 1.1.8.1. Dairy cows

NorFor was used to calculate feed rations for five different regions and five different production levels. The regions were south (Skåne), south west (Halland), south east (Kalmar), west (Västra Götaland) and north (Dalarna) of Sweden. Production levels were 8 000, 9 000, 10 000, 11 000 and 12 000 kg energy-corrected milk (ECM)/year. For dairy cows in organic production, one standard feeding regime based on grass/clover silage was used to calculate rations for three different production levels (8 000, 9 000 and 10 000 kg ECM/year).

**Formula for calculation of faeces quantity:** Faeces, kg/cow and year = (Feed DM, kg * 0,001*organic subst, g/kg DM*(1 – 0.01*digestibility, % of org subst))/K_OrgSubDM/K_ManureDM

Percentage of organic substance in DM: K_OrgSubDM = 0.87 (87%), DM in faeces: K_ManureDM=0.15 (15%)

**Formula for calculation of urine:** Urine, kg/cow and year = Faeces, kg*K_UrineFactor;

K_UrineFactor for dairy cows = 0.5

**Formula for calculation manure (ex animal) nitrogen (N), phosphorus (P) and potassium (K) content**

N in manure (ex animal) = Feed N + Livestock in N – (Milk N + Livestock out N)

Depending on where values are used, standard values for the NPK content of bedding material can also be included. NOTE: The NPK content of the solid and liquid fractions must be corrected considering that a certain part of the urine is absorbed by the bedding material and thus ends up in the solid fraction.

The same formulas are used for P and K.

#### 1.1.8.2. Slaughter pigs

Nutritional recommendations from SLU (Swedish University of Agricultural Sciences) were used. Calculations were made in EvaPig. All mixes except the one for organic pig production contains phytase.

**Average information about slaughter pigs**

| | Mean | Best 25% |
|---|---|---|
| Weight in, kg | 30 | 30 |
| Weight out, kg | 120 | 120 |
| MJ NEv/kg growth | 26,6 | 25,2 |
| Batches per year | 3,14 | 3,38 |

**N, P, K content in body gain**

| | N % | P % | K % |
|---|---|---|---|
| Livestock | 2,60 | 0,54 | 0,22 |

**Formula for calculation of faeces quantity**: Faeces, kg/pig and year = Feed, kg * K_faecesfactor; K_faecesfactor = 0.55

Formula for calculation of urine: Urine, kg/pig and year = Feed, kg*K_UrineFactor; K_UrineFactor for pigs = 1.6

**Formula for calculation manure quantity**: Manure, kg = Faeces, kg + Urine, kg

**Formula for calculation manure nitrogen (N), phosphorus (P) and potassium (K) content**:

N in manure = Feed N + Livestock in N – Livestock out N

The same formulas are used for P and K.

#### 1.1.8.3. Broilers

Last update of standard feeding were made in autumn 2017, before that around 2000. Feeding information based on the two main Swedish feed sellers (Svenska Foder and Lantmännen).

**Information about broiler production**

| | Data used |
|---|---|
| Weight in, g | 42 |
| Weight out, g | 2050 |
| Batches per year | 7 |

| | |
|---|---|
| Mortality, % | 3,7 |
| Mean weight, dead animals, g | 680 |

**N, P, K content in body gain**

| | N % | P % | K % |
|---|---|---|---|
| Livestock | 2,90 | 0,46 | 0,29 |

Calculations based on various literature data, an assumed value of 0.7 kg DM/broiler is used. A dry matter content of 50 % and a bulk density of 600 kg/m$^3$ are other factors used.

**N in manure** = Feed N + Livestock in N – Livestock out N

Mortality and an assumed mean weight of the dead animals are included in the calculations. The same formulas are used for P and K.

### 1.1.9. Main differences between countries

#### 1.1.9.1. Ex-animal (dairy cows) manure calculation

**Faces (kg/year/period)**

| | |
|---|---|
| **Denmark** | Feed DM, kg x (1-DM digestibility%/100) / faeces DM%/100 |
| **Estonia** | Feed DM, kg x (1-DM digestibility%/100) / manure DM%/100 |
| **Finland** | Feed DM, kg x (1-DM digestibility%/100) / faces DM%/100 |
| **Germany** | Feed DM, kg x (100 – % Digestibility) / % faeces DM/100 |
| **Latvia** | Feed DM, kg x (100%-DM digestion%)x100/15% |
| **Poland** | Feed DM, kg x (1-DM digestibility%/100)x 100/faces DM% |
| **Russia** | No formulas |
| **Sweden** | (Feed DM, kg x 0,001 x OM g/kg DM x (1-0,01 x OM digestibility%))/OM%DM/manure DM% |

**Urine (kg/year/period)**

| | |
|---|---|
| **Denmark** | Faeces, kg/k (k = 1,85) per year |
| **Estonia** | Faeces, kg/k (k = 1,85) per year |
| **Finland** | 2,7 + 0,053 x K (potassium) intake, g per day |
| **Germany** | (kg DM of Feed * % Digestibility/100 – kg retention by animal for body weight gain, milk and embryo)/ % urine DM/100 |
| **Latvia** | Faeces, kg x 45/100 per year |
| **Poland** | Feed DM, kg x 0,96 |
| **Russia** | No formulas |
| **Sweden** | Faeces, kg x k (k = 0,5) per year |

**Manure quantity example calculation (kg/cow/year). Based on Swedish default feeding and production values (8000 ECM milk/year), for calculation of faeces and urine country-specific formulas are used**

| **Country** | Faces | Urine | Total |
|---|---|---|---|
| **Denmark** | 13606 | 7355 | 20961 |
| **Estonia** | 12246 | 6619 | 18865 |
| **Finland** | 12246 | 7054 | 19300 |

| | | | |
|---|---|---|---|
| **Germany** | 10483 | 6988 | 17471 |
| **Latvia** | 12246 | 5511 | 17756 |
| **Poland** | 11266 | 5594 | 16859 |
| **Sweden** | 10158 | 5079 | 15237 |

**Manure N, P, K content (kg/year/period)**

| | |
|---|---|
| **Denmark** | Faeces N + Urine N<br>Faeces N = (0,04 x N) + (1,8 x $DM^2$/6,25) + (20 x DM/6,25)<br>Urine N = Feed N - (milk N + body weight gain N + embryo N + Faeces N)<br>Faeces P + Urine P<br>Faeces P = Feed P - (milk P + body weight gain P + embryo P + Urine P)<br>Urine P = 3,0 mg per kg animal weight per day x 365<br>Faeces K + Urine K<br>Faeces K = 3,0 g per kg feed DM<br>Urine K = Feed K - (milk K + body weight gain K + embryo K + Faeces K) |
| **Estonia** | Feed N,P,K – (milk N,P,K + body weight gain N,P,K + embryo N,P,K) |
| **Finland** | Faeces N = Undigested crude protein/6,38<br>Faeces P,K = Undigested P,K<br>Urine N,P,K = Feed (intake) N,P,K - (milk N,P,K + body weight gain N,P,K + embryo N,P,K + faeces N,P,K) |
| **Germany** | Feed N,P,K – (milk N,P,K + body weight gain N,P,K + embryo N,P,K) |
| **Latvia** | Feed N,P,K – (milk N,P,K + body weight gain N,P,K + embryo N,P,K) |
| **Poland** | Feed N,P,K – (milk N,P,K + body weight gain N,P,K) |
| **Russia** | No formulas |
| **Sweden** | Feed N,P,K + livestock in N,P,K – (milk N,P,K + livestock out N,P,K)<br>Livestock in, kg = K recruitment x K body weight (K recruitment - 38%, K body weight – 580 kg)<br>Livestock out, kg = K recruitment x (K body weight + K body weight gain) + K body weight calf (K body weight gain – 60 kg, K body weight calf – 40 kg) |

**Manure N, P, K content example calculation (kg/cow/year). Based on Swedish default feeding and production values (8000 ECM milk/year), for calculation of faeces and urine N, P, K content country-specific formulas are used**

| **Country** | N kg | P kg | K kg |
|---|---|---|---|
| **Denmark** | 120 | 14 | 102 |
| **Estonia** | 119 | 16 | 102 |
| **Finland** | 120 | 14 | 102 |
| **Germany** | 119 | 14 | 102 |
| **Latvia** | 119 | 14 | 104 |
| **Poland** | 120 | 15 | 103 |
| **Sweden** | 120 | 14 | 102 |

## 1.2. Ex-housing and ex-storage

The base formulas by country to calculate ex-housing and ex-storage manure quantity and chemical composition (kg/animal/year) are similar:

**Manure quantity (ex-housing)** = manure quantity (ex-animal) + inputs quantity (bedding, technological water etc.) – grazing – losses (DM decay, water evaporation)

**Manure N, P, K (ex-housing)** = manure N, P, K (ex-animal) + inputs N, P, K (bedding etc.) – grazing – losses (N emission)

**Manure quantity (ex-storage)** = manure quantity (ex-housing) + inputs (precipitation etc.) – losses (DM decay, water evaporation)

**Manure N, P, K (ex-storage)** = manure N, P, K (ex-housing) + inputs N, P, K (covering material etc.) – losses (N emission; N, P, K leaching)

### 1.2.1. Denmark

Calculations based on default values (Danish Normative System). The first step is to choose housing system as this is important for bedding, emission factors etc. In the Danish system, there is currently the possibility to choose between 11 different housing systems for dairy cows.

| Housing system | Manure type |
|---|---|
| Tie-stalls, open manure gutters | Solid manure |
| | Liquid manure |
| Tie-stalls, manure gutters with grates | Slurry |
| Cubicle barns with solid floor | Slurry |
| Cubicle barns with slatted floor, manure channel with scraper | Slurry |
| Cubicle barns with slatted floor and manure channels | Slurry |
| Cubicle barns with solid, sloping floor with urine drainage | Slurry |
| Deep litter (throughout area) | Deep litter |
| Deep litter, feeding area with solid floor | Deep litter |
| | Slurry |
| Deep litter, feeding area with slatted floor, manure channel with scraper | Deep litter |
| | Slurry |
| Deep litter, feeding area with slatted floor and manure channel | Deep litter |
| | Slurry |
| Deep litter, feeding area with solid sloping floor with urine drainage | Deep litter |
| | Slurry |

The next step is to include the amount of bedding (straw) used in the different housing systems as well as water from spill of drinking water and washing. Spill from feed is included in ex. animal values.

**Use of bedding and water for Holstein cows and Jerseys (bedding for Jerseys in brackets)**

| Housing system | Manure type | Straw (kg/d)[1)] | Water, spill drinking (L/y) | Water, washing, (L/y) |
|---|---|---|---|---|
| Tie-stalls, open manure gutters | Manure | 1.2 (1.0) | | |
| | Liquid manure | | 100 | |
| Tie-stalls, manure gutters with grates | Slurry | 1.2 (1.0) | 100 | |
| Cubicle barns with solid floor | Slurry | 0.4 (0.3) | 100 | 8000 |
| Cubicle barns with slatted floor, manure channel with scraper | Slurry | 0.4 (0.3) | 100 | 8000 |
| Cubicle barns | Slurry | 0.4 (0.3) | 100 | 8000 |

| | | | | |
|---|---|---|---|---|
| with slatted floor and manure channels | | | | |
| Cubicle barns with solid, sloping floor with urine drainage | Slurry | 0.4 (0.3) | 100 | 8000 |
| Deep litter (throughout area) | Deep litter | 12 (10) | 100 | 5500 |
| Deep litter, feeding area with solid floor | Deep litter | 10 (8) | | |
| | Slurry | | 100 | 8000 |
| Deep litter, feeding area with slatted floor, manure channel with scraper | Deep litter | 10 (8) | | |
| | Slurry | | 100 | 8000 |
| Deep litter, feeding area with slatted floor and manure channel | Deep litter | 10 (8) | | |
| | Slurry | | 100 | 8000 |
| Deep litter, feeding area with solid sloping floor with urine drainage | Deep litter | 10 (8) | | |
| | Slurry | | 100 | 8000 |

1) 85 % DM, 0.00425 kg N/kg straw, 0.000578 kg P/kg straw, 0.01254 kg K/kg straw

The next step is the partitioning of ex. animal flows to different manure types within housing system. In tie-stalls with open manure gutters all faeces is allocated to the manure fraction whereas all urine is allocated to the liquid manure fraction. In barns with cubicles all manure ex-animal is allocated to slurry. In barns with deep litter in the full area all manure ex-animal is allocated to deep litter, whereas in barns with deep litter and a specific feeding area 60% of the ex-animal manure is allocated to the deep litter and 40% to the slurry. These distributions are important as the emission factor differs between manure types.

