

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 permeability of biogenic matter and the efficiency of microbiological processes.

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 break-through of membrane filtration followed by the crossflow technology, which is not multifunctional, 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 (, bio-gas/sewage sludge, food/ beverages, biotech/chemistry/pharma, pulp/paper...).

Nature's Design Applied

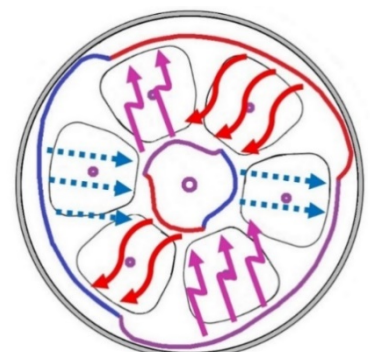
PANTREON has consistently developed ZELIX technology for dynamic effect, but for reduced mechanical stress and energy consumption, too.

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 Way

Sewage or biogas sludges exist mainly of EPS (extracellular polymer substances) that release microorganisms into the ambience. The microorganisms are embedded in these microbial agglomerates. This EPS matrix is maintained by hydrophobic interaction and electrical charge. This further affects the interfacial activity of the colloidal structures. In anaerobic digestion, this ultimately affects biodegradation and the amount of biogas.

Membrane filtration of these sludges has many process advantages. But mechanical stress can damage the EPS structure, oxidizing influence of air can deactivate molecular interfaces.

The ZELIX system has been developed to **efficient, smart dynamics**, especially for viscous liquids, high concentrations, biologically / chemically sensitive ingredients.

Therefore, the natural colloidal properties of EPS and the nutrients they contain, such as proteins, fats, saccharides, ... , are not damaged, but used positively.

According to the *Einstein-Relation*, the mobility/permeation properties of **colloids** depend primarily on electrical charge and electrical mobility (as well as on particle size and viscosity).

Strengthening these properties by integrated electro kinetics creates a **new standard in membrane technics**.

ZELIX MEMBRANe.KINETICS

ELECTRO KINETICS



> **100% performance increase through activated interfaces**

ZELIX flow technology as electrodes set up high-voltage spaces
+ filter modules as counter electrodes
+ mechanical activation through membrane pores.

Cooperation with INNOVUM GmbH
Experience from more than 4.500 electro kinetic projects worldwide.



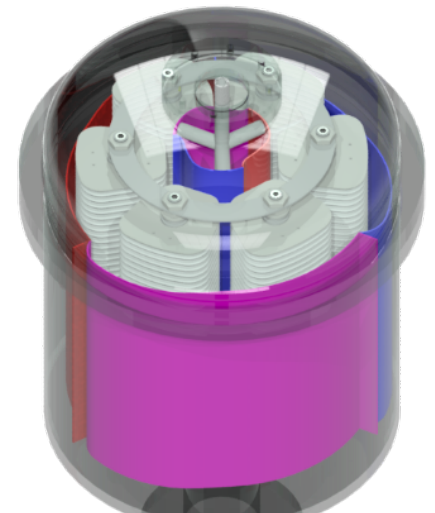
ZELIX MEMBRANe.KINETICS

DIA-INFUSION



> **100% increased performance by precisely dosed additives**

- Infusion of additives and micronutrients via the ZELIX flow technology
- Dosing precisely and effectively DIRECTLY into the membrane-activated interfaces.



ZELIX 60-10 with multifunctional flow technology

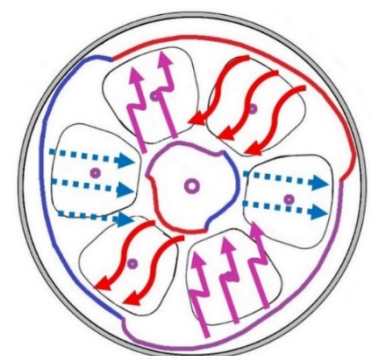
ZELIX MEMBRANe.KINETICS

Δ TEMP



System dynamics intensify heat-/cooling exchange

- Use of ZELIX flow technology for large area heat-/cooling-exchange zones. and optimized ΔT .



