# 7 WATER TREATMENT

## INTRODUCTION



## MECHANICAL PROCESSES



## BIOLOGICAL PROCESSES



## PHYSICAL / CHEMICAL PROCESSES



## COMBINED PROCESSES




### Unit operations in water treatment

*GUNT offers a complete range of units to learn the unit operations involved in water treatment.*

*Our units make it easier to understand the complex theoretical principles on which the processes are based. The use of mainly transparent materials also enables the processes to be observed. In many cases, our products feature data acquisition software to support effective learning.*

***Please note:***

*Your laboratory facilities must be suitable for operation of the units. Depending on the specific process and the materials used, sealed floors, drains, water and/or compressed air connections, ventilators, special foundations, secure material storage facilities etc. may be required.*

*To evaluate many of the experiments you will need professional analysis systems beyond the scope of the training system packages supplied by GUNT.*

*Please contact us. We will be happy to give advise.*

2E

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# UNIT OPERATIONS IN WATER TREATMENT

## What is water treatment?

Water is changed in its characteristics through domestic use or industrial processes. Used water (wastewater) can't be discharged directly to a watercourse. Wastewater must first be treated so that it no longer poses a hazard to the environment. If organically polluted wastewater enters a watercourse, microorganisms will degrade the organic matter, consuming large amounts of oxygen. This may reduce the oxygen level enough to kill fish.

Water treatment can also be used to make water usable for a specific purpose. Examples of this are the production of drinking water or process water in industry.

## What unit operations are employed in water treatment?

There are a number of unit operations for water treatment. The choice of unit operations depends primarily on the substances needing to be removed.

The key unit operations can be classified accordingly as follows:

| Undissolved Substances (Solids)<br>Organic<br>Inorganic | Dissolved Substances | | |
|---|---|---|---|
| | Organic Substances | | Inorganic Substances |
| | Biodegradable | Non-Biodegradable | |
| Mechanical Processes | Biological Processes | Physical/Chemical Processes | |
| ■ Flotation<br>■ Sedimentation<br>■ Filtration | ■ Aerobic Processes<br>■ Anaerobic Processes | ■ Adsorption<br>■ Membrane Separation Processes<br>■ Ion Exchange<br>■ Precipitation / Flocculation<br>■ Chemical Oxidation | |

Removal of undissolved substances (solids) is effected by mechanical processes. Dissolved substances can be removed by either biological or physical/chemical processes.

The aim of biological processes is to remove organic, biodegradable substances. Microorganisms use such substances as a source of nutrition, thereby degrading them. If this process takes place in the presence of dissolved oxygen, they are termed aerobic. They include the activated sludge process and biofilm process. Their main field of application is in the treatment of domestic wastewater by wastewater treatment plants. By contrast, anaerobic processes exclude oxygen. Anaerobic processes are used in the treatment of heavily organically polluted wastewater e.g. from industries like food processing and paper manufacturing.

Non-biodegradable organic and inorganic substances can be removed by means of physical/chemical processes. Examples of this are water softening by ion exchange and the adsorption of chlorinated hydrocarbons on activated carbon.

| | The unit operations... | | ...and the appropriate GUNT unit |
|---|---|---|---|
| Mechanical Processes | Flotation | ▶ | CE 587 *Dissolved Air Flotation* |
| | Sedimentation | ▶ | HM 142 *Separation in Sedimentation Tanks* |
| | Filtration | ▶ | CE 579 *Depth Filtration* |
| Biological Processes | Aerobic Processes | ▶<br>▶ | CE 701 *Biofilm Process*<br>CE 705 *Activated Sludge Process* |
| | Anaerobic Processes | ▶ | CE 702 *Anaerobic Water Treatment* |
| Physical/Chemical Processes | Adsorption | ▶ | CE 583 *Adsorption* |
| | Membrane Separation Processes | ▶ | CE 530 *Reverse Osmosis* |
| | Ion Exchange | ▶ | CE 300 *Ion Exchange* |
| | Precipitation / Flocculation | ▶ | CE 586 *Precipitation and Flocculation* |
| | Chemical Oxidation | ▶ | CE 584 *Advanced Oxidation* |

| Combined unit operations... | | ...and the appropriate GUNT unit |
|---|---|---|
| Filtration<br>Adsorption<br>Ion Exchange | ▶ | CE 581 *Water Treatment Plant 1* |
| Filtration<br>Ion Exchange | ▶ | CE 582 *Water Treatment Plant 2* |

