SINGLE-IMPACT FICHE
MANURE PROCESSING TECHNIQUES

IMPACT: AIR POLLUTANTS EMISSIONS

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Note to the reader: This fiche summarises the effects of Manure processing techniques on AIR POLLUTANTS EMISSIONS. It is based on 10 synthesis papers[1], including from 38 to 172 primary studies.

1. WEIGHT OF THE EVIDENCE

CONSISTENCY OF THE IMPACT

Manure processing techniques, namely composting, anaerobic digestion and solid-liquid separation, have variable effects on ammonia (NH_3) emission as compared to raw manure (**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.

- Composting: Among 7 synthesis papers, 5 reported a positive effect (i.e. decrease of NH_3 emission), while 2 reported negative effect and other 2 non-significant effect. The variability of results mainly depends on the considered composting technique (e.g. C/N adjustment, vermicomposting, addition of bulking agents, periodical turning, forced aeration, and/or the use of either chemical or physical or microbial additives to the composting piles).
- Anaerobic digestion: 3 out of 4 synthesis papers reported non-significant effect, 1 a positive effect (i.e. decrease of NH_3 emission) and 1 synthesis paper reported uncertain results. Results refer to NH_3 emissions at the stage of either storage or land distribution of digested vs raw manure slurries. Results varied according to the configuration of the anaerobic digestion process, e.g. either mono-digestion (only manure) or co-digestion (manure + other substrates) or anaerobic digestion in integration to digestate-treatment technologies, such as filtration, reverse osmosis, microalgae, drying, stripping.
- Solid-liquid separation: 2 out of 3 synthesis papers reported no significant effect, while 1 a positive effect (i.e. decrease of NH_3 emission), at the stage of either storage or land application of either solid or liquid separated fractions, as compared to raw slurry.

Out of the 10 selected synthesis papers, 8 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	Anaerobic digestion	Conventional management	1	0	3	1 (0)
		Composting	Conventional management	5	2	2	0
		Solid-liquid separation	Conventional management	1	0	2	0

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 10 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
Ref2	Pig manure composts	China	68	Optimized composting techniques. Optimal C/N ratios, optimal moisture, turning once weekly, intermittent aeration or optimized aeration rates, and using air-dry or hyperthermophilic pretreatment.	No application of technology	NH_3 emissions from stockpile	Overall, the studied technologies can reduce NH_3 emissions by 32.7%. Controlling feedstock, including the C/N ratio and moisture, could be regarded as N conservation technology. Turning compost piles increased emissions.	69%
Ref3	Dairy manure composts	Global	41	"vermicomposting"	No mitigation measure	Ammonia emission	Results showed vermicomposting can mitigate NH_3 emission with a ME median value of −33.5% (p = 0.002).	69%
Ref4	European agricultural systems with slurry fertilisation	Europe	38	Biological treatment (anaerobic digestion); Solid-liquid separation	No slurry treatment, no storage cover, or band spread application	NH_3 emission	Anaerobic digestion was effective to varying degrees for the abatement of ammonia emission, but also resulted in the increased emission of at least one other greenhouse gas. Solid-liquid separation showed no effect on NH_3 emissions.	50%
Ref9	Soild manure and organic waste	Global	52	Mitigation strategies in solid manure composting, i.e. C/N ratio regulation (C/N RR), optimized aeration rate or turning frequency (OAT).	No mitigation technique	Ammonia-N loss	Carbon/nitrogen regulation in composting did not reduce NH_3 losses, but ompimized aeration rate or turning frequency significantly reduced NH_3-N loss (by 26.9%).	69%
Ref10	European agricultural systems with slurry fertilisation	Global (including EU)	172	Manure aeration, manure turning, anaerobic digestion, solid-liquid separation	No measure	NH_3 emission	Manure aeration and turning showed no significant effect on NH_3 emissions. Anerobic digestion and solid-liquid separation showed no significant effect.	69%
Ref11	Broiler and layer production (chicken)	Global	96	Manure additives for compost (mineral additives, e.g. H_3PO_4, alum, calcium superphosphate, zeolite; or biochar)	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, manure additives during composting (mineral additives, e.g. H_3PO_4, alum, calcium superphosphate, zeolite; or biochar) led to reduce NH_3 emissions of chicken manure treatment and storage in broiler or layer based systems.	62%
Ref12	Pig and cattle manure	Not reported	89	Anaerobic digestion	No abatement options	NH_3 emissions	Estimates showed an increase in NH_3 emissions by 13 ± 76% during the storage of anaerobic digested manure and a decrease of 8 ± 34% when applied to the soils. These results are uncertain, because based only on descriptive statistics and not on a model taking into account between-studies variability.	44%
Ref13	Swine manure	Global	142	Anaerobic digestion; Composting with additives	No mitigation strategy	NH_3 emissions	Land application of digested slurry as compared to raw manure was not efficient in reducing NH_3 emissions (p > 0.05). Composting with additives significantly reduced NH_3 emissions.	62%
Ref15	Liquid manure of dairy cows and swine stables	Global	126	Field application of Solid-liquid separated fractions and digested slurry	Field application of raw slurry	NH_3	Emissions of NH_3 were not significantly different between digestates and raw slurry following field application. Significantly lower NH_3 emissions (18%) were found for separated liquid fraction, relative to raw slurry.	88%
Ref17	Solid manure (dairy cows, swine, poultry, green waste)	Global	76	Solid manure Solid manure improved composting techniques (turning, forced aeration, compaction, covering, bulking agents, additives)	Solid manure conventional storage (heaps)	NH_3	The incorporation of a bulking agent is one of the most effective measures, simultaneously reducing CH_4 and N_2O emissions. Both composting methods (turning and forced aeration) involve an increase in NH_3 emissions.	69%