The Perspectives

Applications

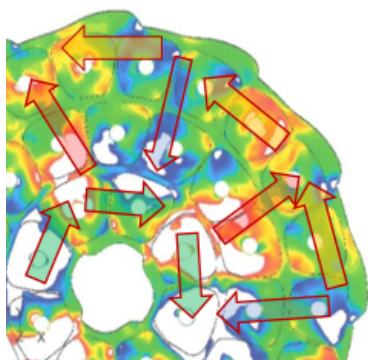
Due to their colloidal nature, EPS are quite membrane-permeable, and so the procedural advantages could also be made usable. However, some sludge treatment methods damage colloidal properties of the EPS, e.g. through air intrusion.

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



CFD calculations as the basis for the smart dynamics of ZELIX flow technology.



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.

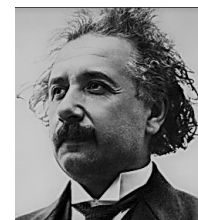
For MBR applications in sewage plants, mostly hollow fiber, or plate + frame systems are installed - with some fouling tendency. This applies even more to spiralwound systems for the filtration of biogas sludge. Intrusion of air, both in the activated sludge and in the retentate stream, changes interfaces.

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.

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

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.



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

INNOVUM GmbH develops and manufactures patented high-tech electrokinetics. Over 4,500 projects worldwide are proof of the company's broad industrial experience. INNOVUM has particular experience in biogas plants. The effect of electric field strength on the hydrophobic, colloidal properties of EPS and the nutrients it contains has been proven.

Test experience and research into the colloid-chemical mechanisms of electrokinetics and membrane filtration has led to a large-scale ZELIX plant constructed, with integrated INNOVUM modules. *Images at the 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 auxiliaries can also lead to stabilized interfaces, which affects the filterability, but also the degradation of organic matter and gas production.

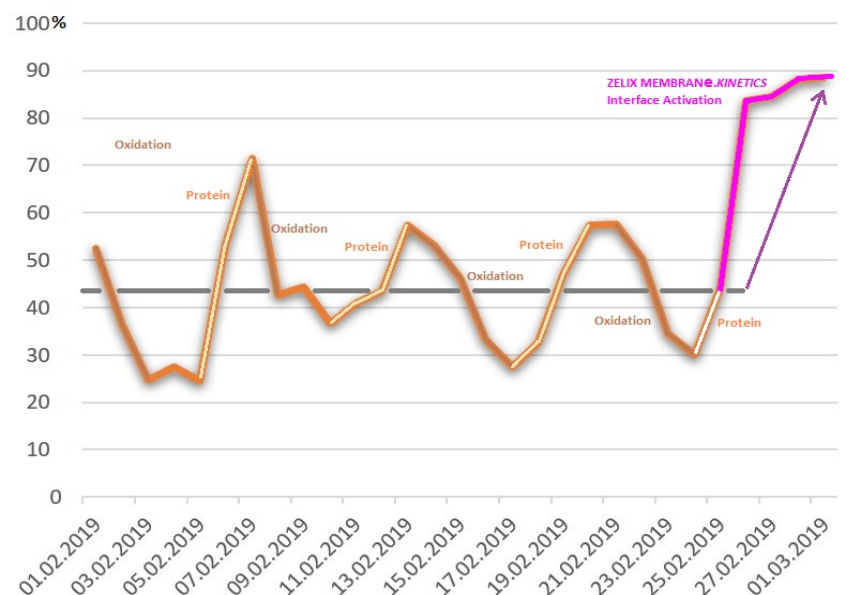
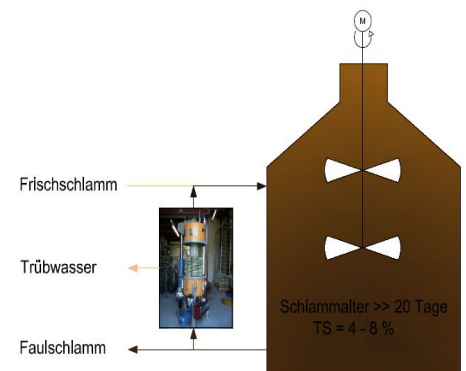
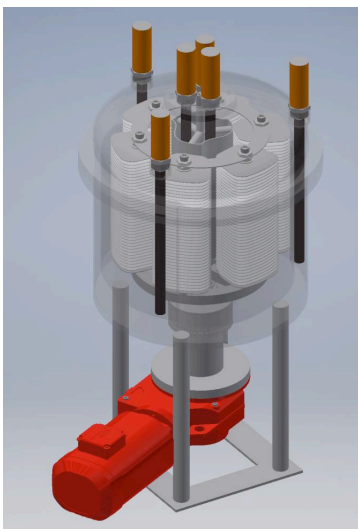
ZELIX membrane system with electrokinetics provided proof of performance of the process combination immediately

