Treatment of anaerobically digested pig manure with membrane processes for nutrient recovery and antibiotics removal

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Water scarcity and depletion of mineral resources are major global issues, while food demand and consequently need for cultivation is constantly increasing. Recovery of nutrients from waste streams is an alternative, environmental-friendly approach for the replacement of chemical fertilizers, the common production of which is associated with high GHG emissions, and simultaneously leads to appropriate wastewater purification, aiming to surface and groundwater protection (Katarzyna, 2020). Innovations in membrane technologies are attracting considerable attention and are preferential over other alternatively applied methods, due to low chemicals' consumption and cost-effectiveness. Therefore, their role in many industrial sectors, e.g. food production, chemical synthesis and water/wastewater treatment, is vital. Pressure-driven processes such as ultrafiltration, nanofiltration and reverse osmosis have been examined quite widely for the treatment of wastes with nutrient content and the obtained results showed that they can separate and concentrate nitrogen or phosphorus from the feed solution into a solution with higher fertilizer value.

Anaerobic digestion (AD) transforms several organic wastes, such as agricultural waste, animal residues, food waste and municipal sludge, which otherwise would commonly end-up in landfills, into energy (renewable biogas), producing digestate as a by-product. The generated digestate is known to be rich in nutrients (e.g. nitrogen, phosphorus and potassium) and is frequently applied in agricultural soils for enrichment with inorganic and organic components (Nkoa, 2014). However, the digestate has variable chemical composition based on the variations of raw materials used as feed in the anaerobic digesters of biogas plants (Li, 2018). Digestate with pig manure origin may contain high ammonium concentrations and organic content as much as antibiotics due to poor absorption from the animals. This creates issues, regarding the utilization of digestate and consequently, a major management issue for storage or disposal of large amounts of materials, which may pose a serious threat to the environment. If this is not managed properly, then the direct disposal in the soil may result in the uncontrolled leaching of nutrients and formulation of antibiotics resistance genes that may cause serious surface and groundwater (Huang, 2017).

Currently, separating digestate into liquid and solid fractions is the most common tactic for easier management, reducing volume and therefore transport costs. The methods used are screw separation, centrifugation and filter press, achieving the separation of the digestate, however they are extremely energy consuming and increase power consumption. Ammonia stripping for nitrogen recovery and membrane separation have been proposed for the liquid fraction treatment. Furthermore, advanced technologies such as electrodialysis, membrane distillation and microbial cell recovery have been studied, but have not been applied on a large scale yet. Composting and drying, either naturally or by thermal means, are the main ways of managing the solid fraction.

The present work aims to investigate a technology for the processing of digestate in a more compact way with the target to reduce the overall volume of the digestate, to recover nutrients from the liquid fraction of the digestate and to remove antibiotics for the production of clean water. Anaerobically digested pig manure that is produced from decentralised anaerobic digestion plant was treated using a series of membrane processes such as microfiltration, ultrafiltration for the removal of solids and organic matter, selective electrodialysis as an alternative method for the recovery of nutrients and reverse osmosis for further removal of antibiotics and clean water production. Results showed that 56.1% of digestate can be recovered as water free of ions and antibiotics for the process needs as well as for irrigation purposes. 51% of NH_4^+ can be recovered from the selective electrodialysis process and further used for fertilizer production tailored to farmers' soil and crop requirements aiming to replace non-renewable mineral fertilizers.

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