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Ammonia emissions: Abatement costs for the storage of liquid manure

The KTBL has updated calculations of the costs of measures to reduce ammonia emissions from agriculture. In the present paper the results for different covers for storages of liquid manure are presented. From the national emission inventory a surface-based reference emission factor without cover of 16 g • m^{-2} • d^{-1} for pig slurry without natural crust and 3.3 g • m^{-2} • d^{-1} for cattle slurry with natural crust is deduced. Notably the coverings by granules or straw are cost-effective abatement measures (pig slurry: 0.26–0.36 resp. 0.48–0.63 €/kg NH_3). Furthermore, the composition of the costs and cost-saving side effects are discussed.

Keywords
Ammonia emissions, ammonia abatement, costs, liquid manure, slurry storage

Abstract
Landtechnik 66 (2011), no. 6, pp. 465–468, 3 figures, 1 table, 8 references

80 % of the agricultural ammonia emissions in Germany are caused by manure management from livestock farming at the process stages animal housing, manure storage and manure application [1]. As possible, abatement measures must be taken at all process stages in order to observe the emission limit determined by international agreements sustainably and reliably and to avoid damage to ecosystems. This article presents NH_3 abatement expenses for slurry storage which have been newly calculated by the KTBL. The study was carried in the frame of a project financially supported by the Federal Ministry of Food, Agriculture and Consumer Protection as well as the Federal Environment Agency [2; 3].

The calculations of the abatement costs of slurry storage were carried out for storage capacities of 500 to 5,000 m³ (tank) and 7,500 m³ (rectangular earth tank/lagoon) of pig and cattle slurry with a storage duration of six months. Since the calculated abatement expenses strongly depend on the chosen system limits and the marginal conditions, the influences of different assumptions and side effects of the tank cover are shown using the calculated abatement costs.

Ammonia abatement costs: reference emissions

The basic method for abatement cost calculation is described in the contribution „Ammonia emissions: Abatement costs in liquid manure application“ in the present issue of Agricultural Engineering [4]. Reference techniques for manure storage are open, uncovered tanks and lagoons. Reliable data are available for the relative abatement provided by different covers [5; 8]. However, great insecurity remains with regard to the absolute NH_3 losses during slurry storage because the few available measurements carried out under practical conditions show a wide range of emission rates [5; 6]. For the calculations in the frame of the national NH_3 emission inventory [1], an emission factor of 15 % of the NH_4-N is used for open tanks. The modelling of differences in the sizes and shapes of tanks as well as storage times, however, requires an area and time-related emission factor. For this reason, the emission factor used in the emission inventories is converted into area-related NH_3 source intensities based on the assumption of a tank having a storage capacity of 1,000 m³, a surface of 250 m², and a storage period of six months. For pig slurry, this leads to a reference emission of 16 g • m^{-2} • d^{-1}. For cattle slurry, a 70 % abatement due to a natural crust is considered according to reference [1]. For the time without a floating cover after the homogenization and application of the slurry, this abatement effect is reduced by 4 %, resulting in a reference emission of 3.3 g • m^{-2} • d^{-1}. These emission factors are within the range of measurements taken in practice (e.g. pig slurry 5–43 g • m^{-2} • d^{-1}, cattle slurry 3–14 g m^{-2} • d^{-1} [7]).

Store covers

The cover reduces the ammonia losses of open stores by 70 to 95 % **(Table 1)**. The effectiveness of granules and plastic beads is impaired when the slurry is stirred. For calculation, 1 to 3 % points (depending on the kind of floating cover) are therefore deducted from the abatement potential determined according to [1; 8]

Table 1

Relative abatement of NH_3-Emissions according to [1; 8] and credit for the value of conserved nitrogen

Abdeckung/Cover	Minderung[1)] *Abatement[1)]* %	N-Gutschrift[2)]/*Credit for N-value[2)]* Rindergülle *Cattle slurry* €/m³	Schweinegülle *Pig slurry* €/m³
Betondecke/*Concrete cover*	90 (85–95)	0,04–0,06	0,29–0,43
Zeltdach/*Tent*	90 (85–95)	0,04–0,06	0,29–0,43
Schwimmfolie, Leichtschüttungen, Schwimmkörper[3)] *Plastic sheet, granules, plastic beads[3)]*	85 (80–90)	0,04–0,06	0,26–0,41
Strohauflage/*Straw cover*	80 (70–90)	0,03–0,05	0,24–0,36

[1)] Spannbreiten in Klammern nach Experteneinschätzung in [8]/*Ranges in brackets according expert estimates in [8].*
[2)] Spätere Verluste bei der Gülleausbringung eingerechnet. Spannbreiten durch je nach Lagergröße unterschiedliche Verhältnisse von Oberfläche zu Volumen/*Later losses from surface-application of slurry considered. Ranges due to different surface to volume ratios of stores.*
[3)] Schwimmkörper: Einsatz nur bei dünnflüssiger Gülle, daher keine Berücksichtigung bei Rindergülle/*Plastic beads: Used only on thin fluid slurry, therefore not considered for cattle slurry.*

with the assumption that the slurry is spread twice per year. Later losses after slurry application have a more significant effect on the ultimately environmentally relevant ammonia abatement caused by the covers. This is considered in the N-value of the conserved nitrogen by reducing it in the amount of the reference value of the application losses, which is 50 % for cattle slurry and 25 % for pig slurry in the present study **(Table 1)**.

