HELCOM Recommendation 42-43/7

Adopted 28 March 2025
having regard to Article 20, Paragraph 1b)
of the Helsinki Convention

BEST AVAILABLE TECHNOLOGY (BAT) AND BEST ENVIRONMENTAL PRACTICE (BEP) TO REDUCE NUTRIENT INPUTS AND GREENHOUSE GAS EMISSIONS FROM MANURE

THE COMMISSION,

RECALLING Article 6 of the Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1992 (Helsinki Convention), in which the Contracting Parties undertake to prevent and eliminate pollution of the Baltic Sea Area from land-based sources,

HAVING REGARD also to Article 3 of the Helsinki Convention, in which the Contracting Parties shall individually or jointly take all appropriate legislative, administrative or other relevant measures to prevent and abate pollution in order to promote the ecological restoration of the Baltic Sea Area,

RECOGNIZING that in order to prevent and eliminate pollution of the Baltic Sea Area the Contracting Parties shall promote the use of Best Environmental Practice (BEP) and Best Available Technology (BAT) as laid down in Article 3(3) and the criteria for which are specified in Annex II of the Helsinki Convention,

RECOGNIZING FURTHER the specific requirements for the Prevention of Pollution from Agriculture as laid down in Annex III, part II of the Helsinki Convention,

RECALLING ALSO the updated Baltic Sea Action Plan (BSAP) adopted at the HELCOM Ministerial Meeting 2021 and the agreement to "Develop by 2025 recommendations for Best Available Technology (BAT)/Best Environmental Practice (BEP) to reduce ammonia and greenhouse gas emissions from livestock housing, manure storage and spreading" and "Develop by 2025 recommendations for manure management specifically for horses, sheep, goats, and fur farming",

RECALLING ALSO the goal in the updated Baltic Sea Action Plan (BSAP) of a Baltic Sea unaffected by eutrophication, accordingly the management objective to minimize inputs of nutrients from human activities,

RECALLING FURTHER HELCOM Recommendation 42-43/5 on Mitigation of Ammonia Emissions from Agriculture,

RECOGNIZING ALSO that eutrophication continues to significantly impact the Baltic Sea and that a substantial part of the nutrient inputs originates from diffuse sources;

EMPHASIZING the urgent need to reduce nutrient inputs to the Baltic Sea to reach the HELCOM nutrient input reduction targets and to reduce greenhouse gas emissions from all sectors to combat climate change;

ACKNOWLEDGING existing national and international legislation and competences and, for those Contracting Parties being EU Member States, also other relevant EU legislation, aiming at preventing further degradation of the marine and freshwater environments and at achieving a healthy sea in good environmental/ ecological/chemical status;

RECOMMENDS to the Governments of the Contacting Parties to the Helsinki Convention to apply the following best available technology (BAT) and best environmental practice (BEP) to reduce nutrient discharges and emissions and greenhouse gas emissions from manure in environmental permit conditions of animal farms (c.f. Annex III part II of the Helsinki Convention, Regulation 4) taking into account the further specifications in Annex 1:

A) BAT and BEP in livestock housing
   a. Reduce emitting manure surfaces
   b. Frequent removal of manure to an external storage
   c. Sufficient use of bedding material especially in solid manure systems
   d. Reduce housing temperature (as permitted by animal welfare) and manure temperature (e.g. slurry cooling)
   e. Control ventilation to reduce air flow over manure surfaces (as permitted by animal welfare)
   f. Use air cleaning systems, such as filters and scrubbers, where applicable
   g. Muck outdoor paddocks regularly and frequently
B) BAT and BEP in manure storage
   a. Slurry/urine tank with tight cover
   b. Slurry/urine tank with tensioned cover (tent-like)
   c. Slurry/urine tank with floating cover
   d. Slurry tank with natural crust
   e. Slurry acidification during storage
   f. Mixing only when necessary
   g. Covered solid manure silo (roof) with intact structure and leachate collection
   h. Covered solid manure silo (plastic cover) with intact structure and leachate collection
   i. Covering temporary manure heaps on fields
   j. Adding a layer of absorbing material under the heap
C) BAT and BEP in manure land application
   a. Careful fertilization planning with regard to rate and timing, considering e.g.
      i. manure nutrient content
      ii. soil type and properties
      iii. crop rotation
      iv. climatic conditions
   b. Band spreading of slurry/urine
   c. Injection of slurry/urine
   d. Slurry acidification during application
   e. Application and incorporation of solid manure
D) BAT and BEP in manure processing
   a. Mechanical separation of slurry
   b. Anaerobic digestion

RECOMMENDS FURTHER that the actions taken by the Contracting Parties should be reported to the Commission in 2028 utilizing the reporting format in Annex 2 and thereafter every four years.

Annex 1. Best Available Technology (BAT) and Best Environmental Practice (BEP) to reduce greenhouse gas and nutrient emissions from manure

Table of contents

1. Introduction

During livestock production, several activities in connection to manure management may result in gaseous emissions into the atmosphere and nutrient loading to soil and water. All losses cannot be prevented, but with well-chosen techniques and practices they can be minimized. This is also the aim in several HELCOM documents.

Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention) sets the principles of marine protection and contains annexes with more detailed procedures, measures and regulations connected to the specific topics of the Convention. In Annex II of the Convention, the criteria for the use of best environmental practice and best available technology are given. The term “Best Environmental Practice (BEP)” is described as the application of the most appropriate combination of measures, while the term “Best Available Technology (BAT)” includes the latest stage of development (state of the art) of processes, facilities or methods of operation which indicate the practical suitability of a particular measure for limiting discharges. Both BAT and BEP are to be used for minimizing or eliminating inputs to water and air by providing control strategies. More specifically for manure management, Annex III, part II on prevention of pollution from agriculture contains several regulations related to minimizing manure-based emissions. The Annex III i) requires basing all included measures on BEP and BAT (Regulation 1), ii) demands having environmental permits for livestock farms (Regulation 4) and iii) sets more detailed measures to be used in livestock housing, manure storage and manure land application (Regulation 2).

HELCOM Recommendation on mitigation of ammonia emissions from agriculture sets principles which should be addressed in agricultural nitrogen management to ensure minimization of ammonia emissions. Many of the principles and more detailed measures included deal with manure management from livestock feeding to manure management, processing and use.

This regional document on BAT and BEP to reduce greenhouse gas (GHG) and nutrient emissions from manure is aimed at implementing the two following actions in the 2021 Baltic Sea Action Plan:

- E13: ‘*Develop by 2025 recommendations for Best Available Technology (BAT)/Best Environmental Practice (BEP) to reduce ammonia and greenhouse gas emissions from livestock housing, manure storage and spreading*’.
- E14: ‘*Develop by 2025 recommendations for manure management specifically for horses, sheep, goats, and fur farming’.*

The document is aligned with the aforementioned HELCOM documents to prevent potential contradictions between them. Also, it intentionally contains the basic principles of environmentally sound manure management on a general level so as not to cause contradictions between more detailed differences in livestock production in the countries of the HELCOM Contracting Parties. These choices are expected to reduce the need to update the document due to e.g. technology development.