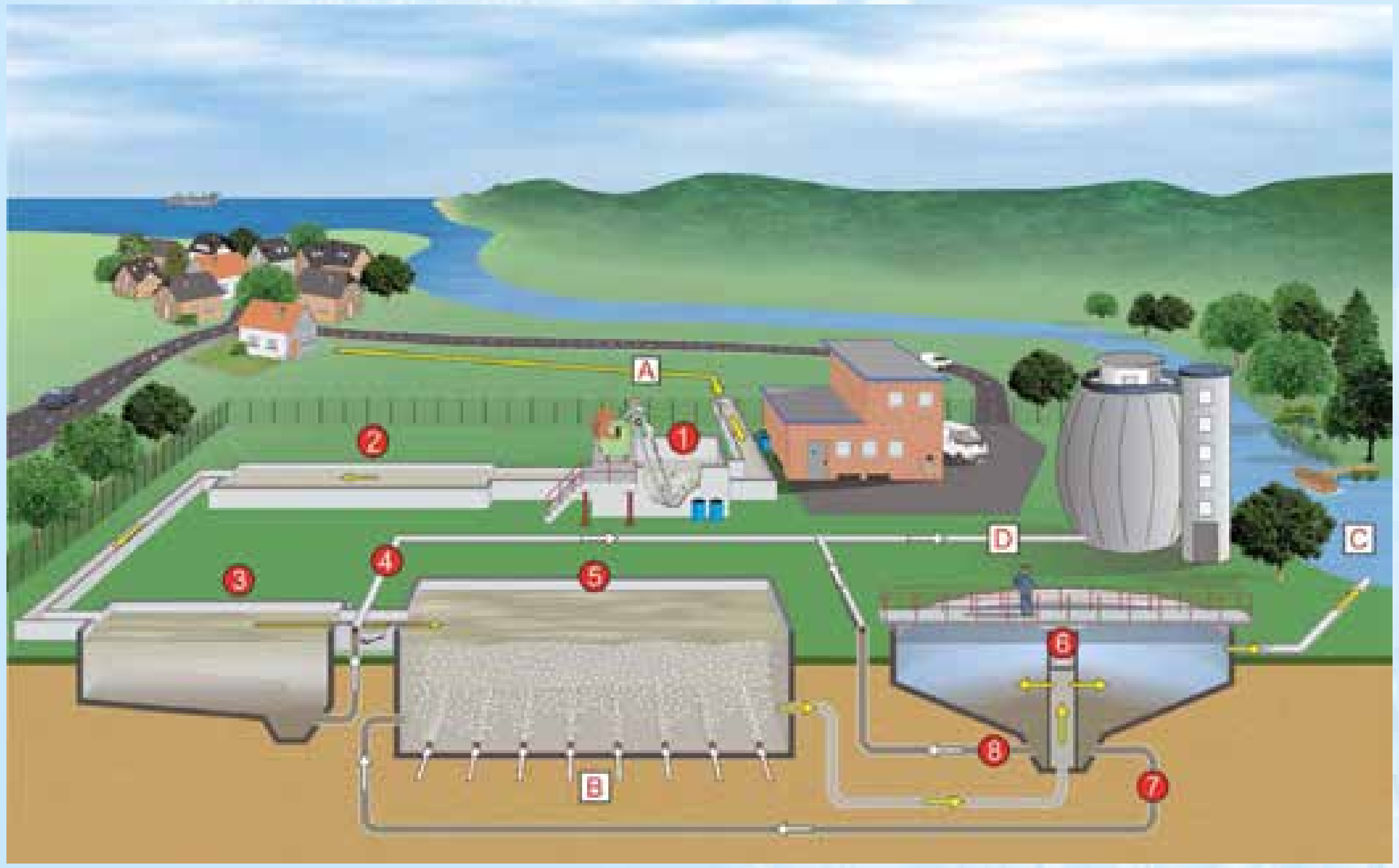
BASIC KNOWLEDGE

# THE WASTEWATER TREATMENT PLANT

In a wastewater treatment plant, domestic wastewater is treated to enable it to be discharged back into a watercourse. The wastewater produced by private households is polluted largely by dissolved biodegradable substances. A wastewater treatment plant is essentially divided into the following sections:

- mechanical treatment
- biological treatment
- sludge treatment

Depending on the properties of the wastewater and the treated water quality requirements, further steps may be necessary, such as removal of phosphates.




*How a wastewater treatment plant works:*

*Mechanical treatment*
***1** bar screen, **2** grit chamber, **3** primary clarifier, **4** primary sludge*

*Biological treatment*
***5** aeration tank, **6** secondary clarifier, **7** return sludge, **8** surplus sludge*
***A** wastewater, **B** compressed air, **C** receiving water, **D** sewage sludge*

### Mechanical treatment

In the first stage, suspended solids are mechanically removed from the wastewater. Initially, course materials such as pieces of wood, plastic bags and fabric are filtered out using a bar screen. Then the water flows into a grit chamber. In this sedimentation tank, mineral solids such as sand and gravel are separated by sedimentation.
Organic solids have a much lower settling velocity than sand and, consequently, a low velocity sedimentation step is required to separate them. This process stage is termed primary clarification and the solids which separate at this stage are termed primary sludge.

### Biological treatment

Mechanical treatment is followed by biological treatment of the wastewater. The principle of biological treatment is the fact that microorganisms use the organic matter as a source of nutrition. In this way, they degrade the organic matter and remove it from the wastewater. The most frequently used method is the **activated sludge process.** In this process, organic matter is degraded by aerobic micro-organisms. In order to provide them with the necessary oxygen, the wastewater is aerated in the aeration tank. The products of the aerobic metabolism are biomass, water and carbon dioxide. The growing microorganisms form flocs – the so called “activated sludge” – which are continuously removed from the aeration tank together with the wastewater.

The activated sludge is separated, by means of sedimentation in the secondary clarifier. The treated water contains only small amounts of organic matter, and can be safely discharged into watercourse (receiving water).

More biomass is removed from the aeration tank than is produced in the same period of time. In order to balance out this loss of biomass in the aeration tank, part of the sludge separated in the secondary clarifier is returned to the aeration tank as “return sludge”.

### Sludge treatment

The portion of the activated sludge which is not returned is termed “surplus sludge”. Together with the primary sludge from the primary clarification, it forms the sewage sludge. Sewage sludge is a waste product, and is treated by further processes.

