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IGB

Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB

Process water in a closed loop

Resource- and energy-efficient water treatment

Industrial process water and wastewater purification

Water is used in numerous production processes as a solvent or means of conveyance, as cooling water or washing water. Increasing costs for the purification and disposal of wastewater, regional and seasonal shortages of water, and also a growing environmental awareness on the part of companies are resulting in using these process waters, which are often required in large quantities, in closed cycles whenever possible, and removing impurities selectively or recovering valuable constituents.

Fraunhofer IGB has at its disposal numerous technologies for treating an extremely wide range of chemically and / or biologically polluted process wastewaters from a wide range of industrial branches such as the chemical and pharmaceutical industries or metal processing, process wastewater with a high organic load from paper and cellulose processing, and also from the food and beverages industries. The IGB supports companies in selecting and establishing an overall process tailored to their process water or wastewater.

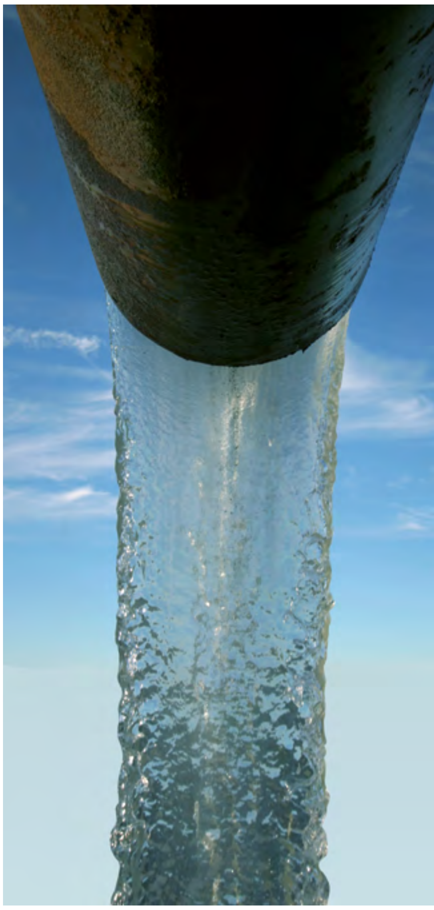
Challenges

Unlike in municipal wastewater purification the impurities in industrial process water are determined to a large degree by the branch of industry and the specific production process. The contaminations can change very quickly even in one and the same production facility. Standardized solutions can therefore only be used in exceptional cases. In order to recirculate process waters and wastewater from industrial production processes, the impurities have to be removed – with as little effort and expense as possible. The solution may require specific material flow management and the selective detection of contaminations, or a customized integrated process technology.

Insufficiently treated process wastewater that is discharged into bodies of water results in long-term damage that then has to be tackled later on at great expense. The pollution of rivers, lakes and groundwater with pesticides, mineral oil residues or pharmaceuticals are examples of this. Emissions of this type are no longer tolerated in current legislation. Additionally, raw water treatment is now confronted with new challenges. Overuse and the pollution of the past have a direct impact today on the natural sources of water such as surface waters and groundwater.

Current challenges in process wastewater treatment are, for example:

- Net zero requirement for water consumption and CO_{2eq} emissions
- Zero emission requirement for active pharmaceutical ingredients (APIs) and specific substance classes (e.g. PFAS)
- Nitrate and nitrite loads at industrial sites without biological wastewater treatment
- Varying wastewater contamination resulting from rapid product change, down times and cleaning cycles



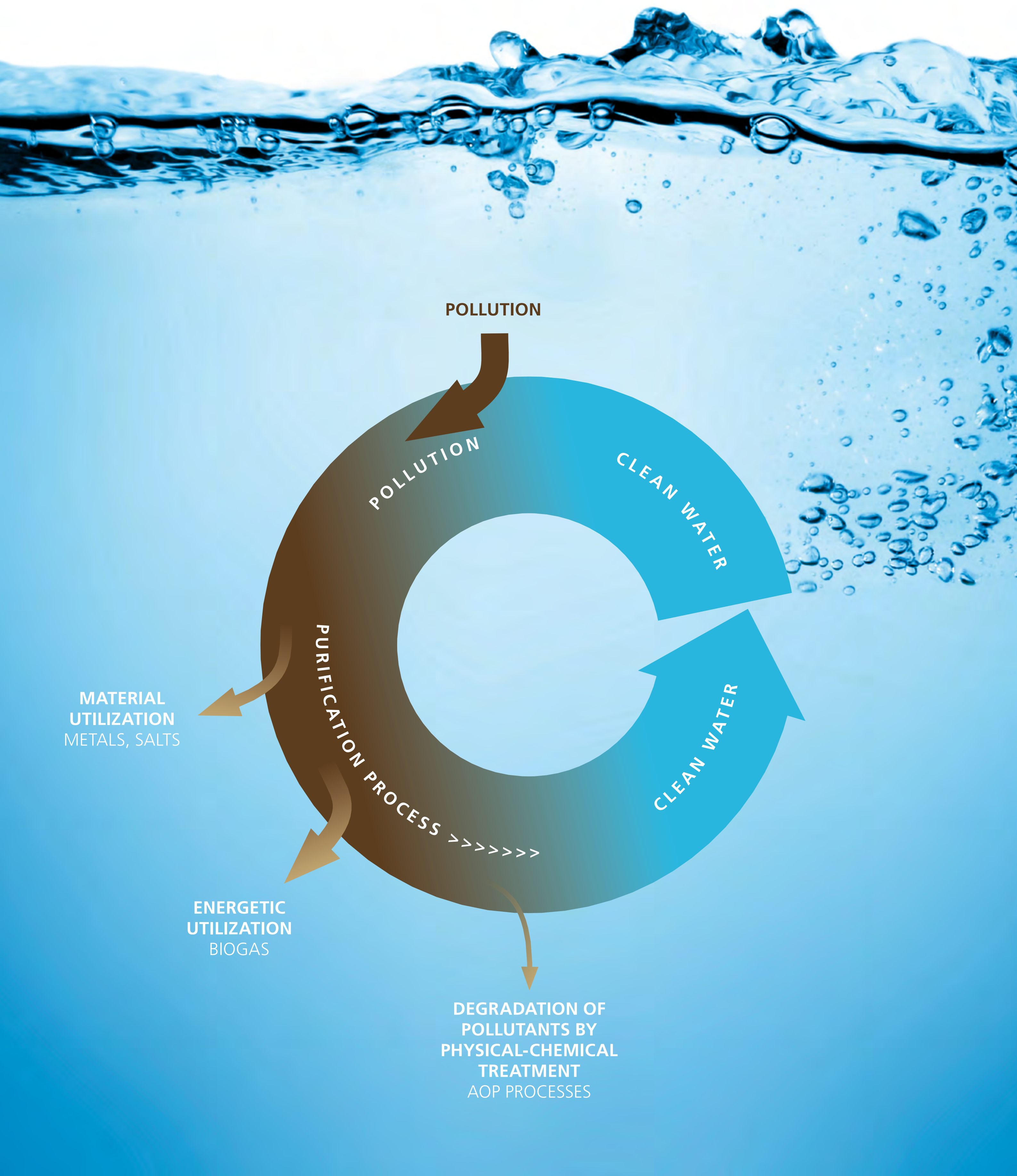
Fraunhofer IGB – All about processing solutions for process water and wastewater

In order to achieve a closed cycle and permanent sustainability of process water management, Fraunhofer IGB is working on process solutions that combine biology and engineering.