The document specifically focuses on BAT and BEP for manure management from the perspective of different manure types (slurry/liquid manure and different solid manure types). This is because the manure types are usually managed and used according to the same principles regardless of the animal producing the manure. However, techniques and practices concerning certain animal categories are included, when deemed necessary.

It should be noted that the presented principles of managing and using manure in an environmentally safe way apply also to recreational animals with no intention to produce agricultural products. However, the implementation of the techniques and practices is not as strict as on actual livestock farms with a higher number of livestock and thus also manure.

2. Environmental impacts of livestock production

Livestock production inevitably produces manure which needs to be handled and used in ways that make the most of the valuable nutrients and organic matter in crop production and maintenance of soil structure. Simultaneously, manure needs to be managed with proper techniques and practices to minimize losses into the environment and their subsequent harmful impacts.

Manure contains a risk for gaseous losses into the atmosphere as greenhouse gases and ammonia. Gaseous emissions can occur in each step of the manure management chain, i.e. during livestock housing, manure storage and manure land application. Potential manure processing and the management and use of its end-products also have impacts on gaseous emissions that need to be considered. Emission reduction of greenhouse gases, especially methane and nitrous oxide, is of importance to mitigate climate change, while ammonia emissions contribute to acidification, eutrophication of soils and waters, and indirectly to climate change due to eventual nitrous oxide formation in soil after ammonia deposition. Ammonia is also a health hazard for both people working and livestock kept in the housing units. As manure is the main source of ammonia emissions for all sectors and a part of agricultural greenhouse gas emissions, reduction of these losses is of significance to reduce their environmental impact and to meet the national and international emission reduction targets set.

Manure use in fertilization contains a risk of nutrient loading to waters after land application. The ratios of different nutrients in manure are rarely optimal for the crop need as the phosphorus content is usually high in comparison to nitrogen content. Repeated high doses of manure applied on fields may increase or maintain high phosphorus status of the field soils and thus increase the risk of phosphorus loading to waters. Suboptimal timing of the application, such as applying manure in the autumn without a winter crop or other plant cover, may also increase nutrient losses. Additionally, the slow release of organic nitrogen may cause nitrogen loading if the timing of release is not during the growing season. Repeated manure application with heavy machinery also causes soil compaction, which may further increase nutrient loading.

The challenges with nutrient loading from manure to waters may be especially significant in regions with dense livestock production. The availability of manure nutrients is high and may exceed the need especially for phosphorus fertilization, creating a regional surplus. Thus, solutions to reallocate manure nutrients between farms and regions are needed to solve the environmental challenges related to i) excess phosphorus fertilization on certain fields (depending on the fertilization regulation) and increased risk of phosphorus loading and subsequent eutrophication of surface waters, and ii) high doses of nitrogen increasing nitrate concentrations in both surface and ground waters.

3. Application of BAT and BEP in the Baltic Sea Region

The Annex III, part II of the Convention contains Regulation 4 on environmental permits on livestock farms. Intensive rearing of cattle, pigs and poultry (more than 40,000 places for poultry, 2,000 places for production pigs (over 30 kg), 750 places for sows or 400 animal units for cattle) are required to have a permit fully co-ordinated by the relevant authorities. Furthermore, the permit conditions must be based on BAT. However, smaller installations with more than 100 animal units are to be permitted with a simplified system, still following the requirements set in the Annex.

The member states of the European Union in the Baltic Sea Region are further subject to the Industrial and Livestock Rearing Emissions Directive (IED 2024/1785 amending Directive 2010/75/EU), which aims for the achievement of a level playing field which ensures a high level of protection of human health and the environment as a whole. Based on the new IED the thresholds for farms are defined in ‘livestock units’ (LSU) -standard measurement units that allows for the aggregation of the various categories of livestock in order for them to be compared. Conversion rates are given in new IED. New thresholds are the following: Rearing of pigs representing 350 LSU or more; rearing of only laying hens representing 300 LSU or more, or rearing of only other poultry categories representing 280 LSU or more; rearing of any mix of pigs or poultry representing 380 LSU or more.

In the new IED included industrial activities of livestock rearing are required to have an environmental permit or registration and to follow BAT which will be elaborated as Uniform conditions for operating rules (UCOL) summarizing the techniques and practices considered BAT. Concerning manure management and use, the Directive still includes a BREF and BAT conclusions for intensive rearing of pigs and poultry (IRPP). Depending on the size of the installation, by 2030-2032 all installations falling under the IED are required to comply with the UCOL containing the emission levels, the environmental performance levels, monitoring requirements, manure management (collection, storage, processing, land spreading), pollution prevention and mitigation practices which are consistent with BAT.

Additionally, the Contracting Parties of HELCOM may have national regulation and/or guidance for implementing BAT and BEP in livestock production.

4. Techniques and practices for reducing nutrient inputs and GHGs from animal farms

The choices made when organizing manure management and use are significant for the environmental impact of livestock production. With a good combination of techniques and practices in all the phases of the manure management chain, the benefits of using manure can be maximized and the harm minimized. In terms of achieving both, it is essential to know the amount and properties, as well as options for management and use of the manure formed on a farm. In regions of dense livestock production and on farms with surplus manure nutrients, it is also important to be aware of the local and/or regional need for nutrients in crop production. This information enables both practical planning and implementation and regulation of manure management and use in a way that ensures the use of manure nutrients on fields needing them. This may entail cooperation between livestock and crop farms and/or manure processing facilities reallocating manure nutrients as locally or regionally necessary.

The most important factor affecting the properties of manure is animal feeding and excretion. Most of the nutrients ending up in manure are excreted by the animals after they have taken up the compounds and energy they need for growth, reproduction and (depending on the animal) forming the separate food product (milk, eggs). The methods for manure management in livestock housing and in subsequent manure storage, potential processing and land application then determine the quantity and properties of manure after each of these phases. For example, the use of bedding materials and the introduction of various waters into the manure determine the manure type produced, including the amount of manure formed and its content of dry and organic matter.

Gaseous nitrogen losses as ammonia (NH_3) from manure strongly depend on the chosen methods of manure removal from housing, manure storage and manure land application. Emissions of greenhouse gases, especially methane (CH_4) and nitrous oxide (N_2O), also depend on manure storage and land application solutions. The runoff of manure-derived nutrients, especially nitrogen (N) and phosphorus (P), into waterways, on the other hand, depends on the amount of nutrients in the manure applied on land, the farming conditions, such as soil properties, crops grown and climatic conditions, and the use of other fertilizing products.

Overall, it is of utmost importance to optimize the manure management chain in each phase to achieve the benefits of manure use and to minimize the emissions. It is also important to note that some of the techniques and practices may have contradicting impacts (trade-offs) with decreasing one emission but increasing the other. Thus, balancing between the pros and cons of management choices in each phase is needed and overall sustainability of the entire manure management chain considered.

