Reference 6

Cao Y, Wang X, Bai Z, Chadwick D, Misselbrook T, Sommer SG, Qin W, Ma L 2019 Mitigation of ammonia, nitrous oxide and methane emissions during solid waste composting with different additives: A meta-analysis Journal of Cleaner Production 10.1016/j.jclepro.2019.06.288

Background and objective

Composting of solid waste can be associated with a loss of the agronomic value (nutrient loss), as well as a source of environmental impact through the emission of the greenhouse gases (GHG) nitrous oxide (N_2O) and methane (CH_4) and volatilization of ammonia (ammonia). Additives have been considered as a useful option to mitigate these environmental emissions, but the wider effects of using different additives on multiple gas emissions is still uncertain. The objectives of this study were: (i) to quantify and compare the mitigation effect of different additives on multiple gases; (ii) to assess the importance of feedstock properties (moisture content, C/N ratio and pH) on mitigation effect; (iii) to investigate the relationship between additive application dosage and mitigation effect; (iv) to explore optimal options to reduce TN loss and ammonia, N_2O and CH_4 emissions. Here the results concerning the impact of additives during composting on ammonia emission are reported.

Search strategy and selection criteria

Peer-reviewed literature, theses and conference papers from 1994 to 11th February 2018 were collected, using the electronic databases: Web of Science, Google Scholar and the China National Knowledge Infrastructure. In this literature search, the following specific keywords were combined: composting, additives (amendments), nitrogen loss, ammonia, nitrous oxide, methane or greenhouse gas emissions. To be included in this meta-analysis, studies needed to meet the following criteria: (i) the study should include control treatments; (ii) the study described the mitigation efficiency of at least one of TN, NH_3, N_2O and CH_4 for each treatment; (iii) aerobic composting process was ensured by forced aeration and/or turning; and (iv), the composting process was complete, as indicated by the compost temperature remaining stable at the ambient temperature.

Data and analysis

Mean effect sizes and bias-corrected 95% confidence intervals were generated by running a bootstrapping procedure with 5000 iterations using Metawin 2.1.4 software. The effects of 3 variables on mean effect were explored: additive type, application dosage and feedstock properties.

Number of papers	Population	Intervention	Comparator	Outcome	Quality score
105	Livestock manure, food waste, sewage sludge and/or green waste	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	Metric: NH_3 emission in terms of cumulative NH_3-N losses as a proportion of the TN of the initial composting material; Effect size: Logarithm of ratio of the considered metrics in the intervention to the considered metrics in the control	62.5

Results

- According to this meta-analysis, the use of additives can significantly reduce ammonia emission (44.5%, on average), compared with the control.
- There was a range in mitigation efficiencies depending on the additive type. Application of chemical additives was more efficient at reducing ammonia emission (48.9%), compared with other additives. The effectiveness of chemical additives on ammonia emission can vary according to additive properties. Specifically, phosphate and magnesium salts had the greatest mitigation potential, reducing ammonia emission by 62.0%; followed by superphosphate. Acids were very effective in reducing ammonia emission during composting (44.5%).
- The application of physical additives was also an effective option to reduce ammonia emission, with average reduction of 37.8%, with biochar and zeolite giving significant reductions.
- The present meta-analysis showed that the application of microbial additives were less effective than chemical or physical additives in reducing ammonia emission, with reductions of 42.8%. The application of these microbial additives can even stimulate N mineralization and increase ammonia emission. Specifically, the application of NOB tended to increase ammonia emission, although this is based on only two studies and further work is needed to confirm this.
- There was significant linear correlation between application dosage of phosphate and magnesium salt and the mitigation efficiency for ammonia emission between 0 and 20%, with ammonia emission decreasing by 3.3% for every 1% increase in the application of phosphate and magnesium salt. The magnitude of the mitigation of ammonia emission increased as the dosage rate of superphosphate increased over the range of 0–20%, with decreases in ammonia emission of 2.8% for every 1% increase in superphosphate application. Chemical additives at low moisture content were more effective in mitigating ammonia emission (54.2%) than these (40.2%) at high moisture content. Physical additives at low moisture content were more effective in mitigating ammonia (49.8%) than these (30.1%) at high moisture content. At low C/N ratios (≤20), chemical additives resulted in a greater mitigation of ammonia emission compared to physical additives, although at high C/N ratios (>20 to ≤ 30) there was a tendency for the opposite effect. Chemical and physical additives showed no significant difference in their effectiveness of mitigating ammonia emission under acidic (pH ≤ 6.5) or neutral (pH > 6.5 to ≤ 7.5) conditions.

Factors influencing effect sizes

- Additive type : The present meta-analysis showed that the application of microbial additives were less effective than chemical or physical additives in reducing ammonia losses. The application of these microbial additives can even stimulate N mineralization and increase ammonia emission.
- Application dosage : Higher impact of chemical and physical additive on ammonia emission for higher dosage;

- Initial moisture content : Low moisture content increased effectiveness of chemical and physical additives
- Initial pH : No effect of chemical and physical additives under acidic (pH $\leq$ 6.5) or neutral (pH $>$ 6.5 to $\leq$ 7.5) conditions
- Initial C/N ratio : Low C/N ratios stimulated the effectiveness of chemical additives to reduce TN loss; high C/N ratios stimulated the effectiveness of physical additives to reduce TN loss;

Conclusion

This global meta-analysis establishes that the use of additives can significantly reduce ammonia emissions during composting.