**Partitioning of N, P and K ex animal on manure types**

| **Housing system** | **Manure type** | **N** | **P** | **K** | **Volume** |
|---|---|---|---|---|---|
| Tie-stalls, open manure gutters | Manure | N from faeces | P from faeces | K from faeces | Faeces volume |
| | Liquid manure | N from urine | P from urine | K from urine | Urine volume |
| Tie-stalls, manure gutters with grates | Slurry | N from faeces + N from urine | P from faeces + P from urine | K from faeces + K from urine | Faeces volume + urine volume |
| Cubicle barns with solid floor | Slurry | N from faeces + N from urine | P from faeces + | K from faeces + K from urine | Faeces volume + urine volume |

| | | | | | |
|---|---|---|---|---|---|
| | | | P from urine | | |
| Cubicle barns with slatted floor, manure channel with scraper | Slurry | N from faeces + N from urine | P from faeces + P from urine | K from faeces + K from urine | Faeces volume + urine volume |
| Cubicle barns with slatted floor and manure channels | Slurry | N from faeces + N from urine | P from faeces + P from urine | K from faeces + K from urine | Faeces volume + urine volume |
| Cubicle barns with solid, sloping floor with urine drainage | Slurry | N from faeces + N from urine | P from faeces + P from urine | K from faeces + K from urine | Faeces volume + urine volume |
| Deep litter (throughout area) | Deep litter | N from faeces + N from urine | P from faeces + P from urine | K from faeces + K from urine | Faeces volume + urine volume |
| Deep litter, feeding area with solid floor | Deep litter | 60% of N from faeces + 60% of N from urine | 60% of P from faeces + 60% of P from urine | 60% of K from faeces + 60% of K from urine | 60% of faeces volume + 60% of urine volume |
| | Slurry | 40% of N from faeces + 40% of N from urine | 40% of P from faeces + 40% of P from urine | 40% of K from faeces + 40% of K from urine | 40% of faeces volume + 40% of urine volume |
| Deep litter, feeding area with slatted floor, manure channel with scraper | Deep litter | 60% of N from faeces + 60% of N from urine | 60% of P from faeces + 60% of P from urine | 60% of K from faeces + 60% of K from urine | 60% of faeces volume + 60% of urine volume |
| | Slurry | 40% of N from faeces + 40% of N from urine | 40% of P from faeces + 40% of P from urine | 40% of K from faeces + 40% of K from urine | 40% of faeces volume + 40% of urine volume |
| Deep litter, feeding area with slatted floor and manure channel | Deep litter | 60% of N from faeces + 60% of N from urine | 60% of P from faeces + 60% of P from urine | 60% of K from faeces + 60% of K from urine | 60% of faeces volume + 60% of urine volume |
| | Slurry | 40% of N from faeces + 40% of N from urine | 40% of P from faeces + 40% of P | 40% of K from faeces + 40% of K from urine | 40% of faeces volume + 40% of urine volume |

| | | | | | |
|---|---|---|---|---|---|
| | | | from urine | | |
| Deep litter, feeding area with solid sloping floor with urine drainage | Deep litter | 60% of N from faeces + 60% of N from urine | 60% of P from faeces + 60% of P from urine | 60% of K from faeces + 60% of K from urine | 60% of faeces volume + 60% of urine volume |
| | Slurry | 40% of N from faeces + 40% of N from urine | 40% of P from faeces + 40% of P from urine | 40% of K from faeces + 40% of K from urine | 40% of faeces volume + 40% of urine volume |

In general, N-emission is calculated as a fixed proportion of urinary nitrogen (table 4). In tie-stalls with open manure gutters all the urine is allocated to the liquid fraction and there is therefore no emission from the manure fraction. In deep litter barns, the emission is calculated based on total N excretion and therefore includes both faeces and urine, as these are part of the same manure type.
Loss of DM during housing (percentage of ex-animal DM flow) is also shown in table. No DM is assumed in tie-stalls with manure gutters.

**N-emission factors (percentage of N ex-animal) and DM-loss (percentage of DM ex-animal)**

| Housing system | Manure type | N-emission (%)[1)] | | DM loss (%) | |
|---|---|---|---|---|---|
| | | Faeces | Urine | Faeces | Urine |
| Tie-stalls, open manure gutters | Manure | | | | |
| | Liquid manure | | 10 | | |
| Tie-stalls, manure gutters with grates | Slurry | | 6 | 10 | 10 |
| Cubicle barns with solid floor | Slurry | | 20 | 10 | 10 |
| Cubicle barns with slatted floor, manure channel with scraper | Slurry | | 12 | 10 | 10 |
| Cubicle barns with slatted floor and manure channels | Slurry | | 16 | 10 | 10 |
| Cubicle barns with solid, sloping floor with urine drainage | Slurry | | 8 | 10 | 10 |
| Deep litter (throughout area) | Deep litter | 6 | 6 | 28 | 28 |
| Deep litter, feeding area with solid floor | Deep litter | 6 | 6 | 28 | 28 |
| | Slurry | | 20 | 10 | 10 |
| Deep litter, feeding area with slatted floor, manure channel with scraper | Deep litter | 6 | 6 | 28 | 28 |
| | Slurry | | 12 | 10 | 10 |
| Deep litter, feeding area with slatted floor and manure channel | Deep litter | 6 | 6 | 28 | 28 |
| | Slurry | | 16 | 10 | 10 |
| Deep litter, feeding area with solid sloping floor with urine drainage | Deep litter | 6 | 6 | 28 | 28 |
| | Slurry | | 8 | 10 | 10 |

1) N-emission is calculated as a proportion of urine-N, except for deep litter where it is calculated as a proportion of total N (faeces + urine)

**Calculation of ex storage values:**

*Faeces:*
N.faeces.ex.storage = N.faeces.ex.animal – N.faeces.emission (only deep litter)+ N.straw – N.Cor1 + N.Cor2
P.faeces.ex.storage = P.faeces.ex.animal + P.straw – P.Cor1 + P.Cor2
K.faeces.ex.storage = K.faeces.ex.animal + K.straw – K.Cor1 + K.Cor2
Vol.faeces.ex.storage = Vol.faeces.ex.animal + Vol.straw - DM.faeces.loss – N.faeces.emission – Vol.Cor1 + Vol.Cor2

*Urine:*
N.urine. ex.storage = N.urine.ex.animal – N.urine.emission + N.Cor1 – N.Cor2
P.urine.ex.storage = P.urine.ex.animal +P.Cor1 – P.Cor2
K.urine.ex.storage = K.urine.ex.animal +K.Cor1 – K.Cor2
Vol.urine.ex.storage = Vol.urine.ex.animal + water, drinking + water, washing - DM.urine.loss – N.urine.emission + Vol.Cor1 – VolCor2

*Total:*
N.ex.storage = N.faeces.ex.storage + N.urine.ex.storage
P.ex.storage = P.faeces.ex.storage + P.urine.ex.storage
K.ex.storage = K.faeces.ex.storage + K.urine.ex.storage
Vol.ex.storage = Vol.faeces.ex.storage + Vol.urine.ex.storage

Cor1: Contamination with faeces in liquid manure and thereby movement from the manure fraction to the liquid manure fraction (5% of faecal N, P, K, DM and Volume) (only in Tie-stalls, open manure gutters).

Cor2: Urine in straw and thereby urine moving from the liquid manure fraction to the manure fraction (2.5 kg of urine/kg straw and the equivalent amount of N, P, K, DM and Volume) (only in Tie-stalls, open manure gutters).

**Ex-housing values 2017/2018 for Heavy breed (Holsteins) (kg/year)**

| **Housing system** | **Manure type** | **N** | **P** | **K** |
|---|---|---|---|---|
| Tie-stalls, open manure gutters | Solid manure | 69.9 | 18.8 | 29.4 |
| | Liquid manure | 58.1 | 2.1 | 73.3 |
| Tie-stalls, manure gutters with grates | Slurry | 142.4 | 20.9 | 103.7 |
| Cubicle barns with solid floor | Slurry | 132.2 | 20.7 | 100.0 |
| Cubicle barns with slatted floor, manure channel with scraper | Slurry | 137.3 | 20.7 | 100.0 |
| Cubicle barns with slatted floor and manure channels | Slurry | 134.7 | 20.7 | 100.0 |
| Cubicle barns with solid, sloping floor with urine drainage | Slurry | 139.8 | 20.7 | 100.0 |
| Deep litter (throughout area) | Deep litter | 152.0 | 23.1 | 153.1 |
| Deep litter, feeding area with solid floor | Deep litter | 95.4 | 14.5 | 104.7 |
| | Slurry | 52.6 | 8.2 | 39.3 |
| Deep litter, feeding area with slatted floor, manure channel with scraper | Deep litter | 95.4 | 14.5 | 104.7 |
| | Slurry | 54.7 | 8.2 | 39.3 |

| | | | | |
|---|---|---|---|---|
| Deep litter, feeding area with slatted floor and manure channel | Deep litter | 95.4 | 14.5 | 104.7 |
| | Slurry | 53.6 | 8.2 | 39.3 |
| Deep litter, feeding area with solid sloping floor with urine drainage | Deep litter | 95.3 | 14.5 | 104.7 |
| | Slurry | 55.6 | 8.2 | 39.3 |

### 1.2.2. Estonia

Calculations based on default values. Default values presented in the regulation "Calculated values of nutrient content of different types of manure, methodology for calculating manure storage capacity and coefficients for the calculation of animal units" (https://www.riigiteataja.ee/akt/116072014008). Example of manure amount and chemical composition ex storage by manure type as calculated by the Estonian manure system.

**Manure amount and chemical composition ex-storage by manure type as calculated by the Estonian manure system**

| No | Species, age or production group | Manure type (dry matter content %) | Manure amount and chemical composition | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Amount t/year | Dry matter content % | N kg | $NH_4$-N kg | P kg | K kg | N kg/t | $NH_4$-N kg/t | P kg/t | K kg/t |
| 1 | Dairy cows | Liquid manure (≤7,9) | 24,7 | 5,9 | 116,9 | 30,4 | 30,1 | 101,0 | 4,74 | 1,23 | 1,22 | 4,09 |
| | | Semisolid manure (8,0-19,9) | 23,9 | 14,1 | 116,9 | 23,2 | 30,1 | 101,0 | 4,89 | 0,97 | 1,26 | 44,22 |
| | | Solid manure (20,0-24,9) | 21,8 | 20,3 | 95,1 | 14,8 | 29,8 | 89,1 | 4,36 | 0,68 | 1,37 | 4,09 |
| | | Deep litter manure (≥25) | 22,6 | 27,3 | 122,7 | 11,1 | 33,1 | 129,7 | 5,43 | 0,49 | 1,47 | 4,74 |
| 7 | Slaughter pigs | Liquid manure (≤7,9) | 0,5 | 7,3 | 2,6 | 1,3 | 0,6 | 1,3 | 5,50 | 2,74 | 1,27 | 2,75 |
| | | Semisolid manure (8,0-19,9) | 0,5 | 11,2 | 2,7 | 1,8 | 0,7 | 1,3 | 5,17 | 3,38 | 1,31 | 2,52 |
| | | Solid manure (20,0-24,9) | 0,5 | 20,5 | 2,7 | 1,8 | 0,7 | 1,3 | 4,92 | 1,45 | 1,25 | 2,40 |
| | | Deep litter manure (≥25) | 0,6 | 26,6 | 3,3 | 1,3 | 0,7 | 2,4 | 5,94 | 2,37 | 1,30 | 4,38 |
| 12 | Broilers (1000 birds) | Liquid manure (≤7,9) | - | - | - | - | - | - | - | - | - | - |
| | | Semisolid manure (8,0-19,9) | - | - | - | - | - | - | - | - | - | - |
| | | Solid | - | - | - | - | - | - | - | - | - | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | manure (20,0-24,9) | | | | | | | | | | |
| | | Deep litter manure (≥25) | 4,2 | 25,6 | 39,5 | 24,4 | 16,1 | 25,8 | 9,31 | 5,75 | 3,79 | 6,08 |

Emission factors (ammonia, methane, laughing gas) by type of farming (ex-housing) and manure storing technology (ex-storage) provided in the regulation “Methods of measurement and calculation of emissions of pollutants emitted to the environment from animal husbandry”. The last update of the regulation was done 2016. Example of nitrogen (ammonia) emission factors for dairy cows by type of keeping technology.