BAT of animal feeding is not included into this document. The basic principle to follow is to use precision feeding so as to give the animal everything it requires for its welfare and productivity, but to avoid overfeeding, especially of nitrogen and phosphorus containing feeds. This document focuses on the BAT and BEP of manure management, thus during livestock housing, manure storage, manure land application and manure processing.

4.1 Manure management in livestock housing

Depending on the housing techniques and practices chosen, different manure types are produced regardless of the animal being reared. The manure types are usually categorized as described in Table 1. The main differences between the manure types come from the choice of manure removal techniques in connection with reared animal, the floor type (slatted, partially slatted, solid), the use of bedding material and the need for washing the surfaces in the housing unit.

Table 1. Manure types commonly produced depending on the animal reared and the housing techniques and practices chosen (adapted from RAMIRAN Glossary of terms on manure management 2011). The manure types in the table correspond to the definitions in Annex III part II of the Helsinki Convention as follows: “solid livestock manures”

includes deep litter, farmyard manure and dung; "liquid livestock manure/slurry" includes slurry and urine. Semi-solid manure is somewhere in between these two types.

Manure type	Description	Animals
Slurry/liquid manure	Faeces and urine produced by housed livestock mixed with a small amount of bedding material and some water used during management. Flows under gravity and can be pumped.	Cattle, pigs
Semi-solid manure	Manure that cannot be pumped or stacked in a heap.	Cattle, pigs, poultry
Deep litter	Solid manure with faeces and a high amount of bedding material into which all urine is absorbed. Bedding material is added on top of the litter bed regularly. Manure is accumulated over a certain time, e.g. several months, on the floors of the housing unit before removal. Does not flow under gravity, cannot be pumped but can be stacked in a heap.	Cattle, pigs, poultry, sheep, goats, horses
Farmyard manure	Solid manure with faeces and a high amount of bedding material into which all urine is absorbed. Removed from the housing unit regularly. Does not flow under gravity, cannot be pumped but can be stacked in a heap.	Cattle, pigs, sheep, goats, horses, fur animals
Dung	Solid manure with faeces and some bedding material into which part of urine is absorbed (urine otherwise separately collected). Does not flow under gravity, cannot be pumped but can be stacked in a heap.	Cattle
Urine	Separately collected urine from the housing unit. Flows under gravity and can be pumped.	Cattle

While some livestock are mainly produced under certain housing techniques only, producing thus also only one manure type, others may use a variety of housing techniques resulting in different manure types. Pigs are mostly reared in housing units producing slurry, but solid manure types may also be produced for example in certain production periods of sows. With dairy cows and bull rearing, slurry-based housing is becoming the norm, especially in larger farms, while with suckler cows, deep litter is often produced. Also, other solid manure types are still produced on cattle farms. Poultry is mostly reared using deep litter systems, though in egg production also semi-solid and farmyard manure are produced. The housing solutions for sheep and goats are usually based on deep litter or farmyard manure, as also are horse stables. Fur animals can be reared either in naturally ventilated housing producing semi-solid manure or in open-sided houses producing manure resembling farmyard manure. In fur production, the use of bedding materials (lower amount as animals are reared in cages with excreta dropping below them) and the removal of manure (less frequent in open-sided housing) differ from the other livestock production, and therefore the usual categorization of manure types is not fully compatible.

Bedding materials are used in livestock housing both to ensure animal welfare and to ease manure handling. The housing techniques chosen determines the amount of bedding material needed and thus the manure type. Abundant bedding use decreases the density of the manure (kg/m^3) and increases its volume. The absorption of urine partially or completely into the bedding material, on the other hand, increases the amount and density of solid manure. Bedding materials also affect the emissions during housing especially by absorbing liquids and ammonia. Different bedding materials have different characteristics in relation to e.g. absorption capacity and emission reduction. The choice of bedding material used is usually dependent on the price, availability and suitability to the animal being reared.

The practices for removing manure from the housing unit vary depending on the livestock produced, the housing techniques and the manure type formed. While water addition is part of the removal system in slurry-based housing, with solid manures the removal is done fully with machinery. The housing structures in connection to manure management, such as floors, manure chutes and manure channels, should be designed so that there is no runoff or leakage of manure to the surroundings.

The technique of removing slurry can affect its properties, for example, in relation to its retention time in the housing unit or in a possible manure pit. Regular removal of slurry and keeping the surfaces clean reduce the risk of nitrogen evaporation as ammonia. A short retention time in the slurry pit prior to transfer or immediate transfer of slurry, e.g. with a scraper, to the collecting well and further to slurry storage (or processing) are of importance. The separately collected urine should also be rapidly directed to a closed storage tank, for example by tilted floor. The pipeline between the housing unit and the slurry or urine tank should be equipped with a cleanable odour trap.

Washing waters of the housing unit are usually mixed into the manure only in slurry systems. Their share of the slurry may be large on dairy farms, where milk processing equipment and facilities, and possibly also animals, are regularly washed. On pig farms, washing waters are produced when the stalls are washed in-between batches of pigs. Water may also be needed for emptying and flushing malfunctioning manure channels, thus directing the water needed to slurry. The amount of washing water added to manure is rarely measured on farms. Water addition to slurry increases the amount of slurry thus increasing also the needed storage and application volume, while diluting the nutrient content, which is why it is good to pay attention to reducing the amount of water ending up in slurry.

With solid manures, the amount of bedding materials needs to be sufficiently high to ensure a stackable form making the use of different farm equipment for transferring manure possible. Abundant use of bedding materials is also positive for animal welfare, while the effects on emissions depend on the liquid absorption capacity, ammonia binding capacity, compostability and hygienic quality of the bedding materials which vary considerably. The manure removal method also affects the density of the solid manure and thus the volume produced. Manure press compacts the solid manure tightly, while the solid manure removed in other ways is looser.

All manure types are susceptible to releasing gaseous compounds, such as ammonia and greenhouse gases during the time they stay inside the housing unit. Rapid removal of manure and keeping the surfaces clean are thus of great importance when aiming at reduced emissions during livestock housing. This excludes deep litter for which sufficient use and good quality of bedding material determines the risk for gaseous emissions as it absorbs the urine, binds ammonia and retains the deep litter bed aerated to avoid methane formation. In slurry systems, a long retention time in slurry pit below the housing unit should be avoided as ammonia is easily evaporated and the risk for methane emissions increases. Slurry cooling in the manure pit can be used to reduce ammonia evaporation and to make use of the manure heat to produce energy with the help of a heat pump. This is usually used in pig production. Slurry can also be acidified already in the housing by addition of e.g. sulphuric acid to decrease the slurry pH and thus the risk of ammonia volatilization and potentially also the formation of methane.

A good ventilation is needed in livestock housing to remove the harmful gaseous compounds and keeping the air inside the buildings healthy for both the animals and the personnel working there. In livestock housing with mechanical ventilation, concerning mainly pig and poultry production, the air removed from the housing unit can be treated to remove ammonia and other gaseous compounds. The air can be directed into a biofilter or a chemical scrubbing unit in which the harmful and/or malodorous compounds are removed microbiologically or chemically. In livestock housing with natural ventilation, the air is usually removed via several outlets which cannot be as controlled as with mechanical ventilation. Thus, the use of filters and scrubbers is limited.

