SINGLE-IMPACT FICHE
MANURE PROCESSING TECHNIQUES

IMPACT: GREENHOUSE GAS EMISSIONS

Data extracted in July 2021

Note to the reader: This fiche summarises the impact of manure processing techniques on GREENHOUSE GAS (GHG) EMISSIONS. It is based on 12 peer-reviewed synthesis research papers[1], including from 7 to 142 individual studies.

1. WEIGHT OF THE EVIDENCE

- CONSISTENCY OF THE IMPACT:
  Compared to absence of manure treatment, manure processing techniques (composting, anaerobic digestion and solid-liquid separation), showed different effects on GHG emissions (biogenic-carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) emissions and on aggregated GHG emissions). Results were reported either at the stage of the composting pile or at the stage of land application of treated manure (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":
  - Composting:
    - *biogenic-CO_2 emission:* results were different, as from 3 synthesis papers, 1 reported a positive, 1 a negative and 1 no significant effect.
    - *CH_4 emission*: among 5 synthesis papers, 2 of high quality (quality score ≥50%) and 1 of poor quality (quality score <50%) indicated no significant effect, while 2 synthesis papers of high quality reported a positive effect (i.e. decrease of CH_4 emission).
    - *N_2O emission*: a positive effect (i.e. decrease of N_2O emission) was reported in 5 (4 of high quality) out of 7 synthesis papers, while 2 reported no significant effect.
    - *Aggregated GHG emissions*: the effect of composting was reported as uncertain in 1 synthesis paper of low quality (without a proper statistical analysis).

    The differences in the effects mainly depend on the type of composting process 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:
    - *biogenic-CO_2 emission*: a positive effect (i.e. decrease of biogenic-CO_2 emission) was reported in 1 synthesis paper.
    - *CH_4 emission*: different effects were reported, with 1 synthesis paper indicated a positive effect, while another synthesis paper of low quality reported an uncertain effect.
    - *N_2O emission*: no significant effect was reported in 2 out of 3 synthesis papers, while 1 showed a positive effect.
    - *Aggregated GHG emissions*: 2 out of 4 synthesis papers report positive effect and other report 2 uncertain results (without a proper statistical analysis).

    Differences in the effects mainly depend on the configuration of the anaerobic digestion process, e.g. either mono-digestion (only manure) or co-digestion (manure + other substrates) or anaerobic

[1] Research synthesis papers include a formal meta-analysis or systematic reviews with some quantitative results

digestion in integration to digestate-treatment technologies, such as filtration, reverse osmosis, microalgae, drying, stripping.

- Solid-liquid separation:
  - *biogenic-CO_2 emission*: there was no effect of solid-liquid separation on according to 1 synthesis paper.
  - *CH_4 emission*: 1 synthesis paper indicated a positive effect.
  - *N_2O emission*: compared to no manure processing, solid-liquid separation showed inconsistent effect. Among 3 synthesis papers, 2 reported no significant effect, while 1 indicated a positive effect.
  - *Aggregated GHG emissions*: the effect of solid-liquid separation was uncertain according to 1 synthesis paper of low quality (without a proper statistical analysis).

Among the 12 reviewed synthesis papers, 10 include data collected in Europe (see **Table 2**).

Table 1. Summary of effects. The effect with the higher score is marked in bold and the cell coloured. 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	Metric	Intervention (Technique)	Positive	Negative	No effect	Uncertain*
Decrease GHG emissions	CO_2-biogenic	Composting	1 (1)	1 (1)	1 (1)	0
		Anaerobic digestion	1 (1)	0	0	0
		Solid-liquid separation	0	0	1 (1)	0
	CH_4	Composting	2 (2)	0	3 (2)	0
		Anaerobic digestion	1 (1)	0	0	1 (0)
		Solid-liquid separation	1 (1)	0	0	0
	N_2O	Composting	5 (4)	0	2 (2)	0
		Anaerobic digestion	1 (1)	0	2 (2)	1 (0)
		Solid-liquid separation	1 (1)	0	2 (2)	0
	Aggregated GHG emissions (CO_2-eq)	Composting	0	0	0	1 (0)
		Anaerobic digestion	2 (2)	0	0	2 (1)
		Solid-liquid separation	0	0	0	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 this document →.*

As shown in the "Quality score" in **Table 2**, the quality level of the synthesis papers was in the range of 19 to 88%. The least frequently satisfied quality criteria were "Number of studies at each step", "Individual effect sizes", "Dataset available" and "Publication bias analysed".

