GENERAL FICHE

MANURE PROCESSING TECHNIQUES

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Note to the reader: This general fiche summarises all the environmental and climate impacts of MANURE PROCESSING TECHNIQUES found in a review of 17 synthesis papers[1]. These papers were selected from an initial number of 277 obtained through a systematic literature search strategy, according to the inclusion criteria reported in section 4. The impacts reported here are those for which there is scientific evidence available in published synthesis papers, what does not preclude the farming practice to have other impacts on the environment and climate still not covered by primary studies or by synthesis papers.

The synthesis papers review a number of primary studies ranging from 7 to 172. Therefore, the assessment of impacts relies on a large number of results from the primary studies, obtained mainly in field conditions, or sometimes in lab experiments or from model simulations.

1. DESCRIPTION OF THE FARMING PRACTICE

- Description:
  - Manure processing techniques can be used to change manure chemical/physical properties and composition and thus increasing manure management efficiency as an amendment and fertiliser, while limiting emissions, as compared to untreated manure[2]
- Key descriptors:
  - In this review, manure processing techniques include:
  - Composting of solid manure using improved techniques (e.g. turning, forced-air, bulking agents).
  - Anaerobic digestion of slurries. Here, the environmental impacts of anaerobic digestion of manure alone (i.e. mono-digestion) or with other substrates (i.e. co-digestion) are reviewed and are considered either as result of the overall processing chain (pre-storage, digesters, post-storage, land distribution, energy generation using biogas) or from single steps.
  - Liquid manure storage in anaerobic lagoons or in aerobic lagoons;
  - Solid manure storage in piles. Improved techniques for manure storage in static stockpiles (e.g. physical, chemical or microbial additives, etc.) are excluded here, and included in a separate set of fiches regarding 'Improved manure storage techniques'.
  - Solid-liquid separation (e.g. decanter centrifuges, screw press, roller presses, decantation). The effects are considered by comparing either handling, storage or land application of the separated fractions, as compared to the raw manure.
  - Drying of solid fractions
  - Recovery of nutrients through physical or chemical treatments (e.g. struvite precipitation, ammonia stripping)
  - Manure pasteurization
  - Note that this is not an exhaustive list of manure processing techniques, but of those found in the literature that meet the requirements to be included in this review
  - NA

2. EFFECTS OF THE FARMING PRACTICE ON CLIMATE AND ENVIRONMENTAL IMPACTS

(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.

All selected synthesis papers included studies conducted in Europe , and 15 have a quality score higher than 50%.

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. 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	

[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.
[2] AMEC – Environment & infrastructure UK limited, in partnership with BIO intelligence service. Collection and analysis of data for the control of emissions from the spreading of manure - Final report 2014 for The European Commission. Available at https://ec.europa.eu/environment/air/pdf/Final%20Report.pdf

				Statistically tested			Non-statistically tested
Impact	Metric	Intervention	Comparator	Significantly positive	Significantly negative	Non-significant	
Decrease Acidification (LCA)	Acidification potential (LCA approach)	Anaerobic digestion	Conventional management	1	0	1	1
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
Decrease Anti-microbial resistance	Antibiotic resistant microbes/genes	Anaerobic digestion	Conventional management	1	0	0	0
		Composting	Conventional management	1	0	0	0
		Drying	Conventional management	1	0	0	0
		Land application of aerobic lagoon stored manure	Conventional management	0	0	1	0
		Land application of anaerobic lagoon stored manure	Conventional management	0	0	1	0
		Land application of pile-stored solid manure	Conventional management	0	0	1	0
		Pasteurization	Conventional management	0	0	1	0
Increase Carbon sequestration	Soil organic carbon	Composting/Anaerobic digestion	Conventional management	0	0	1	0
Decrease Ecotoxicity (LCA)	Ecotoxicity (LCA approach)	Anaerobic digestion	Conventional management	1	0	0	1
Decrease Energy use (LCA)	Energy use (LCA approach)	Anaerobic digestion	Conventional management	0	0	0	1
Decrease Eutrophication (LCA)	Eutrophication (LCA approach)	Anaerobic digestion	Conventional management	1	0	1	0
Decrease GHG emissions	Aggregated GHGs emission	Anaerobic digestion	Conventional management	1	0	0	0
Decrease GHG emissions	CH_4	Anaerobic digestion	Conventional management	1	0	1	2 (0)
		Composting	Conventional management	2	0	3	1 (0)
		Solid-liquid separation	Conventional management	1	0	0	1 (0)
Decrease GHG emissions	N_2O	Anaerobic digestion	Conventional management	1	0	4	2 (0)
		Composting	Conventional management	5	0	4	1 (0)
		Solid-liquid separation	Conventional management	1	0	2	1 (0)
Decrease Global warming potential (LCA)	Global warming potential (CO_2-eq)	Anaerobic digestion	Conventional management	2	0	0	1
Increase Nutrients recovery	P recovery	Treatment with struvite precipitation	Conventional management	1	0	0	1
Increase Nutrients recovery	Total nitrogen loss	Composting	Conventional management	1	1	1	0
Decrease Resource depletion (LCA)	Resource depletion (LCA approach)	Anaerobic digestion	Conventional management	0	0	1	1
Increase Soil biological quality	Soil biological quality	Composting/Anaerobic digestion	Conventional management	1	0	0	0
Increase Soil nutrients	Soil total nitrogen	Composting/Anaerobic digestion	Conventional management	0	0	1	0

