Following Nature's Design

ZELIX MEMBRANE.KINETICS® has essential colloid chemical functions of natural membranes integrated.
It is nature's design applied: strengthening the natural properties of ingredients with electrokinetics.
Membrane filtration of BIOGAS- and SEWAGE SLUDGE has high potentials. ZELIX® strengthens the filterability of biogenic matter and the efficiency of microbiological processes.

ZELIX
MEMBRANE.KINETICS

Following Nature's Design

MEMBRANES have a variety of functions in organic structures. They transport, they separate. They generate and transmit electrical signals. They activate messengers, agents, enzymes ...

These organics are structured in colloidal, microscopic particles. Their electrical charge determines the reactions with other colloids, with the surrounding liquid - and with membranes. The development of artificial membranes was closely linked to colloid-chemical research.

However, the industrial breakthrough of membrane filtration came with the cross-flow technology, which is not multi-functional, but focused on the effects of shear forces and pressure. The limited resistance of colloids to shear forces, to pressure, temperature, oxidation etc. can create problems, particularly when used for filtration of organic matter (, biogas/sewage sludge, food/ beverages, biotech/chemistry/pharma, pulp/paper...).

Nature's Design Applied

PANTREON has consistently developed ZELIX technology for dynamic effect, but for reduced mechanical stress and energy consumption, too.

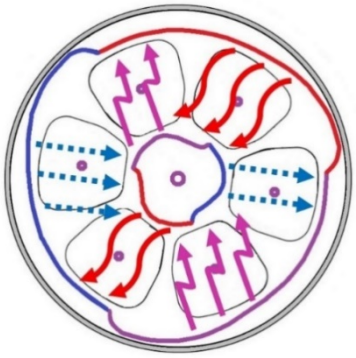
This has improved the performance compared with other membrane systems. But what about the multifunctional properties of natural membranes?

The patented flow technology of ZELIX creates even more potentials.; especially for integrating and implementing essential colloid chemical functions of natural membranes, like kinetic activation.

- to strengthen membrane performance by activating molecular interfaces

- to sustain and strengthen natural functionalities.

ZELIX MEMBRANE.KINETICS - Nature's Design Applied - by *Activated Interfaces* and *Natural Functionalities*



The Challenge

Wastewater treatment plants and the treatment of wastewater in general are facing enormous challenges.

Not only is the removal of contents such as PFAS, micro- and nanoplastics, pharmaceuticals, allergens moving into the public spotlight and cannot be managed by biological processes alone. However, other process effects of conventional wastewater treatment plants, such as CO_2 emissions and the contradiction between current energy consumption on the one hand, and untapped energy potentials on the other, are also questioned, as large R+D funding projects (e.g. *Powerstep*) show.

Innovative membrane technology such as ZELIX MEMBRANe.*KINETICS* will become increasingly important beyond conventional aerobic MBR methods.

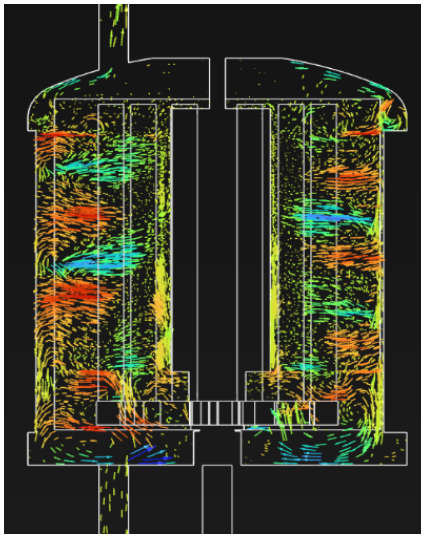
The Way

Sewage sludge or biogas sludge consists mainly of EPS (*Extracellular Polymer Substances*), which release microorganisms into the environment. The microorganisms are embedded in these microbial agglomerates.
Hydrophobic interaction and electrical charge maintain this EPS matrix. This further affects the interfacial activity of the colloidal structures.
In anaerobic digestion, this ultimately influences the biodegradation and the amount of biogas.

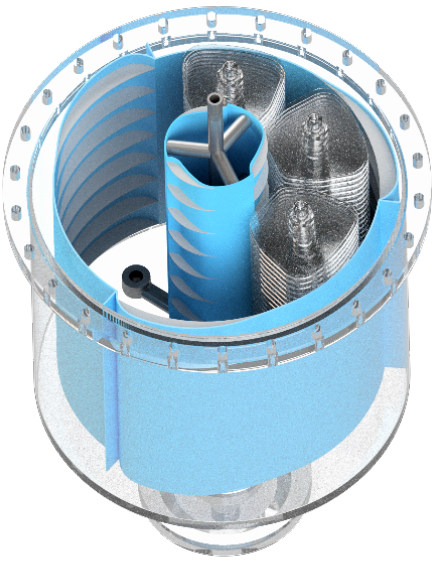
Membrane filtration of these sludges has many procedural advantages. But mechanical stress can damage the EPS structure, oxidizing influence of air can de-activate molecular interfaces.

