SINGLE-IMPACT FICHE
IMPROVED MANURE STORAGE TECHNIQUES

IMPACT: AIR POLLUTANTS EMISSIONS

Data extracted in July 2021

Note to the reader: This fiche summarises the impact of improved manure storage techniques on AIR POLLUTANT EMISSIONS (namely ammonia, NH_3). It is based on 13 peer-reviewed synthesis research papers[1], including individual studies, which number range is from 38 to 172.

1.WEIGHT OF THE EVIDENCE

- CONSISTENCY OF THE IMPACT:
  The literature review shows that improved manure storage techniques decrease overall the ammonia emission, but the robustness of this positive effect varies per technique (see **Table 1**). The number of synthesis papers reporting positive, negative or no effect is based on the statistical comparison of the intervention and the control. The number of synthesis papers reporting relevant results, but without statistical test of the effects is labelled as "uncertain":
  - Storage with additives (either chemical or physical): 7 out of 9 synthesis papers reported positive effect (i.e. decrease ammonia emissions). In 1 synthesis paper, reported no effect for different additives applied to cattle manure stockpiles and another paper reported results without statistical test of the effects (uncertain) regarding the addition of biochar to stockpiles of cattle and poultry manure. Differences in the effects mainly depend on the type of additive (e.g. Physical additives: zeolite, biochar, medical stone, grape seeds and physical mixtures. Chemical additives: acidic substances, metal salts, phosphogypsum, Mg-P salts, Ca-superphosphate, nitrification inhibitors, and chemical mixtures) (see Table 2).
  - Storage with microbial inocula: 3 out of 3 synthesis papers reported positive effect (i.e. decrease of ammonia emission) for microbial inocula, including nitrite oxidizing bacteria, nitrogen turnover bacteria and compound microbial agents (see Table 2).
  - Storage covers: 8 out of 13 synthesis papers reported positive effect (i.e. decrease of ammonia emission) of storage tanks covered, as compared to uncovered ones. 2 synthesis papers reported no significant effect and 3 reported results without statistical test of the effects (uncertain). Differences in the effects mainly depend on the type of cover (e.g. plastic films, floating inert materials, floating biomass, floating oil layers, natural crusts, etc.). Natural crusts and wooden lids, in particular, showed no significant effect on ammonia emission.
  - Storage with biofilters: 3 out of 3 synthesis papers reported positive effect (i.e. decrease of NH_3 emission) for treating air emissions from storage tanks or composting heaps using biofilters to treat air emissions.
  - Acidification during storage: 4 out of 5 synthesis papers reported positive effect (i.e. decrease of ammonia emission) of manure acidification during storage. 1 synthesis paper reported results without statistical test of the effects (uncertain).
  - Compaction during storage: the only 1 synthesis paper reported no significant effects of compaction of (solid) manure heaps.

[1] Research synthesis papers include a formal meta-analysis or systematic reviews with some quantitative results. Details can be found in the methodology section of the WIKI.

Among the 13 reviewed synthesis papers, 10 include data collected in Europe (see **Table 2**).

Table 1. Summary of effects. The numbers between parenthesis indicate the number of synthesis papers with a quality score of at least 50%. Details on quality criteria can be found in the next section.

Impact	Technique	Positive	Negative	No effect	Uncertain*
Decrease ammonia emission	Storage with additives	7 (7)	0	1 (1)	1 (0)
	Storage with microbial inocula	3 (3)	0	0	0
	Storage covers	8 (8)	0	2 (2)	3 (2)
	Storage with biofilters	3 (3)	0	0	0
	Acidification during storage	4 (4)	0	0	1 (0)
	Compaction during storage	0	0	1 (1)	0

* Number of synthesis papers that report relevant results but without statistical test comparison of the intervention and the control.

- QUALITY OF THE SYNTHESIS PAPERS: *The quality score summarises 16 criteria assessing the quality of three main aspects of the synthesis papers: 1) the literature search strategy and studies selection; 2) the statistical analysis; 3) the potential bias. Details on quality criteria can be found in the methodology section of this WIKI.*

2. IMPACTS

The main characteristics and results of the synthesis papers are summarized in **Table 2**. Summaries of the meta-analyses provide fuller information about the results reported in each synthesis paper, in particular about the modulation of effects by factors related to soil, climate and management practices.

