BIOGAS PLANTS:

HOW TO TREAT AND VALORIZE DIGESTATE WITH MEMBRANE-BASED SOLUTIONS

WHITE PAPER
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HYDROTECH ENGINEERING
ADVANCED WATER TECHNOLOGIES

MANAGEMENT OF DIGESTATE

CONVENTIONAL PRACTICES, CHALLENGES & DRIVERS

The number of biogas plants has grown exponentially during the last few years. In Europe, for instance, the Biomethane Map 2022-2023 published by the European Biogas Association (EBA) shows 30% more biomethane plants compared to the 2021's edition, reaching a total of 1,322 biomethane-producing facilities by April 2023. And over 75% of these plants are already connected to the transport or distribution grids. The 'European Gas Decarbonisation Plan' aims to produce at least 1,000 TWh from biomethane by 2050: assuming that 1 MWel biogas plant produces about 20,000 – 30,000 m^3 of digestate per year, it is evident that the increasing demand for biogas-based energy will generate a significant increase in the annual volumes of digestate. And there is no alternative, other than sustainable digestate management in a circular economy framework.
Digestate has been traditionally used as fertilizer for crops without any further processing, substituting industrially produced mineral fertilizers. However, the increasing volumes of digestate produced, together with legal restrictions and the need for efficient nutrient management, make the advanced treatment and/or valorization increasingly important for biogas plant operators, farmers, technology suppliers, and decision-makers:

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- **Legal restrictions** for land spreading, in terms of the mass of nitrogen applied per hectare. For example, the EU Nitrates Directive establishes a maximum of 170kgN/h a year, and equivalent legislation is applied in other regions and countries.
- **Competition for land** in areas with high livestock densities: frequently, livestock production is intensive and concentrated in areas with limited land available for manure application. This creates a permanent excess of nutrients that need to be treated, recovered, or transported outside the vulnerable areas.
- **Seasonal restrictions**, land farming is permitted only during the growing season to avoid nutrient infiltration into the groundwater, soil acidification, and eutrophication of surface waters. For this reason, biogas plants must invest in storage facilities with enough capacity for a 3 to 6-month period.
- **Non-competitive hauling costs** if the biogas plant is far from the agricultural fields: storage, transport, and handling of digestate as fertilizer imply significant costs, due to its large volume and low nutrient concentration compared with its fertilizer value. A clear example is the AD (anaerobic digestion) plants treating municipal organic waste, which is often far from agricultural land where digestate is applied.

MANAGEMENT OF DIGESTATE

CONVENTIONAL PRACTICES, CHALLENGES & DRIVERS

The digestate processing instead of directly spreading is expected to become the general rule

For the above reasons, digestate processing technologies are being implemented for increasing the sustainability, efficiency, and profitability of biogas plants. The benefits are multiple:

- **Cost savings,** mainly related to storage, transportation, and handling. The digestate is efficiently managed when landfarming is not possible.
- **Decrease environmental burden,** whether the digestate is treated for safe disposal or valorized as fertilizer.
- Potential for a **new source of revenue** from the sale of concentrated organic fertilizers, which are competitive with the increasingly expensive chemical-based ones.
- Contribution to effective **resource management**: the depletion of the global natural reserves of phosphorous and potassium, together with the population growth and the increasing demand for nutrients, creates a severe imbalance. Therefore, the interest in alternative fertilizers is growing rapidly.

In conclusion, with the number of biogas plants quickly increasing all over the world, digestate processing instead of direct spreading is expected to become the general rule.
Solid-liquid separation is the most frequent first step in digestate processing, typically using decanter centrifuges or screw press separators.
The liquid fraction can be further processed with two possible approaches: simple volumetric reduction with nutrient recovery for the production of organic fertilizers or a full integrated treatment to allow the discharge or the reuse of the treated water with a high recovery percentage and again the valorization of the by-products.