**Nitrogen (ammonia) emission factors by type of keeping technology (ex-housing)**

| | **Keeping technology, manure removal technology** | **Emission $k_{farm}$, %** |
|---|---|---|
| Dairy or mother cows, female of male heifers, other cattle groups (except calves) | Tie stall, manure removal 2-3 times per day with tractor (open system) | 5,0 |
| | Tie stall, manure removal more than 3 times per day with scraper, plenty of bedding (open system) | 4,5 |
| | Tie stall, manure removal 2-3 times per day with scraper, plenty of bedding (closed system) | 4,0 |
| | Tie stall, manure removal more than 3 times per day with scraper, plenty of bedding (closed system) | 3,5 |
| | Loose housing, manure removal 2-3 times per day with tractor, without bedding | 8,0 |
| | Loose housing, manure removal more than 3 times per day with scraper, without bedding | 7,5 |
| | Loose housing manure channels, without bedding | 10,0 |
| | Loose housing, deep litter | 7,5 |

**Nitrogen (ammonia) emission factors by type of manure storing technology (ex-storage)**

| **Storage and manure type** | **Emission $k_{manure\ storage}$, %** |
|---|---|
| Manure heap, natural crust | 30 |
| Manure heap, covered with peat, sawdust, soil or some other material | 20 |
| Solid manure storage, natural crust | 40 |
| Solid manure storage, roofed | 20 |
| Liquid manure storage, lagoon, natural crust | 20 |
| Liquid manure storage¸ circular ground plan, natural crust | 10 |
| Liquid manure storage, permanent roof (tent or concrete | 2 |

### 1.2.3. Finland

Ex-housing

The Finnish calculation model for gaseous nitrogen emissions from agriculture presented in “Calculation of atmospheric nitrogen and NMVOC emissions from Finnish agriculture“ (https://helda.helsinki.fi/handle/10138/229364). The model is part of the Finnish Normative Manure System, thus all N loss is calculated according to it also in the manure calculation. N losses are calculated (mainly) based on the EMEP/EEA (2016) and IPCC (2006) guidelines. For ammonia, temperature correction factors are applied to consider the low mean temperature in Finland. The impact of emission abatement measures to ammonia emissions is included in the calculation system. Nitrogen transformation processes (mineralization of slurry organic nitrogen, and immobilization of solid manure $NH_4$-N) during manure storing are also taken into account.

Bedding data is one of the weakest datasets in the Finnish calculation. It is especially weak for cattle and pigs. The situation with poultry is better as Luke measured manure quantity and quality on several different poultry farms in 2014 and this included more detailed accounting of bedding use.

Water addition is another weak dataset in the calculation as the information available is old.

DM loss of 10 % is assumed for cattle and pig deep litter. None for broiler deep litter, which is dryer.

Grazing is taken into account according to the information collected with a farm survey on manure management (2013-2014).

Ex-storage

The Finnish calculation model for gaseous nitrogen emissions from agriculture presented in “Calculation of atmospheric nitrogen and NMVOC emissions from Finnish agriculture“ (https://helda.helsinki.fi/handle/10138/229364). Field heaps are only allowed under specific circumstances in Finland, i.e. certain climatic conditions, hygienic reasons, etc. Therefore, field heaps are not taken into account in the calculation.

Average precipitation is added (600 mm), of which half is assumed to evaporate during open storage (all manure types). In case of floating covers (slurry), 1/3 is assumed to evaporate. DM loss is assumed as 10% for all manure types (but urine) for cattle, pigs and poultry during storage.

### 1.2.4. Germany

The calculation of the amount of solid manure and liquid manure (dung water) in housing and storage was newly developed by the KTBL (Association for Technology and Structures in Agriculture) to provide a reliable and consistent data set for Germany. The methodology used and results of this mass balance calculation model was firstly published in 2014.
According to the Fertiliser Ordinance, the minimum storage capacity is 100% of the amount of slurry/liquid manure (or fermentation residues of biogas plants) produced during 6 months. That is, minimum storage capacity is 50% of the amount of slurry/liquid manure produced per year. As of 2020, the time period will be extended to 9 months for farms with more than 3 livestock units per hectare and for farms without own farmland for manure application. Furthermore, the minimum storage capacity will be 100% of the amount of solid manure produced during 2 months.

**Loss rates during storage**

| | FM[1] | Ash | OS[2] | N | | | | P | K |
|---|---|---|---|---|---|---|---|---|---|
| **Leackages (%)** | | | | | | | | | |
| Staple manure | 15 | 6 | 2 | 10 | | | | 2 | 24 |
| Deep stable manure | - | - | - | - | | | | - | - |
| **Losses due to rotting (gaseous) (%)** | | | | | | | | | |
| | | | | cattle | pigs | poultry | Horses, sheep, goats | | |
| Staple manure | - | - | 20[3]/30[4] | 30 | 35 | 40 | 45 | - | - |
| Deep stable manure | - | - | 12 | 30 | 35 | - | 45 | - | - |
| Liquid manure | - | - | - | 30 | 35 | - | 45 | - | - |
| Slurry | - | - | - | 15 | 20 | - | - | - | - |

[1]Fresh matter; assumption: manure storage outside; the change of the FM of staple manure during rotting is assumed as an equilibrium of evaporation and absorption of precipitation, so that an animal category dependent DM content of the manure is reached (e.g. 25 % for dairy cows). The leackage of the staple manure equals the amount of seepage water. [2]organic substance; [3]for cattle and pigs; [4]for laying hens and broilers

In solid manure systems, straw is assumed to absorb 1,8 kg urine per kg fresh matter (FM). The nutrient content of straw is: 5,8 kg N/t FM; 3,4 kg $P_2O_5$/t FM; 16,8 kg $K_2O$/t FM; 86 % DM. In deep litter systems, it is assumed that the bedding material (e.g. straw) totally absorbs any liquid, i.e. no liquid manure arises.

<u>Estimates for the share of ammonium in manure:</u> N of urine less gaseous N losses

- Solid manure (cows and pigs): on average approximately 15 % $NH_4$-N of total N of absorbed urine in straw (maximum 30%)
- Poultry manure (without bedding material): up to 50% $NH_4$-N of total N
- Liquid manure: almost all N exists as $NH_4$-N

**Water inflow to liquid manure[1]**

| Cattle/horses | l/(animal*day) | Pigs | l/(animal*day) |
|---|---|---|---|
| Dairy cows | 5,00 | Breeding sows | 1,00 |
| Suckler cows | 3,00/4,00 | Fattening pigs | 0,50 |
| Fattening cattle | 1,50 | Piglets | 0,15 |
| (yearling) Heifers | 2,00 | Gilts | 0,50 |
| Horses | 0,50 | Boars | 0,80 |

[1]without precipitation and cleaning water of the milking parlour

**Dairy cows**

Like Ex animal, the German system also differentiates between different production systems for Ex housing and Ex storage (e.g. conventional or extensive systems for heifers, grassland farm (grass based diet) or mixed farm (arable fodder as main basis -> mixed diet) for dairy cows; for dairy cows, a distinction is also made with regard to access to pasture [yes/no] within the production system). Furthermore, for dairy cows the system differentiates according to the production level (6.000, 8.000, 10.000 and 12.000 kg ECM/year) and to the amount of bedding material (4 kg FM per cow and day up to deep litter system).

**Amount of faeces, urine, solid and liquid manure for dairy cows (grass based diet with pasture, 4 kg FM bedding material (straw) per animal and day, 8.000 kg ECM/year)**

| Manure type | Amount (kg/cow and year) | | | | | | Contents (g/kg FM) | | |
|---|---|---|---|---|---|---|---|---|---|
| | FM | DM | OS | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| Faeces | 8.501 | 1.700 | 1.351 | 44 | 37 | 32 | 5,2 | 4,3 | 3,8 |
| Urine | 8.768 | 175 | - | 88 | 5 | 132 | 10,0 | 0,50 | 15,1 |
| Fresh manure | 12.589 | 3.037 | 2.553 | 78 | 43 | 93 | 6,2 | 3,4 | 7,4 |
| Rotten manure | 9.787 | 2.447 | 1.991 | 49 | 42 | 71 | 5,0 | 4,3 | 7,2 |
| Liquid manure | 9.853 | 203 | 51 | 48 | 4 | 115 | 4,9 | 0,4 | 11,7 |

**Slaughter pigs**

Like Ex animal, the German system differentiates according to the production level for Ex housing and Ex storage (daily body weight gain: 700, 800 or 900 g in the period “28 - 117 kg live weight” -> results in total body weight gain of 210, 240 and 270 kg per place and year respectively). Within these production levels, the system differentiates according to the feeding regime (standard & N-/P- reduced) and to the amount of bedding material (0,3 kg FM per place and day up to deep litter system).

**Amount of faeces, urine, solid and liquid manure for slaughter pigs (28-117 kg live weight, 800 g body weight gain per day, bedding material 0,5 kg FM per place and day, standard feeding regime)**

| Manure type | Amount (kg/place[1] and year) | | | | | | Contents (g/kg FM) | | |
|---|---|---|---|---|---|---|---|---|---|
| | FM | DM | OS | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| Faeces | 429 | 107 | 82 | 3,0 | 5,5 | 1,2 | 6,9 | 12,9 | 2,8 |
| Urine | 478 | 10 | - | 10,6 | 0,5 | 5,0 | 22,2 | 1,0 | 10,4 |
| Fresh manure | 849 | 245 | 205 | 9,7 | 6,2 | 6,2 | 11,4 | 7,4 | 7,3 |
| Rotten manure | 788 | 197 | 160 | 5,7 | 6,1 | 4,7 | 7,2 | 7,8 | 6,0 |
| Liquid manure | 485 | 11 | 4 | 3,6 | 0,3 | 3,7 | 7,5 | 0,7 | 7,5 |

[1]2,7 batches per year

**Amount of faecs, urine, solid and liquid manure for slaughter pigs (28-117 kg live weight, 800 g body weight gain per day, bedding material 0,5 kg FM per place and day, N-/P-reduced feeding regime)**

| Manure type | Amount (kg/place[1] and year) | | | | | | Contents (g/kg FM) | | |
|---|---|---|---|---|---|---|---|---|---|
| | FM | DM | OS | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| Faeces | 445 | 111 | 86 | 3,1 | 4,4 | 1,1 | 6,9 | 9,9 | 2,6 |
| Urine | 488 | 10 | - | 8,4 | 0,5 | 4,6 | 17,2 | 0,9 | 9,4 |
| Fresh manure | 865 | 249 | 209 | 8,5 | 5,1 | 5,9 | 9,8 | 5,9 | 6,8 |
| Rotten manure | 801 | 200 | 163 | 5,0 | 5,0 | 4,5 | 6,2 | 6,3 | 5,6 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Liquid manure | 498 | 11 | 4 | 3,0 | 0,3 | 3,5 | 6,0 | 0,6 | 7,0 |

[1]2,7 batches per year

**Broilers**

Like Ex Animal, the German system differentiates according to fattening period (up to 33, 37 & 37-40 days) and to the feeding regime (standard feeding regime and N-/P-reduced) for Ex housing and Ex storage. Furthermore, the system differentiates according to the amount of bedding material (211 up to 361 kg FM per 1.000 places and year).