Table 2. Main characteristics of the synthesis papers reporting impacts of improved manure storage techniques on ammonia emission.

Reference	Population	Scale	Num. papers	Intervention (technique)	Comparator	Metric	Conclusion	Quality score
Zhang Z., Liu D., Qiao Y., Li S., Chen Y., Hu C. 2021	Pig manure composts	China	68	Several technologies: covers, amendments, and using air-dry or hyperthermophilic pretreatment. Physical additives: zeolite, biochar, medical stone, grape seeds and physical mixtures. Chemical additives: acidic substances, metal salts, phosphogypsum, Mg-P salts, Ca-superphosphate and chemical mixtures. Microbial additives: NOB (nitrite oxidizing bacteria), NTB (nitrogen turnover bacteria) and compound microbial agents.	No application of technology	NH_3-N loss	Overall, the studied technologies can reduce ammonia-N losses by 32.7%. Applying additives, especially biochar and superphosphate, was found to be an effective method for synergistically mitigating C and N losses. Particularly, storage covers significantly reduced ammonia-N loss by 14.6%.	69%
Zhao, SX; Schmidt, S; Qin, W; Li, J; Li, GX; Zhang, WF 2020	Soild manure and organic waste	Global (including EU)	52	Mitigation strategies in solid manure storage, i.e. microbial inoculation (MI), physical additives (PA), chemical additives (CA), covering (CO). Physical additives were classified into clay, zeolite and biochar. Chemical additives were classified into six types: acidic substances (apple pomace, citric acid, elemental sulphur, phosphoric acid, bamboo vinegar), metal salts ($FeCl_3$, $CaCl_2$, $MgCl_2$, $MgSO_4$), gypsum, Mg-P salts ($Mg(OH)_2$ + H_3PO_4, $MgSO_4$ + H_3PO_4, MgO + H_3PO_4, $MgCl_2$ + H_3PO_4, $MgSO_4$ + KH_2PO_4, $MgCl_2$ + KH_2PO_4, $Ca(H_2PO_4)_2$ + $MgSO_4$), Ca-	No mitigation technique	NH_3-N loss	Covers did not reduce ammonia losses, but all other technologies significantly reduced ammonia-N loss (CA 46.2% > PA 30.9% > OAT 26.9 > MI 25.3%). Biochar and magnesium-phosphate salts emerged as the most effective N-conserving strategies.	69%