The filter and flow technology of ZELIX has been consistently developed for **efficient, smart dynamics - especially for viscous liquids,** for higher concentrations, for biologically and chemically sensitive ingredients.
Therefore, the natural colloidal properties of EPS and the nutrients it contains, such as proteins, fats, saccharides, etc., are not damaged, but used.

Especially in the filtration of digested sludge from anaerobic digestion, phase differences between biogas, liquids and colloidal solids play a role. ZELIX has exceptional properties here with the Helix 4D concept and its four, vertical flow directions. On the basis of CFD calculations by the JKU Linz, the dynamic ZELIX flow technology has been further developed specifically to meet these requirements.



3D simulation of ZELIX flow technology shows the constructive potentials.



ZELIX 60-10 with multidirectional flow technology

The Perspectives

Applications

Due to their colloidal nature, EPS are well filterable by membranes, and so the procedural advantages could also be made usable. However, some sludge treatment methods damage colloidal properties of the EPS, e.g. through air intrusion.
Even with such difficult demands on membrane technology,

ZELIX MEMBRANe.*KINETICS*

is very well suited for a wide range of applications, e.g. for:

- Optimization biogas process
- Concentration of digestate
- Separation of nitrogen
- MBR applications

Facts

The ZELIX functional and design features offer a wide range of options for consistently developing the system for new applications and for efficient, dynamic membrane performance with low stress on substances.
ZELIX, too, requires crossflow for membrane performance. However, strictly following the **Reynolds** principles, the speeds are reduced and are focused via innovative flow geometry.

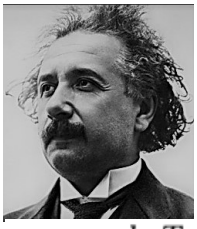
The filtration is designed to be efficient and gentle on the ingredients..

ZELIX has already an outstanding potential due to its innovative filter technology, its flow technology, rotation technology and the *HELIX4D* concept. But it still opens even more innovative potential compared to other processes.

For MBR applications in sewage plants, mostly hollow fiber, or plate + frame systems are installed - with some fouling tendency. This applies even more to spiralwound systems for the filtration of biogas sludge. Intrusion of air, both in the activated sludge and in the retentate stream, changes interfaces.

Air intrusion can lead to oxidation of EPS surfaces, further damage to the colloidal structures. The charge on the surfaces is reduced, the molecular mobility and the filterability are impaired.
EPS immobilized in this way interfere with gas transport and gas yield.

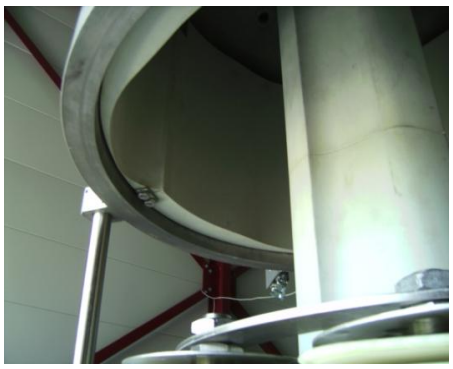
EPS molecules as colloids facilitate increased filterability and precise separation due to their charge potentials and by electrokinetic activation of interfaces. The ***Einstein-Relation*** defines decisive parameters for the mobility / diffusion of charged particles.
These are electrical charge of particles and their electrical mobility; Moreover viscosity of liquids and particles' radii.



$$D = \frac{\mu_q \, k_B T}{q}$$

It is clear that EPS and other molecules, like proteins, get their negative surface charge and hydrophobicity broken through oxidation, i.e. by positively charged bi-radical oxygen molecules. The EPS' charge, thus mobility and permeation rate decrease. The stabilized interfaces also limit spiralwound's ability in filtering and concentrating EPS.

Electrokinetics are able to repair such denaturations, can re-activate interfaces.

