Ecosystem Health and Sustainable Agriculture

Sustainable Agriculture

Editor: Christine Jakobsson
Economy and the Environment

The economy of the farm is very important. One resource that is always available on animal farms and that can be utilised more or less well is manure/slurry/urine. Another factor of great importance for the future of agriculture on the farm is the environmental status of the farm. In the concept environmental status, serious problems can be included such as elevated levels of nitrate in the groundwater which renders the water non-drinkable for people and animals on the farm, pesticide residues in the groundwater, elevated levels of heavy metals or radioactive isotopes or unwanted waste substances in the soil that can affect the quality of the agricultural produce from the farm.

Manure

Manure is the common name for faeces, urine, bedding, spilt feed and water from various sources. The latter includes precipitation during storage and water from leaking water cups, washing of animal houses and equipment, etc. Manure is either handled and stored as solid farmyard manure (FYM), semi-solid manure or slurry according to the dry matter content (Figure 15.1). Poultry manure differs from other types as it can only be heaped if the dry matter content exceeds 25%. The type of bedding also influences the properties of the manure. If finely chopped straw is used instead of longer straw, manure can retain semi-solid properties even when the dry matter content is above 20%.

Figure 15.1. Types of manure, dry matter content and handling characteristics. Deep straw litter has a dry matter content of >25% and can be stacked >1.5 metres.
Recycling of Nutrients

Plant Nutrient Content in Manure

As it is important to know the approximate amounts of nutrients in manure in order to use it efficiently as a fertiliser and not risk polluting the environment, the nitrogen (Total-N and NH$_4$-N), phosphorus and potassium contents can be calculated using norms. This involves step-by-step calculation of:

- Gross nitrogen, phosphorus and potassium content in the manure.
- The amount of plant nutrients which are added to the soil after losses during handling.
- The amount of manure produced.
- The storage requirements.

The norms for the gross plant nutrient content and manure produced account for the per animal or per pen place production over a period of 12 months. By multiplying the norms by the correct number of animals or pen places and the occupation coefficient, the number or pen places used and for how long, the amount of nitrogen, phosphorus and potassium produced is calculated as well as the amount of manure.

Total-N is included mainly to be able to follow the situation of a specific field over time. The amounts of phosphorus and potassium do not need to be reduced due to storage and handling, as long as these take place according to acceptable standards. The gross amount of nitrogen must be reduced to account for losses during storage and handling.

The individual farm can calculate with this method:

- The total annual nitrogen, phosphorus and potassium available.
- The amounts of these nutrients which are added to the soil corrected for losses according to the farm’s storage and handling method.
- The amount of manure to be stored and spread.

On a farm with slurry it is easier to determine the annual amount of manure and the nitrogen content at spreading through chemical analysis. However, the amount of nitrogen left for the crop must be reduced by a factor in order to account for spreading losses.

No animal can produce plant nutrients, they only transform feed to products – milk, meat, eggs, etc. In the process, plant nutrients in their faeces and urine are ‘waste products’ (Figure 15.2).

The production level also affects the amount of nutrients in manure. With rising milk production, the plant nutrient content in manure increases considerably. When straw is used as bedding, the nutrient content in manure is increased, especially the potassium content. As mentioned before under farm-gate balances (page 31), if normal amounts of straw and manure are used on the farm, they may be discounted in the balance, except if straw is purchased or when manure is sold.

Cattle

Table 15.1 shows the norms for fresh manure nitrogen, Total-N, phosphorus and potassium content per dairy cow and 12 months for different production levels and normal feed rations.

Variations exist in the nutrient content even at the same level of production. For nitrogen the variation can be up to 10-12% due to excessive feed rations, year-round housing and pasturing. For phosphorus and potassium the variations are mainly due to the great range of levels of these
Recycling of Nutrients

Table 15.1. Norms for dairy cows for nitrogen, N, phosphorus, P, and potassium, K, contents in fresh faeces and urine at various levels of production, kg per animal and year

<table>
<thead>
<tr>
<th></th>
<th>5,000 kg/year</th>
<th>7,000 kg/year</th>
<th>9,000 kg/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faeces</td>
<td>N</td>
<td>P</td>
<td>K</td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>13</td>
<td>27</td>
</tr>
<tr>
<td>Urine</td>
<td>38</td>
<td>-</td>
<td>63</td>
</tr>
<tr>
<td>Total</td>
<td>75</td>
<td>13</td>
<td>90</td>
</tr>
</tbody>
</table>

Table 15.2. Norms for replacement animals for nitrogen, N, phosphorus, P, and potassium, K, contents in fresh faeces and urine at various levels of production, kg per animal and year.