2. IMPACTS

The main characteristics and results of the synthesis papers are summarized in **Table 2**. Detailed results of each synthesis study are reported in the summary reports.

Table 2. Main characteristics of the synthesis papers reporting impacts of manure processing techniques on GHG emissions. The references are ordered chronologically with the most recent publication date first.

Reference	Population	Scale	Num. papers	Intervention (technique)	Comparator	Metric	Conclusion	Quality score
Zhang, J; Wang, M; Yin, C; Dogot, T; 2021	Dairy farm manure	Global	23	Manure and farming sewage waste-to-energy pathway (anaerobic digestion, including monodigestion (only manure), co-digestion (manure+ other substrates) + integrated treatment techniques (including filtration, reverse osmosis, microalgae, drying, stripping)	No treatment. The only difference of reference and treatment system is implementing an improved strategy. The rest of the two systems remains the same, such as functional unit, system boundaries, LCA methods adopted, and farming practices.	Global warming potential	All types of waste-to-energy (anaerobic digestion) pathways could have a consensus on reducing global warming. However, anaerobic co-digestion did not show significant effects, for lack of data.	62%
Zhang, Z; Liu, D; Qiao, Y; Li, S; Chen, Y; Hu, C; 2021	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	Total C loss, CH_4-C loss, CO_2-C loss, N_2O-N loss	Overall, the studied technologies can reduce total C and N losses, including N_2O, CH_4 and CO_2 emissions.	69%
Xia, F; Mei, K; Xu, Y; Zhang, C; Dahlgren, RA; Zhang, MH 2020	Arable land and grassland	Global	44	Fertilisation with pre-treated manure (either composted or digested farmyard manure (FYM), pig, cattle or poultry.	Fertilisation with raw manure (farmyard manure (FYM), pig, cattle or poultry)	N_2O emission	Raw manure resulted in significantly higher N_2O emission than pre-treated (either composted or digested) manure.	69%
Zhao, SX; Schmidt, S; Qin, W; Li, J; Li, GX; Zhang, WF 2020	Soild manure and organic waste	Global	36	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	N_2O-N loss	Carbon/nitrogen regulation in composting did not reduce NO_2 losses, but optimized aeration rate or turning frequency significantly reduced N_2O-N loss (by 54.9%).	69%
Ba, SD; Qu, QB; Zhang, KQ; Groot, JCJ 2020	Dairy manure composts	Global	41	vermicomposting	No mitigation measure	CO_2, CH_4, N_2O emission	Vermicomposting had no effect on both N_2O and CH_4 emissions from manure.	69%
Emmerling, C; Krein, A; Junk, J 2020	European agricultural systems with slurry fertilisation	Europe	38	Biological treatment (anaerobic digestion); Solid-liquid separation	No slurry treatment	CO_2, CH_4, N_2O emission	Anaerobic digestion was effective to varying degrees for the abatement of CH_4 and CO_2 emissions, but also resulted in the (non-significant) increased emission of N_2O emissions. Solid-liquid separation showed no effect on CO_2 and N_2O emissions, while being effective for CH_4 emission abatement.	50%

Reference	Population	Scale	Num. papers	Intervention (technique)	Comparator	Metric	Conclusion	Quality score
Sajeev, EPM; Winiwarter, W; Amon, B 2018	Pig and cattle manure	Not reported	89	Anaerobic digestion	No abatement options	CH_4, NO_2 emission	This study shows that anaerobic digestion can reduce CH_4 emissions from from pig and cattle manure management. However, several options are associated with tradeoffs on N_2O emissions from storage of digestate. These results are uncertain, because based only on descriptive statistics, and not on a model taking into account between-studies variability.	44%
Wang, Y; Dong, HM; Zhu, ZP; Gerber, PJ; Xin, HW; Smith, P; Opio, C; Steinfeld, H; Chadwick, D 2017	Swine manure	Global	142	Anaerobic digestion; Composting with additives	No mitigation strategy	NO_2 emission	Land application of digestate, as compared to raw manure, was not effective in reducing N_2O emissions. For mitigation of emissions during active composting, additives have proven to be effective in reducing N_2O emissions. The impact was not significant for CH_4 emission.	62%
Jayasundara, S; Appuhamy, JADRN; Kebreab, E; Wagner-Riddle, C 2016	Dairy cattle	Cold climatic countries	7	Composting of solid manure, Solid-liquid separation, Anaerobic digestion of slurry	No mitigation strategy	CH_4 and N_2O emission	This review identify several promising strategies for mitigating GHG emissions from dairy manure, including anaerobic digestion, solid–liquid separation, composting, manure storage covers, and complete emptying of liquid manure storage at spring application. These results are uncertain due to the methodology used in this study (systematic review, no quantitative analysis).	19%
Hou, Y; Velthof, GL; Oenema, O 2015	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	CH_4 and N_2O emission	The overall effect of liquid fractions on N_2O emissions did not differ from that of raw slurry. Field-applied digestates and solid fractions showed on average 25% and 46% lower N_2O emissions than field-applied untreated manure, respectively.	88%

