COSTS OF AMMONIA EMISSION ABATEMENT IN MANURE MANAGEMENT

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Abstract
Ammonia abatement costs are calculated for the most important measures in livestock farming and are evaluated with regard to their effectiveness and suitability for practice. Abatement costs strongly depend on the scale of the respective installation or operation. For pig slurry abatement costs with artificial crusts (e.g. Leca covers or straw) are lower than 1€/kg NH_3 even for small installations. For medium or large slurry stores, tents and plastic sheets are also cost effective. For storage of cattle slurry, abatement costs are much higher and range between 3 and 8 €/kg NH_3. In this case measures at application are more favourable. Incorporation by a following operation costs about 0.6 €/kg NH_3 irrespective of farm size. Similar low costs can be achieved with slot injector or cultivator only at a high degree of capacity utilization. Treatment systems for exhaust air from housing are technically effective, yet costly abatement techniques. All measures except protein-adapted feeding lose in effectiveness due to losses in following stages of the process chain.

Introduction
Ammonia (NH_3) emissions contribute to the acidification and eutrophication of ecosystems and have an indirect effect on the climate. Livestock farming is the most prominent source of NH_3. In order to mitigate the environmental effects and to comply with internationally agreed NH_3-emission ceilings, reducing emissions in livestock farming is essential. A wide range of measures is available, including measures for housing and the storage and incorporation of manures. These measures, however, largely differ with regard to their suitability and effectiveness as well as related costs. The scale of installation or operation as well as the chain of measures from feeding and housing to storage and application of manure may strongly influence the cost efficiency and needs to be considered in the assessment of abatement measures.

Material and Methods
Ammonia abatement costs are calculated for the most important measures in livestock farming and are evaluated with regard to their effectiveness and suitability for practice [1]. The measures were selected based on the UN/ECE guidance document, appendix IX of the Gothenborg Protocol and the BREF reference document “Intensive Rearing of Poultry and Pigs” [2]. For storage of slurry these are permanent covers (concrete cover, tent), plastic sheet and artificial crusts (leca, plastic beads, straw). For application, incorporation within one hour, trailing hose, trailing shoe, open slot injection and application with a cultivator are considered. Emission reduction potentials of these measures are compared to open storage and splash plate application as reference techniques (Table 1). For the references, emission factors from the national emission report are used [3] or derived from literature. Additionally purification of exhaust air from housing and protein adapted feeding strategies are examined.

The costs of the measures are calculated as the difference between the annual costs with and without the application of the abatement measures. These include fixed and variable costs, but also benefits (e.g. saved fertilizer) or indirect costs (e.g. additional water in the manure storage). The influence of downstream farming operations on the effectiveness of measures taken in upstream farming operations is evaluated for selected combinations of measures.

Table 1. Selected abatement measures for ammonia emissions in agriculture

Activity	Reference	Abatement measure	Species	Reduction %
Feeding	Single phase	Two, three and multiple phase, crude protein adapted diet	Pigs	10-30
Housing	Forced ventilation, fully slatted floor	Natural ventilation	Pigs	35
	No exhaust air purification	Exhaust air purification	Pigs	70–90
Storage	No cover	Natural floating layer	Pigs	20–70
			Cattle	30–80
		Chopped straw	Pigs/cattle	70-90
		Granules	Pigs/cattle	80–90
		Floating sheets	Pigs/cattle	80–90
		Floating tiles	Pigs	> 90
		Solid cover	Pigs/cattle	85–95
Application	Broadcast spreader	Trailing hose	Pigs/cattle	30/20
		Trailing shoe	Pigs/cattle	50/40
		Open slot injection	Pigs/cattle	60
		Cultivator	Pigs/cattle	90
		Incorporation within 1 h	Pigs/cattle	90
		Incorporation within 4 h	Pigs/cattle	70/50

Source: [1], [4], [5]

Results and Discussion

Manure storage

Lightweight expanded clay aggregate (LECA) covers are the most cost-effective NH_3 abatement measure. High investment costs are compensated by high durability and low maintenance and repair costs. Thus, annual costs of a LECA cover for a 500 m³ tank are 2.00 €/(m³ slurry • yr). Tents and floating sheets were cost-effective abatement measures for 5,000 m³ tanks, with annual costs of 1.75 €/(m³ slurry • yr) and 1.50 €/(m³ slurry • yr), respectively. Straw is an inexpensive, easily available cover type, but whose costs, however, increase significantly if it must be replaced frequently. As a result of a lower reference emission due to a natural crust, the reduction potential of measures for cattle slurry are lower, leading to higher abatement costs compared to pig slurry. For example, abatement costs of LECA covers are 1.75 €/kg NH_3 for cattle slurry and 0.35 €/kg NH_3 for pig slurry for a 500 m³ tank.

Manure application

Abatement costs of measures for manure application are 11-20% lower for cattle slurry than those for pig slurry. This is due to a higher reference emission of cattle slurry caused by slower infiltration into the soil, resulting in a higher abatement potential of measures. The immediate incorporation of slurry with a separate tractor results in abatement costs of less than 1 €/kg NH_3, independent of the slurry amount applied annually. Lower costs can be achieved only with slurry cultivators or injectors if large amounts of slurry are applied annually.

