SINGLE-IMPACT FICHE
MANURE LAND APPLICATION TECHNIQUES

IMPACT: AIR POLLUTANTS EMISSIONS

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Note to the reader: This fiche summarises the effects of Manure land application techniques on AIR POLLUTANTS EMISSIONS. It is based on 7 synthesis papers[1], including from 38 to 172 primary studies.

1. WEIGHT OF THE EVIDENCE

CONSISTENCY OF THE IMPACT

Manure land application techniques may result in either positive or non-significant effects on ammonia emission, depending on the specific technique (**Table 1**).

The table below shows the number of synthesis papers with statistical tests reporting i) a significant difference between the Intervention and the Comparator, that is to say, a significant statistical effect, which can be positive or negative; or ii) a non-statistically significant difference between the Intervention and the Comparator. In addition, we include, if any, the number of synthesis papers reporting relevant results but without statistical test of the effects. Details on the quality assessment of the synthesis papers can be found in the methodology section of this WIKI.

- Land application with deep placement or immediate incorporation: for these techniques, as compared to surface spreading/broadcasting, 5 out of 8 results reported by the synthesis papers showed positive effect (i.e. decrease ammonia emission), while 1 synthesis paper reported no significant effect and 2 results without statistical test of the effects (uncertain).
- Land application with banding: for this technique, as compared to surface spreading/broadcasting, 2 out of 3 synthesis papers reported positive effects (i.e. decrease ammonia emission), while 1 synthesis paper reported non-significant effect.
- Irrigation coupled to manure application: only 1 synthesis paper was available, and this paper reported positive effect (i.e. decrease ammonia emission).

Out of the 7 selected synthesis papers, 6 included studies conducted in Europe (see **Table 2**).

Table 1: Summary of effects. Number of synthesis papers reporting positive, negative or non-statistically significant effects on environmental and climate impacts. The number of synthesis papers reporting relevant results but without statistical test of the effects are also provided. When not all the synthesis papers reporting an effect are of high quality, the number of synthesis papers with a quality score of at least 50% is indicated in parentheses. The reference numbers of the synthesis papers reporting each of the effects are provided in **Table 3**. Some synthesis papers may report effects for more than one impact or more than one effect for the same impact.

				Statistically tested			Non-statistically tested
Impact	Metric	Intervention	Comparator	Significantly positive	Significantly negative	Non-significant	
Decrease air pollutants emissions	NH_3	Irrigation coupled to manure application	Conventional management	1	0	0	0
		Land application with additives	Conventional management	0	0	2	1
		Land application with banding	Conventional management	2	0	1	0
		Land application with deep placement or immediate incorporation	Conventional management	5	0	1	2 (1)

QUALITY OF THE SYNTHESIS PAPERS

The quality of each synthesis paper was assessed based on 16 criteria regarding three main aspects: 1) the literature search strategy and primary studies selection; 2) the statistical analysis conducted; and 3) the evaluation of potential bias. We assessed whether authors addressed and reported these criteria. Then, a quality score was calculated as the percentage of these 16 criteria properly addressed and reported in each synthesis paper. Details on quality criteria can be found in the methodology section of this WIKI.

2. IMPACTS

The main characteristics and results of the 7 synthesis papers are reported in **Table 2** with the terminology used in those papers, while **Table 3** shows the reference numbers of the synthesis papers reporting for each of the results shown in **Table 1**. Comprehensive information about

[1] Synthesis research papers include either meta-analysis or systematic reviews with quantitative results. Details can be found in the methodology section of the WIKI.

the results reported in each synthesis paper, in particular about the modulation of effects by factors related to soil, climate and management practices, are provided in the **summaries of the synthesis papers** available in this WIKI.

Table 2: Main characteristics of the synthesis papers reporting effects on air pollutants emissions. The references are ordered chronologically with the most recent publication date first.