3. FACTORS INFLUENCING THE EFFECTS ON CLIMATE AND ENVIRONMENTAL IMPACTS

The factors significantly influencing the size and/or direction of the effects on the impacts, according to the synthesis papers included in this review, are reported below. Details about the factors can be found in the **summaries of the meta-analyses** available in this WIKI.

Table 2: List of factors reported to significantly affect the size and/or direction of the effects on environmental and climate impacts, according to the synthesis papers reviewed. The reference number of the synthesis papers where those factors are explored is given in parentheses.

Impact	Factors
Acidification (LCA)	NA (Ref1, Ref1, Ref1, Ref1, Ref1, Ref1, Ref1 and Ref1)
Air pollutants emissions	Bulk density (Ref17), 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, Ref11, Ref11, Ref11, Ref11, Ref11, Ref11, Ref11, 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) and Type of technology (Ref2)
Anti-microbial resistance	NA (Ref5, Ref5, Ref5, Ref5, Ref5, Ref5), Temperature (Ref5) and Type of manure (Ref5)
Carbon sequestration	NA (Ref6, Ref6, Ref6, Ref6, Ref6, Ref6, Ref6 and Ref6)
Ecotoxicity (LCA)	NA (Ref1, Ref1, Ref1, Ref1, Ref1, Ref1, Ref1 and Ref1)
Energy use (LCA)	NA (Ref1, Ref1, Ref1, Ref1, Ref1, Ref1, Ref1 and Ref1)
Eutrophication (LCA)	NA (Ref1, Ref1, Ref1, Ref1, Ref1, Ref1, Ref1 and Ref1)
GHG emissions	Bulk density (Ref17), Climate (Ref8), Crop type (Ref8), Duration of treatment (Ref8), Moisture content (Ref17), NA (Ref2, Ref2, Ref2, Ref2, Ref2, Ref2, Ref2, Ref8, Ref8, Ref8, Ref9, Ref9, Ref9, Ref9, Ref9, Ref9, Ref9, Ref9, Ref3, Ref3, Ref3, Ref3, Ref3, Ref3, Ref3, Ref3, Ref4, Ref4, Ref4, Ref4, Ref4, Ref4, Ref4, Ref4, Ref12, Ref12, Ref12, Ref12, Ref12, Ref12, Ref12, Ref12, Ref13, Ref13, Ref13, Ref13, Ref13, Ref13, Ref13, Ref13, Ref14, Ref14, Ref14, Ref14, Ref14, Ref14, Ref14, Ref14, Ref15, Ref15, Ref15, Ref15, Ref15, Ref15, Ref15, Ref15, Ref17, Ref17, Ref17, Ref17, Ref17, Ref17, Ref16, Ref16, Ref16, Ref16, Ref16, Ref16, Ref16, Ref16), Soil organic carbon (Ref8), Type of technology (Ref2) and Water filled pore space (Ref8)
Global warming potential (LCA)	NA (Ref1, Ref1, Ref1, Ref1, Ref1, Ref1, Ref1, Ref1, Ref16, Ref16, Ref16, Ref16, Ref16, Ref16, Ref16 and Ref16)
Nutrients recovery	Mg:PO_4 ratio (Ref7), NA (Ref9, Ref9, Ref9, Ref9, Ref9, Ref9, Ref9, Ref9, Ref7, Ref7, Ref7, Ref7, Ref7, Ref7, Ref17, Ref17, Ref17, Ref17, Ref17, Ref17, Ref17, Ref17) and pH (Ref7)
Resource depletion (LCA)	NA (Ref1, Ref1, Ref1, Ref1, Ref1, Ref1, Ref1 and Ref1)
Soil biological quality	NA (Ref6, Ref6, Ref6, Ref6, Ref6, Ref6, Ref6 and Ref6)
Soil nutrients	NA (Ref6, Ref6, Ref6, Ref6, Ref6, Ref6, Ref6 and Ref6)

4. SYSTEMATIC REVIEW SEARCH STRATEGY

Table 3: Systematic review search strategy - methodology and search parameters.

