Code of good practice for controlling ammonia emissions from slurry stores

1 Introduction

Ammonia losses from buildings and after spreading livestock manures are highly important emission sources. However, the proportion of the ammonia emissions during storage of liquid manures can also be considerable and account for 15% of total ammonia emissions from livestock production. Furthermore, the environmentally relevant gases methane, nitrous oxide and nitric oxide are also emitted. The following remarks are limited to ammonia.

Ammonia losses from stored manure increase with the increase of

- the concentration of ammonium (NH_4^+-N),
- the temperature,
- the pH value,
- the emitting surface,
- the intensity of air movement on the manure surface
- the frequency of slurry movement (e.g. trough pumping or agitation).

2 Recommendations for emission control measures

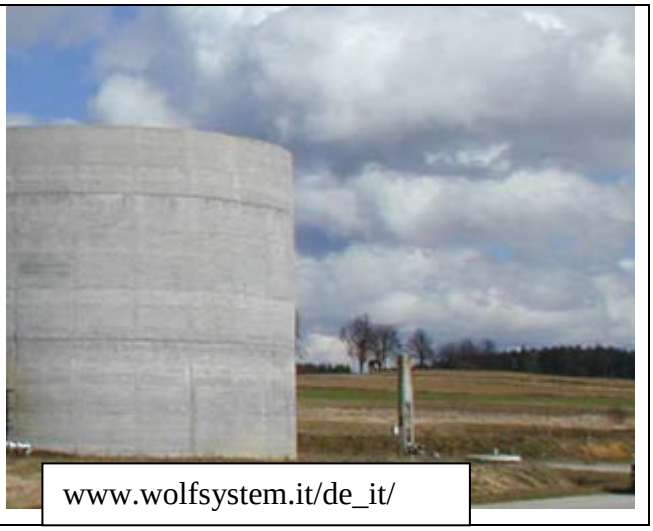
2.1 Adopt the size of the store to the nitrogen requirement of the farm crops

The store should be of sufficient size to avoid spreading on land at times of the year when there is a risk of water pollution (e.g. through nitrate leaching) and to allow application at the best time with regard to crop nitrogen demand. Frequent mixing and emptying should be avoided wherever possible because these operations increase ammonia emission. However, mixing and removal of slurry for spreading is likely to be more frequent on grass than on arable farms to ensure effective utilization of the slurry.

2.2 Reduce the emitting surface

Since emissions increase with increasing emitting surfaces, minimising the surface area, without impeding slurry handling operations, is an abatement option, which can be achieved by the tank design. The surface area of a 1000 m³ slurry tank will be reduced by 40% if instead of a container height of 3 m a height of 5 m is chosen. The container then has a diametre of 16 m instead of 20.6 m. Favorable container dimensions are obtained with a height - diametre ratio of 1:3 : 1:4. Generally, for practical (mixing, reducing required volume

for precipitation) and abatement reasons, the height of the store should be at least 3 m where feasible.



Pic 1: Concrete slurry tanks with a height of more than 3 m and a favourable height – diametre ratio

2.3 Reduce slurry temperature during the storage period

Both below-ground tanks outdoors and shading may reduce the temperature of the slurry in the storage tank and thus result in a significant reduction of ammonia and methane emissions. The investment costs for below-ground tanks are elevated compared to above ground tanks.

Pic : Slurries in below ground tanks warm up considerably slower

2.4 Reduce the air velocity around the slurry tank

Reduction in the air velocity around the slurry tank can be achieved by a sufficiently high freeboard and by planting trees to reduce air movement (The reduction of air velocity on the emitting surface is handeled in chapter “covers”) .

Pic xx: Planting trees around the slurry store reduces wind velocities and air exchange on the manure surface

2.4 Reduce the pH value of slurry

High solid contents in the slurries at low storage temperatures promote microbial acidification and prevent a pH increase, which contributes to the reduction of emissions. Therefore, the water entry must be limited during storage to a minimum. This can be achieved e.g. by predominant dry cleaning of the soiled surfaces followed by use of a high pressure cleaner.

2.5 Avoid unnecessary slurry agitation

Pumping and homogenization of slurry immediately leads to significantly increased odor, methane and ammonia emissions and should thus be limited to a minimum. The storage tanks should be filled without impairing the pollution control effect of the crust or cover by introducing the slurry into the tank below the slurry surface.