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	Anaerobic digestion	Conventional management	Ref4		Ref10, Ref13 and Ref15	Ref12
		Composting	Conventional management	Ref2, Ref3, Ref9, Ref11 and Ref13	Ref2 and Ref17	Ref9 and Ref10	
		Solid-liquid separation	Conventional management	Ref15		Ref4 and Ref10	

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
Bulk density	Ref17

Factor	Reference number
Livestock type	Ref10
Manure characteristics	Ref11
NA	Ref2, Ref2, Ref2, Ref2, Ref2, Ref2, Ref2, Ref9, Ref9, Ref9, Ref9, Ref9, Ref9, Ref9, Ref9, Ref3, Ref3, Ref3, Ref3, Ref3, Ref3, Ref3, Ref3, Ref4, Ref4, Ref4, Ref4, Ref4, Ref4, Ref4, Ref4, Ref11, Ref11, Ref11, Ref11, Ref11, Ref11, Ref11, Ref10, Ref10, Ref10, Ref10, Ref10, Ref10, Ref10, Ref10, Ref12, Ref12, Ref12, Ref12, Ref12, Ref12, Ref12, Ref12, Ref13, Ref13, Ref13, Ref13, Ref13, Ref13, Ref13, Ref13, Ref15, Ref15, Ref15, Ref15, Ref15, Ref15, Ref15, Ref15, Ref17, Ref17, Ref17, Ref17, Ref17, Ref17
Temperature in the heap	Ref17
Type of technology	Ref2

4. KNOWLEDGE GAPS

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

Ref Num	Gap
Ref2	The effects of an air-dry pretreatment on N losses could be further explored because the losses were not considered during the pre-treatment phase.
Ref3	The number of studies quantifying NH_3 emission from dairy manure aerobic composting was limited. More attention should be paid to reducing NH_3 losses and improving nitrogen retention in composted products from dairy manure composting process in the future.
Ref15	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
Ref2	Zhang Z., Liu D., Qiao Y., Li S., Chen Y., Hu C.	2021	Mitigation of carbon and nitrogen losses during pig manure composting: A meta-analysis	Science of the Total Environment 783 147103	10.1016/j.scitotenv.2021.147103
Ref3	Ba, SD; Qu, QB; Zhang, KQ; Groot, JCJ	2020	Meta-analysis of greenhouse gas and ammonia emissions from dairy manure composting	Biosystems engineering	10.1016/j.biosystemseng.2020.02.015
Ref4	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
Ref9	Zhao, SX; Schmidt, S; Qin, W; Li, J; Li, GX; Zhang, WF	2020	Towards the circular nitrogen economy - A global meta-analysis of composting technologies reveals much potential for mitigating nitrogen losses	Sci. Total Environ. 704, 135401	10.1016/j.scitotenv.2019.135401
Ref10	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
Ref11	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
Ref12	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
Ref13	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
Ref15	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
Ref17	Pardo, G; Moral, R; Aguilera, E; del Prado, A	2015	Gaseous emissions from management of solid waste: a systematic review	Glob. Chang. Biol. 21, 1313–1327	10.1111/gcb.12806