MEMBRANE BASED SOLUTIONS

FOR DIGESTATE TREATMENT

Advanced digestate management usually comprises a sequence of several steps. Solid-liquid separation is the first step in digestate processing. For this, decanter centrifuges and screw filters are commonly used. Figure 1 provides the average mass balances for the solid and liquid fractions in the digestate. The less nutritious solid phase can be used as an organic soil amendment, with the advantage of easy storage and reduced volume. Alternatively, it can be further treated by drying or composting for obtaining a solid biofertilizer.
The liquid fraction (also called concentrate) represents 80-90% of the digestate volume. After solid–liquid separation, it still contains considerable amounts of suspended solid sand nutrients and it does not meet the environmental standards for discharge to receiving streams. Part of this liquid fraction is frequently recycled to the head of the process and used for adjusting the dry matter of the input feedstock. The remaining liquid digestate can be managed with different recovery and treatment options. In the simplest case, it is disposed directly into the land for soil conditioning. This entails some benefits, as long as the organic matter and nutrients contained in the digestate are brought back to the land in form of nutrients, but it presents certain limitations that can hamper the future consolidation of the waste-to-energy approach as an alternative to the conventional sources of energy. In this scenario, membrane-based technologies are increasingly implemented for managing the digestate most sustainably.

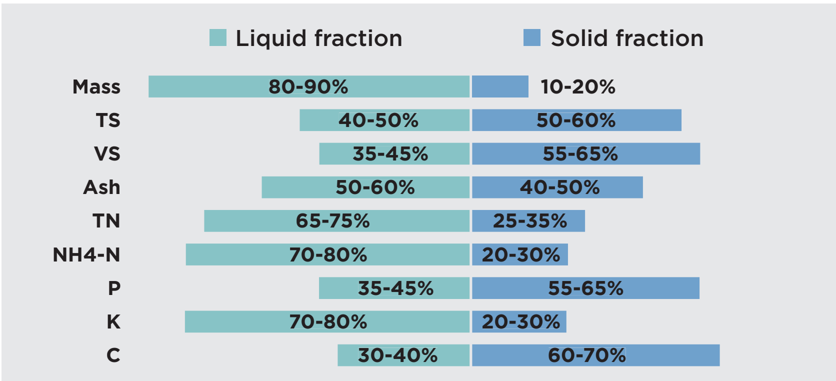


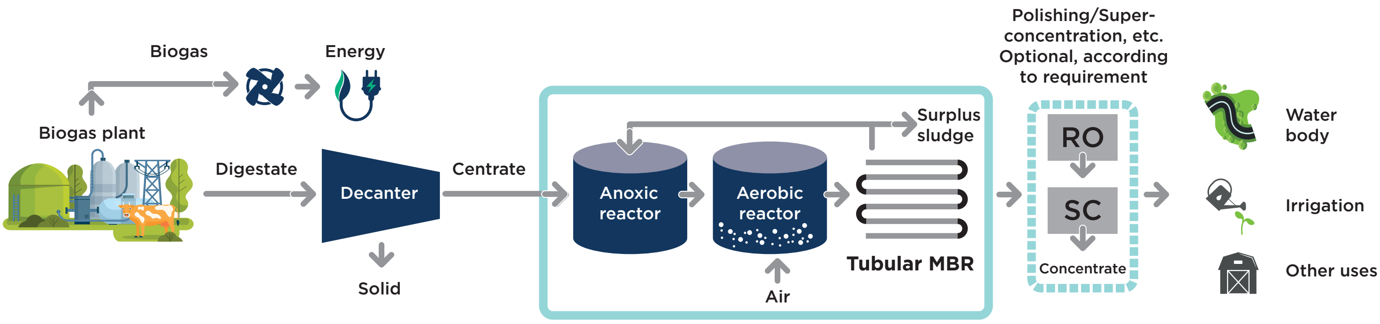
FIGURE 1.
DISTRIBUTION OF THE PRINCIPAL CONSTITUENTS AFTER SOLID–LIQUID SEPARATION.

THE TWO GENERAL APPROACHES

FOR DIGESTATE TREATMENT

1. DIRECT FILTRATION: VOLUMETRIC REDUCTION

Direct filtration with tubular UF membranes preserves and concentrates the nutrients for valorization, producing high-value biofertilizers with reduced use of chemicals. However, this approach is not always feasible or cost-effective: certain laws, such as the EU Fertilizing Products Regulation, impede fertilizer production when certain materials are fed to biogas plants. For instance, the organic fraction of municipal waste can be used exclusively when it has been separated at source; if it has been obtained as a separate fraction of the mixed municipal household, the use of digestate for producing fertilizers is forbidden.



