



Fraunhofer

IKTS

FRAUNHOFER INSTITUTE FOR CERAMIC TECHNOLOGIES AND SYSTEMS IKTS

INDUSTRIAL SOLUTIONS

WATER AND WASTE WATER TECHNOLOGY



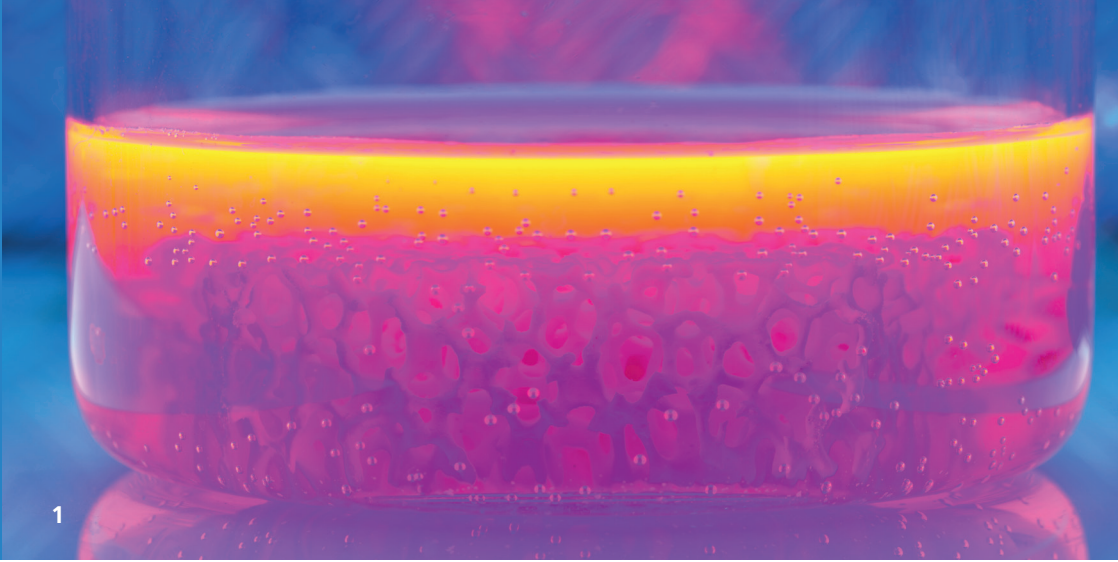
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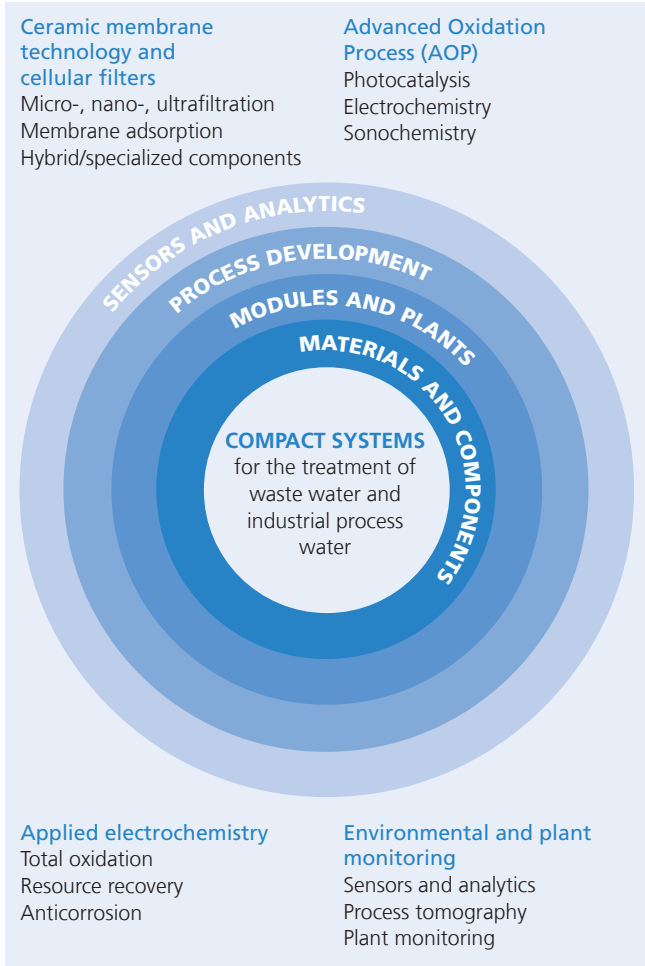
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WATER AND WASTE WATER TECHNOLOGY