after start-up. This increases interfacial activity by over 100%. The economic effects are varied, 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 m² 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

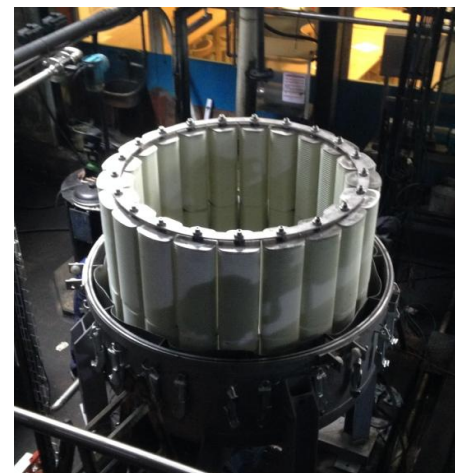
MBR Applications

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 below - and ZELIX 110-70 - pictures right



Plant	Year	Capacity	Membrane Area	Permeate Flow	Sludge Concentration	Energy Consumption	Operating Costs
1	2010	1000 m ³ /d	15 m ²	1000 L/h	29000 mg/l	180 mg/l	45% reduction
2	2011	1200 m ³ /d	20 m ²	1200 L/h	30000 mg/l	180 mg/l	50% reduction
3	2012	1500 m ³ /d	25 m ²	1500 L/h	31000 mg/l	180 mg/l	55% reduction

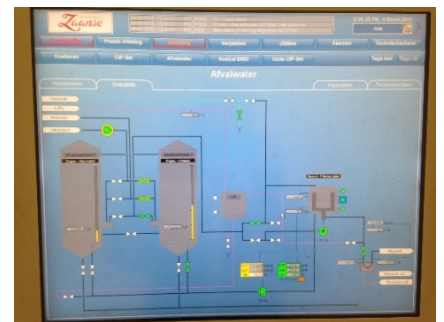


Other applications with biogenic sludge: BEFORE digestion for pre-thickening (e.g. sewage sludge, ...), DURING digestion for concentration in the by-pass and nitrogen separation, AFTER digestion for concentration of digestate.
Pictures below

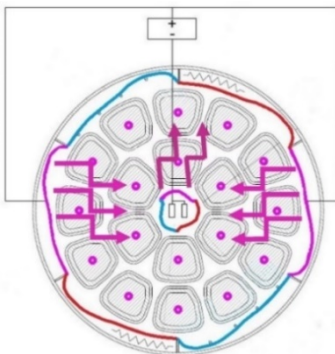


Less wastewater pollution

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.

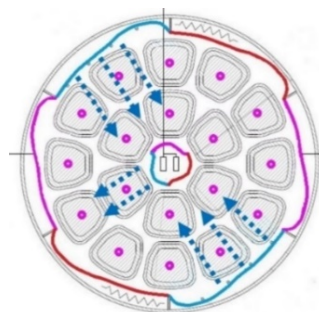


ZELIX MEMBRANE.KINETICS ELECTRO KINETICS



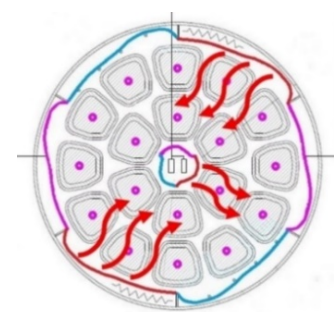
The ZELIX flow technology, as electrodes for high-voltage fields with rotating filter modules as counter electrodes, create a unique activation of interfaces - above all unique and innovative together with the separation effects of membrane pores directly at the phase boundaries. With the influence of electrical charge on the hydrophobic and colloidal properties, ZELIX shows positive effects even AFTER processes, denaturing molecules (e.g. through oxidation).