<table>
<thead>
<tr>
<th>Replacement animal</th>
<th>Replacement animal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 1 year</td>
</tr>
<tr>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>Faeces</td>
<td>14</td>
</tr>
<tr>
<td>Urine</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 15.3. Norms for beef cattle for nitrogen, N, phosphorus, P, and potassium, K, contents in fresh faeces and urine at various levels of production, kg per animal and year.

<table>
<thead>
<tr>
<th>Beef cattle animal</th>
<th>Beef cattle animal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 1 year</td>
</tr>
<tr>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>Faeces</td>
<td>16</td>
</tr>
<tr>
<td>Urine</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>34</td>
</tr>
</tbody>
</table>

Table 15.4. Norms for a sow with piglets for nitrogen, N, phosphorus, P, and potassium, K, contents in fresh faeces and urine at various levels of production, kg per animal and year.

<table>
<thead>
<tr>
<th>Sow incl. piglets and 1/25 boar</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Faeces</td>
</tr>
<tr>
<td>Urine</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Table 15.5. Norms for pig meat production for nitrogen, N, phosphorus, P, and potassium, K, contents in fresh faeces and urine at various levels of production, kg per animal and year.

<table>
<thead>
<tr>
<th>2,5 fattening pigs per pen place and year</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Faeces</td>
</tr>
<tr>
<td>Urine</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

plant nutrients depending on ley productivity, fertilisation and the ability of the soil to deliver these nutrients. In hay the phosphorus content can vary between 0.2-0.4% of the dry matter and potassium between 1.5-5%. If most of the manure is spread on the pasture or grasslands, these variations will not be important. In that case the manure will contain the same amounts of phosphorus and potassium as the roughage and the elements will just be recycled.

Swine
Swine rations are more uniform than those for cattle and therefore the plant nutrient content in their faeces and urine is more uniform. The norm for pig meat production is based on 2.5 batches per year, i.e. 2.5 pigs per pen place and year. Norms for replacement animals are not given, as their rations and growth are similar to those of fattening pigs in meat production. The norms for a sow are based on 2.2 litters per year of 17 piglets each for six weeks, plus one twenty-fifth of a boar. The sow’s requirements during gestation are included.

Storage and Spreading of Manure

Nutrient Losses
The plant nutrients in manure must be stored in the best possible way so that the manure can be spread at the time when the crop needs it. This is usually in connection with spring sowing or in a growing crop. Some exceptions exist, e.g. it can be wise to spread farmyard manure FYM (solid manure) on heavier clay soils late in the autumn and plough it in so that the nitrogen is available for plant uptake in the spring (Jakobsson and Lindén, 1991). Otherwise spreading FYM on heavy clay soils in spring can ruin the seedbed and emergence of the crop. As much as possible of the plant nutrients that have been purchased to the farm as fodder etc. should be left in the manure to be used by the crops after spreading.

Losses in the Stables
It is mainly nitrogen in manure that is at risk of being lost in the house. In both faeces and urine, the nitrogen is organically bound at excretion. In the faeces nitrogen is comparatively firmly bound and the transformation to
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mineral form is slow. The nitrogen in urine is primarily bound as urea and when the urine leaves the animal, the urea begins to split up into ammonia and carbon dioxide. The enzyme urease aids the process.

As fresh urine has a high pH value, the ammonia evolved has a tendency to evaporate from the urine. The general environment of the house – temperature, humidity, air flows etc. – promotes this tendency. These losses are closely related to how long the urine remains in the house and can be called ventilation losses. Quick and effective urine separation can reduce these losses. The degree and type of separation are affected by the amount and type of bedding used, see Table 15.6. Generous amounts of bedding with a high absorption rate cause larger ammonia losses than sparing use in combination with effective urine separation. This is not true for peat-based bedding.

Poultry Pens

Birds, unlike cattle and pigs, discharge their urine in a semi-solid form together with the faeces. Another difference is that the nitrogen is in the form of uric acid instead of urea. Uric acid also breaks down to ammonia and carbon dioxide. In this case it is the enzyme uricase that effects the decomposition, which is considerably slower than for urea.