Water is indispensable as a foodstuff as well as for agricultural and industrial production. It is therefore paramount to use this important resource with care. In this context, more and more production companies all over the world are faced with the challenge of achieving so-called “zero liquid discharge” by introducing closed production cycles.

As a consequence, the processing industry is in need of safe and fully multifunctional components for water treatment. These components must be lightweight and versatile, and allow integration into the companies’ existing supply infrastructures (retrofit systems), as well as into modern manufacturing concepts (industry 4.0). Furthermore, not only should they do without chemicals as operating materials; they should also be able to recover valuable constituents, concentrate any contaminants occurring in the process and break them down without residues.

While industrial processes are characterized by high salt loads and persistent organic residual materials from production and cleaning processes, which stands in the way of any effective closed-loop circulation, urban waste water treatment is more concerned with microbiological pollutants from pharmaceuticals, technical microplastics and nutrients, all in low concentration. Fraunhofer IKTS develops a number of technological solutions for these various issues in the field of water and waste water treatment – from the material, part and component levels up to complete processes and plants. Some of these solutions are presented in this brochure.





WASTE WATER

Efficient solutions for the treatment of contaminated water, free from chemicals or microbiological agents – from consulting to plant design. With the right combination of process steps, even constituents that are difficult to treat can be broken down in a targeted and economical way in centralized and decentralized plants.

Overview of processes and treatable substances

Biological	Organic	Inorganic
Disinfection		
Micro-, ultra- and nanofiltration, photocatalysis, electrolysis		
Bacteria, viruses		
Breakdown of anthropogenic trace substances		
Photocatalysis, electrochemistry, membrane adsorber		
Bacteria, viruses, humic substances	Pharmaceuticals, pigments, pesticides/biocides, hydrocarbons (PAK), TOC, DOC, PCB, AOX, dioxines (only photocatalysis)	Colloid impurities
Treatment of mining water (RODOSAN® process)		
	Carboxylic acid	SO ₄ ²⁻ , Al, Fe, Mn, (U, Th), pH value, partial demineralization
Flocculation and dewatering		
Humic substances, clouding, coloring	Anthropogenic impurities	Colloid impurities

DISINFECTION

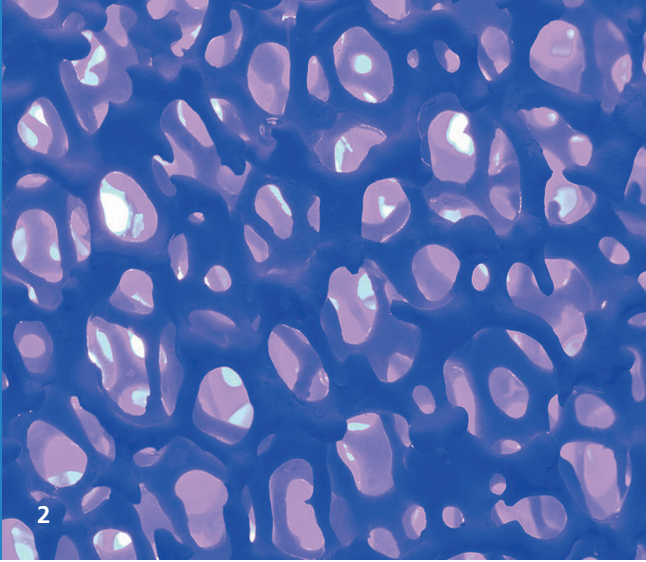
The disinfection of pre-cleaned waste water is of great importance when it comes to improving the hygienic quality of water bodies and utilization as service or irrigation water. Many conventional process types use chemicals, which need to be stocked accordingly and the use of which often requires compliance with strict safety standards. Therefore, Fraunhofer IKTS has developed solutions that can be easily integrated into processes and work without chemicals. For instance, Fraunhofer IKTS has a pilot manufacturing plant for ceramic membranes to be used for sterile filtration and made from titanium dioxide, silicon carbide and aluminum oxide.