The temperature inside the buildings should also be adjusted so that it is suitable for the animals, personnel and equipment used, and not too high to also increase the risk for ammonia evaporation from manure.

Outdoor paddocks in conjunction to livestock housing and horse stables should preferably be built so that the waters seeping through the paddock soil are separately collected and handled. It is also of importance to muck the faeces to a proper solid manure storage regularly and frequently enough to minimize nutrient leaching into soil.

4.2 Manure storage

Livestock farms should have sufficient storage capacity for manure to avoid its land application at unsuitable times from the perspective of reusing the nutrients to support crop growth and of reducing runoff to waters. The minimum storage capacity required varies according to national regulation. In HELCOM Annex III, part II the minimum requirement is 6 months. While most of the manure storages are usually located at the farm center, close to the housing unit, remote storages are recommendable especially to assist in manure logistics for application.

There may also be requirements for the building materials used in the storages to ensure that they endure the conditions under which manure is stored. Moreover, the smaller the surface area of manure during storage, the lower the emitting area for gaseous emissions. This applies to all manure types.

Solid manure storages need to be watertight for both the floor and the walls, such as a concrete silo, to prevent any leachate to enter the soil. Potential leachate needs to be collected via drainage and directed to e.g. a separate tank. A roof over the storage reduces the amount of manure to be applied as it prevents the addition of rainfall into the manure. It may also reduce ammonia volatilization, though a plastic cover on top of the manure heap reduces ammonia volatilization more effectively. Covering also reduces odour emissions. A paved area in the outlet of the storage avoids mixing manure into soil during filling and emptying the storage.

Solid manure may also be stored in a temporary heap on the field parcel where it is to be applied. This should only be used for a short period of time, never as a regularly used part of the storage capacity. Furthermore, measures to minimize potential emissions should be made, such as choosing the heap location so as to minimize potential nutrient leakage, using absorbing material below the heap (to catch leachate) and covering the heap with e.g. plastic cover.

Slurry and urine tanks must be watertight and made from a durable material, such as concrete, steel or plastic membrane. Structural intactness needs to be controlled regularly to avoid potential leakages. Slurry and urine tanks should not be filled to the brim to reduce wind velocity and air exchange on the surface. Covering of the tanks is an effective measure to reduce especially ammonia emissions, though the choice of the cover affects the efficiency of the emission reduction. Tight cover is the most effective, though it may increase the risk of methane emissions, if anaerobic conditions form in the slurry. Tensioned (tent-like) cover is also effective, though not completely airtight. These two also prevent rainfall from entering the slurry (or other liquid manure) and thus diluting it and increasing its volume. Alternatively, different floating covers, such as plastic pellets, may be used, especially when no natural crust is formed (e.g. pig slurry), while natural crust also somewhat reduces ammonia emissions. Acidification of the slurry in the tank is also possible to reduce pH and thus ammonia volatilization and it might also reduce odours and methane emissions but unlike a tight cover it does not prevent rainfall from entering the storage.

The use of slurry lagoons should be avoided and existing lagoons replaced with tanks. Slurry lagoons often have a rather large surface area in relation to the storage volume. This makes them more susceptible to gaseous losses and reduces the options for effective covering. Also, the plastic membrane used as the lagoon material is more susceptible to structural damage than the more solid materials of slurry tanks. If the lagoons become anaerobic, they also emit more methane than slurry tanks with a smaller surface area.

4.3 Manure application

When using manure as a fertilizing product, it is important to plan its use carefully to make most of the nutrients included, while minimizing the risk for emissions. The fertilization rate (dose) of manure applied on land depends on its nutrient content and the regulation to be followed. The rate is also affected by soil type, conditions and slope of the field, crop rotation, field drainage and climatic conditions. It may be possible to calculate the rate based on either the content of phosphorus or nitrogen in the manure. Usually, if phosphorus fertilization is regulated, phosphorus becomes the determining factor for how much manure per hectare can be applied. Simultaneously it limits the amount of nitrogen applied in manure which may need to be supplemented with other nitrogen fertilizers to reach sufficient dose for the crop. In case manure application is based on the nitrogen content, often the amount of phosphorus applied is higher than the crop need increasing the risk of phosphorus loading. It is of importance to fertilize so that the risk for nutrient loading is minimized and the nutrient use efficiency is improved.

The timing of manure application on land follows the same reasoning. It is recommendable to apply manure when seeding or to growing crops to maximize nutrient use efficiency and to avoid nutrient runoff. Consequently, autumn application on bare land with no seeding of winter crops or other plant cover should be avoided, if it is agrotechnically possible. Furthermore, manure should not be applied on frozen, snow-covered or flooded soil or when heavy rainfall is to be expected. At the time of application, the wind velocity should be low and temperature mild to ensure minimal ammonia emissions.

Solid manures (and processed manure-based products applicable with the same equipment; see: section 4.4) should be applied on land using suitable spreaders, such as rota-spreader or rear-discharge spreader. Technology ensuring efficient grinding of the manure into smaller particles prior to spreading increases the precision of dosing. *Incorporation of the solid manure into the soil* should follow as soon as possible after the spreading, excluding application on existing crops. Incorporation can be achieved either by ploughing or other cultivation equipment depending on the soil type and conditions.

With slurry and urine (and processed manure-based products applicable with the same equipment; see: section 4.4.), it is important to mix them thoroughly prior to transferring them into the spreader to ensure as homogeneous nutrient content as possible. Especially slurry forms different layers during storage with cattle slurry typically forming a floating natural crust and pig slurry tending to settle the suspended solids on the bottom of the storage tank. Still, unnecessary mixing during storage should be avoided to prevent gaseous losses.

Slurry and urine can be applied on land with different technologies which have different impacts on emissions. While broadcast spreading is still used, it is not recommendable due to high ammonia losses and poor precision of dosing. *Band spreading* is especially suitable for applying slurry or urine to growing crops, grass or shoots. If it is used on bare soil, stubble or grasses to be renewed, rapid incorporation to soil is to be followed. Slurry *injection* into soil during application reduces ammonia emissions and, depending on the depth of the injection, directs the manure nutrients better to the roots of the growing plants. Also, the total solids content of slurry and other liquid manure types affects the emissions: the lower the solid content, the quicker the slurry is absorbed into the soil with subsequent reduced emissions. Furthermore, acidification of slurry during application reduces ammonia emissions via lowering its pH and thus ammonia volatilization. The use of *umbilical slurry system* avoids the use of heavy slurry tanks which, in turn, reduced soil compaction and subsequent loss of proper soil structure and its harmful impacts on nutrient retention in soil. The precision of the fertilization rate may further be improved with the use of *near-infrared application system* measuring slurry (or other liquid processed manure) nutrient content online during application.