Measures to Prevent Losses

Effective urine separation and daily cleaning are the most important measures in limiting nitrogen losses in the houses. Since ammonia evaporation increases with higher temperatures, the houses should be kept as cool as possible. Poultry manure should be dried as quickly as possible to avoid the breakdown of uric acid into ammonia and carbon dioxide. Only little nitrogen is lost during drying. After drying, the nitrogen content is constant as the reaction requires water. Heated floors and conditioned ventilation air can lead to reduced ammonia evaporation and smells from the house. Peat as bedding reduces the nitrogen evaporation by lowering the pH of the manure and by binding the nitrogen in strong chemical bonds. The addition of chemicals and additives to lower the pH of manure or to reduce ammonia emissions is usually not recommended due to unwanted side-effects or to not being able to deliver the wanted effects.

As some ammonia is bound to leave the house by the ventilation, this can be captured either in a biofilter or a scrubber. A biofilter can be made of different materials, one type is made from a mixture of peat and heather through which the ventilation air is forced. In a scrubber, ammonia is washed out of the air by a wet filter and is dissolved in a suitable acid to be used later on as a plant nutrient. Both biofilters and scrubbers can be expected to remove approximately 50% of the ammonia. Biofilters require careful maintenance and both methods require substantial investments.

Storage Losses

It is primarily nitrogen that is lost during manure storage. Losses of phosphorus only occur when manure spills from insufficient or poorly designed storage facilities and leaky canals. Potassium is water-soluble and can therefore be lost due to leaks in manure pads and tanks. Losses of both phosphorus and potassium are due to inadequate storage facilities.

Storage in Aerobic Conditions

During storage, manure is subject to both aerobic (access to oxygen in air) and anaerobic (absence of air) degradation. In aerobic conditions microorganisms break down

<table>
<thead>
<tr>
<th>Bedding type</th>
<th>Absorption ability, number of times its own weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chopped straw</td>
<td>3-4</td>
</tr>
<tr>
<td>Whole straw</td>
<td>1-2</td>
</tr>
<tr>
<td>Peat</td>
<td>3-12</td>
</tr>
<tr>
<td>Saw dust</td>
<td>2-3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>House type</th>
<th>FYM</th>
<th>Semisolid manure</th>
<th>Slurry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow stable</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Swine stable</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Laying hens</td>
<td>-</td>
<td>10</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 15.6. Absorbency of bedding materials. The variation is due to differences in initial water content.

Table 15.7. Norms for nitrogen losses from the house, ventilation losses, for different types of animals and handling systems. Percentage of manure gross content.
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most of the organic material in the manure to simple inorganic compounds. The material is mineralised into ammonia, carbon dioxide and water and a smaller part is transformed into humus, a biologically more stable material. In favourable conditions, well-aerated manure rich in straw, the oxygen-requiring organisms multiply very quickly as plenty of available energy is available in the carbohydrates from the straw. The carbon is ‘combusted’ in the organisms and given off as carbon dioxide. Water and heat are produced at the same time in the respiratory process:

$$\text{Carbohydrates} + \text{oxygen} = \text{carbon dioxide} + \text{water} + \text{heat}$$

If enough heat is produced to raise the temperature to 60-70°C, the manure is composted (see Figure 15.3) and the energy in the manure is consumed. Most pathological organisms die and weed seeds lose their ability to germinate at such high temperatures. After composting, manure is almost odourless. To achieve such composting, mixing is necessary.

**Immobilisation**

A very high straw content in manure may elevate the carbon content to 40 times the nitrogen content, i.e. the carbon-nitrogen ratio (C/N) is 40. This material is low in nitrogen but high in energy for the microorganisms and in the beginning no nitrogen will be released as ammonia. The microorganisms need all nitrogen for their protein synthesis and nitrogen is immobilised. This can also happen in the soil. Eventually, as the energy is being used, the C/N ratio will diminish and when it reaches 20, more nitrogen is released as ammonia than the microorganisms require. The environment will be alkaline, as pH will be higher than 7 and in the presence of oxygen, gaseous ammonia will evaporate. If the composting process continues until only humus is left, the C/N ratio will be around 10 and about 50% of the original nitrogen will be lost and the rest bound to humus and dead organisms.