Furthermore, photocatalytic electrochemical processes for the complete removal of pathogenic microorganisms through oxidation processes based on radicals (AOP: Advanced Oxidation Processes) are being developed. In accordance with the specific requirements, these processes can be used readily and efficiently in various operating modes.

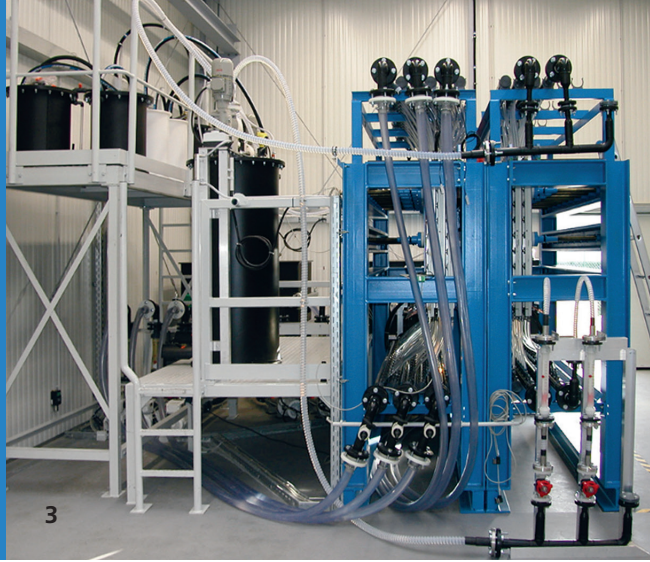
Advantages

- Safe disinfection
- Cost-efficient and durable materials
- Versatile use according to specific needs
- Energy-efficient operation
- No consumables required

1 Test setup for photocatalytic oxidation.



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BREAKDOWN OF ANTHROPOGENIC SUBSTANCES

The contamination of water bodies with organic substances of anthropogenic origin – pharmaceutical trace substances in particular – is a growing concern. Effective and efficient elimination is possible with adsorptive, as well as oxidative, processes and process combinations. For the selective removal of pollutants, Fraunhofer IKTS has developed an integrated process combination of activated carbon adsorption and membrane filtration (MF/UF). This combination has already been tested successfully for the elimination of various trace substances, such as carbamazepine and diclofenac.

AOP processes, such as photocatalytic or electrochemical treatment processes, are suitable for the complete breakdown of persistent contaminants. To achieve this, Fraunhofer IKTS has developed TiO₂-coated cellular ceramics which require lower energy input compared with other AOP procedures, thanks to their large interaction areas and better penetration depth of light irradiation.

Advantages

- Complete breakdown or selective separation of organic compounds
- Versatile use according to specific needs
- No consumables required
- Regenerable materials
- Simultaneous disinfection possible