Current research at Fraunhofer IGB is therefore focused on processes such as adsorption, filtration, flocculation/precipitation, electrodialysis, oxidation and disinfection and a transition to biobased feedstocks. On the basis of many years of experience biological processes, both aerobic and anaerobic, are being further developed and optimized for an extremely wide range of applications, and combined with membrane and chemical-physical processes.

The integration into regional energy and material flow concepts in the spirit of the bioeconomy enables new solutions here. In addition to new requirements, the rapid development of the legal framework and local markets also offers great opportunities.

Scientific advice to our customers regarding their production process and its water flows is provided independently of technology and suppliers. In cooperation with industrial partners, new concepts and technologies for the sustainable treatment and purification of process water for a very wide range of applications are being developed and optimized at Fraunhofer IGB as well as scaled up to industrial scale.



POLLUTION
POLLUTION
CLEAN WATER
CLEAN WATER
PURIFICATION PROCESS >>>>>>>
MATERIAL UTILIZATION
METALS, SALTS
ENERGETIC UTILIZATION
BIOGAS
DEGRADATION OF POLLUTANTS BY PHYSICAL-CHEMICAL TREATMENT
AOP PROCESSES

Sustainable water treatment

The introduction of stricter environmental guidelines, the path to climate neutrality, and rising costs for raw water are leading to continuous efforts to reduce the amount of contaminants and wastewater to be disposed of, to close loops locally and regionally, and to integrate water and energy systems even further. Today, rising prices for dwindling resources are already insuring that waste and wastewater are seen as a source of secondary resources. The purification of the wastewater that occurs by recovering valuable substances, to be either reused or sold, is therefore becoming more and more attractive from the economic point of view.

From analysis to tailored solution

A comprehensive analysis of the production steps in which water is used always comes first. If water can be saved or the mixing of process wastewater streams that are better treated separately can be prevented, then this is frequently more economical than universal treatment of the combined process wastewater. In addition, production-integrated water recycling permits greater independence from natural water resources and thus enables production at water-scarce locations – through to complete independence from natural water resources by means of zero liquid discharge (ZLD).

For individual solutions we analyze process water flows and develop concepts for the concentration or selective removal of specific contaminants (single flow or partial flow treatment). If mixed loads occur due to the type of production, we also have at our disposal technologies for separation and combined treatment.

Objectives: zero emission, resource-saving, energy-efficient

Our research and development for the purification of industrial process water and wastewater focuses on innovative technologies and integrated system solutions. The aims of these are to avoid or reduce emissions into the environment and to increase the resource efficiency of the water treatment processes.

An ever more important criterion – not least as part of the worldwide energy transition – is the energy efficiency of the methods used. We therefore develop energy-optimized technologies, work on solutions for the use of renewable energies and waste heat and, when implementing them, take into account that plants can be controlled on the basis of power grid utilization – stabilizing the grits and enabling sourcing at low energy and electricity prices. These factors also result directly in an improved cost efficiency of the processes, so that both ecological and economic requirements can be met in equal measure.

Efficient and sustainable water treatment processes

- Avoidance or minimization of the use of chemicals in water treatment (metal salts as flocculants, high-molecular polymers as flocculating agents, oxidants)
- Integrated recovery of valuable media and materials (acids, bases, metals)
- Selective removal of impurities

Sustainable process operation

- Energy-efficient process control by means of load-dependent operation
- Modular design for flexible use and plant modification
- Robust operation with little maintenance and monitoring required
- Use of renewable electrical, surplus thermal or chemical energy generated in the process itself (e.g. hydrogen)
- Flexible operation of electrophysical treatment plants depending on capacity utilization of the power grid

Contaminants and treatment strategies

Contaminants in the water may be inorganic or organic in nature and may occur in suspended, emulsified or dissolved form, so that different technologies are employed to remove them.

Frequently requested are solutions for the removal of:

- Nitrogen (ammonium, nitrate/nitrite)
- Phosphorus (organic and inorganic phosphate load)
- Salt load (chloride, sulfate)
- Heavy metals
- Microorganisms: colony forming units (CFU); fecal indicators; biofilms
- Trace substances, micropollutants (MP), trace organic compounds (TrOC), hormones, endocrine disrupting compounds (EDC), drug residues
- Per- and polyfluorinated alkyl substances (PFAS)
- Non-biodegradable organics ("hard COD")
- Wastewater from hydrothermal carbonization (HTC) and pyrolysis water

Suspended particulate contaminants

Solid organic or inorganic particles can be separated from water by filtration methods, hydrocyclones or sedimentation. The particle sizes, their shape and elasticity define the required pore or screen size of the membranes or filters used as well as the process parameters. If the particles are large enough and heavier than water, they can be separated by means of sedimentation. Smaller particles can be separated by means of coagulation and flocculation.

Microorganisms

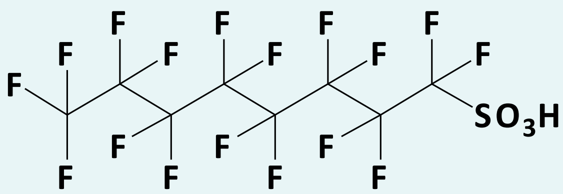
As living organisms and potential pathogens, microorganisms occupy a special position among the particles. Insuring the microbiological quality of water is a central task in water treatment. At Fraunhofer IGB we research hygienically relevant parameters of filtration and disinfection processes under the specified conditions relevant to each process. If required, we adapt the detection methods for microorganisms to those special conditions. Some of the processes developed or optimized at the IGB are specifically suited to the hygienization of process water.

Emulsions and suspensions

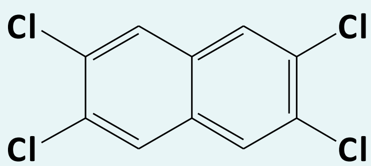
Hydrophobic liquid contaminants such as oils and fats can occur in water in an emulsified form. Whereas instable, temporary emulsions and suspensions can be separated using simple methods such as coalescence separators, stable emulsions require further treatment steps. Their cleavage can be achieved, for example, by electrocoagulation.

