From fermentation residues to nutrient concentrate

Treatment of fermentation residue substrates from biogas plants by means of ceramic membranes

The growing number of biogas plants makes it increasingly difficult to return the fermentation residue substrates to green spaces or arable land. Especially large-scale plants are often unable to find sufficient disposal possibilities in acceptable distances. Therefore it is sensible to treat fermentation residue substrates by suitable screening processes in such a way that they can be discharged and re-used in the form of free flowing solids and nutrient-poor process service water.

Gerhard Klink, Christian Salewski, Peter Bolduan

The main steps in the treatment of fermentation residue substrates from biogas plants are: liquid - solid - matter separation, ultrafiltration using ceramic membranes and reverse osmosis. For the filtration of liquids will highly abrasive components - such as undissolved macro-molecules in fermentation residue substrates - a highly abrasion-resistant membrane named Duratech has been developed. During fermentation only easily degradable organic matter is decomposed to methane and carbon dioxide leaving fermentation residue substrates which mainly consist of relatively stable organic substances that are more difficult to decompose. The nutrients contained in these residues, such as organic nitrogen, potassium and phosphorus, are mineralized by the fermentation process. This means that fermentation residue substrates from biogas plants are an equivalent substitute for inorganic fertilizers, in particular because they can be spread on crop areas without the need for a lot of technical equipment, penetrate the ground quickly and because their nutrients are available to the plants.

During the planning phase of the first reference plant built by A3-Water Solutions GmbH - which has a capacity of 64,000 liters per year and has been in operation for approximately 18 months - it was assumed that the costs for the treatment of fermentation residues including debt services would be EUR 5.10 per 1,000 kg. Already during the first year of operation optimizations in process engineering and an efficient operations management made it possible to remain under this amount. Treating fermentation residues produces a permeate with a high pure water quality and a solid and a liquid residue with the qualities of a valuable substance.

Three-stage treatment

Fermentation residues undergo a complete treatment process developed by A3-Water Solutions GmbH, involving the following treatment stages:

- Decanter, combined with metered adding of precipitants as needed to eliminate solids and to reduce organic components, followed by screening.
- Ultrafiltration using ceramic membranes made by atech innovations gmbh to reduce undissolved macromolecules.
- Reverse osmosis to remove dissolved low-molecular substances such as hardness constituents and salts.

During the first treatment stage the fermentation residue substrates from the storage tank undergo a liquid-solid-matter separation in a decanter centrifuge. If the fermentation residue substrates contain coarse-fibred substances they are first treated in a pressure worm separator before entering the decanter. If needed to better separate solid particles, colloidal turbid matter and organic matter contained in the feed line to the decanter an anorganic flocculator is added which dramatically reduces the fouling potential of the fermentation residue substrates.

The solids discharged from the separator and the decanter are fed onto a screw conveyor and transported to an outdoor storage area. The separated liquid phase (“centrate”) still has a dry substance content of up to 2% and is led to a subsequent screening process. Any fibrous substances and fine particles that can not be removed by the decanter are separated by means of a screen. This is mainly required in order to prevent particles from blocking the downstream ultrafiltration modules. The separated solids are removed from the screen through a discharge opening and are also fed to the screw conveyor to be transported to the outdoor storage area. The discharge water is collected in a pump tank and led into the receiving container of the downstream ultrafiltration plant.

Authors: G. Klink und C. Salewski, A3-Water Solutions GmbH, Gelsenkirchen; Dipl.-Ing. Peter Bolduan, atech innovations GmbH, Gladbeck.
High abrasion resistance

In the ultrafiltration stage a selective pore membrane with pore diameters between 0.2 and 0.05 µm is used to remove macromolecular particles from the centrate. The preferred membranes are ceramic multi-channel membranes made by atech innovations gmbh which due to their special material properties have proved their worth in the treatment of fermentation residues. In this respect, high flux rates combined with a very high chemical, thermal, and mechanical resistance and the resulting operational reliability are of particular importance. For applications involving highly abrasive media such as those encountered during the treatment of fermentation residues atech innovations gmbh has developed Duratech®, a ceramic membrane made of titanium oxide. Thanks to an innovative coating process which is essentially based on controlled crystal growth Duratech has an abrasion resistance that is even higher than that of standard membranes, which are also very rugged. This has been proven by standardized scratch test measurements that were performed under defined conditions and by several applications.

In the treatment of fermentation residues ultrafiltration using ceramic membranes is used to:
- separate solids and dissolved macromolecules
- eliminate germs and bacteria
- retain the fermenter biomass
- remove the particulate COD

To incorporate the membranes in filtration plants they are arranged in so-called modules where several supports are combined in stainless steel vessels. These pressure vessels as well are offered by atech in various steel qualities and pressure vessels as well are offered by atech innovations gmbh which during the treatment of fermentation residues they are arranged in so-called modules where several supports are connected in series. "Multi-permeate stage configuration" means that several reverse osmosis plants of different pressure levels are connected in series and where permeate from the first reverse osmosis stage is further purified in a second and a third reverse osmosis stage. The permeate produced in the first reverse osmosis stage is already substantially free of salts dissolved in water, nitrogen and other nutrients but, due to the shift in the carbonate balance, still has a high carbonic acid content that needs to be removed. Therefore, a forced-draft degasifier is installed between the first and the second reverse osmosis stage. In this way it is possible to reduce the content of free carbonic acid to < 10 mg/l.

During the planning phase of the first reference plant built by A3-Water Solutions GmbH - which has a capacity of 64,000 litre per year and has been in operation for approximately 18 months - it was assumed that the costs for the treatment of fermentation residues including debt services would be EUR 5.10 per 1,000 kg. Already during the first year of operation optimizations in process engineering and an efficient operations management made it possible to remain under this amount. Treating fermentation residues produces a permeate with a high pure water quality and a solid and a liquid residue with the qualities of a valuable substance.

Added value potential

The liquid fermentation residue obtained as concentrate in the reverse osmosis plant complies with the legal stipulations of the German Regulation on the Principles of Good Manuring and Fertilising Practice ("Duengerverordnung"), the German Ordinance on Biowastes ("Bioabfallverordnung") and the German Soil Protection and Contaminated Sites Ordinance ("Bodenschutz- und Altlastenverordnung"). The mass concentrations of nutrient salts contained in the concentrates exceed those in the original, untreated fermentation residue substrates by approximately 10 to 15 mass percent. Meanwhile, the liquid fermentation product has been awarded the RAL quality mark "Fermentation Product" (RAL-GZ 256/1). Similar to the liquid fermentation product, the solid fermentation product obtained from the decanter, or the screen complies with all applicable requirements and has also been awarded the RAL-GZ 256/1 quality mark. This quality mark is evidence that the fermentation products obtained by decantation or screening and membrane filtration are certified valuable substances that can be used for sustainable soil improvement and for manuring and fertilizing. This considerably increases the added value potential of a treatment plant for fermentation residues.