2 Functionalized cellular ceramics for waste water treatment.

TREATMENT OF MINING WATER

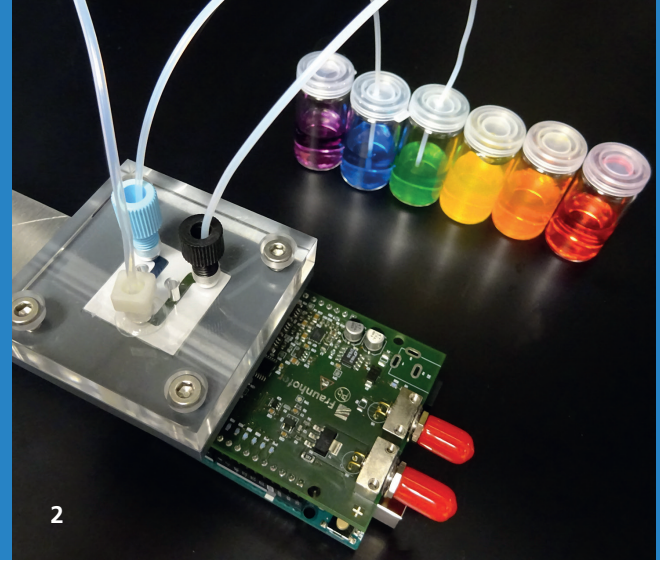
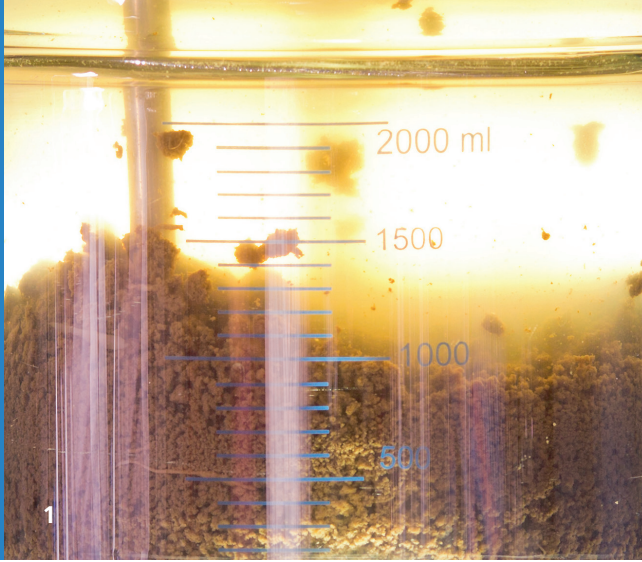
Sulfuric acid and mining water that is sulfate-rich and contains heavy metals wreak havoc on water bodies worldwide. Aside from the RODOSAN® process, there are hardly any alternatives at all when it comes to the possible treatment of such water, especially in terms of separating sulfates (sulfuric acid). The RODOSAN® process involves membrane electrolysis and enables a largely selective separation of sulfate. At the same time, heavy metals (Fe, Mn) and aluminum are eliminated quantitatively and buffer capacity is generated in-situ by electrochemical means. The separated sulfate can then be converted into reusable material, such as fertilizer.

The process has been pilot tested for various use cases on the level of industrial electrolytic cells and configured in a modular way, which makes it possible to treat smaller water volumes, as well as larger ones. A pilot plant with a capacity of 6 m³/h (roughly 1,600 US gallons per hour) is available for technical analysis and for optimizing the procedure.

Advantages

- Sulfate separation 45–70 %, partial demineralization
- Quantitative separation of aluminum, iron, manganese
- Generating buffer capacity
- Production of fertilizer as a co-product
- Wide range of applications (hydrochemistry, flow rate)
- Production of hydrogen and utilization of CO₂

3 Pilot plant for the separation of sulfates.



FLOCCULATION AND DEWATERING

Potable water and waste water treatment plants use so-called flocculants to eliminate undesirable substances, reduce the water content and thus closely control the properties of sludge. The remaining water content often contributes significantly to the costs when utilizing the sludge produced. This means the more efficient flocculation and dewatering are, the more economical utilization or disposal becomes.

In the future, the introduction of new legislation will regulate the use of conventional synthetic flocculants in the field of potable and waste water treatment more closely, possibly to the extent of prohibiting it completely. Therefore, Fraunhofer IKTS is focusing on developing, testing and implementing, within the process, cost-efficient and highly effective flocculants based on renewable raw materials – in addition to optimizing conventional flocculation and dewatering processes by means of measuring technology.

Advantages

- Use of sustainable and non-toxic raw materials
- Materials that equal or outperform conventional flocculants
- Legal compliance possible when used in potable and waste water treatment

1 Flocculated organic suspension.

ENVIRONMENTAL SENSORS

Detecting pollutants and trace substances in water and waste water is indispensable for the control of environmental and water engineering equipment, in particular with regard to the use of energy and chemicals. However, the intervals typically applied for sampling and chemical analyses are often too long to allow for efficient control.