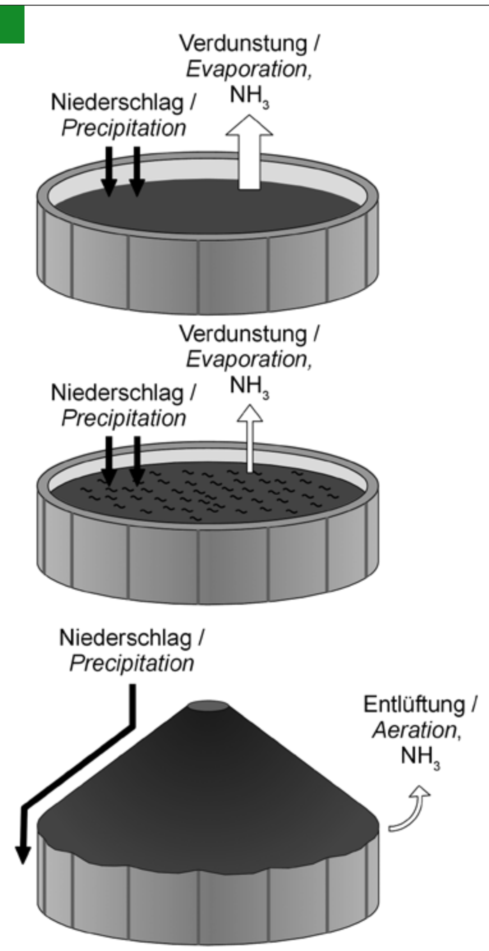
The cover types „tent“ and „concrete cover“, which are impermeable to rain, provide the most significant emission abatement. However, they also require the highest investments. Their service life is long (20 to 30 years), and they need little maintenance. Rainwater is effectively kept away from the liquid manure. This saves application costs **(Figure 1,2)**. Floating covers, in contrast, increase the liquid manure quantity to be spread because they allow for precipitation water input while preventing evaporation.

Additional expenses and cost savings due to conserved nitrogen and precipitation water are not included in the NH_3 abatement costs [4]. Especially in the case of solid covers, however, the inclusion of these side effects in the calculation would lead to lower abatement costs **(Figure 2)**. The straw cover is mixed in during stirring and spread together with the slurry. Therefore, straw covers must be partially or entirely replaced several times per year with the aid of a forage harvester. Floating covers consisting of granules, however, only require the replacement of slight losses every year. Annual losses of 10 % were assumed, which are replaced by a telescopic loader every two years.

Costs of storage and emission abatement

The annual expenses for slurry storage decrease regardless of the cover type with growing storage capacity, because larger tanks have a more favourable surface-to-volume ratio **(Figure 3)**. In addition, the area prices of tents and plastic sheets and to a lesser extent also granules decrease with growing size. If the additional expenses for covers per area unit (concrete cover, plastic beads) are constant, the NH_3 abatement costs are also independent of the tank size because the emissions per area unit are considered constant as well **(Figure 3)**. Despite constant provision costs per bale, the abatement expenses for straw sink with growing tank size because the application of larger quantities causes lower provision and set-up times for the machines.

Fig. 1



Tanks without cover (top), with natural or artificial floating cover (middle) and with roof (bottom): Precipitation, evaporation and NH_3-emissions

For cattle slurry, the relative conditions regarding the abatement costs correspond to those for pig slurry shown in **Figure 3**. Since natural crusts form on cattle slurry, however, additional covers provide less emission abatement as compared with open storage. This leads to considerably higher abatement expenses for cattle slurry (€ 1.3–12.3 per kg NH_3, pig slurry: € 0.26–2.5 per kg of NH_3).