**Amount of faeces and solid manure for broilers (fattening up to 33 days, standard feeding regime, bedding material 343 kg FM per 1.000 places and year)**

| Manure type | Amount (kg/1.000 place[1] and year) | | | | | | Contents (g/kg FM) | | |
|---|---|---|---|---|---|---|---|---|---|
| | FM | DM | OS | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| Faeces | 19.092 | 4.200 | 3.384 | 224 | 125 | 162 | 11,8 | 6,5 | 8,5 |
| Fresh manure | 19.435 | 4.502 | 3.667 | 226 | 126 | 168 | 11,6 | 6,5 | 8,6 |
| Rotten manure | 5.670 | 3.402 | 2.567 | 136 | 126 | 168 | 23,9 | 22,2 | 29,5 |

[1]8 batches per year

**Amount of faces and solid manure for broilers (fattening up to 33 days, N-/P-reduced feeding regime, bedding material 343 kg FM per 1.000 places and year)**

| Manure type | Amount (kg/1.000 place[1] and year) | | | | | | Contents (g/kg FM) | | |
|---|---|---|---|---|---|---|---|---|---|
| | FM | DM | OS | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| Faeces | 19.176 | 4.219 | 3.403 | 205 | 104 | 162 | 10,7 | 5,4 | 8,5 |
| Fresh manure | 19.520 | 4.521 | 3.685 | 206 | 105 | 168 | 10,6 | 5,4 | 8,6 |
| Rotten manure | 5.692 | 3.415 | 2.580 | 124 | 105 | 168 | 21,8 | 18,5 | 29,4 |

[1]8 batches per year

**Emission factors – General information**

Source: Emission factors (ammonia, methane, laughing gas) by housing and storage type are provided by the Thünen Report 57 – Calculations of gaseous and particulate emissions from German agriculture 1990 – 2016: Report on methods and data (RMD) Submission, 2018. The last update of the report was done in 2018.

## Dairy cows

**Table 4.2: Cattle, maximum methane producing capacity ($B_o$) and methane conversion factors (*MCF*)**

| Maximum methane producing capacity $B_o$ | Maximale Methanbildungs-Kapazität $B_o$ | **0.23** | $m^3$ $CH_4$ $(kg\ VS)^{-1}$ |
|---|---|---|---|
| **Methane conversion factor *MCF*** | **Methanumwandlungsfaktor *MCF*** | | |
| slurry (untreated) | Gülle (unbehandelt) | | |
| slurry tank | Güllelager | | |
| open tank (without natural crust) | offen (ohne natürliche Schwimmdecke) | **0.17** | $m^3$ $m^{-3}$ |
| solid cover (incl. tent structures) | feste Abdeckung (inkl. Zelt) | 0.17 | $m^3$ $m^{-3}$ |
| natural crust | natürliche Schwimmdecke | **0.10** | $m^3$ $m^{-3}$ |
| floating cover (chaff) | schwimmende Abdeckung (Strohhäcksel) | 0.17 | $m^3$ $m^{-3}$ |
| floating cover (plastic film) | schwimmende Abdeckung (Folie) | 0.17 | $m^3$ $m^{-3}$ |
| underneath slatted floor > 1 month | Lager unter Spaltenboden > 1 Monat | **0.17** | $m^3$ $m^{-3}$ |
| solid manure/heap (tied systems, loose housing[a]) | Festmist/Misthaufen (Anbindehaltung, Laufstall[a]) | **0.02** | $m^3$ $m^{-3}$ |
| solid manure/heap (deep bedding, sloped floor) | Festmist/Misthaufen (Tiefstreu, Tretmist) | 0.17 | $m^3$ $m^{-3}$ |
| pasture | Weide | 0.01 | $m^3$ $m^{-3}$ |

[a] loose housing other than deep bedding and sloped floor

Sources: see text

**Table 4.3: Cattle, partial emission factors for $NH_3$-N from housing (related to TAN)**

| Housing type | | Haltungssystem | | Emission factor (kg $kg^{-1}$) |
|---|---|---|---|---|
| tied systems | slurry based | Anbindehaltung | güllebasiert | 0.066 [a] |
| | straw based | | strohbasiert | 0.066 [a] |
| loose housing | slurry based | Laufstall | güllebasiert | 0.197 [a] |
| | straw based | | strohbasiert | 0.197 [a] |
| fully slatted floor | slurry based | Vollspaltenboden | güllebasiert | 0.099 [b] |
| deep bedding | straw based | Tiefstreu | strohbasiert | 0.197 [a] |
| sloped floor | straw based | Tretmist | strohbasiert | 0.213 [a] |

[a] estimated according to DÖHLER et al. (2002), pg. 49, and DÄMMGEN et al. (2010a), pg. 97

[b] estimated according to DÖHLER et al. (2002), pg. 49, and DÄMMGEN et al. (2010a), pg. 97, UNECE (1999), Table 3

**Table 4.4: Cattle, partial emission factors for $NH_3$-N from storage (related to TAN)**

| Storage type | Lagerungsart | Emission factor (kg $kg^{-1}$) |
|---|---|---|
| slurry (untreated) | Gülle (unbehandelt) | |
| slurry tank | Güllelager | |
| open tank (without natural crust) | offen (ohne natürliche Schwimmdecke) | 0.150 [a] |
| solid cover (incl. tent structures) | feste Abdeckung (inkl. Zelt) | 0.015 [b] |
| natural crust | natürliche Schwimmdecke | 0.045 [b] |
| floating cover (chaff) | schwimmende Abdeckung (Strohhäcksel) | 0.030 [b] |
| floating cover (plastic film) | schwimmende Abdeckung (Folie) | 0.023 [b] |
| underneath slatted floor > 1 month | Lager unter Spaltenboden > 1 Monat | 0.045 [a] |
| leachate, storage with solid cover | Jauche, Lagerung mit fester Abdeckung | 0.013 [a] |
| solid manure/heap (deep bedding, sloped floor) | Festmist/Misthaufen (Tiefstreu, Tretmist) | 0.600 [a] |
| solid manure/heap (tied systems, loose housing [d]) | Festmist/Misthaufen (Anbindehaltung, Laufstall) | 0.600 [a] |

[a] estimated according to DÄMMGEN et al. (2010a)

[b] calculated according to DÖHLER et al. (2002), Table 3.14

[c] Assumption: Same emissiion factor as for storage of untreated slurry in open tanks

[d] loose housing other than deep bedding and sloped floor

**Table 4.5: Cattle, partial emission factors for direct $N_2O$-N from housing and storage (applied to $N_{excr}$ + $N_{straw}$)**

| Storage type | Lagerungsart | Emission factor (kg $kg^{-1}$) |
|---|---|---|
| slurry (untreated) | Gülle (unbehandelt) | |
| slurry tank | Güllelager | |
| open tank (without natural crust) | offen (ohne natürliche Schwimmdecke) | 0.000 [a] |
| solid cover (incl. tent structures) | feste Abdeckung (inkl. Zelt) | 0.005 [b] |
| natural crust | natürliche Schwimmdecke | 0.005 [a] |
| floating cover (chaff) | schwimmende Abdeckung (Strohhäcksel) | 0.005 [c] |
| floating cover (plastic film) | schwimmende Abdeckung (Folie) | 0.000 [d] |
| underneath slatted floor > 1 month | Lager unter Spaltenboden > 1 Monat | 0.002 [a] |
| leachate, storage with solid cover | Jauche, Lagerung mit fester Abdeckung | 0.005 [e] |
| solid manure/heap (deep bedding, sloped floor) | Festmist/Misthaufen (Tiefstreu, Tretmist) | 0.010 [a] |
| solid manure/heap (tied systems, loose housing[g]) | Festmist/Misthaufen (Anbindehaltung, Laufstall) | 0.013 [f] |

[a] Source: IPCC(2006)-10.62 et seq.; for details see text
[b] A natural crust can develop and enough oxygen is available for $N_2O$ formation. Hence the EF of natural crust is adopted.
[c] Assumption (worst case) due to missing data: Floating covers produced by chaff act like natural crusts.
[d] Floating covers do not allow for the formation of a natural crust. Hence it is assumed that no $N_2O$ can develop.
[e] Assumption: comparable to solid-covered storage of slurry
[f] Source: VANDRÉ et al. (2012, 2013)
[g] loose housing other than deep bedding and sloped floor

## Pigs

**Table 5.2: Pigs, maximum methane producing capacity ($B_o$) and methane conversion factors (*MCF*)**

| Maximum methane producing capacity $B_o$ | Maximale Methanbildungs-Kapazität $B_o$ | 0.30 | $m^3$ CH4 (kg VS)$^{-1}$ |
|---|---|---|---|
| **Methane conversion factor *MCF*** | **Methanumwandlungsfaktor *MCF*** | | |
| slurry (untreated) | Gülle (unbehandelt) | | |
| slurry (tank) | Güllelager | | |
| open tank (without natural crust) | offen (ohne natürliche Schwimmdecke) | **0.25** | $m^3 m^{-3}$ |
| solid cover (incl. tent structures) | feste Abdeckung (inkl. Zelt) | 0.25 | $m^3 m^{-3}$ |
| natural crust | natürliche Schwimmdecke | **0.15** | $m^3 m^{-3}$ |
| floating cover (chaff) | schwimmende Abdeckung (Strohhäcksel) | 0.25 | $m^3 m^{-3}$ |
| floating cover (plastic film) | schwimmende Abdeckung (Folie) | 0.25 | $m^3 m^{-3}$ |
| underneath slatted floor > 1 month | Lager unter Spaltenboden > 1 Monat | **0.25** | $m^3 m^{-3}$ |
| solid manure/heap (deep bedding) | Festmist/Misthaufen (Tiefstreumist) | 0.25 | $m^3 m^{-3}$ |
| solid manure/heap (other systems) | Festmist/Misthaufen (übrige Systeme) | **0.03** | $m^3 m^{-3}$ |

Sources: see text

**Table 5.3: pigs, partial emission factors for $NH_3$-N from housing (related to TAN)**

| | | Sows and suckling-pigs | Fattening pigs and weaners |
|---|---|---|---|
| **Housing type** | **Haltungssystem** | $EF_{house}$ (kg $kg^{-1}$) | $EF_{house}$ (kg $kg^{-1}$) |
| slurry based | güllebasiert | 0.34 | |
| closed insulated stable [a] | wärmegedämmter Stall [a] | | |
| fully slatted floor | Vollspaltenboden | | 0.3 |
| partly slatted floor | Teilspaltenboden | | 0.3 |
| free ventilated | Außenklimastall | | |
| kennel house | Kistenstall | | 0.2 |
| straw based | strohbasiert | 0.34 | |
| closed insulated stable [a] | wärmegedämmter Stall [a] | | |
| deep bedding | Tiefstreu | | 0.4 |
| plane floor with bedding | planbefestigt mit Einstreu | | 0.4 |
| free ventilated | Außenklimastall | | |
| kennel house | Kistenstall | | 0.2 |
| deep bedding | Tiefstreu | | 0.35 |

[a] synonymous with "housing with forced ventilation "
Source: Dämmgen et al. (2010b)

**Table 5.4: Pigs, partial emission factors for $NH_3$-N losses from storage (related to TAN)**

| Storage type | Lagerungsart | emission factor (kg kg$^{-1}$) |
|---|---|---|
| slurry (untreated) | Gülle (unbehandelt) | |
| slurry tank | Güllelager | |
| open tank (without natural crust) | offen (ohne natürliche Schwimmdecke) | 0.150 [a] |
| solid cover (incl. tent structures) | feste Abdeckung (inkl. Zelt) | 0.015 [b] |
| natural crust | natürliche Schwimmdecke | 0.105 [b] |
| floating cover (chaff) | schwimmende Abdeckung (Strohhäcksel) | 0.030 [b] |
| floating cover (plastic film) | schwimmende Abdeckung (Folie) | 0.023 [b] |
| underneath slatted floor > 1 month | Lager unter Spaltenboden > 1 Monat | 0.105 [a] |
| leachate, storage with solid cover | Jauche, Lagerung mit fester Abdeckung | 0.030 [a] |
| solid manure/heap (deep bedding) | Festmist/Misthaufen (Tiefstreumist) | 0.600 [a] |
| solid manure/heap (other systems) | Festmist/Misthaufen (übrige Systeme) | 0.600 [a] |

[a] estimated according to DÄMMGEN et al. (2010b)
[b] calculated according to DÖHLER et al. (2002), Table 3.14

**Table 5.5: Pigs, partial emission factors for $N_2O$-N from housing and storage (applied to $N_{excr}$ + $N_{straw}$)**

| Storage type | Lagerungsart | Emission factor (kg kg$^{-1}$) |
|---|---|---|
| slurry (untreated) | Gülle (unbehandelt) | |
| slurry tank | Güllelager | |
| open tank (without natural crust) | offen (ohne natürliche Schwimmdecke) | 0.000 [a] |
| solid cover (incl. tent structures) | feste Abdeckung (inkl. Zelt) | 0.005 [b] |
| natural crust | natürliche Schwimmdecke | 0.005 [a] |
| floating cover (chaff) | schwimmende Abdeckung (Strohhäcksel) | 0.005 [c] |
| floating cover (plastic film) | schwimmende Abdeckung (Folie) | 0.000 [d] |
| underneath slatted floor > 1 month | Lager unter Spaltenboden > 1 Monat | 0.002 [a] |
| leachate, storage with solid cover | Jauche, Lagerung mit fester Abdeckung | 0.005 [e] |
| solid manure/heap (deep bedding) | Festmist/Misthaufen (Tiefstreumist) | 0.010 [a] |
| solid manure/heap (other systems) | Festmist/Misthaufen (übrige Systeme) | 0.013 [f] |

[a] Source: IPCC(2006)-10.62 et seq.; for details see text
[b] A natural crust can develop and enough oxygen is available for $N_2O$ formation. Hence the EF of natural crust is adopted.
[c] Assumption (worst case) due to missing data: Floating covers produced by chaff act like natural crusts.
[d] Floating covers do not allow for the formation of a natural crust. Hence it is assumed that no $N_2O$ can develop.
[e] Assumption: comparable to solid-covered storage of slurry
[f] Source: VANDRÉ et al. (2012, 2013)

## Broilers

According to IPCC (2006)-10.82, the maximum methane producing capacity $B_O$ and the methane conversion factor MCF are 0.36 m$^3$ kg$^{-1}$ and 0.015 kg kg$^{-1}$ respectively.