Fraunhofer IKTS is dedicated to the development of robust molecule and contaminant sensors for applications in the field. On account of their reduced sensitivity, these substance-specific sensors should not be seen as competing with analyses in the lab, but rather as reliable on-site rapid-alert systems, integrated into the specific plant, in case of elevated local contaminant concentrations. They can focus on a variety of molecular types, depending on the plant's requirements.

Advantages

- Plant-integrated analytics with short sampling intervals in the region of a few minutes
- High robustness and failure safety
- Chemicals used offer good shelf life and are very easy to handle
- Versatile detection of various molecular types

2 Analytical system for pollutants and trace substances in the water.



INDUSTRIAL PROCESS WATER

Systems for the treatment of industrial waste and process water, tailored to specific requirements – Fraunhofer IKTS provides support in the development of suitable strategies for closing cycles and recovering reusable materials.

Main areas of industrial waste water treatment

Biological	Organic	Inorganic
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Solvent cleaning

Organophilic filtration: oMF, oUF, oNF/oSN/SRNF

-	Organocatalysts, homogeneous catalysts, plant substances, oil, lubricating oil	Particulate impurities, (homogeneous) catalysts, ionic liquids
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Recycling of alkaline solutions

Washing processes, alkaline solutions, degreasing

Biofilm, EPS	Oils, greases, COD	Particulate impurities, carbonates
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Treatment of radioactive waste water

(Electrochemical total oxidation)

Enzymes	Aliphatic and aromatic hydrocarbons, alcohols, aldehydes, carboxylic acids, ester, amines, nitroso and nitro compounds, chlorofluorocarbons, mercaptans, cyanides, heterocycles	Oxosyntheses
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Active/passive deposition

-	-	Pb-210, Po-210, Th, U (As)
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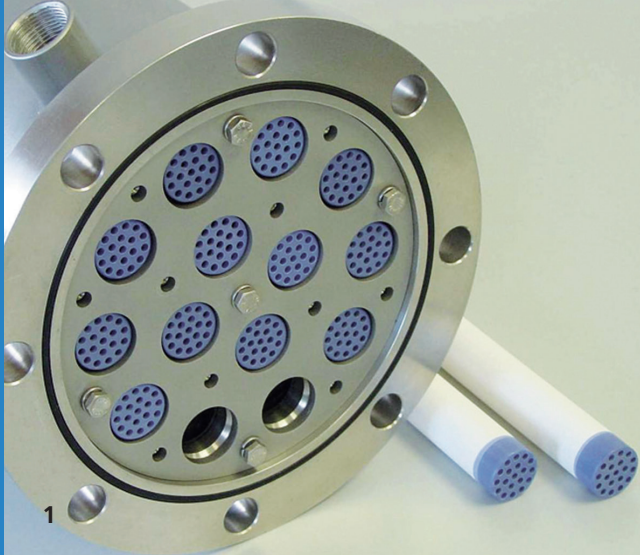
SOLVENT CLEANING

Manufacturing processes in the chemical and pharmaceutical industries may produce contaminated organic solvents which need to be cleaned before any reuse. Also, the recovery of homogeneous catalysts is garnering more interest due to the scarcity and soaring price of precious metals. Both processes are currently performed using distillation. However, since they also result in high energy costs, ecological and economically viable alternatives are in high demand.

One alternative or supplementary process may be a filtration stage with organophile nanofiltration membranes. This enables recovering a large part of the reusable materials in a pressure-driven physical process, which thus does not require any external heating or cooling energy. Thanks to their stability in organic solvents, ceramic membranes are well-suited as the basis for developing such processes. One strength of Fraunhofer IKTS is the capability to develop and modify specific membranes individually for each client.