Dissolved substances

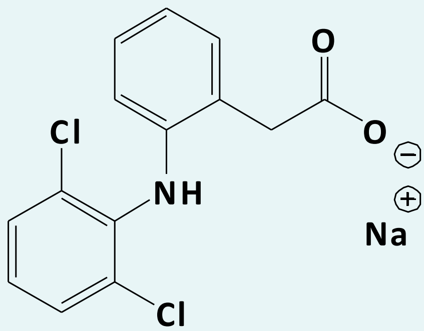
Numerous inorganic and organic molecules as well as ions occur dissolved in the water. A number of organic compounds serve microorganisms as a source of carbon or energy and can be broken down easily in a biological purification stage. When they are completely degraded, they are separated into their basic building blocks CO_2, H_2O and sometimes inorganic compounds.



perfluorinated surfactants / industrial chemicals



polychlorinated aromatics / flame retardants



pharmaceuticals

Xenobiotics and persistence

The introduction of certain functional groups (e.g. halogens) in organic molecules as well as the occurrence of aromatic structures and highly polar groups complicate or prevent biological degradation, for example in a municipal sewage treatment plant. So most polycyclic aromatic hydrocarbons (PAH), chlorinated/halogenated hydrocarbons or polyphenols cannot or can only with difficulty be degraded biologically; they also accumulate in the environment.

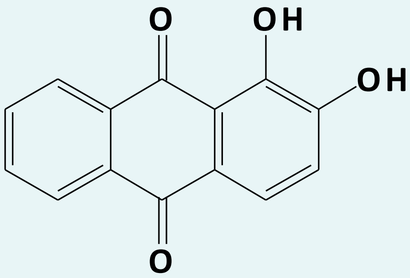
Such persistent substances have to be removed from process wastewater before these are discharged into central municipal wastewater treatment plants or into bodies of surface water. Also, toxic substances, among these pesticides, cyanides, heavy metals or pharmaceutically active substances, must also not be released into the environment – not even as so-called micropollutants in low concentrations. Persistent organic pollutants (e.g. PFAS) as well as some inorganic compounds (cyanide and ammonium salts) can be degraded by oxidative or reductive processes.

Besides these conversion processes, straight separation methods can also be used for dissolved contaminants, especially when they occur in low concentrations. Here the substances are either enriched (adsorption, membranes, ion exchange) or transferred to another physical state (precipitation, stripping) and removed from the water in this way.

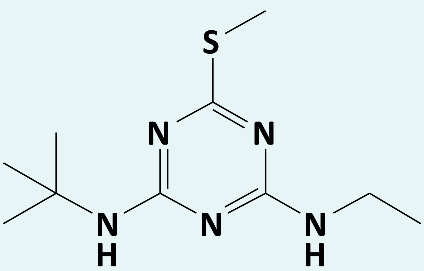
Salts

The multiple recirculation of the water means that salts can accumulate, resulting in concentrated material flows. For the recovery of salts and recycling as acids and bases we investigate above all electrophoretic and capacitive methods (some of them using conductive membranes) where charged particles can be separated and concentrated by their motion in an electrical field.

Persistent structures.



dyes



pesticides

IGB Technologies for process water treatment

Biological processes

Biological processes make use of the self-cleaning properties of the ecosystems in which organisms prevail that can break down organic substrates most efficiently. The precondition for this is that the substrates are, as a matter of principle, biodegradable. By using technical processes for biomass retention, these natural processes can take place with high efficiency in a very small space.

Fraunhofer IGB has developed various bioreactors for wastewater treatment, for example anaerobic and aerobic loop reactors (gaslift/airlift reactors), membrane bioreactors and a fixed-bed circulation reactor in which the particle bed is periodically recirculated. Fixed-bed reactors are used in anaerobic technology to retain and thus enrich the active biomass that can become immobilized on and between the particles. On the Fraunhofer IGB fixed-bed circulation reactor the fixed bed is partially recirculated at certain times, thus permitting trouble-free operation on a sustained basis.

We support you from analysis to implementation
We select suitable bioreactors and the corresponding process concepts on the basis of the specific wastewater requirements and the intended reutilization. Mobile plants (sequencing batch reactor, SBR; expanded granular sludge bed, EGSB) are available for piloting on site. We not only advise our customers on process selection, but also support them in the selection of plant constructors, on operating models, during commissioning and during future production changes.

Anaerobic processes for wastewater with high organic load

Anaerobic wastewater purification processes are especially suitable for treating wastewater with a high biological oxygen demand (BOD5) found, for example, in the food and beverages industries, in slaughterhouses and also at airports (de-icing agents). Larger companies often run their own biological treatment plants. These are usually aerobic and have several disadvantages such as high power requirements for aeration and mixing, a common lack of nutrients (N and P) and the generation of large quantities of sewage sludge, which is expensive to dispose of. Modern anaerobic technology is much more economical and has already proven to be long-term efficient

Fixed-bed circulation reactor.

for many of our partners. The advantages are that the biogas (biomethane) formed can be used energetically and the amount of sludge is reduced by a factor of ten.

Reactor concepts for biomass retention and concentration

A slow growth of biomass is characteristic of anaerobic conversion as the majority of the energy contained in the wastewater components can pass straight over into the final product, i.e. methane. If turnover rates are to be increased, the active biomass must therefore be retained in the reactor. Three principal methods are available for this: use of a microbial sludge with good sedimentation properties in appropriate reactors (upflow anaerobic sludge blanket), immobilization of the biomass on a carrier material in a fixed-bed or fluidized-bed reactor (biofilm processes) or mechanical biomass retention in a membrane reactor. Fraunhofer IGB has various types and sizes of reactors for examining the anaerobic purification of wastewater samples. The first step here is an analysis of the degradability of the specific wastewater based on the procedure in DIN EN ISO 11734 "Complete anaerobic biodegradability in digested sludge" and DIN 38414 "Sludge and sediments", Part 8 "Determining degradation behavior". Once a process has been optimized on a semi-technical scale in our biotechnical pilot plant, the scale-up is carried out on-site for our customers or the implementation is supported by commercial partners.

Removal and recovery of metals – biosorption and bioprecipitation

Metals from process wastewater can be bound to microbial surfaces by means of biosorption. In bioprecipitation dissolved metals ($CuSO_4$, $NiSO_4$, $ZnSO_4$) are precipitated in the aqueous phase by microbial processes, for example with anaerobic microorganisms as catalysts and transferred to particulate components that are difficult to dissolve (CuS, NiS, ZnS). For effective process control we use immobilized or suspended biomass. In this way, heavy metals can be concentrated from solutions with metal ion concentrations in the mg/L range and precipitated as solids with metal concentrations in the g/kg range.

Optimization of wastewater treatment plants by systematic analysis

Fraunhofer IGB has many years of experience in developing and optimizing purification processes for both municipal and industrial wastewater treatment plants. In numerous projects, systematic analysis and detailed measurements were the key to the improvement of processes such as nitrification and denitrification, and to an increase in the production of biogas in various sewage treatment plants. In most cases, it was possible to optimize the entire operation significantly. This method saves funds which would otherwise have to be spent on plant reconstruction or alterations. The Fraunhofer IGB approach to a solution begins with a careful evaluation of the operational logbooks. Here we not only determine all the usual design parameters, but also analyze how well a sewage treatment plant functions using process measurement and control measures for each and every section of the plant. In addition, we often carry out a specific measurement program to determine how efficiently the individual purification steps are operating. This results in optimum customized solutions bringing each treatment plant up to state-of-the-art standards in a cost-effective way and helping operators to meet the specified target values. Such an approach is always worthwhile because it saves considerable sums otherwise needed for extending existing treatment plants.