Parameter	Details
Keywords	WOS: TOPIC: (manure OR slurry OR digestate OR (digested near/3 manure)) AND TOPIC: (management OR storage OR lagoon* OR "anaerobic digest*" OR tank* OR treatment OR process* OR technolog* OR techni* OR (soil near/3 application) OR (soil near/3 distribution) OR (soil near/3 amend*) OR biogas OR precision) AND TOPIC: ("meta-analy*" OR "systematic* review*" OR "evidence map" OR "global synthesis" OR "evidence synthesis" OR "research synthesis") and SCOPUS: TITLE_ABS_KEY: (manure OR slurry OR digestate OR (digested near/3 manure)) AND TITLE_ABS_KEY: (management OR storage OR lagoon* OR "anaerobic digest*" OR tank* OR treatment OR process* OR technolog* OR techni* OR (soil near/3 application) OR (soil near/3 distribution) OR (soil near/3 amend*) OR biogas OR precision) AND TITLE_ABS_KEY: ("meta-analy*" OR "systematic* review*" OR "evidence map" OR "global synthesis" OR "evidence synthesis" OR "research synthesis")
Time reference	No time restriction.
Databases	Web of Science and Scopus: run on 01 July 2021
Exclusion criteria	The main criteria that led to the exclusion of a synthesis paper are: 1) The topic of the meta-analysis is out of the scope of this review., 2) The paper is neither a systematic review nor a meta-analysis of primary research., 3) The analysis is not based on pairwise comparisons, 4) The paper is not written in English., 5) The full text is not available, 6) The analysis did not deal with manure processing techniques or dealt with other stages of manure management (e.g. storage, land application, animal housing techniques) and 7) The analysis synthetized studies with absolute values of emission factors, without comparing processing techniques with a reference management scenario. The search returned 0 synthesis papers from WOS and SCOPUS on Manure processing techniques plus other 277 retrieved in the search of other farming practices, potentially relevant for the practice object of our fiche. From the potentially relevant synthesis papers, 96 were excluded after reading the title and abstract, and 40 after reading the full text according to the above-mentioned criteria. Finally, 17 synthesis papers were selected.

5. SYNTHESIS PAPERS INCLUDED IN THE REVIEW

Table 4: 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	Zhang J., Wang M., Yin C., Dogot T.	2021	The potential of dairy manure and sewage management pathways towards a circular economy: A meta-analysis from the life cycle perspective	Sci. Total Environ. 779, 146396.	10.1016/j.scitotenv.2021.146396
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	Agronomy 10, 1633	10.3390/agronomy10111633

Ref Num	Author(s)	Year	Title	Journal	DOI
			Consequences for Greenhouse Gas Emissions		
Ref5	Goulas, A; Belhadi, D; Descamps, A; Andremont, A; Benoit, P; Courtois, S; Dagot, C; Grall, N; Makowski, D; Nazaret, S; Nelieu, S; Patureau, D; Petit, F; Roose-Amsaleg, C; Vittecoq, M; Livoreil, B; Laouenan, C	2020	How effective are strategies to control the dissemination of antibiotic resistance in the environment? A systematic review	Environmental Evidence 9, 1–32	10.1186/s13750-020-0187-x
Ref6	Liu, SB; Wang, JY; Pu, SY; Blagodatskaya, E; Kuzyakov, Y; Razavi, BS	2020	Impact of manure on soil biochemical properties: A global synthesis	SCIENCE OF THE TOTAL ENVIRONMENT, 745, 141003.	10.1016/j.scitotenv.2020.141003
Ref7	Lorick, D; Macura, B; Ahlstrom, M; Grimvall, A; Harder, R	2020	Effectiveness of struvite precipitation and ammonia stripping for recovery of phosphorus and nitrogen from anaerobic digestate: a systematic review	Environmental Evidence 9, 1–20	10.1186/s13750-020-00211-x
Ref8	Xia, F; Mei, K; Xu, Y; Zhang, C; Dahlgren, RA; Zhang, MH	2020	Response of N2O emission to manure application in field trials of agricultural soils across the globe	SCIENCE OF THE TOTAL ENVIRONMENT, 733, 139390.	10.1016/j.scitotenv.2020.139390
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
Ref14	Jayasundara, S; Appuhamy, JADRN; Kebreab, E; Wagner-Riddle, C	2016	Methane and nitrous oxide emissions from Canadian dairy farms and mitigation options: An updated review	CANADIAN JOURNAL OF ANIMAL SCIENCE	10.1139/cjas-2015-0111
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
Ref16	Miranda, ND; Tuomisto, HL; McCulloch, MD	2015	Meta-Analysis of Greenhouse Gas Emissions from Anaerobic Digestion Processes in Dairy Farms	Environ. Sci. Technol. 49, 5211–5219	10.1021/acs.est.5b00018
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