**Loss of Dry Matter (Energy) and Nitrogen**

When carbohydrates decompose, the dry matter diminishes. The evaporation of ammonia and other volatile substances also contributes to this reduction. In well-composted manure the losses of dry matter and nitrogen are approximately 50% (Figure 15.4). For the climate in the Baltic Sea Region, 3-12 months are needed for complete decomposition if the composted manure is rich in straw.

**Storage in Anaerobic Conditions**

In anaerobic circumstances decay takes place. The losses of nitrogen and dry matter will be considerably smaller than for aerobic degradation. The lower loss of dry matter is a consequence of the limited production of carbon dioxide. Much of the energy remains in the manure in the form of organic acids. No increase in the temperature takes place. Methane, hydrogen sulphide and various foul gases are produced and the process is termed ‘fermentation’. The number of microorganisms is much lower, only 10% of that in aerobic degradation.

**Nitrogen Losses**

Nitrogenous compounds in the manure are again broken down into ammonia, which is dissolved in the manure’s water phase. The pH is neutral or about 7 and ammonia is transformed into ammonium. Only about 0.5% remains as dissolved ammonia and it is in equilibrium with the ammonia trapped within the manure in gaseous form. Should the amount of gaseous ammonia above the manure heap decline due to an exchange of air with the atmosphere, it will be replaced by ammonia from the solution until equilibrium is reached.

When ammonia evaporates from the manure, new ammonia is formed from the ammonium until equilibrium is also achieved here. The more intensive the gaseous exchange at the manure surface, the larger the evaporation.
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of ammonia nitrogen, reducing the remaining amount of ammonium (Figure 15.5). These losses will seldom amount to much more than 8-10% of the nitrogen content in the manure because the ammonia content is low. These are common circumstances in slurry pits.

To minimise nitrogen losses to the air as ammonia, urine and slurry stores should be covered and filling should take place beneath the covering (Figure 15.6). In the house, the losses should be minimised by actions such as using suitable bedding material, e.g. chopped straw, peat or sawdust, and also by regularly mucking out the houses. It is important to remember that all the nitrogen that is saved throughout the manure management chain can be lost in connection with spreading. Therefore it is important when spreading manure/slurry/urine to incorporate it as soon as possible, preferably within 4 hours.

Type of Manure Handling System
As regards the type of manure handling system that is preferable both from an economic and environmental point of view, slurry handling has most benefits. It is more economical to build a system for one type of manure, slurry, instead of for two different kinds, FYM and urine. Only one storage container and only one spreader are needed instead of two of each. Suitable measures exist to minimise the losses at all stages when handling manure. It is also easier to get better plant nutrient effect from slurry than from FYM. Another benefit is that slurry is easier to spread evenly and in the right amounts. In the case of deep-straw bedding in loose housing, the environment for the animals is better but the deep-straw bedding manure is difficult to use as a fertiliser in crop husbandry and large nitrogen losses are common. It has been shown that mixing in peat when establishing a deep-straw bed can reduce nitrogen losses.

Environmental Concerns with Manure Handling

When planning manure handling systems, consideration should be given to feeding and medication of the animals. The majority of what the animals are fed will appear in the manure and then be spread on the soil as a fertiliser.
A better balance should be provided when feeding with protein and phosphorus to avoid getting large amounts of nitrogen and phosphorus in the manure. Heavy metals and other waste products in manure must also be avoided and consideration taken to this when planning animal feed rations and medication, i.e. treating piglets with zinc in connection with weaning to reduce diarrhoea and also to reduce the usage of antibiotics for this. Another important issue is to reduce the usage of antibiotics and all medication that is not absolutely necessary. Other actions such as good hygiene and care of animals can be taken, as farms do exist that manage weaning without zinc and antibiotics. Research can be an important strategy to find alternative methods. Delivery of cadmium through imported concentrates and fertilisers can also be a problem for manure quality.

On the farm it is important to minimise all losses in all stages of manure handling. It is much easier to minimise losses from point sources, e.g. by having fully functioning manure storage containers or wells and good handling of sewage from households and milking parlours. It is much more difficult to reduce losses from diffuse sources, e.g. leaching from arable land through spreading excessive amounts of manure or fertilisers, spreading at incorrect timing or poor management of the farm. These types of losses can lead to negative effects on surface water and groundwater and eutrophication of lakes and rivers, coasts and oceans.

Chapter 13


Chapter 14


Chapter 15


Chapter 16


Chapter 17