Biological processes are supplemented by further methods when, for example, inorganic substances such as phosphates or ammonium salts are also to be recovered from wastewater.

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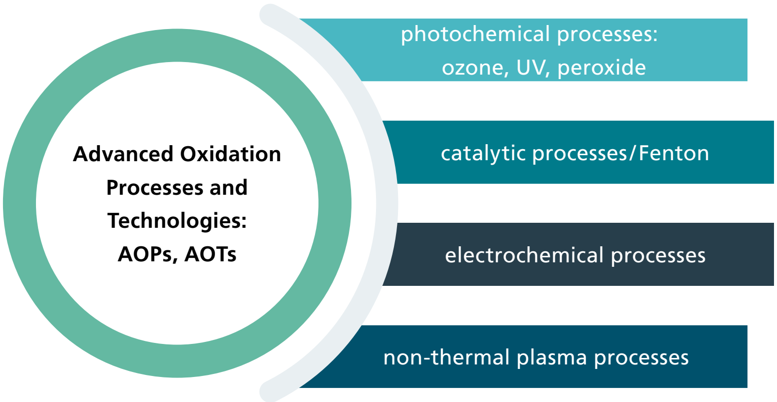
Physical-chemical Processes

Advanced Oxidation Processes (AOP)



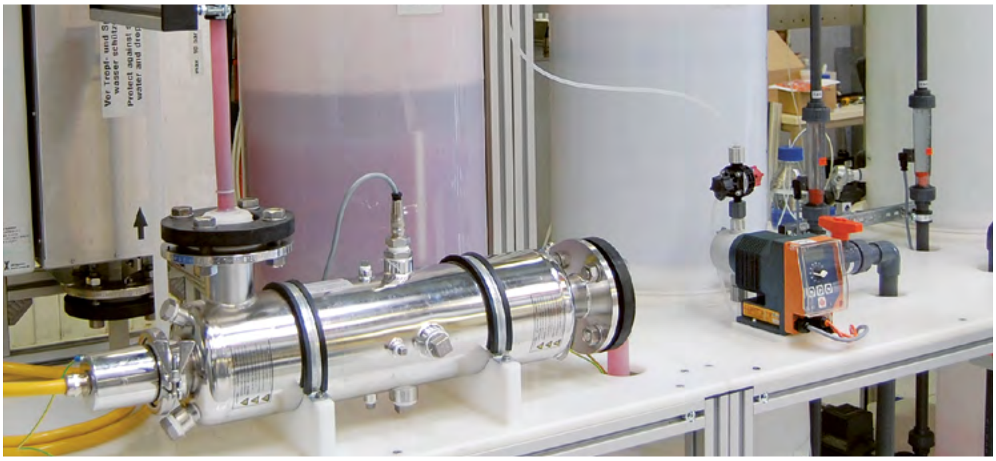
AOP/AOT – advanced oxidation processes/technologies.

Oxidative water treatment (AOP, advanced oxidation processes or AOT, advanced oxidation technologies) is understood as processes for chemical treatment in which highly reactive hydroxyl radicals are formed and used for oxidation reactions. AOPs are always used when a biological decomposition is not feasible or cannot be carried out efficiently, for example because the contaminations contain persistent substances. Also, AOPs are the method of choice when the process wastewater has a toxic effect on the microorganisms of a biological purification stage or occurs extremely discontinuously.

AOP processes thus make it possible to close process water loops and significantly reduce fresh water requirements. In many cases a combination of processes is advisable with an oxidative treatment and an adapted biofilter. The possibility of testing an extremely wide range of combined treatments in the IGB laboratories and technical-scale facilities is one of our unique service features.

Which AOP process is suitable?
In general, the formation of the reactive hydroxyl radicals can be achieved by metering oxidizing substances such as ozone and

Laboratory cell for anodic oxidation and cathodic reduction.



Test facility for AOP treatment: UV-C/H_2O_2 treatment, ozone treatment, Fenton oxidation and combination processes.

hydrogen peroxide, and also by introducing energy using plasma technology, in photocatalysis using UV-A or UV-C radiation, ultrasound, electric current or by a combination of these methods.

Processes with hydrogen peroxide metering (Fenton reaction, UV/H_2O_2 and O_3/H_2O_2) and in particular ozone treatment are already established on an industrial scale. For these reference processes, we offer cost estimates and studies with the customer's wastewater.

A rough cost estimate based on literature data is often already very helpful for our customers. In addition to the degradation of the organic contaminant, we regularly analyze the reaction products and their further (oxidative or biological) degradation to obtain a statement on the general suitability of the AOP process for the specific process water.

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Disinfection of water using UV light.

Disinfection

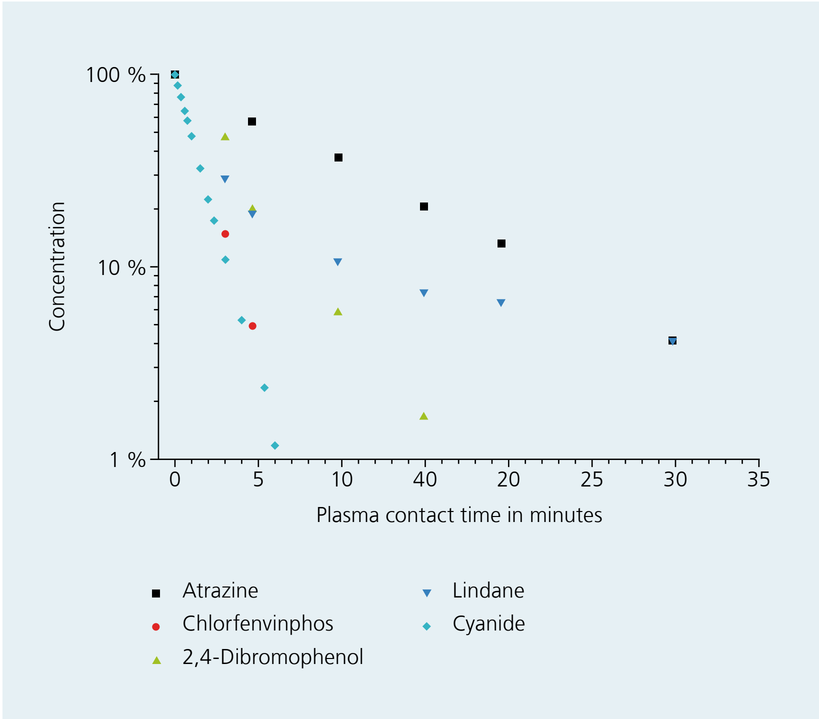
A disinfection step is of the utmost importance to supply the population with safe, high-quality drinking water. Also high-quality, hygienically safe water is required as process water in the pharmaceutical and food industries. In addition to the classical method of chlorination, treatment with ozone and disinfection by means of UV light have been established as reliable and environmentally friendly processes. Mainly tubular low-pressure mercury vapor lamps that emit radiation of the wavelength 254 nm are currently in use.