Advantages

- Energy-efficient alternative for crystallization and rectification
- No replacement of phases required
- Significantly reduced side and decomposing reactions (lower thermal load)
- No additives used
- High chemical and thermal resistance of the ceramic membranes



RECYCLING OF ALKALINE SOLUTIONS

The efficiency of any industrial cleaning stage is also dependent on the purity of the actual medium used. It makes sense, therefore, to separate the impurities absorbed by the cleaning agent so as to maintain the cleaning effect. One of the most important cleaning media in the industry, used above all in the foodstuff and beverage industry, is hot alkaline solution. The cleaning of alkaline solutions involves the removal of contamination, such as paint, COD and particles, but also carbonates that have formed. The process stage proposed here can help enhance the recycling of alkaline solutions and minimize the usage of additives.

On account of the challenging chemical and thermal requirements, ceramic membranes perform better than polymer membranes. Beyond this, ceramic membranes allow for more compact plants as they yield a better filtration performance than polymer membranes in relation to the filtration area. Fraunhofer IKTS provides client-specific membrane development and modification.

Advantages

- Reduction of fresh alkaline solution and savings on additives
- Minimizing carryover into downstream process stages
- Increased membrane service life if ceramic membranes are used
- Potentially minimized area usage (compared to polymer membranes) if using ceramic membranes

1 Filtration module with ceramic membranes.

RECOVERY OF REUSABLE MATERIALS

We use our comprehensive technological capabilities and experience to develop processes for recovering reusable materials from waste water and liquid process media, as well as from secondary and non-conventional raw material sources. Fraunhofer IKTS is able to cover the full wet chemical process chain, starting with the extraction (leaching) from solids, to enriching using membrane-supported extraction processes, through to the pure metal or target product. In this regard, electrochemical processes are preferred, but combinations of processes including extraction processes are also used. The corresponding chemical recovery and waste water treatment are of course also part of the IKTS portfolio.

Fraunhofer IKTS has extensive experience in recovering rare earth concentrate from secondary raw material sources, preparing rare earth compounds in a pure state, as well as in recovering special and precious metals (indium, gallium, tellurium, silver, palladium, platinum, rhodium) from scrap metal and dump materials. Hypolimnic water is one non-conventional source, allowing the extraction of many important raw materials, depending on the specific site.

Advantages

- Comprehensive technological know-how on membrane and electrochemical processes
- Wide range of experience in terms of chemistry and materials (rare earths, special metals, precious metals)
- Pilot and research facility for process development and optimization, available at short notice

2 Electrochemical production of rare earth compounds from display cover sheets.



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TREATMENT OF RADIO-ACTIVE WASTE WATER

Radioactively contaminated waste water is a byproduct in many sectors of the industry. It needs to be treated to prevent radioactive substances from being released into the environment. To be able to treat liquid organic waste containing C-14, which is notoriously difficult to handle, Fraunhofer IKTS has further developed a process for electrochemical total oxidation. It is a relatively simple process which allows transforming the radioactive carbon (C-14) that is bound within the organic substances into alkaline earth metal carbonates suitable for ultimate disposal.

The electrochemical total oxidation process is also suited for the removal of many other highly persistent organic contaminants, for instance carcinogenic compounds, such as nitroaromatics or endocrine substances. If correctly designed and planned, the process is superior to all currently established options in terms of cleaning performance. The recovery of certain raw materials (rare earths, niobium/tantalum, coltan and others) and the use of geothermal sources for heat generation also result in enriched natural radionuclides of the radioactive uranium and thorium series, which can be separated in suitable electrochemical processes.

Advantages

- Easy production of C-14 carbonates that are suited for ultimate disposal
- Treatment of ignitable and/or aggressive organic waste materials
- Application for a wide range of substances
- Efficient separation of geogenous nuclides using electrochemical processes