4.4 Manure processing

Manure can be processed using different processing technologies with one or more of the following aims:

- separating nitrogen and phosphorus into separate fractions to enhance their use in fertilization,
- concentrating nutrients into smaller volumes to improve their transportability,
- modifying manure properties in relation to their storage and/or land application techniques,
- producing renewable energy,
- reducing emissions related to manure management and use.

Manure processing can be implemented in different scales, i.e. on a single farm (farm-scale), in a local cooperation between two or more farms (farm-co-operative) or in a large, centralized processing plant (Figure 1). While farm-scale and farm-co-operative manure processing usually change manure management and use on a more local scale, centralized manure processing can make a difference on a regional scale. This may be of importance especially in regions with dense livestock production and thus a high availability of manure nutrients. Depending on the overall agricultural production in that region, and the need for manure nutrients in fertilization, manure nutrients may be in oversupply and need processing for concentrating them into more efficiently transportable fertilizing products, deliverable to other regions in deficit of nutrients.

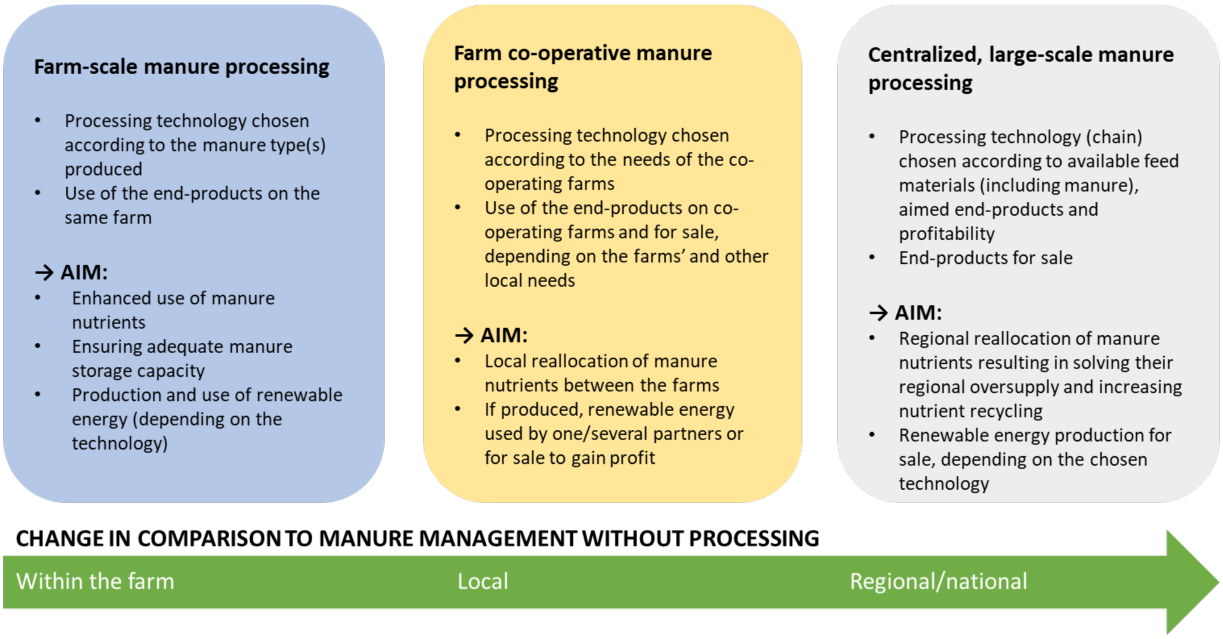

Figure 1. A simplified description of the different scales of manure processing and their main aims.

Different manure processing technologies have different impacts on emissions. It is important to understand that the overall environmental impacts of manure processing include not only the processing phase, but also the manure management before the processing and the management and use of the end-products. Thus, each of the phases needs to be optimized to reduce emissions and to ensure effective use of the valuable components.

In this document, the most common manure processing technologies are described with regard to their implementation according to BAT and BEP. The list is not exhaustive and new technologies may arise and/or these technologies be developed further.

Mechanical separation

Mechanical separation of slurry can be achieved with different equipment or by gravity. In *settling*, the suspended solids of especially pig slurry settle easily to the bottom of the slurry tank. With careful removal of the clarified liquid fraction on top, much of the nutrients bound to the solids can be separated into the settled solid fraction. To achieve a more efficient separation and higher dry matter content, *a screw press, a filter press or a decanter centrifuge* can be used. Their separation efficiency differs due to the differences in operation and in the principles which the separation is based on. Screw press and filter press push the slurry through sieves, and the pressure applied and pore size chosen affect the separation efficiency. When aiming at a high dry matter content in the solid fraction, more small particles are pressed through the sieve decreasing the nutrient separation efficiency. High dry matter content may be desirable when using the solid fraction as a bedding material, but it is not very efficient for nutrient separation. Decanter centrifuge has higher nutrient, especially phosphorus, separation efficiency into the solid fraction, as the centrifuge is able to separate the smaller particles more effectively. However, this may require the use of polymers to floc smaller particles into larger ones. The polymers are often oil-based plastics the application of which to soil is a controversial issue.

All mechanical separation methods are applicable at all scales and provide a liquid and solid fraction from slurry (or digestate; see: section 4.4.2). While the fractions are usually applied on land as part of fertilization, the solid fraction may also be used as bedding material in the housing unit especially in farm-scale solutions. Solid fraction may also be transported more effectively over longer distances, potentially easing the use of slurry on faraway fields. The separation may also benefit manure storage via changes in the capacity needed for slurry alone.

The impact of mechanical separation on emissions depends on the choices of storage and land application of the resulting fractions. The same BAT and BEP for storage and land application as for unprocessed manure types apply also to the separated solid and liquid fractions. They may also be even more important due to the changes in properties in comparison to unprocessed slurry. For instance, the liquid fraction contains most of the soluble nitrogen in slurry which is mostly in the form of ammonium nitrogen. With the solid removed during separation, the liquid fraction does not form natural crust leaving its surface more susceptible to ammonia evaporation. Covered storage is thus highly recommended.

Anaerobic digestion

During anaerobic digestion the organic matter in manure (and potential co-feeds) is microbiologically degraded, forming biogas, a mixture of mainly methane and carbon dioxide, and digestate, the residual mass containing all nutrients available in the original feed. Methane in biogas is a renewable energy source which can be used to produce heat, combined heat and power, or biomethane to replace natural gas. While the process requires both heat and electricity, its energy balance is usually always positive, i.e. it produces more energy than its operation consumes. To ensure efficient collection and energy use of the biogas and to minimize methane emissions, the biogas plant must be operated and maintained properly to avoid leakages. Also, the retention time of the manure in the digester or in a combination of a digester and a post-digestion tank with gas collection needs to be sufficiently long to ensure high biogas yield and little residual methane formation during digestate storage and use. Residual methane emissions can further be reduced by recovering heat from the digestate as it is removed from the digester. The recovered heat can be recirculated to heat the feed or the digester using heat exchangers.