ZELIX MEMBRANE.KINETICS DIA-INFUSION

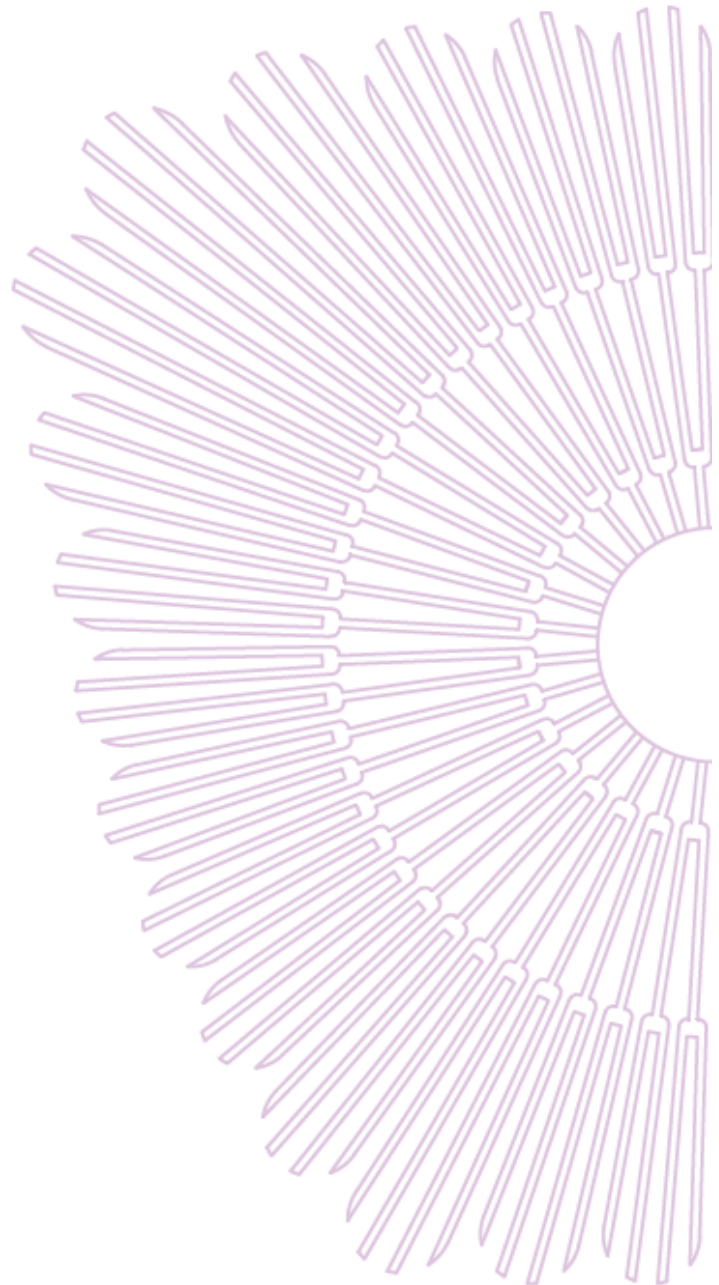


The ZELIX flow technology enables the infusion of auxiliary substances (enzymes, ...) in process media - precisely and most effectively dosed into the interfaces, activated by filter modules and membranes. Auxiliaries are used in a targeted and efficient manner, e.g. to optimize biological/chemical processes.

ZELIX MEMBRANE.KINETICS Δ - TEMP



ZELIX flow technology allows large-area heat/cooling exchange zones being integrated. This offers high efficiency thanks to the dynamic and even flow of process media flowing over the exchange surfaces for optimized ΔT .



*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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