Optimal struvite recovery from anaerobic digestate using central composite design

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Keywords: anaerobic digestion, magnesium ammonium phosphate, struvite, crystallization, optimization

INTRODUCTION

Anaerobic digestion (AD) in a sewage treatment plant produces digestate that contains high concentrations of nutrients thus it requires post-treatment to prevent a potential environmental risk (Gulyás et al., 2012). Forming struvite is one of the better ways to remove nutrients from AD digestate in a sewage treatment plant. Struvite is formed in a 1:1:1 molar ratio of magnesium, ammonium, and phosphate ions (Le Corre et al., 2005) and the reaction is known to occur spontaneously under approximately alkali conditions (Bouropoulos and Koutsoukos, 2000). The crystallization of the struvite not only reduces nitrogen and phosphorus but also forms valuable by-products. Since nitrogen and phosphorus contents in anaerobic digestate are significantly higher than that of magnesium, additional magnesium should be injected to form struvite. Unfortunately, there remains a need for an optimal crystallization method that can guarantee better productivity of the struvite. This study, therefore, investigates the optimal condition for the recovery of struvite from AD digestate via statistical optimization based on response surface methodology according to the pH and the molar ratio of Mg.

MATERIALS AND METHODS

Design of Experiment (DOE)

Optimal conditions were searched using the response surface method (RSM)-central composite design (CCD). The amount of magnesium injected and the pH of the solution was set on the x-axis and y-axis, and the z-axis was set as the reduced nitrogen, reduced phosphorus, and SS increase as struvite. The optimal conditions were also explored using a computer software, Design-Expert®.

Experimental setup

Struvite was precipitated in the anaerobic digestate of sewage sludge through a jar-tester. To observe the formation of struvite in anaerobic digestate, jar-testers were used to conduct the struvite formation experiments following the experimental design set-up and the protocol in Table 1.

Table 1. Experimental conditions

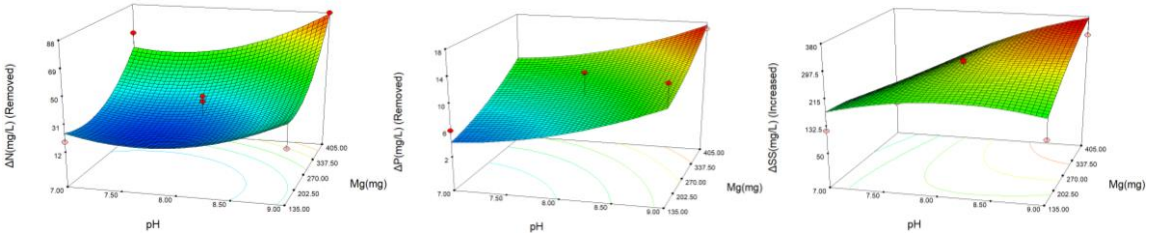
Flocculator	Reactor type	Working volume	Stirring time	Stirring speed	Temperature
Jar-tester	Batch	1 L	60 min	120 rpm	20 ± 2 ℃

RESULTS AND DISCUSSION

Response surfaces for nitrogen removal, phosphorus removal, and struvite formation

The obtained response surfaces show the variations of nitrogen, phosphorus, and struvite according to experimental conditions. Although the degree of removal was different, N and P removal increased as the pH and magnesium injection increase, and the amount of SS increase also presented a similar pattern. This reveals the direct association of nitrogen and phosphorus removal with the struvite formation. The phosphorus removal was up to 53%. The increase in SS (58%) can be inferred by the increase in struvite.

Figure 1. Response surface plot showing effect pH and the amount of magnesium injected



The optimal conditions

By overlaying the three graphs together, an optimal condition was derived via the statistical desirability analysis. The level to obtain the optimal response value using the response surface was set to 70% or more of the maximum response value, and the value of the independent variable derived to reach this level is 8.4<pH<9.0 and 1.25<[magnesium ion]/[phosphate]<1.5.

CONCLUSION

This study demonstrates that the struvite formation can be a viable option to reduce nutrients from anaerobic digestate while producing a value-added product, which supports the cost-effectiveness of AD operation in a sewage treatment plant.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No. 2020R1F1A1056613) and Korea Ministry of Environment(MOE) as 「Knowledge-based environmental service(Waste to energy) Human resource development Project」.

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