2.6 Cover of storage facility for slurry

Natural crust

Natural crusts are the simplest and most inexpensive form of slurry store covering. Natural crusts primarily form on cattle slurry, but they also develop on pig slurry, if they the slurry is rich in fibre and dry matter. The reduction potential ranges between 30 and 80% for cattle slurry and between 20 and 70% for pig slurry. Liquid manures from FYM stores and most digestates (residues from manure only anaerobic digestion) do not form crusts or even very thin crust layers. To reduce emissions in these cases, additional measures for the control of ammonia emission abatement are required. On farms, where frequent agitation is necessary, natural crusts are not a suitable measure for the reduction of ammonia emissions. The store must be filled from below the crust to avoid breaking it up.

PIC xx: Natural crusts represent a cost-effective abatement measure

Straw cover

A chopped straw layer should be at least 10 cm thick, in order to ensure a reliable emission reduction. To achieve this, approximately 4-7 kg straw per square metre are required. Application to the slurry surface is preferably done with a forage harvester. By stirring the slurry before spreading the straw is mixed in and breaks down after spreading manure on the field. Therefore straw layers need to be renewed partially or completely several times a year.

The emission reduction is 40-90. Straw is suitable for all types of slurries. The store must be filled from below the cover to avoid breaking it up. Straw covers are also suitable for lagoons, in this case more straw (7-12 kg/m^2) is required.

Straw covers may likely lead to an increase in CH_4 and N_2O emissions. The slurry dry matter is also increased which as a consequence raises NH_3 emissions after slurry application.

PIC xx Chopped straw applied by a forage harvester (right) is an NH_3 emission abatement measure, but may raise CH_4 and N_2O emissions.

Granulates

If G**ranulates** such as expanded clay balls or perlite are used for emission control, material losses are much lower than in the case of straw. Also there are no negative side effects on CH_4 and N_2O emissions. This material is well suited for covering thin pig slurry, where granules float up again shortly after the slurry has been stirred. Therefore, only a small amount of granulates is spread with the slurry. Emission reduction up to 90% is possible. For more viscous slurry and / or those that form a floating layer, expanded clays and perlite are not suitable.

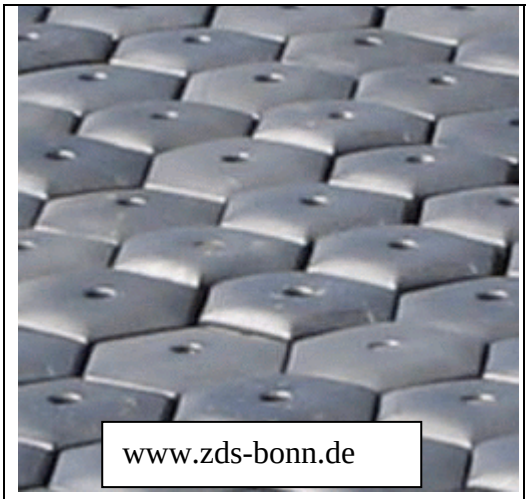
PIC xx : Granulates (here Perlite) are easily to be applied on the manure surface

Floating plastic bodies

Floating hexagonal plastic bodies form a closed floating ceiling on the slurry surface. The vertical ribs in the bodies prevent the elements from being pushed one on top of the other. They may be used only in pig slurry or other liquid manures without natural crust.

During homogenization and extraction of slurry particular care is required in order to avoid blockages/clogging or damage caused by the plastic elements to that technical equipment. For some agitators baffles are on the market, which allow the slurry to be stirred even at low filling levels. Emission reductions of up to 95% are possible.

Here: Hexagonal plastic bodies are expensive but effective.



Particularly high emission reduction effects up to 95% can be achieved by using the following covering options:

Floating foil

Two types of systems are available: Floating plastic foils without stabilizing elements are less practicable, since gas bubbles may form and parts of the foils may sink due to rain water. This can be avoided by using double sheets with shrink-wrapped polystyrene. Floating covers should be fixed to vertical ropes that are fastened to the store wall. This prevents the cover from turning during manure mixing and being lifted off by wind. The foils should have maintenance openings, which allow the use of homogenization or other equipment. Rainwater can also be collected separately, then a regular pumping and inspection after each rainfall is required. Filling must take place below the foil.

Pic xx Floating plastic foils on concrete tanks (left) and on earth banked lagoons (right) can be applied without technical difficulties

Tent

In order to adjust a tent cover on a slurry tank in the centre of the tank a column with stiffened edges is mounted or a column is fixed with a concrete bed (without stiffening). A tissue foil is placed and secured at the edge of the tank. Not every container is suitable for this type of the cover. Particularly steel constructions usually have not the required static load capacity (wind, snow). Whilst it is important to guarantee that covers are well sealed to

minimize air exchange, there must be small openings or a facility for venting to prevent the accumulation of inflammable methane gas, especially with tent structures. Emission reduction is up to 95 %.