**Table 8.13: Broilers, derivation of partial emission factors for $NH_3$-N losses from housing**

| Fattening period d | EF [a] kg $NH_3$ (pl · a)$^{-1}$ | EF [b] kg $NH_3$-N (pl · a)$^{-1}$ | Standard N excretion [c] kg N (pl · a)$^{-1}$ | EF related to standard N excretion kg $NH_3$-N (kg $N_{excr}$)$^{-1}$ | EF used in the inventory kg $NH_3$-N (kg $N_{excr}$)$^{-1}$ |
|---|---|---|---|---|---|
| 33 | 0.035 | 0.029 | 0.319 | 0.090 | 0.090 |
| 42 | 0.0486 | 0.040 | 0.469 | 0.085 | |

[a] Source: EURICH-MENDEN et al. (2011)
[b] Source: EURICH-MENDEN et al. (2011), data multiplied by 14/17 to transform from $NH_3$ to $NH_3$-N units
[c] Source: DLG (2005), pg. 49/50

For the partial $NH_3$-N emission factor for storage, the value given in EMEP (2013)-3B-27, Table 3.7, is used: 0.17 kg kg$^{-1}$. The factor relates to the UAN amount entering the storage.

| Table 8.2: | Poultry, partial emission factors for $N_2O$-N, NO-N, and $N_2$-N from housing and storage (applied to $N_{excr}$ + $N_{straw}$) | | | |
|---|---|---|---|---|
| $N_2O$ | poultry manure | Geflügelkot | 0.001 | kg $kg^{-1}$ |
| NO | poultry manure | Geflügelkot | 0.0001 | kg $kg^{-1}$ |
| $N_2$ | poultry manure | Geflügelkot | 0.003 | kg $kg^{-1}$ |
| Source: see text | | | | |

**Additional information**

- All straw N is considered to be organic N, of which 50 % mineralize to TAN (expert judgement Döhler, H., KTBL).
- For untreated slurry, it is assumed that 10 % of the TAN entering storage is converted to $N_{org}$, while 10 % of the $N_{org}$ entering storage is converted to TAN.
- According to expert judgement of the EAGER working group it is assumed that in solid manure management systems of mammals 40 % of the TAN entering the storage will be immobilized, if enough bedding material is available (which is assumed to be true in the inventory). In contrast to that, it is assumed that in poultry husbandry with bedding there is no immobilisation of UAN, because the preferably dry conditions in poultry husbandry impede the respective chemical processes.
- According to expert judgement (Döhler, H., KTBL), the inventory assumes that in solid systems of mammals (except deep bedding and sloped floor) the N stored as leachate ("Jauche") is 25 % of the N excreted in the housing minus $NH_3$-N emissions from housing. For sloped floor the inventory uses a lower value (13 %).
- Deep bedding does not produce leachate (0 %).
- According to Table 2.14 in Döhler et al. (2002), the TAN content of leachate is set to 90 %.

### 1.2.5. Latvia

In the ex-housing level, nitrogen loss emission factors are 10 % for dairy cows, 18 % for pigs, no values for poultry. Bedding calculation are based on survey data (what bedding materials farmers actually use and how much) and experimental analyses of corresponding bedding materials. For water addition, default values for different animal groups are used. There are no DM decay coefficients for ex-housing level, but coefficients for different animal groups exist at ex-storage level. Similarly, to ex-housing level estimated N loss used at ex-storage level. According to national regulation, manure storing in field heaps allowed only for smaller farms with less than 10 animals units or less than five animal units in highly vulnerable zones.

**Dairy cows**

The information and data provided below based on 2007 – 2009 project. The data have not been recalculated or changed since then.

Calculations and formulas used:

$$\mathrm{NPK}_{\mathrm{ex-housing}}, \mathrm{kg} = \mathrm{NPK}_{\mathrm{ex-animal}}, \mathrm{kg} - \mathrm{NPK}_{\mathrm{housing\ loses}}, \mathrm{kg} - \mathrm{NPK}_{\mathrm{grazing\ loses}}, \mathrm{kg}$$

$$\mathrm{NPK}_{\mathrm{grazing\ loses}}, \mathrm{kg} = \frac{\mathrm{NPK}_{\mathrm{ex-animal}}, \mathrm{kg} - \mathrm{t}_{\mathrm{days\ grazing}}}{\mathrm{t}_{\mathrm{days\ per\ year}}}$$

$$\mathrm{NPK}_{\mathrm{ex-storage}}, \mathrm{kg} = \left(\mathrm{NPK}_{\mathrm{ex-housing}}, \mathrm{kg} + \mathrm{NPK}_{\mathrm{bedding}}, \mathrm{kg}\right) \times \frac{100 - \mathrm{NPK}_{\mathrm{storage\ loses}}, \%}{100}$$

$$\mathrm{DM}_{\mathrm{ex-storage}}, \mathrm{kg} = \mathrm{DM}_{\mathrm{ex-storage}}, \mathrm{kg}\left(\mathrm{DM}_{\mathrm{faeces}}, \mathrm{kg} + \mathrm{DM}_{\mathrm{urine}}, \mathrm{kg} + \mathrm{DM}_{\mathrm{bedding}}, \mathrm{kg} - \mathrm{DM}_{\mathrm{grazing\ loss}}, \mathrm{kg}\right) \times \frac{100 - \mathrm{DM}_{\mathrm{storage\ loss}}, \%}{100}$$

$$\mathrm{Manure}_{\mathrm{ex-storage}}, \mathrm{kg} = \frac{\mathrm{DM}_{\mathrm{ex-storage}}, \mathrm{kg} \times 100\ \%}{20\ \%} + \mathrm{Water}, \mathrm{kg}$$

Experimental data from surveys and laboratory analyses for cows with milk production 6200 kg. Similar data for cows with milk production with 6421 kg, 7000 kg, 7350 kg, 10250 kg, 11000 kg and 11700 kg were gathered.

**Bedding per one milking cow per year**

| Bedding | Consumption, kg | Composition, natural moisture, % | | | | Consumption, kg | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Dry matter | N | $P_2O_5$ | $K_2O$ | Dry matter | N | $P_2O_5$ | $K_2O$ |
| Saw dust | 1825 | 70 | 0,04 | 0,02 | 0,04 | 1277,5 | 0,7 | 0,4 | 0,7 |
| Total | | | | | | 1277,5 | 0,7 | 0,4 | 0,7 |

**Example of calculation per one milking cow (milk production 6200 kg) per year**

| No. | Variables, comments | Calculation, result |
|---|---|---|
| 1.3. | DM in faeces, kg<br>(per year) | 2252 |
| 1.5. | Amount of urine, kg<br>(literature data Standard values (1998), assuming urine makes up 45 % of faeces) | 6825 |
| 1.6. | DM in urine, %<br>(average data from literature) | 5 |
| 1.7. | DM ex-animal, kg<br>(faeces + urine) | 1.3. + 1.5. × 1.6. / 100 = 2593 |
| 1.8. | Out of barn days | 150 |
| 1.9. | DM left out of barn, kg | 1.7. × 1.8. / 365 = 1066 |
| 1.10. | DM in litter, kg | 1277,5 |
| 1.11. | DM loses during storage, % | 20 |
| 1.12. | DM in manure ex-storage, kg | (1.7. - 1.9. + 1.10.) × (100 – 1.11.) / 100 = 2244 |
| 1.13. | DM in manure ex-storage, $kg{\cdot}t^{-1}$ | 187,3 |
| 2.7. | N ex-animal, kg<br>(faeces + urine, N excreted) | 136,1 |
| 2.8. | In-barn N loses, %<br>(Assumed value totaling all loses, deliberately high) | 10 (or 13,61 kg) |
| 2.9. | N excreted during grazing, kg<br>(calculated from grazing time) | 2.7. × 1.8. / 365 = 55,9 |
| 2.10. | N ex-housing, kg<br>(Theoretically feasible) | 2.7. - 2.8. - 2.9. = 66,6 |
| 2.11. | N loses during storage, %<br>(Assumed value totaling all loses, deliberately high) | 20 |
| 2.12. | N added with bedding, kg<br>(survey and experimental data, for some reason used for ex-storage instead of ex-housing level) | 0,7 |
| 2.13. | N ex-storage, kg | (2.10. + 2.12.) - × (100 – 2.11.) / 100 = 54 |
| 2.14. | N ex-storage, $kg{\cdot}t^{-1}$ | 4,5 |
| 3.6. | $P_2O_5$ ex-animal, kg<br>(faeces + urine, N excreted) | 38,6 |

| | | |
|---|---|---|
| 3.7. | In-barn $P_2O_5$ loses, %<br>(Assumed value totaling all loses, deliberately high) | 2 (or 0,8 kg) |
| 3.8. | $P_2O_5$ excreted during grazing, kg<br>(calculated from grazing time) | 3.6. × 1.8. / 365 = 15,9 |
| 3.9. | $P_2O_5$ ex-housing, kg<br>(Theoretically feasible) | 3.6. - 3.7. - 3.8. = 22 |
| 3.10. | $P_2O_5$ loses during storage, %<br>(Assumed value totaling all loses, deliberately high) | 5,0 |
| 3.11. | $P_2O_5$ added with bedding, kg<br>(survey and experimental data, for some reason used for ex-storage instead of ex-housing level) | 0,4 |
| 3.12. | $P_2O_5$ ex-storage, kg | (3.9. + 3.11.) × (100 – 3.10.) / 100 = 21 |
| 3.13. | $P_2O_5$ ex-storage, $kg \cdot t^{-1}$ | 1,8 |
| 4.6. | $K_2O$ ex-animal, kg<br>(faeces + urine, N excreted) | 106,6 |
| 4.7. | In-barn $K_2O$ loses, %<br>(Assumed value totaling all loses, deliberately high) | 3 (or 3,2 kg) |
| 4.8. | $K_2O$ excreted during grazing, kg<br>(calculated from grazing time) | 4.6. × 1.8. / 365 = 43,8 |
| 4.9. | $K_2O$ ex-housing, kg<br>(Theoretically feasible) | 4.6. - 4.7. - 4.8. = 60 |
| 4.10. | $K_2O$ loses during storage, %<br>(Assumed value totaling all loses, deliberately high) | 5 |
| 4.11. | $K_2O$ added with bedding, kg<br>(survey and experimental data, for some reason used for ex-storage instead of ex-housing level) | 0,7 |
| 4.12. | $K_2O$ ex-storage, kg | (4.9. + 4.11.) × (100 – 4.10.) / 100 = 57 |
| 4.13. | $K_2O$ ex-storage, $kg \cdot t^{-1}$ | 4,8 |
| 5.1. | Water added, kg<br>(washing water, silage effluent and other liquids) | 100 |
| 5.2. | DM in faeces, urine, litter, etc., %<br>(average value for recalculation to natural moist basis) | 20 |
| 5.3. | Amount of manure ex-storage, kg | 1.13. × 100 / 5.2. + 5.1. = 11983 |

**Slaughter pigs**
The information and data provided based on 2007 – 2009 project. The data have not been recalculated or changed since then.