Reference number	Population	Scale	Num. papers	Intervention	Comparator	Metric	Conclusion	Quality score
Ref1	European agricultural systems with slurry fertilisation	Europe	38	Injection, Incorporation, or Band application	No slurry treatment, no storage cover, or band spread application	NH_3 emission	Different field application techniques (injection, incorporation, band application) 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%
Ref2	European agricultural systems with slurry fertilisation	Global (including EU)	172	Deep placement; Incorporation; Injection; Irrigation; Band spreading; Fertilisation using digestate; Fertilisation using liquid separated phase	No measure	NH_3 emission	Techniques such as covering the manure, the application of acidifiers and additives, could significantly reduce ammonia emission. Manure aeration and turning showed no significant effect. Mitigation measures such as deep placement, incorporation, injection, and irrigation could significantly reduce ammonia emissions. Band spreading, digestion and solid-liquid separation shoed no significant effect.	69%
Ref3	Broiler and layer production (chicken)	Global	96	Land application mitigation strategies for chicken manure (incorporation, additives).	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	Due to lack of data (only one or 2 observations), the effect of manure incorporation and the addition of additives before land application (superphosphates and sawdust) was considered as uncertain on ammonia emission.	62%
Ref5	Pig and cattle manure	Not reported	89	Manure shallow injection	No abatement options	NH_3 emissions	Shallow injection of manure reduced ammonia emissions compared to spreading of manure. However, these results are considered uncertain, because they are based on descriptive statistics, and not on a model taking into account between-studies variability.	44%
Ref6	Cattle manure	Global	104	Manure incorporation; Manure additives (lava meal)	No mitigation strategy	NH_3 emissions	This study shows that manure incorporation significantly reduced ammonia emissions, compared to land application, while adding additives to manure had no significant effect.	69%
Ref8	Swine manure	Global	142	Slurry injection; Slurry incorporation; Solid incorporation; Digested slurry; Land application with nitrification inhibitor	No mitigation strategy	NH_3 emissions	This study shows that injecting or incorporating (both liquid and solid phases) swine manure was effective in mitigating ammonia emissions, compared to surface spreading. Applying digested manure or adding nitrification inhibitors showed no significant effects.	69%
Ref10	Liquid manure of dairy cows and swine stables	Global	126	Manure land application techniques (Band spreading, incorporation, injection), Anaerobic digested slurry	Conventional storage technique, surface spreading with broadcast, Raw slurry	NH_3	Injection, bandspreading or direct incorporation of manure into soil significantly decreased ammonia emissions, but significantly increased N_2O emissions.	88%

Table 3: Reference numbers of the synthesis papers reporting for each of the results shown in **Table 1**.

				Statistically tested			Non-statistically tested
Impact	Metric	Intervention	Comparator	Significantly positive	Significantly negative	Non-significant	
Decrease air pollutants emissions	NH_3	Irrigation coupled to manure application	Conventional management	Ref2			
		Land application with additives	Conventional management			Ref6 and Ref8	Ref3
		Land application with banding	Conventional management	Ref1 and Ref10		Ref2	
		Land application with deep placement or immediate incorporation	Conventional management	Ref1, Ref2, Ref6, Ref8 and Ref10		Ref1	Ref3 and Ref5

3. FACTORS INFLUENCING THE EFFECTS ON AIR POLLUTANTS EMISSIONS

Table 4: List of factors reported to significantly affect the size and/or direction of the effects on air pollutants emissions, according to the synthesis papers reviewed.

Factor	Reference number
Livestock type	Ref2
Manure characteristics	Ref3

4. KNOWLEDGE GAPS

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Table 5: Knowledge gap(s) reported by the authors of the synthesis papers included in this review.

Ref Num	Gap
Ref6	There are only 2 papers that studied the impact of compost additives on gas emissions from beef cattle manure, with one study specified for CH_4 and N_2O and the other for ammonia;
Ref10	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.

5. SYNTHESIS PAPERS INCLUDED IN THE REVIEW

Table 6: List of synthesis papers included in this review. More details can be found in the summaries of the meta-analyses.

Ref Num	Author(s)	Year	Title	Journal	DOI
Ref1	Emmerling, C; Krein, A; Junk, J	2020	Meta-Analysis of Strategies to Reduce NH_3 Emissions from Slurries in European Agriculture and Consequences for Greenhouse Gas Emissions	Agronomy 10, 1633	10.3390/agronomy10111633
Ref2	Ti, CP; Xia, LL; Chang, SX; Yan, XY	2019	Potential for mitigating global agricultural ammonia emission: A meta-analysis	Environ. Pollut. 245, 141–148	10.1016/j.envpol.2018.10.124
Ref3	Wang, Y; Xue, W; Zhu, Z; Yang, J; Li, X; Tian, Z;Dong, H; Zou, G;	2019	Mitigating ammonia emissions from typical broiler and layer manure management - A system analysis	Waste Management	10.1016/j.wasman.2019.05.019
Ref5	Sajeev, EPM; Winiwarter, W; Amon, B	2018	Greenhouse Gas and Ammonia Emissions from Different Stages of Liquid Manure Management Chains: Abatement Options and Emission Interactions	Journal of environmental quality	10.2134/jeq2017.05.0199
Ref6	Wang, Y; Li, XR; Yang, JF; Tian, Z; Sun, QP; Xue, WT; Dong, HM	2018	Mitigating Greenhouse Gas and Ammonia Emissions from Beef Cattle Feedlot Production: A System Meta-Analysis	Environmental Science & Technology	10.1021/acs.est.8b02475
Ref8	Wang, Y; Dong, HM; Zhu, ZP; Gerber, PJ; Xin, HW; Smith, P; Opio, C; Steinfeld, H; Chadwick, D	2017	Mitigating Greenhouse Gas and Ammonia Emissions from Swine Manure Management: A System Analysis	ENVIRONMENTAL SCIENCE & TECHNOLOGY	10.1021/acs.est.6b06430
Ref10	Hou, Y; Velthof, GL; Oenema, O	2015	Mitigation of ammonia, nitrous oxide and methane emissions from manure management chains: a meta-analysis and integrated assessment	Glob. Chang. Biol. 21, 1293–1312	10.1111/gcb.12767

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