Here: Illustration picture

Rigid covers

Rigid covers like plastic elements lids, concrete lids of roofs are characterized by a long service life and high emission reduction. For plastic lids reinforced glass fiber plastic elements are used. Below ground tanks with passable concrete covers provide additional manoeuvering space, but are very expensive. Non-structural concrete slabs are much cheaper and have the same reduction effects. Condensation of water and emission of hazardous gases from the slurries may attack constructional components via corrosion.

Here: Illustration picture

Slurry storage bag

Storage bags are made from suitable for reducing emissions from slurry on small farms (e.g. < 150 fattening pigs). Usually a “soft bedding layer” (e.g. woodchips) needs to be spread and on top of this a puncture-proof geotextile needs to be laid out, before the bag is unraveled. This storage system may not in each country get a permission by the licensing authority for the risk of water pollution.

PIC xx : By using storage bags the emission from can be reduced to almost zero

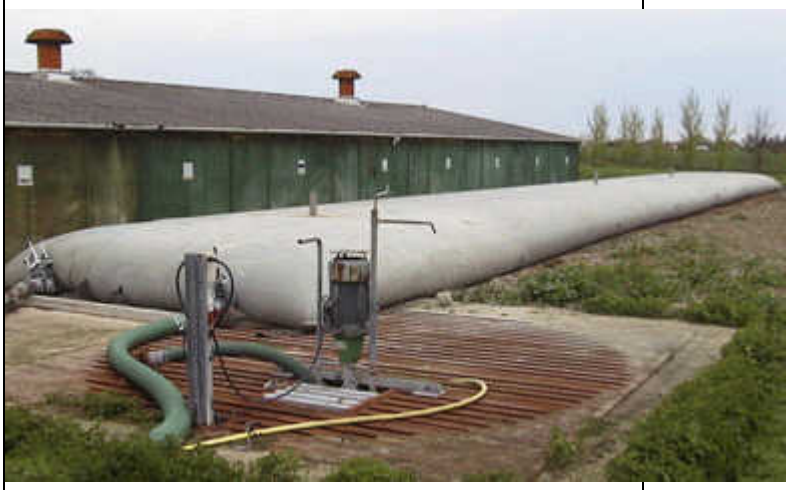


Table 1: Effectiveness and applicability of ammonia abatement techniques for slurry stores [I don't think the values below are consistent with the GD]

Abatement Measure	Emission reduction (%) compared to open storage without cover or crust	Applicability / Remarks
Natural crust	30-80 (cattle slurry) 20-70 (pig slurry)	Cattle slurries with > 5% DM, pig slurries > 7 % DM not on farms with frequent slurry spreading
Chopped straw	40-90	not practicable on very thin liquid manures, not on farms with frequent spreading increased N_2O and methane emissions Also suitable for lagoons
Granulates (leca balls, perlite)	80-90	also on thin liquid manures, not on viscous slurries not on farms with frequent spreading, loss of granules through pumping Also suitable for lagoons
Floating plastic bodies (hexagonal)	80-90	Not on viscous slurries. Also suitable for lagoons
Floating foil	80-90	All slurry types, all storage types Also suitable for lagoons

Tent	85-95	tanks and silos only no additional capacity for rain water needed, limitation through static requirements, long service period
rigid lid (plastic, concrete) or roof	85-95	tanks and silos only no additional capacity for rain water needed, limitation through static requirements, long service period
Oil (rape seed oil)		Hardly any practical experience, not recommended, increase in methane emissions
Peat		Hardly any practical experience, not recommended, Increase in methane emissions
Storage bags	100	Only for small farms

3 Costs of slurry storage and of ammonia emission abatement measures

Slurry storage costs: For storage facilities without covers, the annual expenses for slurry storage range between € 1.1 (earth tank) and € 1.8 per m³ (small circular tank, storage capacity 500 m³ **Fehler! Verweisquelle konnte nicht gefunden werden.**). Assumed storage duration is 6 months so that these expenses are based on an annual slurry quantity which is twice as large as the storage capacity. The investment requirements of the round tanks include a residual volume of 0.5 m (depth). In all stores, a freeboard of 0.2 m is considered.