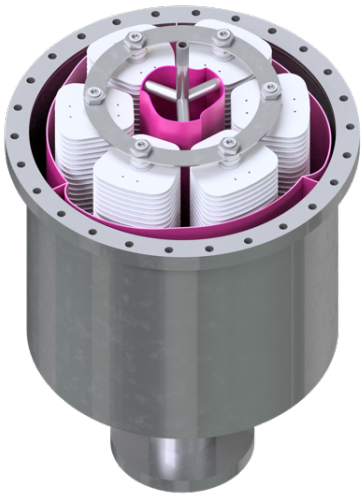


ZELIX filter technology (left) and flow design (right) as innovative results.

The patented **ZELIX design** enables **integration of process combinations** inside its filter vessel next to membrane-active interfaces. This offers even more performance-potentials.

The effect of electric field strength on the hydrophobic, colloidal properties of EPS and the nutrients it contains has been scientifically proven.
Tests and research on colloidal chemical effects of electrokinetics and membranes led to the construction of a large-scale ZELIX system in which the ZELIX flow technology is used as electrodes to build up a (high) voltage field, the ZELIX filter modules as counter electrodes.
The system is internationally patented.

Images at bottom left



Especially in biogas processes with food substrates, there are some concentrations of **disintegrated** EPS and nutrients such as proteins, lipids etc. - caused by the oxidation of the molecular surfaces. Overdosed additives can also lead to stabilized interfaces, which affects the filterability, but also the degradation of organic matter and gas production.

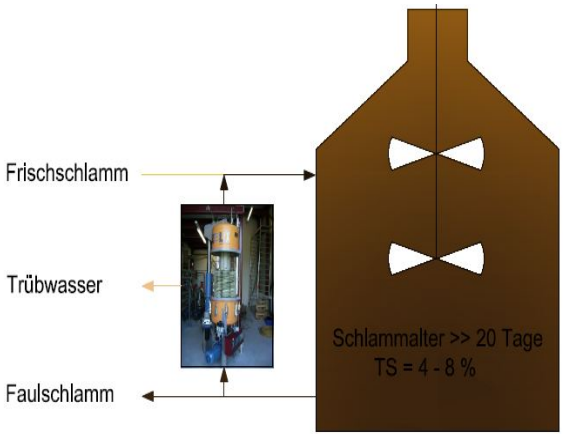
ZELIX membrane system with electrokinetics provided proof of performance of the process combination immediately after start-up. This increases **interfacial activity by over 100%.**

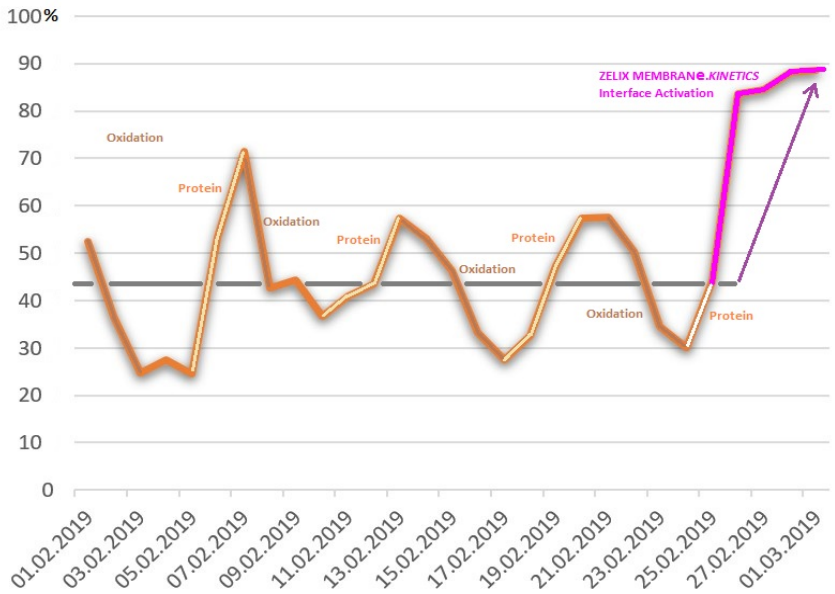
The economic effects are various, with more gas production (+ 60%), more organic degradation (+ 65%), with less digestate (-65%) and consequently increased economic efficiency (€ 100,000 / a).

Graphic at bottom right

Increase in biogas yield

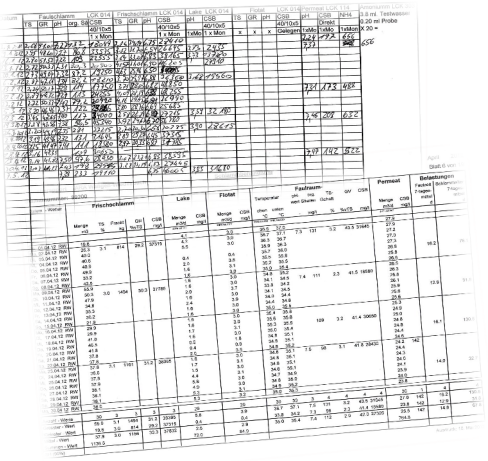
ZELIX also has advantages for low-energy substrates, such as municipal sewage sludge. But even this energy potential can be used with intensified fermentation by concentrating the digested sludge. One has to abandon the process based on the principle of a thermostat - by separating sludge and sludge liquor in the digester. The sludge liquor is continuously separated in bypass by membranes and the sludge concentrated. So, digestion is prolonged, and nitrogen is also extracted from the sludge liquor.