The other end-product, digestate, is of nearly the same mass as the original feed because only a small part of it is transformed into biogas. While containing all the original nutrients, the degradation of organic matter releases soluble nitrogen, mostly in the form of ammonium nitrogen, during digestion. The nitrogen in digestate is thus more readily available for crops than the nitrogen in unprocessed manure. As the pH of the digestate is usually higher than that of unprocessed manure and its temperature may also be higher (in case heat exchangers are not used to cool the digestate prior to storage or further processing), the risk for ammonia volatilization is also higher than with unprocessed manure. Therefore, emissions from digestate should be reduced with covered storages and emission-reducing land application methods.

All manure types can be anaerobically digested, though separately collected urine contains so little organic matter that its digestion would not provide biogas. Anaerobic digestion can be performed as wet or dry digestion referring to the dry matter content in the digester. In wet digestion, the dry matter content in the digester is usually approximately 12% at maximum, thus the resulting digestate is also sludge-like and pumpable. The feed to wet digestion is often mainly slurry, but can contain also solid manures, just as long as there is sufficient amount of slurry or other dilutive material to retain the dry matter content in the optimal range. In dry digestion, the dry matter content in the digester can roughly vary between 20-60% depending on the technological solution. It can be applied to solid manures and mechanically separated solid fraction of slurry. While wet digestion is fed regularly and the digester content constantly stirred, dry digestion can be organized either in batch mode or as a regularly fed system. Applications of all these digester technologies are available for all manure processing scales.

Digestate may also be further processed. On farm-scale, this usually entails only simple mechanical separation, but in larger biogas plants also other processing technologies can be used to separate and/or concentrate nutrients into more advanced recycled fertilizing products. As a biogas plant is a rather high investment already on farm-scale, the further processing is usually economically viable only in large, centralized biogas plants (see: section 4.4.3). Centralized biogas plants are also often considered suitable options for regions of dense livestock production and the need to reallocate surplus manure nutrients. In these cases, it is crucial to plan the digestate use carefully and invest in sufficient further processing of the digestate to ensure its transportability to farms and regions in need of the nutrients.

Other processing technologies

Other processing technologies are usually implemented only in large-scale manure processing, meaning very large farms, farm co-operatives or centralized processing plants. They may operate in conjunction to a biogas plant, thus actually further processing digestate rather than unprocessed manure, but are applicable also to manure directly. Connection with anaerobic digestion offers the benefit of producing renewable energy either for the use of the digestate processing or for sale to increase overall income of the processing plant. The list of other processing technologies listed here is not exhaustive.

Drying and pelletizing/granulation

To concentrate manure nutrients into a significantly smaller volume to enable effective transportation, to eliminate pathogens and potentially also ensure suitability for land application simultaneously with seeding (as with mineral fertilizers), manure can be dried and pelletized or granulated. The process is suitable for solid manure (and solid digestate) and the solid fraction of mechanically separated slurry (or solid fraction of digestate).

To enable pelletizing or granulation, manure needs to be pre-dried to a high dry matter content of about 90-95%. This can be achieved with conveying hot air to the manure on discs, drums, belts or in flash dryers. Also, infrared drying can be used, decreasing the otherwise high energy consumption of the drying process, which is its major downside.

To meet the principles of BAT and BEP, the nitrogen evaporating during drying should be scrubbed for nitrogen recovery. This can be achieved so that the resulting liquid product can be utilized as a nitrogen fertilizer (e.g. ammonium sulfate). Another option is to acidify the manure before drying so that ammonia is not evaporated. Also, the offgas should be treated to avoid emissions of dust and volatile compounds into the atmosphere.

The dried fraction can further be pelletized or granulated to improve transportability, ease of storage and applicability on fields. The process entails molding the very dry manure fraction into dense pellets or granules resembling mineral fertilizers. The processes to produce either pellets or granules differ slightly from each other. The granulation proceeds from size agglomeration to drying and screening to ensure even-sized granules as the end-product. In pelletizing, the dried manure is pressed through a die with holes of the desired shape and size. Binding agents may be added to the pre-dried manure to improve the durability of the granules or pellets, if needed.

Thermal processes

Thermal processes utilize heat in different ways to achieve different end-products. They are often preceded by thermal drying to the desired dry matter content. The shared benefit of thermal processes is hygienization and elimination of harmful organic compounds (depending on the temperature and retention time), but they are energy-intensive and manure nitrogen may be lost if it is not recovered.

Combustion (incineration) oxidizes manure fully in presence of oxygen and in high temperature (over 900 °C). The heat can be recovered or transformed into electricity using a steam generator and turbine. Manure is usually combusted as part of a feedstock with other biomasses, not alone, and in large scale, though farm-scale combustion may also be allowed with certain criteria. Flue gas treatment to avoid air pollutants is needed, nitrogen is lost, and the remaining ash is subjected to quality criteria given in EU-level and often also in national fertilizing product regulation. The phosphorus recovered in the ash is less available for plants than in unprocessed manure. All the organic matter is lost, though its recycling into field soil is also important.

Gasification converts manure into carbon monoxide, carbon dioxide and methane, i.e. syngas, in low oxygen conditions and at high temperature (over 700 °C). Injection of oxygen, air or steam into the combustion chamber enable partial oxidization. The remaining small volume of ash contains the minerals, including phosphorus, present in manure, while nitrogen is lost unless it is separately recovered. Plant-availability of the phosphorus is usually reduced and the organic matter is lost.

Pyrolysis decomposes manure into three fractions: carbon containing solid fraction (may be referred to as biochar, though pyrolyzed manure rarely achieves the criteria given to biochar), liquid (oil) fraction and gas fraction. Pyrolysis is done under oxygen-depleted conditions by increasing the temperature to 350-700 °C in a relatively short time. The heating rate and desired temperature change the yield and properties of the three fractions. Slow pyrolysis maximizes the yield of solid fraction, while fast pyrolysis that of liquid fraction. The solid fraction is usually aimed to be used as a soil improver or part of a growth media, while the liquid and gas fractions may be combusted to recover the heat needed in the process. Pyrolysis is effective in concentrating manure phosphorus into a small volume in the solid fraction, but it may reduce the plant-availability of the phosphorus. Also, nitrogen may be lost if it is not recovered both during pre-drying and from the gas phase. The remaining organic matter in the solid fraction contains recalcitrant carbon.

Unlike most other thermal processes, *hydrothermal carbonization (HTC)* can process slurry and semi-solid manure as it uses water as a reaction media. As with pyrolysis, HTC also produces three fractions as end-products: solid hydrochar, liquid fraction and gas fraction, but the process temperature is lower (125-350 °C) and heating rate slower, turning water into a mild acid and base under subcritical conditions. Pressure is applied to avoid water evaporation. Oxygen or hydrogen peroxide can also be used as an oxidizing agent. HTC of manure is under development at the time of writing.

