Sustainable exploitation of biogas plant digestate within circular economy: high quality organic fertilizer production

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Keywords: nutrients recovery, digestate, circular economy
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The reuse of waste in order to create raw materials in a sustainable and efficient way is a new development strategy for the transition to a circular economy. Biogas plants transform organic waste such as agricultural waste, animal residues, food waste and municipal sludge that otherwise would end up in landfill, into energy (renewable biogas) using anaerobic digestion. Such plants, also produce digestate as a by-product, a rich source of nutrients and its application in soil is suitable for enrichment with inorganic and organic components. The latter is an alternative, environmentally-friendly approach for the replacement of chemical fertilizers and soil conditioners, the production of which is associated with high GHG emissions and a continuous reduction of mineral resources.

However, the digestate has variable chemical composition based on the variations in the raw materials that are used as feed in the anaerobic digesters of the biogas plants. This creates issues in the utilization of the digestate and consequently a major management issue for storage or disposal of large amounts of materials, that may pose a serious threat to the environment. Direct disposal in the soil results in an uncontrolled leaching of nutrients (nitrogen, phosphorus and potassium) that are transported to the surface and groundwater causing pollution. Depending on its origin digestate may contain high risk contaminants, such as pharmaceuticals, in cases of livestock or municipal sludge waste treatment. Moreover, the increased microbial load makes digestate direct disposal in the soil dangerous to public health. Other factors to consider is the large volumes, due to its high-water content, which increases the cost of transportation from the biogas plants to the fields.

The constant need for environmental protection and stricter establishment of rules regarding the disposal of fertilizer and soil conditioners results in the need for new treatment methods of digestate aiming at compliance with rules in the most economical and at the same time ecological way.

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 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 focuses on the design of a technology for the processing of digestate in a more compact way with the target to reduce the overall volume of the digestate by 85-90%, to recover nutrients from the liquid fraction of the digestate and to remove antibiotics for the production of clean water. Digestate solid-liquid separation, filtration and alternative methods for the recovery of nutrients (selective electrodialysis) and the removal of antibiotics (advanced oxidation) are integrated into a system that uses as a feed digestates from different origins (agricultural, animal residues, municipal waste) that are produced from decentralised anaerobic digestion plants. The digestate-derived fertilizers and soil amenders are tailored to farmers' soil and crop requirements aiming to replace non-renewable mineral fertilizers and to produce clean water for the process needs as well as for irrigation purposes. The technology addresses key digestate management issues including environmental and health risks, handling, variable composition and the increasing volume being produced. Currently, turning digestate into fertiliser products is not feasible for most small biogas plants that cannot afford investing on expensive and energy consuming installations for the processing of a "waste" by-product.

The technology that is studied in the current work could be key to reducing the overall cost, complexity and footprint of small biogas plants, creating new revenue streams and improving their economic viability, adding value to streams and by-products that were otherwise considered as wastes.

Acknowledgements: This work is conducted within the scope of the Horizon 2020 EU funded project NOMAD (GA 863000).