2. MEMBRANE BIOREACTOR FOR AN INTEGRATED DIGESTATE TREATMENT

Due to regulatory barriers, competitive constrains or even location-based restrictions, the main target could be to reach the highest volumetric reduction (minimum generated amount of concentrated streams) of the digestate at the optimal running cost even if some nutrients are not completely recovered. In such cases, the implementation of an advanced biological pretreatment where the reduction of organic, alkalinity, and nitrogen loads is carried on, allows a subsequent consistent and economical super-concentration of the liquid fractions. Digestate is rich in organic matter – part of it refractory or difficult to biodegrade – and nutrients, especially nitrogen: it can be compared to the most complex industrial wastewaters and its treatment demands a high-efficient and robust technology. External tubular MBR copes with the digestate treatment with maximum efficiency: the bioprocess operates stably with increased removal rates, and the highest nitrification rates are achieved. The MBR consists of a biological reactor combining anoxic and aerobic stages coupled to the external tubular UF for biomass/effluent separation. Figure 3 summarizes the general approach for digestate treatment with external MBR. The liquid fraction obtained in the centrifugal decanter is fed to the tubular MBR, where the liquid fraction pre-treatment is carried on: in this unit the reduction of the organic matter and nitrogen is obtained by combining anoxic and aerobic reactors.

ADVANTAGES OF MBR TECHNOLOGY

The MBR technology for digestate treatment has numerous advantages over conventional biological processes:

Highly efficient biological treatment: high MLSS concentration and long SRTs favor the growth of specialized biomass that assimilates the difficult-to-biodegrade organic matter.

Nitrogen removal: Long SRT promotes the growth and acclimatization of nitrifying biomass. Even with the unbalanced high N-content of digestate, it is removed highly efficiently by nitrification / denitrification.

Superior effluent quality, for discharge or reuse: the UF membranes are a physical barrier for suspended and colloidal matter: a high-quality permeate is obtained, free of solids, turbidity, and pathogens. Direct RO post-treatment is possible when water reuse schemes are of interest (SDI < 3).

Robustness and flexibility against the complex composition of digestate. COD and nitrogen removals are high and stable, even with large variability in digestate composition. The filtration conditions are easily adapted to influent fluctuations, providing the most stable operation under any circumstance.

Compactness: external MBRs are one of the most compact technologies for digestate treatment, with minimized bioreactor volume and a modular and plug-and-play UF system. Retrofitting and upgrading existing CAS or SBR plants is simple and fast.

Hydrotech Engineering uses the latest technology in the field of semi-permeable membranes to enable the removal and recovery of nitrogen in digestate

CASE STUDY TUBULAR MBR OF A PLANT IN ITALY

FOR DIGESTATE TREATMENT

- LOCATION:
  NORTH ITALY
- YEAR:
  2018
- GOAL:
  WASTEWATER TO BE DISCHARGED TO SURFACE WATER

- WATER'S QUALITY REQUESTED:

  - COD < 80PPM
  - TOTAL NITROGEN < 15,0 PPM
  - AMMONIA < 5,0 PPM

- TYPES OF MEMBRANES

  TUBULAR PVDF ULTRAFILTRATION MEMBRANE

- WATER INPUT:
  150 TON/DAY
- WATER OUTPUT:
  126.5 TON/DAY
- TO DATE:
  - NO MAINTENANCE AND NO SPARE PARTS
  - LOW MANAGEMENT COSTS

The case study addresses the digestate treatment process in a biogas plant located in north Italy, where the MBR process is applied. Figure 3 below details the flow sheet and mass balance applied on this site.
The solid-liquid separation is performed in a decanter: 75-80% of the phosphorus and 15-20% of the nitrogen are recovered in the solid fraction. The liquid fraction is a clarified solution with an average of 0.5% suspended solids (SS) and 1.0-1.5% total solids (TS) concentrations.

