FARMING PRACTICE
MANURE PROCESSING TECHNIQUES

IMPACT: NUTRIENTS RECOVERY

Reference 7

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

Background and objective

A regular supply of nutrients such as nitrogen and phosphorus to agriculture is needed for global food security, and increased recycling of nutrients back to agriculture from organic waste streams is necessary for increased rural–urban sustainability. Anaerobic digestion of sewage sludge and agricultural wastes is widely applied to stabilize the substrate and capture some of its energetic value via biogas production. Anaerobic digestate is a concentrated source of nutrients to which nutrient recovery technologies can be applied. By combining anaerobic digestion and nutrient recovery technologies on the digestate, both energy and nutrient recovery can be achieved. Two promising technologies that could increase nutrient recycling from different types of wastewater are struvite precipitation and ammonia stripping. The primary review question for this review was as follows: How effective are struvite precipitation and ammonia stripping for the recovery of phosphorus and nitrogen from the liquid phase of anaerobic digestate? This review focused on struvite precipitation and ammonia stripping currently developed and applied globally. Specifically, we have chosen to investigate P (and to some extent N) recovery through struvite precipitation and N recovery through ammonia stripping. The liquid phase of anaerobic digestate was chosen as nutrient source, since it is commonly produced in the current management of both manure and municipal wastewater.

Search strategy and selection criteria

Searches were performed in March 2019 using subscriptions of Warsaw University of Life Sciences and Stockholm University. These searches were conducted using English language search terms. All searches were restricted to articles published after 2013. WoS, Scopus, eThOS, DOAJ, DART. (struvite OR "$MgNH_4PO_4$" OR "NH_4MgPO_4" OR "Magnesium ammonium phosphate*" OR "Crystal green" OR (ammonium AND (sulphate* OR sulfate* OR nitrate)) OR mascagnite* OR ((stripp* OR scrub) AND (ammoni* OR NH_3 OR nitrogen OR air OR steam))) AND (digest* OR centrate* OR supernatant* OR dewater* OR"solid–liquid" OR "bio refiner*" OR "reject water" OR effluent* OR "liquid phase"). Searches in Google Scholar were performed between March and December of 2019. Searches were performed in English, Swedish, Finnish and Polish. Google Scholar searches were restricted to articles published after 2013, as above. Additionally, to identify grey literature, searches were performed across a suite of relevant organisational websites. Study validity assessment included evaluation of (1) study set up and design flaws (due to calculation errors, invalid outcome measurements or failure to control for the effect of additional competing interventions such as irradiation, dialysis or microwave treatment) and (2) susceptibility to bias (in the form of reporting bias, i.e. selective reporting of study findings). Studies judged to have flaws in design and setup or reporting bias were excluded from the narrative and quantitative synthesis. Then, studies without these issues were assessed for clarity of reporting on reactor input, recovery process and composition of the final product. Studies deemed to be unclear on two or more of these domains were classified as 'unclear' and excluded from quantitative synthesis but were still included in the narrative synthesis. The studies that passed both of these two appraisal steps were included in the quantitative synthesis. Since all the studies included in the quantitative synthesis were judged to be similar in quality, no distinction was made between different quality studies, and as such no weighting was done. The validity of each study was assessed by two independent reviewers. Final decisions regarding doubtful cases were taken by the whole review team.

Data and analysis

The struvite precipitation experiments included in the quantitative synthesis were subjected to meta-analyses, which were performed using proc MIXED in the statistical software package SAS Enterprise Guide 6.1. More specifically, to separate variation between and within studies, the extracted data were fitted to variance component models $Y=\beta+b+\varepsilon$, in which Y is a vector of observed effect sizes (struvite recovery data in percent), the intercept β denotes the expected effect size, b is a vector of random errors (residuals) on the between-study level, and ε is a vector of random errors (residuals) on the within-study level. Separate analyses were performed on the entire dataset and subsets representing struvite precipitation from manure and sewage sludge, respectively. In all cases, the confidence limits for the expected effect size were based on the assumption that the random errors on the between-study and within-study levels were independent and normally distributed. Due to high heterogeneity between studies and lack of data, no quantitative synthesis was performed for ammonia stripping.

Number of papers	Population	Intervention	Comparator	Outcome	Quality score
28	Digestate liquid fraction	Struvite precipitation	No treatment	Metric: Nitrogen and Phosphorous removal from liquid phase; Effect size: Removal efficiency	75

Results

- The recovery of struvite was substantial regardless of the type of substrate and other conditions in the performed experiments. High removal rates were achieved, with mean and median removal rates of PO_4 reaching 86.2% and 91.8%, respectively.
- As such, no conclusions are presented regarding the influence of different process parameters on the outcome of ammonia stripping. Total nitrogen removal varied between 17 and 95%. Low data availability and high heterogeneity between studies in the evidence base precluded quantitative synthesis for ammonia stripping dataset.

Factors influencing effect sizes

- pH : The response to pH was found to be non-linear, with a maximum average removal found to be around pH 9.5.

- Mg:PO_4 ratio : The response in removal efficiency to Mg:PO_4 ratio was found to be almost linear, with an average of around 85% removal at 1:1 ratio, increasing to approach almost complete removal at 4:1 ratio.

Conclusion

When performed under the right conditions (i.e. pH around 9.5 and Mg:PO_4 ratio of at least 1:1), struvite precipitation is an effective technology for the recovery of nutrients from the liquid phase of anaerobic digestate. The evidence base was limited for ammonia stripping.