Calculations and formulas used:

$$\text{NPK}_{\text{ex-housing}}, \text{kg} = \text{NPK}_{\text{ex-animal}}, \text{kg} - \text{NPK}_{\text{housing loses}}, \text{kg}$$

$$\text{NPK}_{\text{ex-storage}}, \text{kg} = \left(\text{NPK}_{\text{ex-housing}}, \text{kg} + \text{NPK}_{\text{bedding}}, \text{kg}\right) \times \frac{100 - \text{NPK}_{\text{storage loses}}, \%}{100}$$

$$\text{DM}_{\text{ex-storage}}, \text{kg} = \left(\text{DM}_{\text{faeces}}, \text{kg} + \text{DM}_{\text{urine}}, \text{kg} + \text{DM}_{\text{bedding}}, \text{kg} - \text{DM}_{\text{grazing loss}}, \text{kg}\right) \times \frac{100 - \text{DM}_{\text{storage loss}}, \%}{100}$$

$$\text{Manure}_{\text{ex-storage}}, \text{kg} = \frac{\text{DM}_{\text{ex-storage}}, \text{kg} \times 100\ \%}{20\ \%} + \text{Water}, \text{kg}$$

**Bedding per one slaughter pig per fattening period**

| Bedding | Consumption, kg | Composition, natural moisture, % | | | | Consumption, kg | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Dry matter | N | $P_2O_5$ | $K_2O$ | Dry matter | N | $P_2O_5$ | $K_2O$ |
| Saw dust | 92 | 70 | 0,04 | 0,02 | 0,04 | 64,4 | 0,0 | 0,0 | 0,0 |
| Total | | | | | | 64,4 | 0,0 | 0,0 | 0,0 |

**Example of calculation per one slaughter pig per fattening period**

| No. | Variables, comments | Calculation, result |
|---|---|---|
| 1.3. | DM in faeces, kg (per year) | 43,10 |
| 1.5. | Amount of urine, kg | 280,80 |
| 1.6. | DM in urine, % (average data from literature) | 5 |
| 1.7. | DM ex-animal, kg (faeces + urine) | 1.3. + 1.5. × 1.6. / 100 = 57,14 |
| 1.8. | DM in litter, kg | 64,4 |
| 1.9. | DM loses during storage, % | 30 (or 12,93 kg) |
| 1.10. | DM in manure ex-storage, kg | (1.7. + 1.8.) × (100 – 1.8.) / 100 = 85,08 |
| 1.11. | DM in manure ex-storage, $kg \cdot t^{-1}$ | 186,93 |
| 2.4. | N ex-animal, kg (faeces + urine, N excreted) | 4,40 |
| 2.5. | In-barn N loses, % (Assumed value totaling all loses, deliberately high) | 18,00 (or 0,79 kg) |
| 2.6. | N ex-housing, kg (Theoretically feasible) | 2.4. - 2.5. = 3,60 |
| 2.7. | N loses during storage, % (Assumed value totaling all loses, deliberately high) | 20 |
| 2.8. | N added with bedding, kg (survey and experimental data, for some reason used for ex-storage instead of ex-housing level) | 0,00 |
| 2.9. | N ex-storage, kg | (2.6. + 2.8.) - × (100 – 2.7.) / 100 = 2,88 |
| 2.10. | N ex-storage, $kg \cdot t^{-1}$ | 6,34 |
| 3.4. | $P_2O_5$ ex-animal, kg (faeces + urine, N excreted) | 2,12 |
| 3.5. | In-barn $P_2O_5$ loses, % (Assumed value totaling all loses, deliberately high) | 2 (or 0,04 kg) |
| 3.6. | $P_2O_5$ ex-housing, kg (Theoretically feasible) | 3.4. - 3.5. = 2,07 |
| 3.7. | $P_2O_5$ loses during storage, % (Assumed value totaling all loses, deliberately high) | 5 |
| 3.8. | $P_2O_5$ added with bedding, kg (survey and experimental data, for some reason used for ex-storage instead of ex-housing level) | 0,00 |
| 3.9. | $P_2O_5$ ex-storage, kg | (3.6. + 3.8.) × (100 – 3.7.) / 100 = 1,95 |

| | | |
|---|---|---|
| 3.10. | $P_2O_5$ ex-storage, $kg \cdot t^{-1}$ | 4,28 |
| 4.4. | $K_2O$ ex-animal, kg<br>(faeces + urine, N excreted) | 1,62 |
| 4.5. | In-barn $K_2O$ loses, %<br>(Assumed value totaling all loses, deliberately high) | 3 (or 0,05 kg) |
| 4.6. | $K_2O$ ex-housing, kg<br>(Theoretically feasible) | 4.4. - 4.5. = 1,57 |
| 4.7. | $K_2O$ loses during storage, %<br>(Assumed value totaling all loses, deliberately high) | 12 |
| 4.8. | $K_2O$ added with bedding, kg<br>(survey and experimental data, for some reason used for ex-storage instead of ex-housing level) | 0,00 |
| 4.9. | $K_2O$ ex-storage, kg | (4.6. + 4.8.) × (100 – 4.7.) / 100 = 1,39 |
| 4.10. | $K_2O$ ex-storage, $kg \cdot t^{-1}$ | 3,04 |
| 5.1. | Water added, kg<br>(washing water, silage effluent and other liquids) | 50 |
| 5.2. | DM in faeces, urine, litter, etc., %<br>(average value for recalculation to natural moist basis) | 21 |
| 5.3. | Amount of manure ex-storage, kg | 1.10. × 100 / 5.2. + 5.1. = 455,14 |

**Broilers**

The information and data provided based on 2007 – 2009 project. The data have not been recalculated or changed since then. Formulas for calculations at ex-housing level not exist. Ex-housing losses are included in ex-storage level.

Calculations and formulas used:

$$\mathrm{NPK}_{\text{ex-storage}}, \mathrm{kg} = \left(\mathrm{NPK}_{\text{ex-animal}}, \mathrm{kg} + \mathrm{NPK}_{\text{bedding}}, \mathrm{kg}\right) \times \frac{100 - \mathrm{NPK}_{\text{storage and housing loses}}, \%}{100}$$

$$\mathrm{DM}_{\text{ex-storage}}, \mathrm{kg} = \left(\frac{\mathrm{DM}_{\text{faeces}}, \%}{100} \times \text{ Faeces, kg} + \mathrm{DM}_{\text{bedding}}, \mathrm{kg}\right) \times \frac{100 - \mathrm{DM}_{\text{storage loses}}, \%}{100}$$

**Example of calculation per one broiler per period**

| No. | Variables, comments | Calculation, result |
|---|---|---|
| 25. | DM in faeces, % | 22 |
| 26. | Faeces, kg | 2,95 |
| 27. | DM in litter, kg | 0,39 |
| 28. | DM loses during storage, % | 20 |
| 29. | DM in manure ex-storage, kg | (26. × (25. / 100) + 27.) × (100 – 20.) / 100 = 0,83 |
| 11. | N ex-animal, kg<br>(faeces + urine, N excreted) | 0,059 |
| 31. | N loses during storage, % | 30 |
| 33. | N added with bedding, kg | 0,0002 |
| 32. | N ex-storage, kg | (11. + 33.) × (100 – 32.) / 100 = 0,0415 |
| 16. | $P_2O_5$ ex-animal, kg | 0,019 |
| 35. | $P_2O_5$ loses during housing and storage, % | 5 |
| 37. | $P_2O_5$ added with bedding, kg | 0,0002 |
| 36. | $P_2O_5$ ex-storage, kg | (16. + 37.) × (100 – 35.) / 100 = 0,0182 |

| | | |
|---|---|---|
| 21. | $K_2O$ ex-animal, kg | 0,024 |
| 39. | $K_2O$ loses during housing and storage, % | 15 |
| 41. | $K_2O$ added with bedding, kg | 0,0002 |
| 40. | $K_2O$ ex-storage, kg | (21. + 41.) × (100 – 39.) / 100 = 0,0207 |

### 1.2.6. Poland

Calculation of fresh matter of manure:

*Deep litter barn*
**Manure (solid manure)** = faeces + urine + straw + water (from washing and drinking)
*Shallow litter barn*
**Solid manure** = 95% faeces + straw + urine and water absorbed by straw (1kg of straw absorbs 2,5 kg of liquids)
**Liquid manure** = 5% faeces + urine + water (not absorbed by straw)

*Straw less barn*
**Slurry** = faeces + urine + water

Calculation of N and P content in manure:
N and P in excrement are distributed proportionally to fresh matter distribution shown above. Fresh matter of faeces and urine, as well as N and P in excrements and straw, quantity of straw used and water dropping in are standardized for selected animal groups are presented in the next table.

**Quantity and composition of excrement from selected group of animal**

| Animal species | Faeces (kg) | | | | Urine (kg) | | | | Straw (kg) | Water (kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh matter | N | P | K | Fresh matter | N | P | K | | |
| Cow (365 days) | 10130 | 39,4 | 14,8 | 1,48 | 4939 | 50,3 | 0,37 | 72,6 | 1460 | 1000 |
| Slaughter pig (50 days) | 93,8 | 0,69 | 0,38 | 0,34 | 234 | 1,62 | 0,16 | 0,51 | 27 | 8 |
| Broiler (56 days) | 4,63 | 0,072 | 0,009 | 0,021 | - | - | - | - | 5 | |

Quantity of N in manure is reduced respectively to gas emission as shown in next table.

**N losses from manure (percentage of total quantity of N)**

| Housing system | Animal species | Inside the barn | At storage |
|---|---|---|---|
| Deep litter | Cattle | 8 % | - |
| | Pigs | 25 % | - |
| Shallow litter – solid manure | Cattle | 6% | 15% |
| | Pigs | 13% | 25% |
| | Poultry | 20% | 20% |

| | | | |
|---|---|---|---|
| Shallow litter – liquid manure | Cattle | 6% | 5% |
| | Pigs | 26% | 5% |
| | | | |
| Strawless – slurry | Cattle | 4% | 5% |
| | Pigs | 17% | 12% |
| | Poultry | - | 25% |

In 2013, new ready to use tabular system for manure production was published. Standard values established experimentally for all main species of livestock. These analyses were conducted in National Research Institute for Animal Production. The research covered population of: 1080 dairy cows, 1800 slaughter pigs and 7000 broilers. The results of quantity and chemical composition analysis statistically elaborated for different animal housing systems: deep, shallow and straw less barn. Analysis were performed between 2004 – 2011. The next monitoring program is planned for 2019-2021.

