Nutrient recovery from biogas digestate by adsorption and ion-exchange using clinoptilolite

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Abstract
In recent years, environmental sustainability is the guiding concept for reducing pollution, for protection of the environment and for controlled use of natural resources. Within that context, recycling of waste and producing energy from these materials is being promoted. Anaerobic digestion of organic wastes is increasingly popular as a biological treatment technology which produces biogas as an energy source and digestate (nutrient containing sludge) that can be used as fertilizer. The aim of the study is the recovery and up- concentration of plant nutrients from the rather dilute liquid fraction of digestate resulting from anaerobic digestion of animal manure. Clinoptilolite was used as a sorbent material to remove nutrients from the liquid fraction of digestate; and the ion exchange/adsorption processes were investigated.

Introduction

The focus of waste management has shifted from disposal to minimization, recovery and recycling. Anaerobic digestion as a biological treatment technology applied to organic wastes is becoming widespread. The products generated from this technology comprise biogas (methane), which is an energy source, and a nutrient-rich digestate, which can be used as fertilizer. Thus, the recovery of biogas as well as the recovery of nutrients makes anaerobic digestion of organic waste a valuable waste treatment concept [1].

Digestate has a nutrient content which is favorable for its use as a fertilizer. However, it is not an easy by-product of anaerobic digestion to handle and directly applied as a fertilizer, due to its high volume. In many countries, fertilizer spreading periods on agricultural land are regulated in order to minimize nutrient leaching and therefore storage capacity for digestate becomes expensive and transportation problems may occur during application periods. Even if it is stored and transported properly, environmental problems such as gaseous emission of malodors and ammonia and nutrient runoff to streams and waterways may occur when digestate is applied on agricultural land. Hence, treatment of digestate is beneficial in order to overcome practical and environmental problems related to the direct application of digestate.

In order to reduce environmental impacts and improve the fertilizing efficiency of digestate, liquid and solid fractions are often separated before spreading the digestate on land [2, 3]. Separation of liquid and solids will also partly separate nitrogen and phosphorus. The liquid fraction contains the majority of nitrogen and potassium, while phosphorus mainly remains in the solid fraction. However considerable amount of phosphorus still remains in the liquid fraction of digestate.

Techniques for the treatment or concentration of the liquid fraction of digestate are: struvite precipitation, membrane filtration, ammonia stripping, evaporation and adsorption/ion exchange. Ion exchange and adsorption are well-known processes for industrial and domestic wastewater treatment.

Clinoptilolite (a natural zeolite) is a highly selective cation exchanger, especially for potassium and ammonium. Its cation exchange capacity (CEC) is dependent on the cationic composition. The homoionic form is usually leading to higher cation exchange capacities [4].

Clinoptilolite is an easily available natural mineral, of which deposits have been found in different parts of the world. The low-cost availability of clinoptilolite is the most important factor for its large scale use.

In a number of publications, ion exchange with clinoptilolite has been shown to be very effective for the removal of ammonium from domestic wastewater. Furthermore, more than 90% removal efficiencies for both ammonium and potassium from source-separated human urine had been reported in the literature [5, 6, 7]. Since the liquid fraction of the digestate contains nutrients, particularly nitrogen and potassium, and they basically exist in ionic forms, we hypothesize that ion exchange and adsorption technologies can be applied to recover and concentrate valuable nutrients from the digestate.

The objective of the study is to test the possibilities of using clinoptilolite to recover the plant nutrients from the liquid fraction of digestate resulting from anaerobic digestion of animal manure.

Materials and Methods

In this study the ability of clinoptilolite to remove nutrients from the liquid fraction of digestate was investigated. This was done in batch and column experiments to determine removal efficiencies for ammonium, phosphate and potassium.

As clinoptilolite's CEC is dependent on the cationic composition, the effect of sodium chloride solutions with different concentrations was therefore tested in batch experiments. Thereby the optimal preconditioning of clinoptilolite was determined.

After determining the optimal preconditioning of clinoptilolite, nutrient loading experiments was conducted to transfer nutrients onto clinoptilolite in batch mode. The initial nutrient loading of the clinoptilolite is a significant factor affecting the removal process efficiency [5]. Therefore, column experiments with various nutrient/clinoptilolite loading rates were conducted. The surface concentrations and removal efficiencies were determined as a function of loading rate.

Results and Discussion

The results from batch experiments have revealed that sodium chloride solutions with different concentrations do not have a significant effect on ammonium and phosphorus removal efficiency from the liquid fraction of digestate. However clinoptilolite preconditioned with increasing concentrations of sodium chloride resulted with higher potassium removal efficiencies.

Ammonium and potassium but also to some extent phosphorus in the liquid fraction of digestate could be transferred from the liquid phase onto the solid phase through processing with clinoptilolite.

Currently, optimum nutrient/clinoptilolite loading rate is determined in the column experiments, and results will be presented in the poster.

Conclusion and Perspectives

In this study, the recovery of plant nutrients from the liquid fraction of digestate was investigated as an indirect route to apply nutrients as fertilizer for crops. Our results indicate that ion exchange and adsorption processes by using clinoptilolite can be used as a potential route to concentrate nutrients from the liquid fraction of digestate, but its applicability in practice still remains to be demonstrated, as does the use of the nutrient enriched clinoptilolite as fertilizer. With the current surge in implementation of anaerobic digestion of organic wastes for bioenergy, technologies for digestate management will be in great demand; the current ion-exchange method is one of the potential solutions to avoid disposal or discharge into the environment.

References

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