Our interdisciplinary team of experts will also be happy to advise you on hygiene concepts.

Plasma AOP

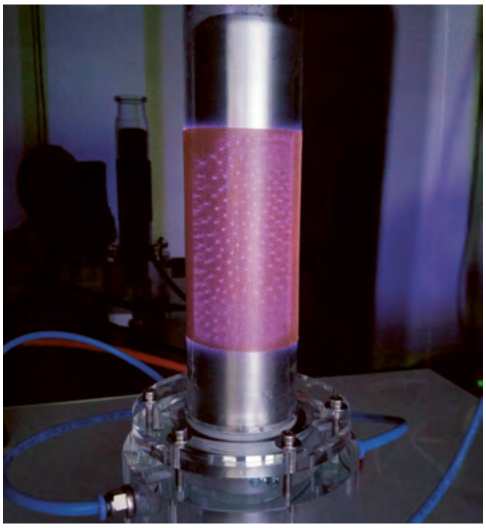
Ions, highly reactive radicals and short-wave radiation are created in an electrical discharge (plasma) from ambient air and atmospheric oxygen in order to degrade organic components in wastewater. The specific construction of the plasma reactor insures the efficient transfer of the highly reactive species formed in the plasma to the polluted water. To achieve this, the plasma has to be in direct contact with a flowing water film.

An advantage of the plasma process is that there is no solid area of contact and the water surface being treated is constantly renewed. There is no longer any need to clean surfaces in order to remove biofilms or sediments. In cooperation with various partners within the FP7 EU-funded project "WaterPlasma" (grant agreement no. 262033), it was demonstrated that pollutants such as Atrazine, Lindane, 2.4-Dibromophenol and Chlorfenvinphos (pesticides) as well as Cyanides are broken down very quickly and effectively in an open plasma reactor. Recently, the decomposition of perfluorinated surfactants and several pharmaceuticals was shown as well ("WasserPlasmax", funded by the German Federal ministry of Education and Research (BMBF), promotional reference 13N13172). In the current project "AtWaPlas" (BMBF-funded, promotional reference 02WQ1601B), the degradation of per- and polyfluorinated chemicals (PFAS) from environmentally sourced groundwater, leachate and washing water is specifically investigated using an atmospheric water plasma.



Degradation of Atrazine, Chlorfenvinphos, 2,4-Dibromophenol, Lindane and Cyanide in an open water plasma reactor.

We investigate the degradation of contaminants in your process or wastewater using various laboratory-scale plasma processes, characterize the degradation products, and scale the process according to your requirements.



Laboratory setup of a plasma reactor for water purification.

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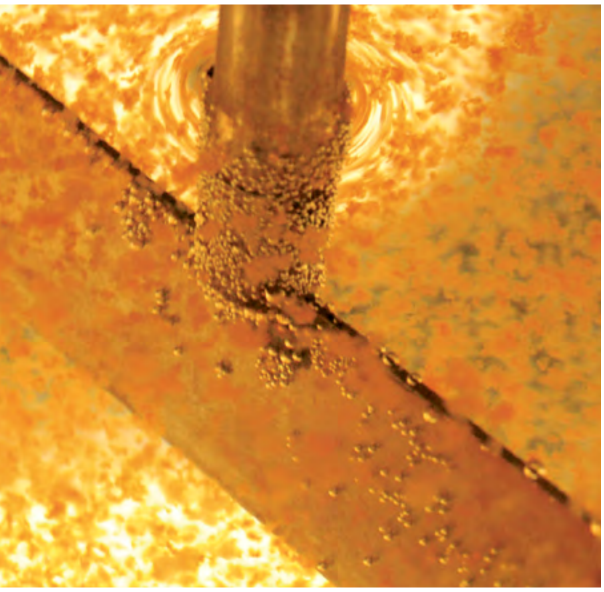
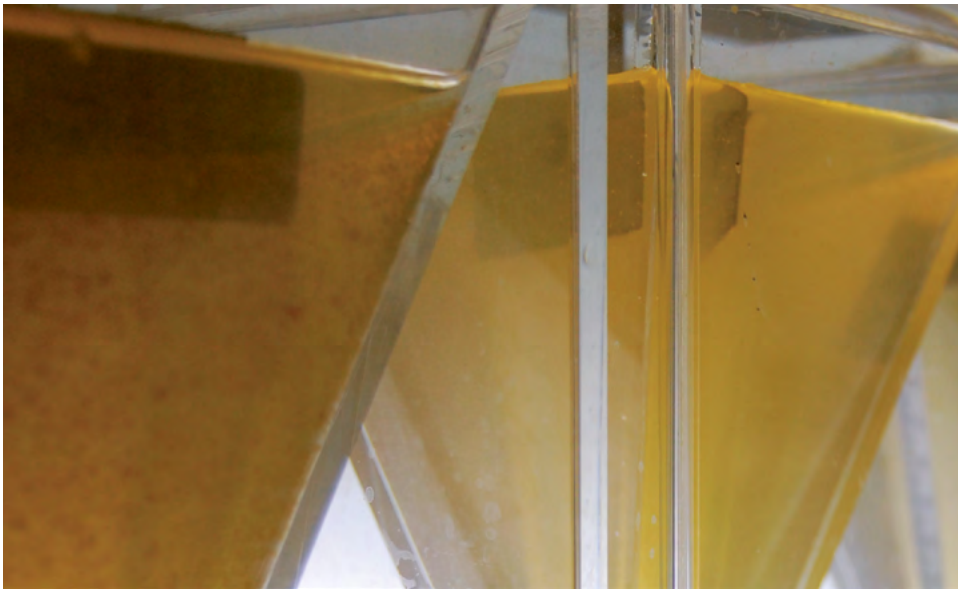
Electrocoagulation





from left to right:
Electrolytically generated iron hydroxide.

Electrocoagulation.

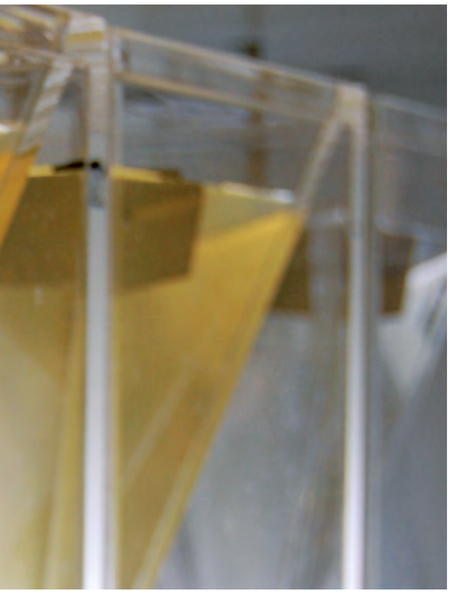
Deposition of hydroxide flocculation.