3 Laboratory test stand for C-14 total oxidation.

PLANT MONITORING

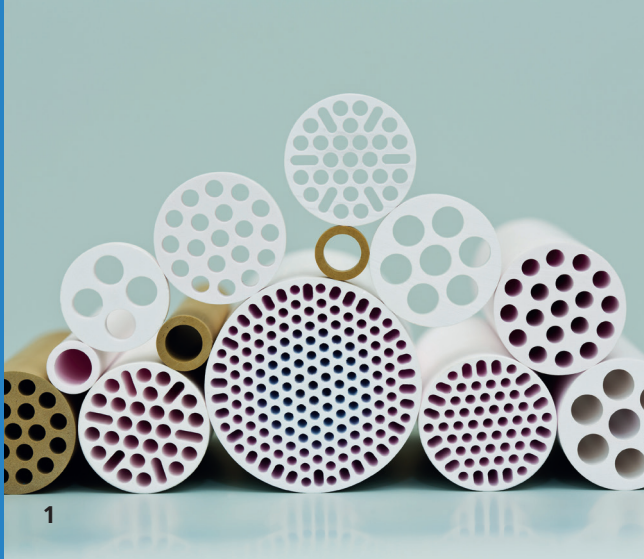
The term plant monitoring describes the competent and professional evaluation of a plant and its components with regard to its operative behavior. It is the basis for optimizing processes and serves to identify operative problems and their solutions. The research facilities developed, built and used by Fraunhofer IKTS provide all the options for process development and optimization – from “proof of principle” up to pilot testing.

Applied sensor systems permit the early identification of defects and material-related fatigue during plant operation. The condition monitoring of pipelines, tanks and many other production processes increases the availability and safety of the plant, contributing significantly to reduced operating costs.

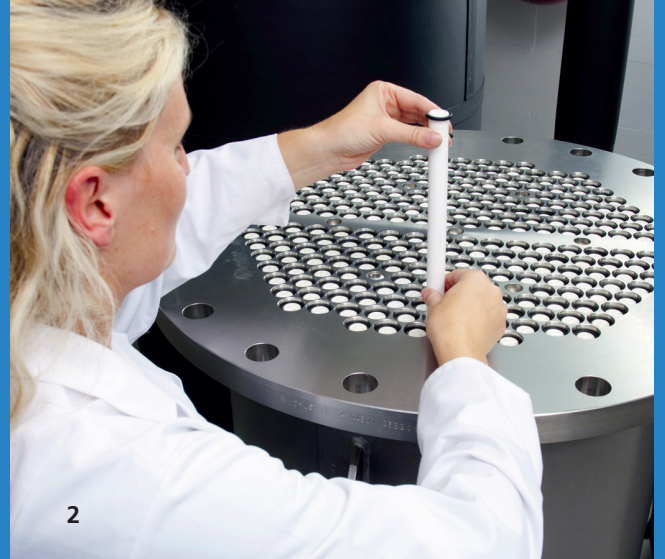
Advantages

- Diagnostically supported basic engineering, such as dimensioning and design of heat exchangers, pumps etc.
- CFD-supported development of components (e.g. modules, housings, heat exchangers, etc.)
- Long-term monitoring of processes with the help of pilot plants (lab and/or field setup)
- Increased plant availability and safety through condition monitoring

4 Radio sensor node for plant monitoring.



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EXPERTISE

Materials and components

- Ceramic filtration membranes in various geometries (pipes, plates, capillary tubes, honeycombs) and carrier material variants (Al_2O_3 , SiC, TiO_2)
- Specific electrolytic cells for electrochemical treatment
- Development of catalysts for galvanic in-situ contaminant elimination
- Cellular ceramic structures as catalyst carrier
- Functional surfaces based on nanostructures for filtration and catalytic conversions

Modules and plants

- Modules for all membranes available in-house up to the industrially relevant scale
- Modular electrochemical pilot plants for process optimization and treatment of small batches
- Membrane plants from lab to pilot scale (MF, UF, NF, UO, PV, DP, membrane extraction) up to 100 bar max.
- Filtration plants to be rented out, with automated filling, product extraction and cleaning function
- Mobile filtration container in accordance with ATEX (e.g. for oNF/SRNF)
- Mobile test stand for photocatalytic and electrochemical water treatment

Process development

- Filtration processes with ceramic membranes (micro- to nanofiltration)
- Photocatalytic processes using cellular ceramic catalyst carriers
- Electrochemical processes for water treatment, contaminant elimination and chemical recycling
- Electrolytic processes for the extraction/recovery of reusable materials and their preparation in a pure state
- Selective extraction processes
- Combined processes