This stream is fed to the MBR where the liquid fraction is pre-treated generating only a UF permeate stream and a surplus sludge stream that can be recirculated at the AD inlet or the sludge dewatering unit. The UF permeate does not contain suspended solids and it has a modified chemical characterization: this allows a subsequent membrane concentration stage with minimized chemicals and energy consumption and with a high recovery.

FIGURE 2. EXPTERNAL MBR: UF SYSTEM WITH BERGHOF MEMBRANES MODULES

CASE STUDY TUBULAR MBR OF A PLANT IN ITALY

FOR DIGESTATE TREATMENT

The aerobic-anoxic bioreactor has also the advantage to operate with a biological mixed liquor with stable characteristics and with a better filterability than the raw digestate (lower energy costs for the separation process). If useful, a further membrane-based super-concentration stage can also be applied. In the end, with this process approach the customer can obtain the goal to have only a minimized solid fraction obtained with a minimum or nil evaporation process - so with a very low energy cost – and a purified reusable or dischargeable water stream.

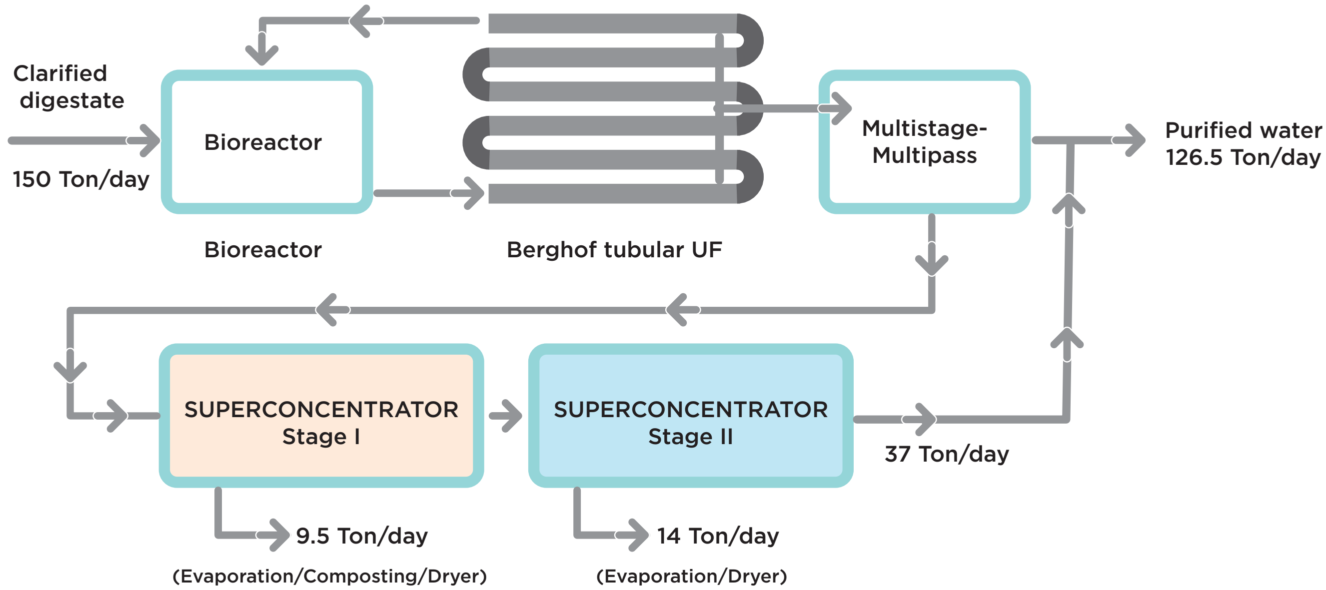


FIGURE 3.
FLOW SHEET AND MASS BALANCES OF THE DIGESTATE TREATMENT PROCESS.

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Hydrotech Engineering would like to thank Berghof Membranes for being a trusted partner for this project and for sharing information for this white paper.

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Hydrotech Engineering realizes turn-key water treatment plants for the treatment of process and waste waters utilizing the most advanced semi-permeable membrane and biological technologies for water recycling and reuse.
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