Continuously operating electrocoagulation reactor for the treatment of up to 5 m^3/h process wastewater.

In electrocoagulation, the water to be treated passes metal electrodes. These sacrificial electrodes dissolve releasing their metal ions. Metal hydroxide flocs are produced in the process and the pH changes.

The electrolytically generated metal hydroxide flocs have a high adsorption capability and can bind finely dispersed particles in the size range of a few micrometers or less removing turbidity. Coprecipitation and occlusion precipitation reactions, in which dissolved organic and inorganic substances are removed in addition to the fine particles also take place. The pollutants can then be separated mechanically together with the metal hydroxide flocs by sedimentation, flotation or filtration.

Electrocoagulation replaces conventional chemical flocculation techniques with the advantage that the flocculants are made available electrolytically from solid state electrodes in molecularly dissolved form – directly at the place where they are required – and are easily metered on the basis of requirements. Iron or aluminum from standard sheets can be used as electrode material; these are inexpensive, always available and easy to handle. Only the metal ion is added to the water; an increase in the salt content does not occur. Costs for the purchase, handling and dispersing of flocculants and flocculating additives are saved.



Case studies

Halving the treatment costs for paper wastewater by means of electrophysical precipitation
For a paper manufacturer we optimized the plant for purification of the process wastewater and increased its capacity. We replaced conventional flocculation with a plant on the principle of electrocoagulation. By saving chemicals such as flocculants, polyelectrolytes and caustic soda it was possible to reduce the costs for the wastewater treatment by half.

Removal of finely suspended substances from paint wastewater by means of electrophysical precipitation
In a feasibility study for an aircraft manufacturer we successfully treated paint wastewater from the painting systems by means of electrocoagulation. The turbidity of the wastewater was reduced by 95 percent, the COD (chemical oxygen demand) value by 75 percent. Similar studies were carried out for paint manufacturers. Here too, we were able to show that it was possible to reduce the turbidity, the COD value and the smell significantly.

R&D services

We offer our customers

- Advice on expected removal rates and energy requirements
- Consulting on the integration of electrocoagulation plants into existing water treatment plants
- Laboratory testing of flocculation/precipitation for comparison of chemical and electrochemical precipitation with estimation of material, chemical and power requirements as well as pH and conductivity development (salt load)
- On-site testing
- Planning, support and evaluation of on-site tests performed by the customer's own personnel
- Market study of commercial suppliers

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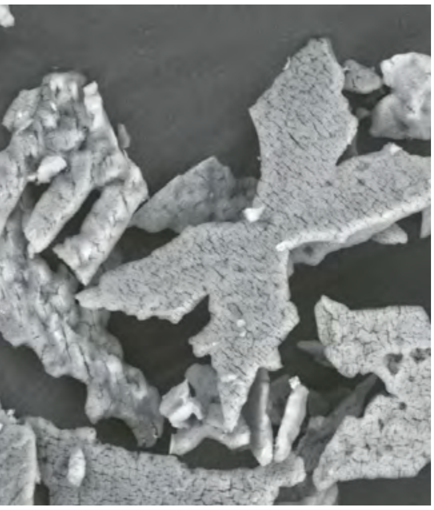
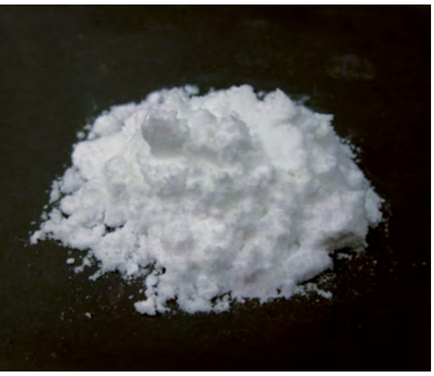
Desalination





top:
Recovered struvite crystals under scanning electron microscope.

bottom:
Recovered struvite from wastewater that can be used directly as a slow releasing fertilizer.

Inorganic salts occur, for example, in the extraction and processing of ores, in electroplating and in the production of fertilizers. Organic acids and their salts are formed during biological wastewater purification. Since the concentration of salts rises in process wastewater due to continuous recirculation, they have to be removed before discharge. If salts are recovered in a sufficiently pure form they can be recycled or sold directly.

While distillation, nanofiltration and reverse osmosis evaporate the complete water volume or force it through a membrane, leaving the salts in a concentrated form, ion exchange and electrophoretic (membrane) processes separate the salts from the water stream. Therefore, the latter processes are particularly energy efficient in certain cases. In electrophoretic membrane processes, charged particles from an aqueous solution are transported in an electric field through ion exchange membranes or are temporarily stored in three-dimensional electrodes. These separation processes can be integrated cost-effectively in the process chain of wastewater treatment yielding recycled salt.

In many cases, a first cost estimation, which we can prepare based on water analysis data, manufacturer price information and simulation results, is already very helpful for our customers. Our scientific consulting services are open to all technologies and independent of manufacturers. Therefore, we will select and optimize the technical solution in the best interest of our customers.