**The average annual production of manure and the concentration of nitrogen (N) and phosphorus ($P_2O_5$)**

| Animal | Animal housing systems | | | | | | | | | | | | Coorrection coefficient Ncoef | Coorrection coefficient Pcoef |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Deep litter barn | | | Shallow litter barn | | | | | | Strawless barn | | | | |
| | Solid manure | | | Solid manure | | | Liquid manure | | | Slurry | | | | |
| | quantity ($t \cdot year^{-1}$) | N content ($kg \cdot t^{-1}$) | P2O5 content ($kg \cdot t^{-1}$) | quantity ($t \cdot year^{-1}$) | N content ($kg \cdot t^{-1}$) | P2O5 content ($kg \cdot t^{-1}$) | quantity ($m^3 \cdot year^{-1}$) | N content ($kg \cdot t^{-1}$) | P2O5 content ($kg \cdot t^{-1}$) | quantity ($m^3 \cdot year^{-1}$) | N concentration ($kg N \cdot m^{-3}$) | | | |
| Dairy cows 1 [a] | 18,8 | 2,6 | 0,81 | 10,0 | 2,8 | 0,87 | 6,2 | 2,7 | 0,84 | 17,6 | 3,4 | 1,06 | 0,97 | 0,70 |
| Dairy cows 2 [b] | 23,8 | 3,1 | 0,97 | 14,8 | 3,2 | 1,03 | 7,6 | 3,2 | 1,0 | 23,0 | 4 | 1,25 | 0,97 | 0,65 |
| Dairy cows 3 [c] | 26,0 | 3,7 | 1,16 | 16,2 | 4 | 1,25 | 8,4 | 3,8 | 1,19 | 25,4 | 4,5 | 1,41 | 0,95 | 0,60 |
| Slaughter pigs | 2,0 | 4,2 | 1,83 | 1,5 | 4,4 | 1,37 | 1,0 | 4,6 | 2,0 | 1,9 | 4,6 | 2,0 | 0,75 | 0,65/0,80 |
| Broilers | 0,05 | 12,7 | 7,05 | - | - | | | | - | 0,03 | 17 | 5,83 | 0,86 | 0,66/0,80 |

a – dairy cows with 6 thousand liters of milk production per year
b – dairy cows with 6-8 thousand liters of milk production per year
c – dairy cows with 8 thousand liters of milk production per year

**Ncoef –** coefficient used for decreasing N content resulting from proven and well-known nutritional practices by the farmer, using reduced protein concentrations in the feed, protein digestibility, multiphase feeding

**Pcoef**– concentration coefficient used for decreasing P2O5 content resulting from proven nutritional practices (phytase application etc.)

## 1.2.7. Russia

Manure quantity and quality at the ex-housing and ex-storage level is calculated according to a number of legislative documents:

- Management Directive for Agro-Industrial Complex “Recommended Practice for Engineering Designing of Cattle Farms and Complexes” РД-АПК 1.10.01.02-10 in force since 2011;
- Management Directive for Agro-Industrial Complex “Recommended Practice for Engineering Designing of Pig Farms and Complexes” РД-АПК 1.10.02.04-12 in force since 2012;

- Management Directive for Agro-Industrial Complex “Recommended Practice for Engineering Designing of Poultry Farms” РД-АПК 1.10.05.04-13 in force since 2013;
- Management Directive for Agro-Industrial Complex “Recommended Practice for Engineering Designing of Systems for Animal and Poultry Manure Removal and Pre-application Treatment” РД-АПК 1.10.15.02-17 in force since 2017;
- Management Directive for Agro-Industrial Complex “Recommended Practice for Designing of Systems for Animal and Poultry Manure Removal, Treatment, Disinfection, Storage and Utilization” РД-АПК 3.10.15.02-17 in force since 2017;
- Recommendations to calculate atmospheric pollutant emissions from the objects of animal and poultry production.

The maximum single emissions and gross emissions of pollutants (ammonia, in particular) into the air from animals in animal houses and products of their vital activity recommended to calculate by the formula:

$$M_{\max} = (1 - \frac{\lambda^K}{100}) \times K_{2X} \times 10^{-6} \times \sum_{i=1}^{n} (y_i \times N_{i\max} \times (\frac{q}{1000})) \times (1 + K_{5\max} \times K_{6\max} \times K_7 \times K_8 \times K_9)$$

$$G = \left(1 - \frac{\lambda^K}{100}\right) \times 3.6 \times 10^{-9} \times \sum_{j=1}^{m} (K_2 \times \tau \times D \times y_j \times N_j \times (\frac{q}{1000})) \times (1 + K_5 \times K_6 \times K_7 \times K_8) \quad ,$$

where $M_{\max}$ is the maximum single emission of pollutants from the $i^{th}$ stationary and / or fugitive source (animal housing and manure storage), g / s;

$G$ - gross emission of pollutants from the $i^{th}$ stationary and / or fugitive source (animal housing and manure storage), t/year;

$\lambda^K$ - average operating gas cleaning efficiency in the gas treatment unit, %;

$K_2$ - coefficient that takes into account the temperature conditions of animal housing. For gaseous pollutants under the air temperature in animal houses below +5°C $K_2 = 1.1$;

$N_{\max}$ - maximum number of animals of the corresponding category housed in the considered source with due account for the average live mass;

$N$ - average number of animals of the corresponding category housed in the considered source during the considered period with due account for the average live weight;

$\tau$ - residence time of animals of the corresponding category with an average live weight in the animal house, h/day;

$y$ - specific indicators of ex-animal pollutant emissions of the corresponding category with an average live weight (adjustment of basic specific indicators for compliance with actual feeding norms and average live weight);

$q$ - average weight of one animal of the corresponding category housed in the considered source during the considered period, kg;

$K_5$ - coefficient, which takes into account the temperature of the middle layers of manure found in the animal house or in the manure storage. The maximum value of $K_5$ is determined under the temperature of the middle layers of manure in one of the hottest months of the year;

$K_6$ - coefficient, which takes into account maximum and minimum age of manure found in the animal house or in the manure storage;

$K_7$ - coefficient, which takes into account the application of bedding. The maximum value is 1.3. The weighted average value is 1.15. In the case of bedding-free manure, $K_7$ is ignored;

$K_8$ - coefficient of manure covering. It is set based on the data of field measurements. The maximum value of the coefficient is 1 if the manure surface is completely uncovered.
$K_9$ - coefficient, which takes into account the animal housing system: under stable (cage) housing $K_9 = 1$, under animal keeping on pastures $K_9 = 0.9$
$D$ - residence time of animals of the corresponding category in the animal house, day/year;

Specific atmospheric emissions of ammonia directly from

- Healthy poultry (chicken) are 116 µg/t of live weight
- Healthy pig are 81.6 µg/t of live weight
- Healthy cow are 59.4 µg/t of live weight

For the conditions of the North-Western Federal District of the Russian Federation the formula to calculate ex-house ammonia emissions per animal category per day (kg/day) takes the form:

$$M_{NH3} = 86.4 \times 10^{-6} \times \sum_{i=1}^{n} (y_i \times N_{i\max} \times (\frac{q}{1000}))$$

Ex-housing nitrogen loss per animal category (kg/day) is calculated by the formula:
$$L_{nitrogen\_house\_category\_losses} = M_{NH3} * 0.83$$

Mass of manure per one animal per day (kg/day) is calculated by the formula:
$$Q_{manure\_animal} = Q_{excrements\_animal} + Q_{water\_animal} + Q_{bedding\_animal} + Q_{feed\_animal}$$

Manure moisture content (%) per animal is calculated by the formula:
$$W_{manure\_animal} = \frac{Q_{excrements\_animal} * W_{excrements\_animal}}{Q_{excrements\_animal} + Q_{water\_animal} + Q_{bedding\_animal}} + \frac{Q_{water\_animal} * 100}{Q_{excrements\_animal} + Q_{water\_animal} + Q_{bedding\_animal}} + \frac{Q_{bedding\_animal} * W_{bedding\_animal}}{Q_{excrements\_animal} + Q_{water\_animal} + Q_{bedding\_animal}}$$

Mass of excrements per animal category per day (kg/day) calculated by the formula:
$$Q_{excrements\_category} = Q_{excrements\_animal} * i$$

Mass of water getting into manure per animal category per day (kg/day) calculated by the formula:
$$Q_{water\_category} = Q_{water\_animal} * i$$

Mass of bedding material per animal category per day (kg/day) calculated by the formula:
$$Q_{bedding\_category} = Q_{bedding\_animal} * i$$

Mass of feed leftovers, which get into manure, per animal category per day (kg/ day) calculated by the formula:
$$Q_{feed\_category} = Q_{feed\_animal} * i$$

Mass of manure per animal category per day (kg/day) calculated by the formula:

$$Q_{manure\_category} = Q_{excrements\_category} + Q_{water\_category} + Q_{bedding\_category} + Q_{feed\_category}$$

Moisture content of manure per animal category (percentage) calculated by the formula:

$W_{manure\_category} = \frac{Q_{excrements\_category} * W_{excrements\_category}}{Q_{excrements\_category} + Q_{water\_category} + Q_{bedding\_category}} + \frac{Q_{water\_category} * 100}{Q_{excrements\_category} + Q_{water\_category} + Q_{bedding\_category}} + \frac{Q_{bedding\_category} * W_{bedding\_category}}{Q_{excrements\_category} + Q_{water\_category} + Q_{bedding\_category}}$

Mass of manure from all animal categories on the animal complex per day (kg/day) calculated by the formula:

$Q_{manure\_complex} = \sum_{1}^{m} Q_{manure\_category}$ , where $m$ is the number of animal categories

Manure moisture content from all animal categories on the animal complex (percentage) calculated by the formula:

$W_{manure\_complex} = \frac{\sum_{1}^{m} Q_{manure\_category} * W_{manure\_category}}{Q_{manure\_complex}}$

Mass of nitrogen in manure per animal category (kg/day) calculated by the formula:

$N_{manure\_category} = N_{excrements\_category} + N_{bedding\_category}$

Ex-housing mass of total nitrogen in manure per animal category per day (kg/day) calculated by the formula:

$N_{house\_category} = N_{manure\_category} - L_{nitrogen\_house\_category\_losses}$

In the pig houses, the maximum allowable concentration of ammonia in the air is 20 mg/m$^3$.
The mass of excrements from all the slaughter pigs on the animal complex (kg/day) calculated by the formula:

$$Q_{excrements\_category} = 6.5 \times i$$

The moisture content of excrements of slaughter pigs is 87.5 %
The most common pig housing system is bedding-free housing on partially slatted floors. The bedding housing is only on fully solid floors. In this case, the bedding rate is 50 kg/head/year. Sawdust and straw used as a bedding material. In justified cases, peat may be used for this purpose; with its per head rate being 1.5 times bigger than that of sawdust and straw.

<u>The bedding housing on fully solid floors:</u> the mass of bedding material (kg/day) for all slaughter pigs, calculated by the formula:

$$Q_{bedding\_category} = \frac{50}{365} \times i = 0.14 \times i$$

**Moisture and nutrients content of applied bedding material**

| Bedding material | $W_{bedding}$ , % | N content in oven-dry substance, % | $P_2O_5$ content in oven-dry substance, % |
|---|---|---|---|
| Peat | 60 | 1.5-2.0 | 0.2-0.3 |
| Grain crops straw (chopped) | 14 | 0.5 | 0.3 |
| Sawdust | 22 | 0.25 | 0.3 |
| Bark | 26 | 0.5 | 0.1 |

Bedding housing on fully solid floors – the water getting into manure is zero

The amount of process water (bedding-free housing on partly slatted floor), which gets into manure, is 4.5 kg/head/day. This value based on the calculation of washing and disinfection of one box for 600 pigs once every two days.

**Water consumption for washing manure canals**

| Manure removal system from an animal house | Water consumption rate per pig per day, l (under group housing) |
|---|---|
| Continuous gravity flow (manure moisture content – 88-92%) | 1.5 |
| Batch gravity flow (manure moisture content – not less than 96.5%) | 7 |
| Flush | 20 |

The coefficient of daily unevenness of water consumption K on pig farms and complexes should be taken as 1.25. It should also be taken into account that for the accumulating manure not to adhere to the walls and bottom of manure canals (pits) there must be a layer of water 100 mm high in them. The relevant mass of water calculated, based on the size and number of manure-collecting canals (pits).

The mass of water (kg/day), which gets into manure per animal category per day, calculated by the formula:

$$Q_{water\_category} = Q_{process\_water\_category} +$$

$$Q_{water\_washing\_category} + Q_{water\_manure\_canal\_category}$$

$$Q_{process\_water\_category} = 4.5 \times i$$

- for continuous gravity flow

$$Q_{water\_washing\_category} = K \times 1.5 \times i = 1.9 \times i$$

- for batch gravity flow

$$Q_{water\_washing\_category} = K \times 7 \times i = 8.75 \times i$$

- for flushing

$$Q_{water\_washing\_category} = K \times 20 \times i = 25 \times i$$

In cattle houses, the maximum allowable concentration of ammonia in the air is 20 mg/m$^3$. Mass of excrements of all dairy cows (kg/day) calculated by the formula:

$$Q_{excrements\_category} = 55 \times i$$

Moisture content of dairy cows excrements is 88.4 %.
Loose housing with bedding on fully solid floors (kg/day)

$$Q_{bedding\_category} = 0.5 \times i$$

Loose housing without bedding on fully solid or partly slatted floors or partly slatted floors (kg/day):

$$Q_{bedding\_category} = 0$$

Tied housing with bedding on fully solid floors (kg/day)

$$Q_{bedding\_category} = 1.5 \times i$$

Tied housing – pipeline milking, fully solid floors, and manure removal with mechanical scrapers (no water used).