Reference	Population	Scale	Num. papers	Intervention (technique)	Comparator	Metric	Conclusion	Quality score
Pardo, G; Moral, R; Aguilera, E; del Prado, A 2015	Solid manure (dairy cows, swine, poultry, green waste)	Global	76	Solid manure improved composting techniques (turning, forced aeration, compaction, covering, bulking agents, additives)	Solid manure conventional storage (heaps)	CO_2, CH_4, N_2O emission	The incorporation of a bulking agent is one of the most effective measures, simultaneously reducing CH_4 and N_2O emissions. Turning have shown potential for reducing GHGs emissions, whereas no clear effects were detected for forced aerated system.	69%
Miranda, ND; Tuomisto, HL; McCulloch, MD 2015	Dairy farms slurry manures	Global	30	Anaerobic digestion of manure only.	Raw slurry	The selected articles report emissions of different GHGs per functional unit [f.u.] (GHGi, i = CH_4, N_2O, or CO_2). To standardize the emissions, these are expressed as carbon dioxide equivalents (CO_2e).	The median reductions in emissions from the baseline scenarios, according to operation units, are -43.2% (n.s.) for storage, -6.3% for field application of slurries, -11.0% for offset of energy from fossil fuel, and +0.4% (n.s.) for offset of inorganic fertilizers. The leaks from digesters are found to significantly increase the emissions from baseline scenarios (median = +1.4%).	56%

3. KNOWLEDGE GAPS

Zhang et al., 2021	The effects of an air-dry pre-treatment on C losses could be further explored because the losses were not considered during the pre-treatment phase.
Xia et al. 2020	The number of individual studies included in this synthesis paper is low and more field experiments are needed to measure N_2O emission after processed manure application, including various agricultural practices (tillage and irrigation) and soil properties (soil temperature and microbial community). With increasing data availability in recent and future studies, it is important to critically identify the influence and integrated mechanisms involved in N_2O emissions to achieve optimal manure management and agricultural practices for field manure application.
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.
Pardo et al., 2015	The number of studies reporting CH_4 losses from solid waste management applying additives is limited. The results of this synthesis paper are based on 9 experiments from only 2 studies examining the effect of phosphogypsum addition on gaseous emissions. Average values suggest that this strategy tends to reduce CH_4 emissions (mean: -59%). However, more data are still required to confirm this trend. Although the number of experiments investigating the influence of management practices on GHG emissions has grown during the last decade, an important restriction of the dataset is that there is still a limited knowledge basis with respect to gaseous losses from solid waste management, particularly for CH_4 and N_2O emissions at commercial scale. In addition to this, the collected results showed large variability, which emphasizes the need to produce additional data through precise and accurate research methods to obtain robust emission factor estimates that can help reduce current uncertainties.

4. SYSTEMATIC REVIEW SEARCH STRATEGY

Keywords	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") or TITLE-ABS-KEY: (manure OR slurry OR digestate OR (digested W/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 W/3 application) OR (soil W/3 distribution) OR (soil W/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")
Search dates	No time restrictions
Databases	Web of Science and Scopus, run in July 2021
Selection criteria	The main criteria that led to the exclusion of a synthesis paper were if the paper: (1) was out of the scope; (2) did not deal with manure processing techniques or dealt with other stages of manure management (e.g. storage, land application, animal housing techniques); (3) reported studies with absolute values of emission factors, without comparing processing techniques with a reference management scenario; (4) did not clearly state the intervention and comparator; (5) was not either a systematic review or a meta-analysis; (6) was not written in English. Synthesis papers that passed the relevance criteria were subject to critical appraisal carried out on paper-by-paper basis. The search returned 269 synthesis papers potentially relevant for the practice object of our fiche. Searches for other farming practices added another 8 potentially relevant synthesis papers. From the 277 potentially relevant synthesis papers, 207 were excluded after reading the title and abstract, and 53 after reading the full text according to the above-mentioned criteria. Finally, 17 synthesis papers were selected for manure processing techniques, from which 12 were relevant for this impact.