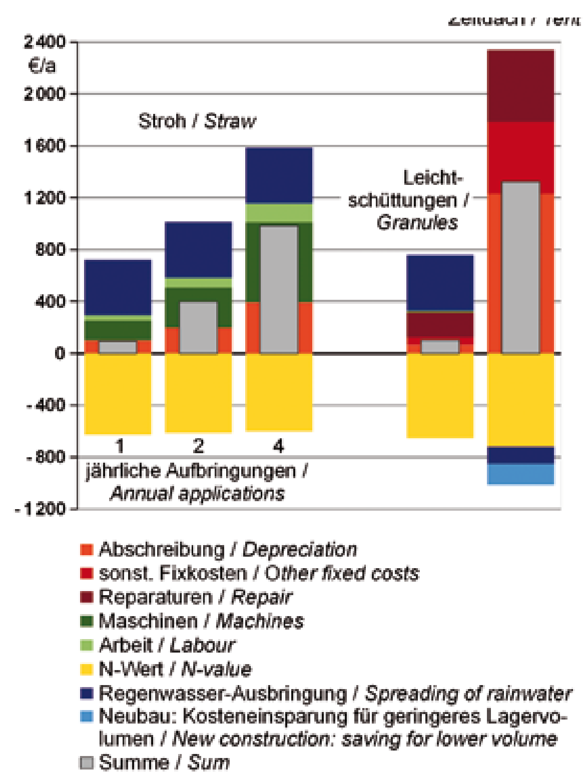
Straw and granules prove to be the most cost-effective abatement measures **(Figure 3)**. However, a straw cover becomes expensive if it must be applied several times per year **(Figure 2)**. The additional costs in comparison with the reference technique are determined by the material costs **(Figure 2)**. In the case of straw and granules, they also include the repair costs, i.e. the replacement of the material lost due to application. The labour and machinery expenses for granules, which account for 4 % of the additional expenses (without side effects, see above), are insignificant. The machine and labour expenses for straw covers, however, amount to 71 % of the additional costs. The additional expenses for solid covers are determined by fixed and repair costs. The tent is the most expensive type of cover for the 1,000 m³ tank shown in **Figure 2**.

For the storage of pig slurry, the value of the conserved N (yellow part of the column) and the additional expenses for the application of precipitation water (blue parts of the column) are considered in **Figure 2**. For straw and granule covers, the value of the conserved N is significant (15 to 68 % of the additional expenses) so that the additional costs decrease considerably if these effects are taken into account **(Figure 2, grey bars)**. For the tent as a solid cover, annual savings due to conserved N and precipitation water add up to more than € 1,000 per year or 43 % of the additional expenses. The bonus for conserved nitrogen is considerably lower for cattle slurry (€ 86–105 per year) than for pig slurry (€ 602–719 per year).

Conclusions

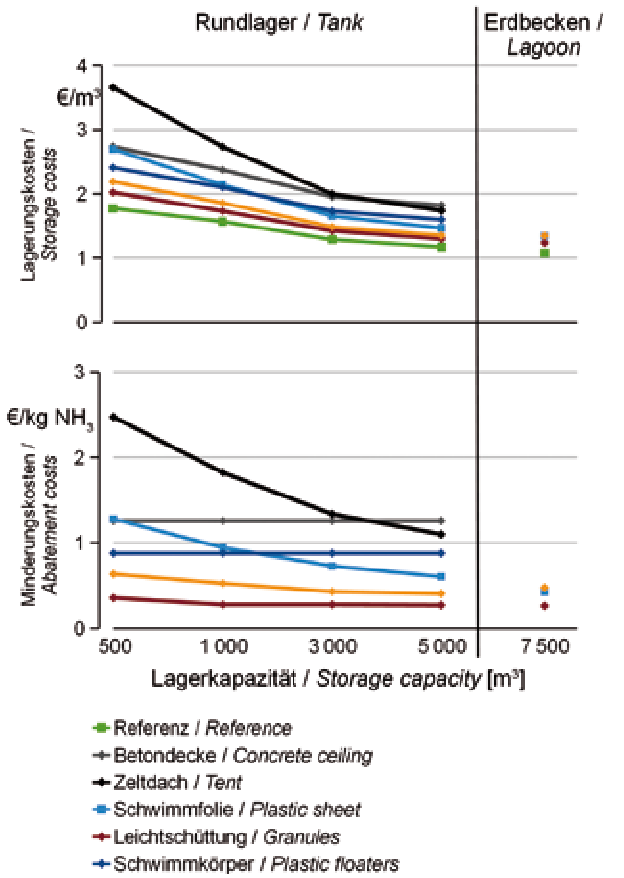
A stable natural crust reduces ammonia emissions significantly. Measures for additional ammonia abatement cause high abatement costs. Granules are the most cost-efficient abatement technique under the condition that the material is regularly restocked and thus reaches a service life of decades. Solid covers provide particularly high ammonia abatement and prevent rainwater input. Even if these aspects are considered, however, they are more expensive than artificial floating covers. Straw is an inexpensive, easily available cover type, whose costs, however, increase significantly if the cover must be replaced frequently.

Fig. 2



Additional costs for covers on a 1 000 m³ tank with pig slurry

Fig. 3



Storage costs (top) and NH_3-abatement costs (bottom) for pig slurry dependent on storage type, storage capacity and cover type

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