Feeding

Fixed costs of multi-phase feeding systems are 27-52% higher than those of single-phase feeding systems, depending on the number of animal places and the feeding system. However, variable costs, notably feed costs, are 10-13% lower, because cost-intensive protein-rich feed is saved. This compensates the increase in fixed costs, and total annual costs are thus lower in multi-phase feeding compared to single-phase feeding. NH_3 emissions decrease most clearly (by 32%) when applying two-

phase feeding instead of single-phase feeding, while a further increase in the number of phases only has a small additional effect. Hence, a two phase feeding system tends to be the most cost-effective abatement measure. The cost saving along with the reduction of NH_3 emissions result in negative abatement costs.

Housing

Pig fattening in naturally free-ventilated houses leads to 28% higher investment costs and thus higher fixed costs than in houses with forced ventilation. In addition, more labor is required. However, the higher labor costs are compensated by lower energy costs for ventilation and heating; as a consequence total variable costs for the two housing systems are equal. For houses with 960 animal places, NH_3 abatement costs of 9.20 €/kg NH_3 are obtained. The main reason for free-ventilated houses is increased animal welfare. If 80% of the costs are allocated to this aim, NH3 abatement costs are 1.84 €/kg NH_3.

Exhaust air purification

Exhaust air purification systems are a cost-intensive abatement measure with total annual costs amounting to 15-28 €/(AP • yr), depending on the number of animal places and system type. With 10-year depreciation, 50% of annual costs relate to fixed costs, a further 25-30% result from higher energy requirements, while labor costs only amount to 10%. Calculated abatement costs range between 4.60 €/kg NH_3 for large farms (2,000 AP) with three-stage air purification and 8.60 €/ kg NH_3 for smaller farms (500 AP).

Abatement costs, €/kg NH_3	1.03	0.76	0.75	3.46	8.46
Additional costs, €/(AP • yr)	0.77	2.00	1.23	19.91	17.91
Abatement, %	11	38	24	84	31

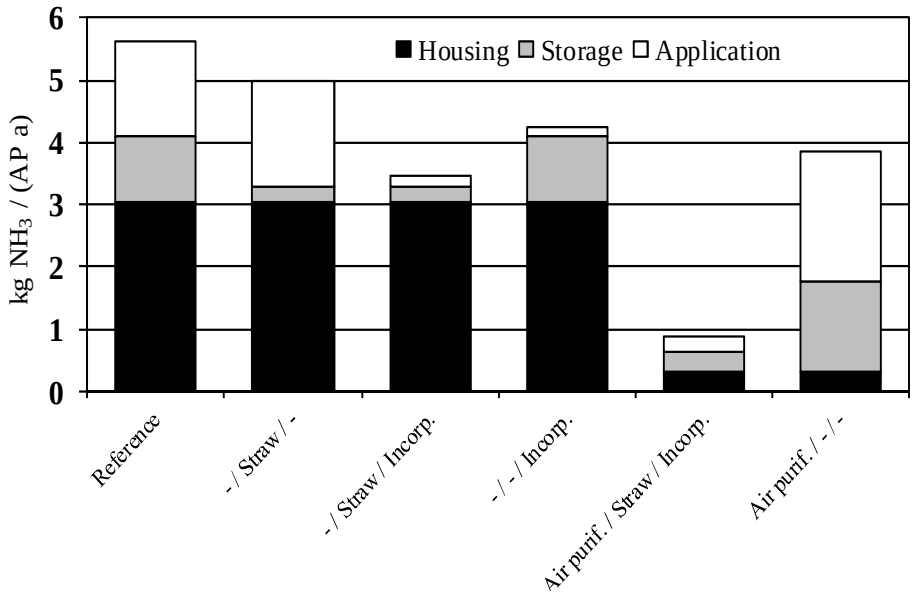

Figure 1. NH_3 emissions and associated abatement costs of selected combinations of measures in pig fattening. Measures are indicated at housing/storage/application with air purification, straw cover for stores and incorporation at application as examples. (-) indicates no difference compared to reference (Reference: housing with forced ventilation, 1,000 animal places, uncovered 1,000 m³ tank, broadcast application without incorporation).

Combination of measures

While immediate incorporation is an efficient and cost-effective individual abatement measure, covering the tank or exhaust-air purification have a lower efficiency if applied without any further measures in downstream farming activities. If emissions are reduced in housing, more NH_3 reaches the slurry tank, increasing the emissions there. Consequently, part of the mitigation effect in animal housing is lost. At the same time, however, the reduction measure in the tank becomes more cost-effective. Through a combination of measures for emission abatement in different farming activities, maximum emission abatement is achieved (Figure 1).

Conclusions

The incorporation of slurry and, if a high degree of capacity utilization can be achieved, trailing shoes, open slot injectors or the direct incorporation with a cultivator, are effective and cost-efficient abatement measures. Treatment systems for exhaust air are technically effective, yet costly abatement techniques; also free ventilated houses cause high mitigation costs. Both techniques, however, serve other goals in addition to ammonia reduction, e.g. the reduction of odour and dust emissions or the improvement of animal welfare. Covers for slurry stores, particularly for pig slurry, are cost-efficient abatement measures but lose in effectiveness due to losses in following stages of the process chain if no further abatement techniques are used there. Protein-adapted feeding strategies not only have the advantage of high benefits due to saved feeding costs, but also cannot be reduced in efficiency by downstream losses of ammonia.

References

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