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				superphosphate ($Ca(H_2PO_4)_2$), and nitrification inhibitor DCD.				
Ba, SD; Qu, QB; Zhang, KQ; Groot, JCJ 2020	Dairy manure composts	Global (including EU)	41	Six mitigation practices in the dairy manure composting process: "sawdust or straw additive", "microorganism additive", "phosphogypsum additive", "compressed and covered", "vermicomposting" and "compost biofilter".	No mitigation measure	NH_3 emission	Applying biofilters, storage covers and additives as sawdust, straw, microorganisms and phosphogypsum were effective ways to reduce ammonia emissions during manure storage/composting.	69%
Emmerling, C; Krein, A; Junk, J 2020	European agricultural systems with slurry fertilisation	Europe	38	Acidification, Biological treatment, Separation, Cover during storage, Injection, Incorporation, or Band application	No slurry treatment, no storage cover, or band spread application	NH_3 emission	Slurry acidification was effective for the reduction of ammonia emissions, and had no pollution swapping effect with other greenhouse gases, like nitrous oxide, methane, and carbon dioxide. All other management strategies, like different storage types and the concealing of the liquid slurry with different materials were effective to varying degrees for the abatement of ammonia emission, but also resulted in the increased emission of at least one other greenhouse gas.	50%
Ti, CP; Xia, LL; Chang, SX; Yan, XY 2019	European agricultural systems with slurry fertilisation	Global (including EU)	172	"covering the manure", "application of acidifiers", "manure additives", "manure aeration", "manure turning"	No measure	NH_3 emission	Techniques such as covering the manure, the application of acidifiers and additives, could significantly reduce ammonia emission.	69%
Wang, Y; Xue, W; Zhu, Z; Yang, J; Li, X; Tian, Z;Dong, H; Zou, G; 2019	Broiler and layer production (chicken)	Global (including EU)	96	Mitigation strategies in chicken house or in outdoor manure treatment. Land application mitigation strategies.	A reference litter based or layer manure belt based system (diet: conventional, in house: no treatment, outdoor: composting, land application: spreading)	NH_3 emission factor	Overall, biofilters and application of mineral additives to stockpiles led to reduce ammonia emission of chicken manure treatment and storage in broiler or layer based systems.	62%
Cao Y, Wang X, Bai Z, Chadwick D, Misselbrook T, Sommer SG, Qin W, Ma L 2019	Livestock manure, food waste, sewage sludge and/or green waste	Global (including EU)	105	Additives (chemical additives, e.g. phosphate, magnesium salts, superphosphate, gypsum etc.; physical additives, e.g. biochar, zeolite, bentonite, etc.; microbial additives, e.g. nitrite-oxidizing bacteria (NOB), NTB (ammonifiers, nitrobacteria, azotobacter) agent, etc.)	No additive	NH_3 emission in terms of cumulative NH_3-N losses as a proportion of the Total Nitrogen of the initial composting material	This global meta-analysis establishes that the use of additives can significantly reduce ammonia emission during composting.	62%
Akdeniz, N 2019	Animal waste	Not reported	Not reported	Biochar addition on livestock and poultry waste compost (biochar-compost)	Compost of animal waste without biochar addition	NH_3 emission	Biochar addition to animal waste composting could reduce ammonia emission, but these results are uncertain due to the methodology used in this study (systematic review, no quantitative analysis).	38%
Sajeev, EPM; Winiwarter, W; Amon, B 2018	Pig and cattle manure	Not reported	89	Abatement options at different stages of the manure management system (feeding strategies, animal housing, manure treatment, storage and land application)	No abatement options	NH_3 emission	Overall, the different abatements options decrease ammonia emission from pig and cattle manure management. However, these results are based only on descriptive statistics, and not on a model taking into account between-studies variability.	44%
Wang, Y; Li, XR; Yang, JF; Tian, Z; Sun, QP; Xue, WT; Dong, HM 2018	Cattle manure	Global (including EU)	104	Additives to cattle manure stockpiles; Stockpile covers; biofilters	No mitigation strategy	NH_3 emission	This study shows that compost biofilter and stockpile covering were significantly effective in reducing ammonia emission, while adding additives to manure was not effective.	62%
Wang, Y; Dong, HM; Zhu, ZP; Gerber, PJ; Xin, HW; Smith, P; Opio, C; Steinfeld, H; Chadwick, D 2017	Swine manure	Global (including EU)	142	Storage covers, Storage with acidification, Storage with additives	No mitigation strategy	NH_3 emission	Overall, this study shows that all investigated mitigation strategies, with the exception of stockpile cover for which not enough data was available, were effective in reducing ammonia emissions.	62%
Hou, Y; Velthof, GL; Oenema, O 2015	Liquid manure of dairy cows and swine stables	Global (including EU)	126	Manure storage/treatment techniques (acidification, storage cover: lid, crust, straw, granules, plastic films, oil)	Conventional storage technique, surface spreading with broadcast, Raw slurry	NH_3 emission	Slurry acidification significantly decreased emissions of ammonia and methane from slurry storages. Covering slurry storages with straw significantly decreased	88%

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							ammonia emission and increased nitrous oxide emission.	
Pardo, G; Moral, R; Aguilera, E; del Prado, A 2015	Solid manure (dairy cows, swine, poultry, green waste)	Global (including EU)	76	Solid manure storage/treatment techniques (turning, forced aeration, compaction, covering, bulking agents, additives)	Solid manure conventional storage (heaps)	NH_3 emission	Covering or compaction decrease NH_3 volatilization. The use of specific additives reduces ammonia losses. Nevertheless, their effectiveness varies depending on the substance, dosage, and operational conditions.	69%

3. KNOWLEDGE GAPS

Zhang et al., 2021	The effects of an air-dry pre-treatment on Nitrogen losses could be further explored because the losses were not considered during the pre-treatment phase.
Ba et al. 2020	The number of studies quantifying ammonia emission from dairy manure aerobic composting was limited. More attention should be paid to reducing ammonia losses and improving nitrogen retention in composted products from dairy manure composting process in the future.
Hou et al. 2015	The results collected did not allow comparing management options across animal species (e.g. pigs vs. cattle). Data from both field-and laboratory-scale studies were included in our database as data solely from field-scale studies were insufficient.