Table 2: Annual costs of slurry storage

	Circular tank				Earth banked lagoon
	Storage capacity [m^3]				
	500	1000	3000	5000	7500
	Diametre [m]				Length x Width [m]
	13,7	17,7	27,9	35,5	75 x 25
	Annual storage costs [€/(m^3•a)]				
Open (reference)	1.78	1.57	1.29	1.17	1.08
Concrete lid	2.74	2.38	1.96	1.82	-
Tent	3.67	2.74	2.00	1.74	-
Floating foil	2.70	2.14	1.66	1.47	1.34
Granules	2.03	1.73	1.43	1.30	1.23
Floating plastic bodies	2.42	2.11	1.73	1.60	-
Straw	2.20	1.86	1.49	1.35	1.35

Including the covering, the 500 m³ circular tank under a tent causes the highest annual storage expenses in the amount of € 3.67 per m³. Due to the long period of use, even the annual costs of a tank with a concrete cover are € 0.9 lower in this case. As the size of the store grows, however, the specific investment requirements for tent construction decreases from ca. € 100 per m² to € 46 per m² so that they fall below the costs of a concrete cover when storage capacity reaches 5,000 m³. Floating foil shows similarly high economies of scale (€ 34 per m² for a capacity of 500 m³, € 16 per m² for 5,000 m³, and € 11.50 per m² for the earth tank). For light bulk material and floating bodies, economies of scale with growing surface are smaller or negligible (expanded clay: € 10.20 per m² to € 7.60 per m², floating body "Hexa-Cover": € 39.50 per m²). The expenses for the applying procedure for these long-lived floating covers with the aid of a front loader and/or a telescopic loader are very low as compared with the material costs (< 1%).

Store coverage with chopped straw causes expenses of € 0.40 to 0.60 per m² depending on the thickness of the layer. These are by far the lowest material expenses. Here, the calculated machinery and work expenses for spreading with a front loader and a forage harvester exceed the costs of straw collection and supply by the 2.6-fold amount. Since the floating cover gets lost during the homogenization and distribution of the slurry, two coverings per year were calculated.

Ammonia abatement costs. The difference in reduction costs between the storage of cattle and pig slurry is significant. Given costs of € 1.3 to 12.0 per kg NH_3, the reduction expenses

for cattle slurry with a natural floating layer exceeds those for pig slurry without a floating cover (€ 0.26 – 2.5 per kg NH_3) by the fivefold amount. These differences in reduction expenses are caused by the reference emissions. For cattle slurry, which generally has a natural crust, these emissions were assumed to be 3.3 g/(m^2•d). Pig slurry generally or mostly does not form an emission-reducing natural crust. Therefore, reference emissions are considerably higher at 16 g/(m^2•d). Abatement measures on pig slurries lead to a significantly stronger reduction of NH_3 emissions, which makes them more cost-effective.
Granules are the most cost-effective form of covering followed by straw and floating bodies in smaller stores. Despite high investment costs, granules and floating bodies are cost-effective due to their long service life and the low expenses for repairs and maintenance. In the large store variants, tent roofs and floating foils catch up due to their large economies of scale. Floating covers out of chopped straw are an alternative in particular for tanks which cannot be equipped with solid covers without greater technical requirements.

4 Building permission

Rigid covers and tent structures are usually subject to building permission and require a construction static approval. The installation of a rigid cover is therefore to be approved by the responsible approval authority (construction or pollution control authority). Licensing authorities may also make certain requirements for the optical design (shape, color).

5 Prevention of accidents

Tent covers and films are not walkable. Therefore during maintenance work safeguard measures must be taken. Floating covers do not represent a measure to prevent from accidents. Fencing as a fall protection is therefore still required. As a safeguard against risk of explosion ventilation openings are necessary in rigid covers and tents. All covers must be ascertained with / by the trade association in terms of workplace safety.

6 Summary

Good agricultural practice for the emission abatement during storage of animal manures are the techniques as following:

Slurry (cattle, pigs)

• Guarantee sufficient storage capacity for aligning the application time to the nutrient requirements of the crops to be fertilized and to favorable weather conditions

• cover of the storage tanks with efficient natural crusts or artificial techniques
• Fill the tank without affecting the pollution control effect of the floating covers / rigid covers by introducing the slurry below the slurry surface
• For new buildings: reduce the emitting surface by choosing favorable tank design measures (ratio of height: diametre = 1:3 to 1:4)
• Avoid unnecessary movements of manure

Solid manure (cattle, pigs, poultry)

• reduce of the surface of the stored solid manure by construction, structural and technical measures or mobile stacking technique
• collect rain and seepage water in a closed container

Poultry

• store air dried laying hen manure from manure belts under a roof
• store chicken farmyard manure on dry and water proof impermeable layer and cover