Mass of water getting into manure (kg/day) from all dairy cows is

$$Q_{water\_category} = 5 \times i$$

Loose housing – milking in the milking parlor, fully solid floors, and manure removal with mechanical scrapers (no water used).

Mass of water getting into manure (kg/day) from all dairy cows is

$$Q_{water\_category} = (1.5 + 20) \times i = 30 \times i$$

Loose housing – robotic milking, fully solid floors, and manure removal with mechanical scrapers (no water used).

Mass of water getting into manure (kg/day) from all dairy cows is

$$Q_{water\_category} = 1.5 \times i$$

Loose housing – milking in the milking parlor, partly slatted floors, and manure removal by water wash

Mass of water from all dairy cows getting into manure (kg/day) is:

- for continuous gravity flow

$$Q_{water\_category} = (1.5 + 20 + K \times 15) \times i + Q_{water\_manure\_canal\_category} =$$
$$38 \times i + Q_{water\_manure\_canal\_category}$$

- for batch gravity flow

$$Q_{water\_category} = (1.5 + 20 + K \times 30) \times i + Q_{water\_manure\_canal\_category} =$$
$$54.5 \times i + Q_{water\_manure\_canal\_category}$$

Loose housing – robotic milking, partly slatted floors, and manure removal by non-mechanical methods.

Mass of water getting into manure (kg/day) from all dairy cows is:

- for continuous gravity flow

$$Q_{water\_category} = (1.5 + K \times 15) \times i + Q_{water\_manure\_canal\_category} =$$
$$18 \times i + Q_{water\_manure\_canal\_category}$$

- for batch gravity flow

$$Q_{water\_category} = (1.5 + K \times 30) \times i + Q_{water\_manure\_canal\_category} =$$
$$34.5 \times i + Q_{water\_manure\_canal\_category}$$

**Water consumption for washing manure canals** $Q_{water\_washing\_category}$

| Manure removal system from an animal house | Water consumption rate per dairy cow per day, l |
|---|---|
| Continuous gravity flow (manure moisture content – 88-92%) | 15 |
| Batch gravity flow (manure moisture content – not less than 96.5%) | 30 |

The coefficient of daily unevenness of water consumption K on cattle complexes for dairy cows should be taken as 1.1. It should also be taken into account that for the accumulating manure not to adhere to the walls and bottom of manure canals (pits), there must be a layer of water 100 mm high in them.

In poultry houses, the maximum allowable concentration of ammonia in the air is 15 mg/m$^3$
Mass of excrement from all broilers (kg/day) calculated by the formula:

- broilers, floor housing, with due account for mass (moisture) loss

$$Q_{excrements\_category} = \frac{1}{1000} \times 158 \times (1-0.5) \times i = 0.079 \times i$$

- broilers, cage housing, with due account for mass (moisture) loss after 12 hours

$$Q_{excrements\_category} = \frac{1}{1000} \times 135 \times (1-0.16) \times i = 0.11 \times i$$

- broilers, cage housing, with due account for mass (moisture) loss after 24 hours

$$Q_{excrements\_category} = \frac{1}{1000} \times 135 \times (1-0.33) \times i = 0.09 \times i$$

**Mass and moisture content of excrements**

| Animal category | Excrements, g/head/day | Moisture content, % |
|---|---|---|
| Broilers (1 - 9 weeks old), floor housing | 158 | 66-74 |
| Broiler (1 - 8 weeks old), cage housing | 135 | 66-74 |

**Coefficients of mass (moisture) loss**

| Animal category | Coefficient of mass (moisture) loss after 12 hours, % | Coefficient of mass (moisture) loss after 24 hours, % |
|---|---|---|
| Broilers (1 - 9 weeks old), floor housing | 50 | 50 |
| Broiler (1 - 8 weeks old), cage housing | 16 | 33 |

Moisture content of excrements of broilers is 66-74%.
In cage poultry housing, no bedding is used; in floor housing, the deep bedding is applied.
In floor housing the mass of bedding material for all broilers (kg/day) is

$$Q_{bedding\_category} = 1.8 \times i$$

The water consumption for cleaning and disinfection of poultry houses and equipment after the stock has been removed:

Calculation of cleaning water amount based on the rate of 15 $l/m^2$ of cleaned surface. This rate conditionally accepted for the premises with floor housing of poultry with equal area of the floor, walls and ceiling. For the premises with cage housing, this rate is 1.5-2 times higher.

The spillage water rate during poultry drinking is 0.014 - 0.017 kg/head/day for trough-type drinkers and 0.015 - 0.017 kg/head/day for bowl-type drinkers. Currently nipple drinkers are most widely used, which do not allow the water to get into manure.

- Cage housing

The rates of room cleaning water, which gets to poultry manure, are 0.02 to 0.03 kg/head/day.
The mass of water (kg/day), which gets into poultry manure in a poultry house, calculated by the formula:

$$Q_{water\_category} = Q_{process\_water\_category} + Q_{water\_washing\_bird\_category}$$
$$+ Q_{\text{water\_splashing\_category}}$$

- broilers under 6 weeks

$$Q_{process\_water\_category} = 0.02 \times i$$

- broilers over 6 weeks

$$Q_{process\_water\_category} = 0.03 \times i$$

- for trough-type drinkers

$$Q_{\text{water\_splashing\_category}} = (0.014...0.017) \times i$$

- for bowl-type drinkers

$$Q_{\text{water\_splashing\_category}} = (0.015...0.017) \times i$$

- Floor housing

The mass of water (kg/day), which gets into poultry manure in a poultry house, calculated by the formula:

$$Q_{water\_category} = Q_{water\_washing\_bird\_category} + Q_{\text{water\_splashing\_category}}$$

- for trough-type drinkers

$$Q_{\text{water\_splashing\_category}} = (0.014...0.017) \times i$$

- for bowl-type drinkers

$$Q_{\text{water\_splashing\_category}} = (0.015...0.017) \times i$$

When animal/poultry manure processed to become an organic fertilizer, it loses the mass and nutrients. The values of the loss factors for mass and nutrient elements specified in the reference books issued in the 1980s. Currently, research institutions are engaged in the studies of mass and nutrients loss in various animal/poultry manure processing technologies.

**Most common technologies for processing animal/poultry manure into an organic fertilizer and the corresponding loss factor values**

| Type of manure and moisture content | Technology | Loss of manure mass, $L_{mass\_manure\_technology}$ % | Loss of total nitrogen, $L_{mass\_nitrogen\_technology}$ % | Loss of phosphorus, $L_{mass\_phosphorus\_technology}$ % |
|---|---|---|---|---|
| **Solid** moisture content 70% - 85%<br><br>**Slurry** moisture content 85% - 92% | Active composting | 19-25 | 20-35 | 4-10 |
| | Passive composting | 15-20 | 22-28 | 7-15 |
| **Slurry** moisture content 92% - 97%<br><br>**Liquid** moisture content more than 97% | Long-term maturing | 5-10 | 8-11 | 1-3 |

The mass of produced organic fertilizer (kg/day) calculated by the formula:

$$Q_{organic\_fertilizers} = \frac{100 - L_{mass\_manure\_technology}}{100} \times Q_{manure\_complex}$$

The mass of nitrogen (kg) in produced organic fertilizer calculated by the formula:

$$N_{organic\_fertilizers} = \frac{100 - L_{mass\_nitrogen\_technology}}{100} \times N_{manure\_house}$$

The mass of phosphorous (kg) in produced organic fertilizer calculated by the formula:

$$P_{organic\_fertilizers} = \frac{100 - L_{mass\_phosphorus\_technology}}{100} \times P_{manure\_house}$$

### 1.2.8. Sweden

Emission factors at ex-housing level expressed as a percentage of total amount of nitrogen in the manure used (see table below). The values originate from measurements made in Sweden and other countries with similar systems. For slurry from dairy cows, we calculate on the emission from a loose housing system, which is nowadays the most common system in Sweden.

| Animal category | Solid | Urine | Deep litter | Slurry | Semi solid |
|---|---|---|---|---|---|
| Dairy cows | 4% | 4% | 20% | 7%* | 4% |
| Slaughter pigs | 10% | 10% | 25% | 14% | 10% |
| Broilers | - | - | 5% | - | - |

In our software VERA (a software used mainly by advisors within Focus on nutrients); you can change type of bedding material and, e.g., lower ammonia emissions by using peat as bedding material.

- Loose housing system

The bedding calculation differ depending on where our standard values are used. In our table standard values, e.g. in regulations and in recommendations for fertilization and liming, specific default values of bedding material for different animal groups and manure types are included. Straw used for most animal types, but for broilers sawdust used as default.

VERA uses standard values for manure without bedding material. The impact of the bedding material specified on a separate row in order to make the calculations more transparent. As default, straw is added in the same amounts as above, but the user can change both the amount and type of bedding material. It is possible to choose between straw, sawdust and peat.

For dairy cows and slaughter pigs, water spill is included in standard values for amount of manure produced. For dairy cows the volume included is 2 l/cow and day and for slaughter pigs 1.8 l/pig and day. For slaughter pigs, we also include water from cleaning, 36 l/pig and turn. For dairy cows, dish- and cleaning water can be included. In VERA, the amount of water depends on how many cows it is on the farm and if a milking robot is used or not. Less than 200 dairy cows, 300 l/cow and month, more than 200 cows, 200 l/cow and month. If a milking robot is used, 450 l/cow and month.

Coefficients describing dry matter decay at ex-housing level not used, but for deep litter the calculation of decay in ex storage level based on the total amount of manure, regardless if the deep litter are stored in the barn or on a manure pad. However, we have a plan to adjust this since it sometimes results in strange values.

In standard table values in regulations, we do not calculate the manure amount produced during the grazing period since the legal requirements on storage capacity are expressed as the manure production during a certain period.

In VERA however, the user have a possibility to make a grazing calculation. We use default values for slurry to get amount of and nutrient content in grazing manure. Nitrogen losses via ammonia emissions  calculated using an emission factor of 20% on meadow and 30% on natural pasture. The VERA user can also state how much of the dry matter (DM) in feed that is consumed on pasture and how big a part that is eaten inside during the grazing period. We then assume that corresponding part of the manure ends up on grazing land and in the stable, respectively.

At ex-storage level, emission factors expressed as a percentage of total amount of nitrogen in the manure ex housing used (see table below). The values originate from Swedish measurements summarized in a report made by JTI – Swedish Institute of Agricultural and Environmental Engineering (now RISE) 2002. For liquid manure and urine, we have reduction factors for different types of covers. Emission factors in this table are without cover.

| **Animal category** | **Solid** | **Urine** | **Deep litter** | **Slurry** | **Semi solid** |
|---|---|---|---|---|---|
| Dairy cows | 20% | 40% | 30% | 6% | 10% |
| Slaughter pigs | 20% | 40% | 30% | 8% | 10% |
| Broilers | - | - | 10% | - | - |

For rainwater addition standard values used in regulations and recommendations, we use half of the mean annual precipitation in Sweden. Thus, we assume that half of the precipitation evaporate from a storage tank covered with a natural crust.

In VERA we use specific values for the annual mean precipitation in the municipality were the farmer lives. The annual precipitation multiplied with a precipitation factor, which varies depending on type of cover of the slurry/urine tank. For a tank covered with a roof or tent, this factor is zero.

In VERA, drainage water from solid manure pads also added to urine/slurry tank. The user can also specify the area of other solid surfaces that are drained to the tank and add (or remove) extra water if our default values are too low or too high.

If there is a bunker silo on the farm and the silage effluent drained to the slurry or urine tank, you have the possibility to add this in VERA.

Decay factor of 20% of total amount of manure (wet weight) for solid manure and 40% for deep litter used to characterize the degradation of dry matter. The factors are 10% for broilers, turkeys and laying hens in enriched cages and 20% for other poultry categories respectively.

Manure Standards

*www.luke.fi/manurestandards*

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EUROPEAN UNION
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