Electrodialysis

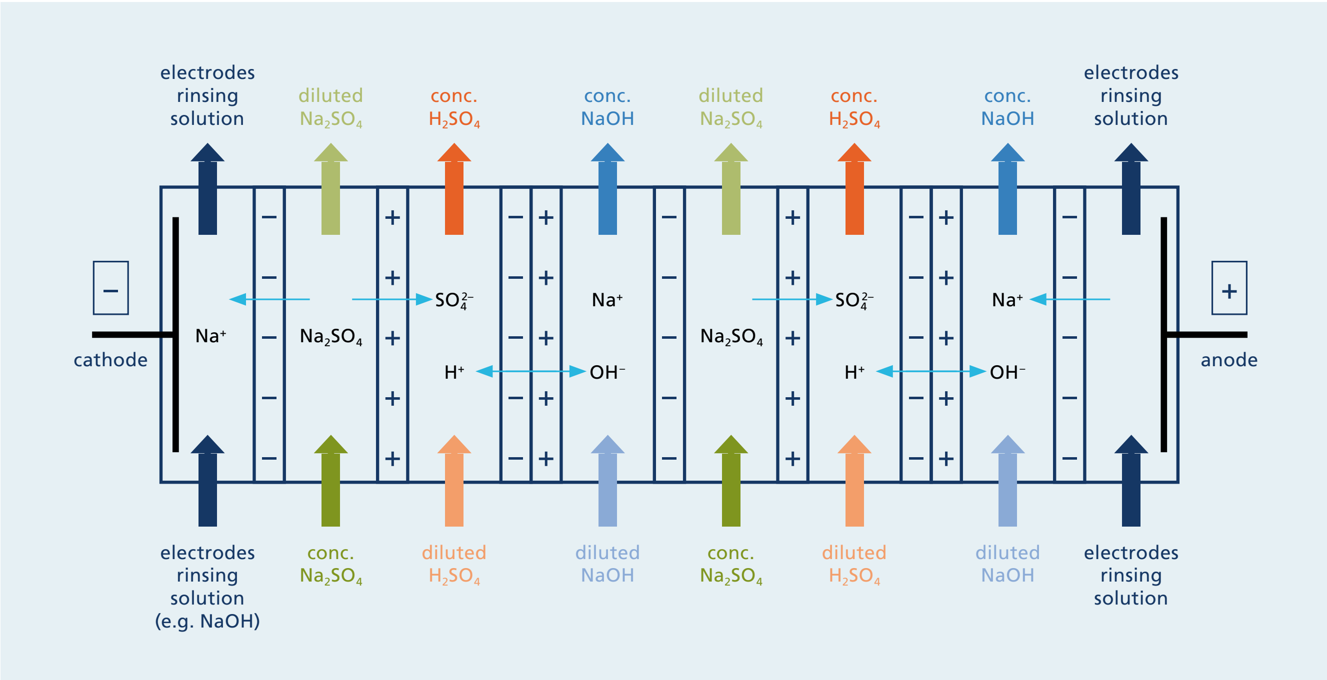
Electrodialysis is a process for separating charged from uncharged substances and is therefore suitable for separating and concentrating salts, acids or bases from (waste)water streams. In addition, salts can be converted into their corresponding acids and bases. The necessary separation of ions is driven by an electric field applied via an anode and a cathode as well as by sequential ion exchange membranes.

In many types of industrial production, it is necessary to add acids and bases to aqueous processes. However, this increases the salt concentration and the conductivity. The recirculation of the water is limited as a result of this accumulation. Additionally, the acids and bases are themselves lost for the process.

Using electrodialysis, salts, acids and bases can be recovered and reused as well as the process water.

Capacitive deionization

Another process for the separation of ions from an aqueous solution is capacitive deionization. Here the ions to be separated are stored in adsorber-like electrodes and released in a concentrate during a subsequent regeneration phase. In this process, no electrode reactions such as hydrogen and oxygen evolution take place. The process requires only low cell voltages of less than 2 V and is particularly energy-efficient for the desalination of low to moderately concentrated solutions.



Schematic design of an electrodialysis module for the extraction of acid and brine of a salt solution.

Recovery of phosphate salts by electrochemical precipitation (struvite, K-struvite)

Besides organic substances, wastewater also contains large amounts of nutrients such as nitrogen, phosphorus, magnesium or potassium. Great efforts and in some cases huge amounts of energy are being put into eliminating nutrients from wastewater by means of nitrification, denitrification and/or biological and chemical phosphorus elimination, to prevent them from entering surface waters and causing eutrophication. At the same time, the worldwide demand for food and consequently the need for nutrients for the production of fertilizers is increasing continuously.

For this purpose, IGB researchers have developed and patented an electrochemical process in which nitrogen and phosphorus from municipal and industrial wastewaters pass a magnesium electrode and are precipitated as magnesium-ammonium-phosphate (struvite). Using this ePhos® process the phosphorus concentrations in the effluent of a biological wastewater treatment stage were reduced by 99.7 percent to below 2 mg/L. The recovered product (struvite) can be used directly in agriculture as a slow release high-quality fertilizer.

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Thermal processes

Evaporation through pressure reduction.

Thermal water treatment processes are today widely used in many branches of industry. Besides simple heating these processes include, for example, distillation, sterilization and rectification (thermal material separation). One advantage of these methods is that the technologies are often relatively simple and robustly designed. Thermal energy supply can generally be achieved without great expense by means of direct firing, process vapor or electric heating. On the other hand, thermal treatment methods are energy-intensive. New technical solutions are necessary to ensure a responsible use of energy resources and to offset the increasing cost pressure.

Fraunhofer IGB has set itself the objective – by developing innovative concepts as well as optimizing and combining various methods – of realizing efficient and inexpensive thermal treatment methods in order to be able to use waste heat or to apply thermal solar technology. The concentration of industrial wastewater and the recovery of solvents are examples of applications that are being worked on at Fraunhofer IGB.

Vacuum evaporation to reduce volume

Many small and medium-sized industrial firms produce highly polluted wastewater that may not be discharged into the municipal sewage system. Some of the contaminants are very complex and difficult to break down or remove (heavy metals, cyanide salts, solvents, complex chemical compounds) even by AOP processes. This liquid waste has to be disposed of externally as special waste often to be incinerated thermally at great expense. Since the disposal costs are calculated on the basis of the volume of waste, the percentage of water is of decisive importance.

In this case, vacuum evaporation for the purpose of concentration of the pollutants offers significant potential for savings – by efficient reduction of the wastewater volume. During vacuum evaporation contaminating substances, for example solvents, become volatile. These substances can be recovered by means of a fractionating distillation. The principle of this thermal separation process is to remove the water and other volatile components by means of evaporation and condensation – at the same time retaining the residual wastewater contents. The process developed at the IGB is very simple and robust in design, can be operated with low-pressure differences and waste heat and dispenses with costly components.

Concentration in the disposal tank

In cooperation with a partner from industry Fraunhofer IGB has investigated this principle of evaporation under vacuum for various types of wastewater from the electroplating industry, from colorant production and from the cleaning of printing cylinders and has implemented it in a mobile prototype plant. The innovative plant design permits the evaporation of the wastewater in an ordinary disposal tank and thus minimizes the expenditure for decanting and cleaning work. As a result of the vacuum-reduced boiling temperature, heat flows from a temperature of approx. 50 – 60°C and also other low-temperature waste heat or solar heat can be used for this process. The energy set free in the condensation of the vapor can then be used, for example, to preheat the wastewater or various process flows in the production operations. In many cases the water removed in this process can be reutilized for production or also for rinsing purposes.

Separation of multicomponent systems by batch distillation

Distillation is the most important process for separating homogeneous liquid mixtures. Batch operated units allow distillation and rectification of different products or multiple mixtures in only one unit. Batch distillation is usually used to separate rather small volumes, but high value-added products. The challenge here is to find the best possible process control, for example to increase productivity or improve product purity.

Fraunhofer IGB develops innovative concepts for the integration of batch distillation plants into existing processes. With the help of complex simulation tools and an automated laboratory plant, we optimize different operation management concepts to achieve targeted product quality while reducing energy consumption.

The technology is frequently used in the pharmaceutical industry for solvent recovery or purification of valuable volatile substances. It is also suitable for use in wastewater treatment plants when smaller quantities of a valuable substance are to be recovered.

top:
Multiple-effect evaporator.

bottom:
Separated fractions with Batch-Distillation.