Struvite precipitation

Struvite (MAP, magnesium ammonium phosphate) can be precipitated and crystallized from slurry and other manure-based liquid fractions (digestate) and it serves directly as a fertilizing product. The process pH is adjusted to 8.3–10 and the nutrient ratios are ideally 1.3:1:0.9 for Mg:N:P. The struvite crystals formed from soluble nutrients are separated from the bottom of the process vessel or separately with a centrifuge. With manures, crystals have usually been too small for separation. Phosphorus can also be precipitated as other crystals, such as K-struvite or calcium phosphates. There is a need for CO_2 stripping to avoid calcium carbonate formation and precipitation. Phosphorus removal efficiencies with calcium phosphate production can be as high as 100%, but 50–60% is more common. The precipitation of calcium or other phosphates can also be a non-wanted phenomenon during struvite precipitation. The remaining liquid after precipitation is dilute and contains residual nutrients. Its management should be adequately addressed as part of the struvite precipitation process.

Ammonia stripping and recovery

In ammonia stripping, ammonia is forced to evaporate into gas phase from the liquid fractions of slurry and digestate by increasing the pH (10) and temperature (40-80 °C) and blowing air into the liquid flow in a stripping column. Ammonia is then recovered in a separate scrubber unit, where it is absorbed into an acidic solution producing a nitrogen solution to be used as a fertilizer (often ammonium sulfate or ammonium nitrate). Stripping can also be used to produce vapor in high temperature (over 100 °C) and by condensing ammonia with water vapor into ammonium water without the need for scrubbing unit. It is important to note that the remaining liquid after ammonia stripping also needs to have a sustainable solution. It still contains e.g. phosphorus and can be used as a fertilizer or processed further.

Membrane filtration

Membrane filtration technologies can be used to separate and concentrate different compounds from liquid fractions of slurry and digestate. The liquid filtrated is forced to pass through a membrane by pressure, and the separation efficiency is dependent either on the pore size and the pressure applied or the dissolution to the membrane and the diffusion velocity. Filtration results in two end-products: concentrate, which forms from the particles retained by the membrane, and permeate, which contains the water and ions passing through the membrane. There are four different membrane technologies available depending on the pore size. Microfiltration (MF) and ultrafiltration (UF) are mainly used as a pretreatment to remove solids from the liquid flow. More precise recovery of e.g. nutrients is achieved with nanofiltration (NF) and reverse osmosis (RO). Especially with manure-based liquids, it is usual to have two or more filtration units in series due to the solids still contained in them. Due to the solids, membranes may be clogged and fouled. The concentrate formed can serve as a fertilizing product, while the permeate is usually very dilute and is discharged to the environment directly or after additional treatment or used as recycled process water in the processing facility.

Evaporation

Vacuum evaporation of manure-based liquid fractions removes water and thus concentrates nutrients (and remaining solids) into a smaller volume under negative pressure and elevated temperature in a closed vessel. The vacuum reduces the boiling point of water to 40-75 °C. The resulting concentrate is usable as a fertilizing product. Ammonia is often recovered separately in a scrubber, but it can also be recovered into the same concentrate by lowering the pH of the liquid prior to evaporation to a level of 4.5. The residual liquid (condensate) is dilute and can be either purified before discharge or recirculated in the processing facility.

5. BAT and BEP in manure management

The following summarizing tables list the significant BATs and BEPs to reduce manure-based emissions to air and waters in livestock housing, manure storage and manure land application, and in conjunction to manure processing. The lists are not exhaustive.

Indicative impacts on gaseous emissions and nutrient loading are described, including notifications of potential trade-offs and the need to consider also other practices in conjunction to the measures to fulfil the emissions reduction potential.

The techniques and practices can be used separately or in different combinations. It is of great importance to choose the most suitable BATs and BEPs for all phases in the manure management chain to achieve overall sustainability.

BAT and BEP in livestock housing

BAT/BEP	Impact on gaseous emissions	Impact on nutrient loading to waters
Reduce emitting manure surfaces	Reduces ammonia emissions	Reduction via less ammonia induced nitrogen deposit
Frequent removal of manure to an external storage	Reduces ammonia emissions and methane formation	Reduction via less ammonia induced nitrogen deposit
Sufficient use of bedding material especially in solid manure systems	Reduces ammonia emissions and methane formation	Reduction via less ammonia induced nitrogen deposit
Reduce housing temperature (as permitted by animal welfare) and manure temperature (e.g. slurry cooling)	Reduces ammonia emissions and methane formation	Reduction via less ammonia induced nitrogen deposit
Control ventilation to reduce air flow over manure surfaces (as permitted by animal welfare)	Reduces ammonia emissions	Reduction via less ammonia induced nitrogen deposit
Use air cleaning systems, such as filters and scrubbers, where applicable	Removes ammonia and other malodorous compounds	Reduction via less ammonia induced nitrogen deposit
Muck outdoor paddocks regularly and frequently	Reduces ammonia emissions	Reduces nutrient leaching to soil

BAT and BEP in manure storage

BAT/BEP*	Impact on gaseous emissions	Impact on nutrient loading to waters
Slurry/urine tank with tight cover	Effectively reduces ammonia emissions, may increase methane formation due to potential anaerobic conditions	Prevents direct nutrient runoff, reduces manure amount due to preventing rainwater addition, storage capacity affects application timing and thus risk for runoff from fields
Slurry/urine tank with tensioned cover (tent-like)	Effectively reduces ammonia emissions	Prevents direct nutrient runoff, reduces manure amount due to preventing rainwater addition, storage capacity affects application timing and thus risk for runoff from fields
Slurry/urine tank with floating cover	Reduces ammonia emissions	Prevents direct nutrient runoff, storage capacity affects application timing and thus risk for runoff from fields
Slurry tank with natural crust	Somewhat reduces ammonia emissions, may oxidize and thus reduce methane emissions	Prevents direct nutrient runoff, storage capacity affects application timing and thus risk for runoff from fields
Slurry acidification during storage	Reduces ammonia emissions and greenhouse gas emissions	n.a.
Mixing only when necessary	Reduces ammonia emissions	n.a.
Covered solid manure silo (roof) with intact structure and leachate collection	Somewhat reduces ammonia emissions	Prevents direct nutrient runoff if leachate is drained and collected, reduces manure quantity due to preventing rainwater addition, storage capacity affects application timing and thus risk for runoff from fields
Covered solid manure silo (plastic cover) with intact structure and leachate collection	Reduces ammonia emissions	Prevents direct nutrient runoff if leachate is drained and collected, reduces manure quantity due to preventing rainwater addition, storage capacity affects application timing and thus risk for runoff from fields
Covering temporary manure heaps on fields	Reduces ammonia emissions	Reduces risk of nutrient loading by avoiding rainwater to seep through the heap
Adding a layer of absorbing material under the heap	n.a.	Reduces risk of nutrient leaching to soil

*applies also to storage of end-products from manure processing; n.a. not applicable