ZELIX practice: The concentration of sludge with a ZELIX Type 60-15, a 15 m^2 membrane area and approx. 1000 L/h permeate output increases the residence time massively and thus the gas yield:

2010 – before ZELIX	300 m^3/d
2010 – with ZELIX	550 m^3/d
2011	> 600 m^3/d
from 2012	Ø 800 m^3/d
Residence time	2,5 -> 5 week
COD-sludge	29.000 mg/l
COD-permeate	180 mg/l



Other applications with biogenic sludge:
BEFORE digestion for pre-thickening (e.g. sewage sludge, ...),
DURING digestion for concentration in the by-pass and nitrogen separation,
AFTER digestion for concentration of digestate.

Pictures below

Manure Fermentation

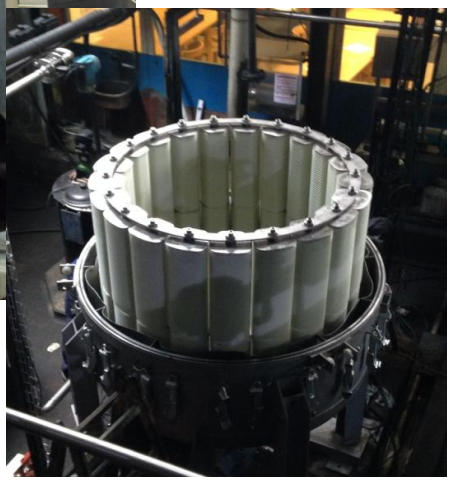
Laboratory and pilot tests with digested sludge from pig, calf and chicken manure have shown significantly better permeate performance with smaller UF membrane pores (< 20 kD) than with MF. Membrane filtration of the digestate centrate (decanter) reduces COD, phosphorus + nitrogen in the residual water.

Pilot tests with digested sludge from pig manure in Germany showed a continuous filtration with ZELIX and UF membranes (< 20kD), a reduction of the organic load from residual water from screw press to ZELIX permeate from 4.09% to 0.38%. With the construction of a voltage field of 30 kV in the ZELIX filter vessel, an eKin activation and recirculation of 71 L/kg DM of additional gas potential was achieved via the ZELIX retentate in the secondary fermentation.

	Schneckenpresse-Trübwasser %	ZELIX MeK-Permeat in %
Trockensubstanz	5,65	1,15
Organische Substanz	4,09	0,38
Mineralische Substanz	1,56	0,77
Stickstoff	0,48	0,22
Phosphor	0,15	0,01
Kalium	0,55	0,51

MBR Applications

The advantages of ZELIX in MBR (membrane bioreactors) can be seen in a large Swiss laundry. The 110-70 system separates permeate from the reactor sludge in the bypass. Continuous filtration of the sludge with ZELIX reduces the COD load and by 45% the energy costs compared to the previously installed ceramic crossflow system - with much lower service / maintenance costs.

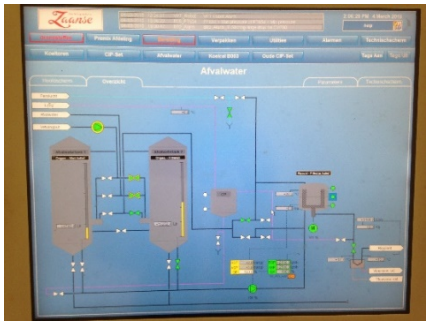


Bioreactor – picture left
ZELIX 110-70 – pictures top + right

Less wastewater pollution

Wastewater disposal via external sewage plants is a considerable cost factor for companies. However, contamination and costs can be considerably reduced with membrane separation. Emulsified ingredients, e.g. from food production can be problematic for conventional processes. Auxiliaries used can cause downstream disturbances. ZELIX, on the other hand, has proven itself to be a powerful, reliable, low-maintenance and economical process.

ZELIX 80-35 for wastewater from mayonnaise production – Picture right



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The model of nature's design also applies to the design of the ZELIX filter modules: The robust structure of diatoms

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