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Combination of processes and system integration

In the treatment and recirculation of process water, it is necessary to distinguish between the separation of substances, for example the extraction or recovery of materials, and the degradation of pollutants. Thus in many applications processing has to be carried out in at least two process stages.

The growing necessity for conserving resources means that the separation of substances in a value preserving and selective way, is becoming ever more important. Especially in the case of typical industrial wastewaters with a complex composition, efficient separation of substances is frequently not possible with just one single process stage.

We support our customers in combining and integrating various processes to create efficient, well-matched solutions.

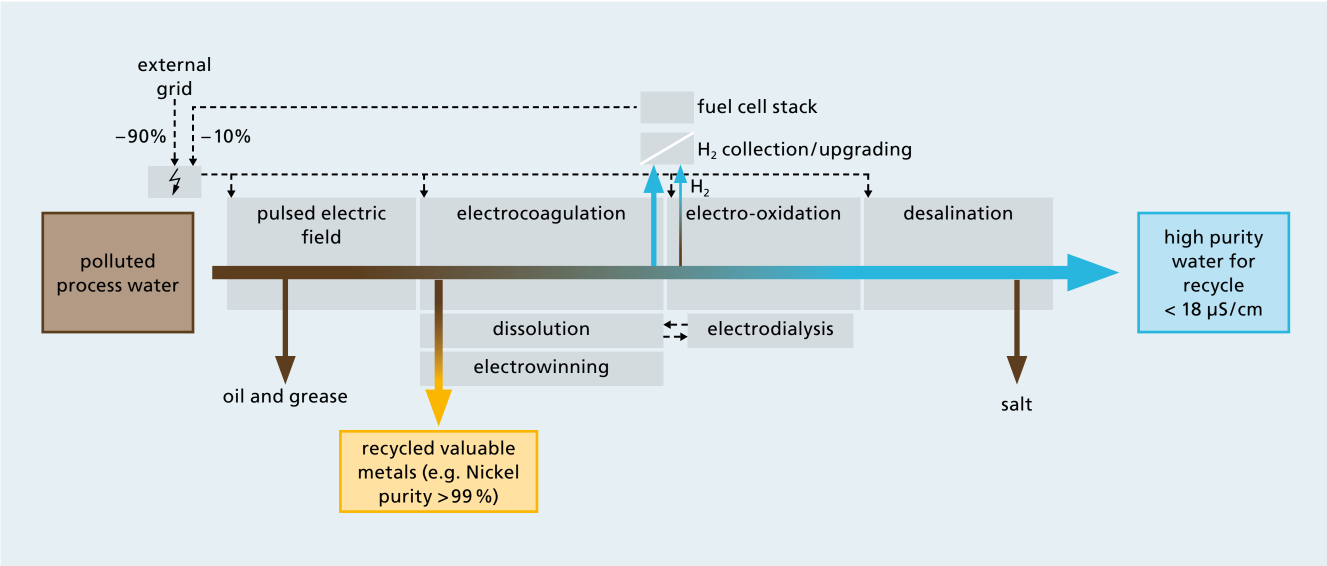
Our unique selling point is the combination of knowledge of biological, chemical and physical fundamentals with detailed knowledge of individual subprocesses and their automation, as well as many years of process engineering expertise from laboratory to pilot scale.

Present in many networks, we also help shape technology strategies. We contribute to the transformation of the global energy supply and a circular industrial value chain as well as to regulatory guidelines.

Depending on your needs, specific expertise is available. You will benefit from our previous experience. Further special competences and technologies can, if necessary, be made available through our network with other research establishments and industrial partners.

left:
Process integration.

right:
Recyclable fractions are recovered from wastewater.



Case study

Efficient purification of process water from the metal processing industry
In the EU-funded project "ECOWAMA" Fraunhofer IGB has developed – together with a European project consortium – a multistage process for purification of process water from the metal and plastics processing industries. These waters streams are rich in organic load such as oils and fats, but also in salts and metals such as nickel, copper, zinc and precious metals. The aim of the electrophysical and electrochemical treatment of this process water with various harmonized processes is the recovery of pure recyclable materials, in particular the metals, as well as generation of high-purity water, for reutilization in the production process. At the same time the hydrogen generated in the process can be reused in the plants' electrical energy supply.

To purify the wastewater, electrophysical and electrochemical processes are favored because in this way the addition of chemicals can be prevented. In a first step oils and fats are separated using the method of pulsed electrocoalescence. Finely dispersed oil droplets move in an electrical field under the influence of their surface charge and flow together to form larger oil drops that can be separated mechanically. Particulate contaminants are separated in a subsequent step by means of electrocoagulation. The iron electrodes used here release iron ions into the water that react to produce iron hydroxide flocs. The metals are precipitated with these flocs, dissolved by electrodialysis again, and then recovered in elemental form. In a third electrochemical cell, dissolved organic components are degraded by means of electro-oxidative processes, for example using a diamond electrode. Finally a fourth stage also removes dissolved salts by means of capacitive deionization, by concentrating cations and anions on the correspondingly charged electrodes and then separating them. The hydrogen generated as a by-product from the electrolysis of the water in the electrocoagulation and electro-oxidation process is returned, purified and, by means of a fuel cell, used to supply energy for the system.

Recovery of metals.

Info

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Range of services

The Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB offers scientific consulting, analytical services and treatment trials in the field of water treatment. Our excellent infrastructure insures prompt results and our long-term experts deliver an integrated analysis. We are also happy to offer studies on the adaptation of standard processes to varying requirements and expert support during piloting and operation. From confidential contract research to large-scale research projects involving international research partners and companies, cooperation with Fraunhofer will fit your need.

Services at a glance

Analytics, proof-of-concept and feasibility studies

- Comprehensive, state-of-the-art analytics for characterizing process water
- Microbiological quality assessment of water
- Proof-of-concept studies of biological (aerobic, anaerobic), mechanical, electrolytic and oxidative processes as well as membrane methods of water treatment
- Market and technology studies, feasibility studies for material and energy use and purification of process water

Process development and plant design

- Proof-of-concept laboratory demonstration
- Design parameters
- Cost effectiveness
- Planning of technical pilot plant
- Application-oriented optimization
- Adapted concepts for water management
- Recovery of resources
- Development of reactor systems in modular design
- Modeling and simulation
- System analysis and optimization
- Integration of new process steps into existing production and treatment chains
- Process control with full data sovereignty (data storage with worldwide access without significant costs)
- Real-time and predictive control systems
- Integration of plant technology without an IoT interface into the Internet of Things

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We combine biology and engineering

The Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB develops and optimizes processes, technologies, and products for health, sustainable chemistry, and the environment. For this, we rely on the combination of biological and process engineering competencies in order to provide solutions for individualized medicine, a sustainable bioeconomy and climate-neutral as well as resource-efficient circular economy. We offer our customers research and development services ranging from feasibility studies to implementing new processes in industrial practice, accompanied by a wide range of analysis and testing services. Our strengths are offering complete solutions from the laboratory to pilot scale applications.

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