BAT and BEP in manure land application

BAT/BEP*	Impact on gaseous emissions	Impact on nutrient loading to waters
Careful fertilization planning with regard to rate and timing, considering e.g. • **manure nutrient content** • **soil type and properties** • **crop rotation** • **climatic conditions**	Reduces risk of ammonia emissions e.g. when little or no wind and mild temperature during application	Reduces risk of runoff
Band spreading of slurry/urine	Somewhat reduces ammonia emissions when applying manure into shoots, reduction dependent on the following incorporation when applying to bare soil, stubble or grass to be renewed	Dependent on dose and timing
Injection of slurry/urine	Reduces ammonia emissions (the deeper, the better)	Dependent on dose and timing
Slurry acidification during application	Reduces ammonia emissions and greenhouse gas emissions	n.a.
Application and incorporation of solid manure	Reduction of ammonia emissions dependent on the time interval from spreading to incorporation into soil when applying to bare soil, stubble or grass to be renewed	Dependent on dose and timing

*applies also for land application of end-products from manure processing; n.a. not applicable

BAT and BEP in manure processing

BAT/BEP	Impact on gaseous emissions	Impact on nutrient loading to waters
Mechanical separation of slurry	Some ammonia may be evaporated during separation, otherwise emissions depend on chosen storage and land application methods of the fractions	Emission risk dependent on chosen land application techniques and practices
Anaerobic digestion	Reduces gaseous emissions provided that: • retention time of the manure under gas collection is sufficiently long, • methane leakage during processing phase is minimized with proper operation and maintenance, • methane losses during biogas energy use are minimized, • gaseous emissions from digestate handling and use follow the BATs and BEPs of manure storage, land application and/or further processing	Emission risk dependent on chosen land application techniques and practices
Other processing technologies • *Drying and pelletizing/granulation* • *Thermal processes* • *Struvite precipitation* • *Ammonia stripping and recovery* • *Membrane filtration* • *Evaporation*	Emission risk dependent on the chosen methods for management of gas phases, syngas and/or offgas produced and the storage and land application methods of the end-products	Emission risk dependent on chosen land application techniques and practices of the end-products

Annex 2. Reporting format

Reporting format for HELCOM Recommendation xx on xx	
Country:	Year:
1. Cattle	
Number of cattle (animal units using the EUROSTAT definition)	
Are cattle farms required to have an environmental permit? (yes/no) If yes, what is the minimum number of animals requiring a permit?	
Proportion of cattle in farms requiring a permit (if available)	
Is there a national BAT/BEP document including best practices for cattle farms? (yes/no) If yes, please provide a link. How are BAT/BEP applied to cattle farms that require an environmental permit?	
How are BAT/BEP applied to cattle farms that do not require an environmental permit?	

2. Pigs	
Number of pigs (animal units using the EUROSTAT definition)	
Are pig farms required to have an environmental permit? (yes/no) If yes, what is the minimum number of animals requiring a permit?	
Proportion of pigs in farms requiring a permit (if available)	
Is there a national BAT/BEP document including best practices for pig farms? (yes/no) If yes, please provide a link. How are BAT/BEP applied to pig farms that require an environmental permit?	
How are BAT/BEP applied to pig farms that do not require an environmental permit?	

3. Poultry	
Number of poultry (animal units using the EUROSTAT definition)	
Are poultry farms required to have an environmental permit? (yes/no) If yes, what is the minimum	

number of animals requiring a permit?	
Proportion of poultry in farms requiring a permit (if available)	
Is there a national BAT/BEP document including best practices for poultry farms? (yes/no) If yes, please provide a link. How are BAT/BEP applied to poultry farms that require an environmental permit?	
How are BAT/BEP applied to poultry farms that do not require an environmental permit?	

4. Horses	
Number of horses (on farms or hobby animals, please provide an estimation if no statistics available)	
Are horse farms required to have an environmental permit? (yes/no) If yes, what is the minimum number of animals requiring a permit?	
Proportion of horses in farms requiring a permit (if available)	
Is there a national BAT/BEP document including best practices for horse farms? (yes/no) If yes, please provide a link. How are BAT/BEP applied to horse farms that require an environmental permit?	
How are BAT/BEP applied to horse farms that do not require an environmental permit?	

5. Sheep and goats	
Number of sheep and goats (animal units using the EUROSTAT definition)	
Are sheep and goat farms required to have an environmental permit? (yes/no) If yes, what is the minimum number of animals requiring a permit?	
Proportion of sheep and goats in farms requiring a permit (if available)	
Is there a national BAT/BEP document including best practices	

for sheep and goat farms? (yes/no) If yes, please provide a link. How are BAT/BEP applied to sheep and goat farms that require an environmental permit?	
How are BAT/BEP applied to sheep and goat farms that do not require an environmental permit?	

6. Fur animals	
Number of fur animals (option to give the average number of the past 5 years)	
Are fur animal farms required to have an environmental permit? (yes/no) If yes, what is the minimum number of animals requiring a permit?	
Proportion of fur animals in farms requiring a permit (if available)	
Is there a national BAT/BEP document including best practices for fur animal farms? (yes/no) If yes, please provide a link. How are BAT/BEP applied to fur animal farms that require an environmental permit?	
How are BAT/BEP applied to fur animal farms that do not require an environmental permit?	

7. Please describe which of the following BAT/BEP included in this Recommendation are applied in your country: (Please mark which BAT/BEP that are applied for the different animals with an x. Several BAT/BEP can be marked for each type of animal.)							
	BAT/BEP	Cattle	Pigs	Poultry	Horses	Sheep/goats	Fur animals
In livestock housing	Reduce emitting manure surfaces						
	Frequent removal of manure to an external storage						
	Sufficient use of bedding material especially in solid manure systems						
	Reduce housing temperature (as permitted by animal welfare) and manure temperature (e.g. slurry cooling)						
	Control ventilation to reduce air flow over manure surfaces (as permitted by animal welfare)						
	Use air cleaning systems, such as filters and scrubbers, where applicable						
	Muck outdoor paddocks regularly and frequently						
	Other, please describe below …..						
In manure storage	Slurry/urine tank with tight cover						
	Slurry/urine tank with tensioned cover (tent-like) Slurry/urine tank with floating cover						
	Slurry tank with natural crust						
	Slurry acidification during storage						
	Mixing only when necessary						
	Covered solid manure silo (roof) with intact structure and leachate collection						
	Covered solid manure silo (plastic cover) with intact structure and leachate collection						
	Covering temporary manure heaps on fields						
	Adding a layer of absorbing material under the heap						
	Other, please describe below …						

In manure spreading	Careful fertilization planning with regard to rate and timing, considering e.g. - manure nutrient content - soil type and properties - crop rotation - climatic conditions						
	Band spreading of slurry/urine Injection of slurry/urine						
	Slurry acidification during application						
	Application and incorporation of solid manure						
	Other, please describe below …						

8. Emissions	
Is there estimation available for ammonia emissions from manure for different animal categories for national or sub-national scale (yes/no)? If yes, please provide further information or a link. Are you able to distinguish the share of waterborne nutrient discharges from manure?	
Is there estimation available for greenhouse gas emissions from manure for different animal categories for national or sub-national scale (yes/no)? If yes, please provide further information or a link.	