Sensor systems and analytics

- Molecule-specific spectroscopic analytics (IR and Raman spectroscopy) for the detection of contaminants and trace substances
- Lab-based plasmon resonance spectroscopy (SPR) for the detection and assessment of molecular binding processes in analytes
- (Bio-)Functionalization of SPR sensor surfaces
- Development of adapted, robust SPR sensors for field application

1 Porous, ceramic support pipes with various geometries.

2 Filtration module with ceramic membranes.



TECHNICAL EQUIPMENT

Pilot plants and lab facilities

The sites of Dresden and Hermsdorf in Germany offer a total of approx. 3,200 square feet of well-equipped areas with labs and pilot plants. These include specialist labs for handling biogenic and explosive materials, as well as a radionuclide lab 10E4 x FG for radiotracer tests and process analyses with radioactively contaminated material.

Sample production

Once membrane development has been successfully completed on a lab scale, membrane technologies are transferred to larger, industrially relevant geometries and pilot production is set up. This step allows to develop processes for subsequent production on an industrial scale. Furthermore, pilot plants are equipped with membranes to evaluate the respective use case on a realistic scale.

Application Center for Membrane Technology, Schmalkalden

Fields of activity include client- and application-specific membrane testing and piloting processes, the development and construction of membrane housing prototypes and test plants, the development of cleaning strategies, the implementation, support and assessment of field tests, as well as the development of concepts for integrating membrane processes in the client's production cycle.

Application Center for Bioenergy, Pöhl

When it comes to developing technologies in the field of biomass, often linked to the treatment of process water and selective material separation from aqueous solutions, it is usually impossible to transfer lab results directly into daily industrial

practice. The aim of the Application Center for Bioenergy is to close, by technological means, the divide separating lab work and practical application. Various test areas and facilities are provided for research projects and industrial contract research.

Technical pilot plant for mining water, Rainitz

With the purpose of technical testing of the RODOSAN® process for electrochemical sulfate separation and mine water cleaning, the site of GWRA Rainitz hosts a pilot plant. It has a modular design and achieves a treatment capacity of up to 10 m³/h (approx. 2,600 US gallons per hour). The pilot plant enables sulfate separation of up to 65 %, with full separation of Al and Fe. It includes, among other things, a control station, an on-site lab, and comprehensive logistic facilities to implement different testing programs and process variants simultaneously.

Test stands for deep geothermal processes

For corrosion and scaling tests, as well as for tests on the electrochemical conditioning of geothermal brine and water, including raw material recovery, in-situ test stands are available at the sites in Neustadt-Glewe (Mecklenburg-Western Pomerania) and Pullach (Upper Bavaria). These are operated in parallel next to the respective exploitation wells. They are equipped with the appropriate sensors, control and safety equipment and provide a large number of opportunities for experimenting.

FRAUNHOFER IKTS IN PROFILE

The Fraunhofer Institute for Ceramic Technologies and Systems IKTS conducts applied research on high-performance ceramics. The institute's three sites in Dresden and Hermsdorf (Thuringia) represent Europe's largest R&D institution dedicated to ceramics.

As a research and technology service provider, Fraunhofer IKTS develops modern ceramic high-performance materials, customized industrial manufacturing processes and creates prototype components and systems in complete production lines from laboratory to pilot-plant scale. Furthermore, the institute has expertise in diagnostics and testing of materials and processes. Test procedures in the fields of acoustics, electromagnetics, optics, microscopy and laser technology contribute substantially to the quality assurance of products and plants.

The institute operates in eight market-oriented business divisions to demonstrate and qualify ceramic technologies and components as well as non-destructive test methods for new industries, product concepts and markets beyond the established fields of application. Industries addressed include ceramic materials and processes, mechanical and automotive engineering, electronics and microsystems, energy, environmental and process engineering, bio- and medical technology, optics as well as materials and process analysis.



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Industrial solutions
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technology**

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