## Primary components of a wastewater treatment plant

*Aeration tank*

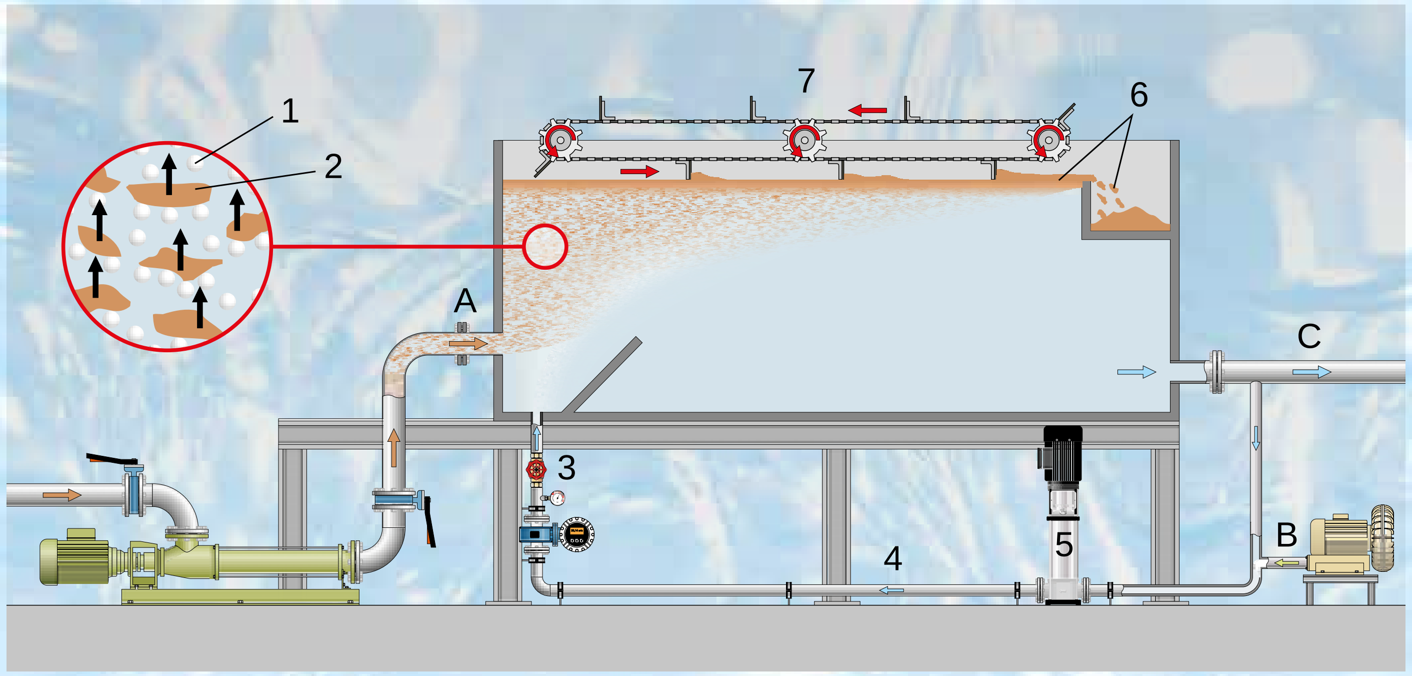
*Secondary clarifier*

BASIC KNOWLEDGE

# FLOTATION

Suspended solids with a density close to or less than that of water can't be removed by sedimentation. Such solids would sediment only very slowly or would remain suspended. The aim of flotation is to increase the buoyancy of the solids. This is done by forming small gas bubbles that attach to the solids. This makes them rise to the surface of the water where they can be skimmed off. It is required that the solids should be hydrophobic. That means that they are more wettable with air than with water. The separated solids are termed float. The key factor influencing flotation is the size of the gas bubbles. The smaller they are the less will be their rate of rise. This is compensated by larger numbers of small gas bubbles attaching to the solids than large bubbles.

The main process used in water treatment is **dissolved air flotation.** Another flotation variant is electro-flotation. The two processes differ primarily in the way the gas bubbles are produced.




*Fundamental principle of dissolved air flotation:*
***1** air bubbles, **2** solids, **3** relief valve, **4** recycle water, **5** pump, **6** float, **7** scraper*
***A** raw water, **B** compressed air, **C** treated water*

### Dissolved air flotation

Dissolved air flotation uses the fact that the solubility of air in water increases as the pressure rises at constant temperature. Some of the treated water is saturated with air under pressure (recycle water). The recycle water is then injected into the flotation tank through a special valve that causes an instantaneous reduction in pressure (relief valve). The sudden relief to atmospheric pressure causes the dissolved air to precipitate as a cloud of small bubbles. A scraper clears the float from the surface of the water. To improve the performance of the process, coagulants and flocculants may be added to the raw water. This helps to optimise the size of the solids so that more air bubbles can be attached to the solids.

### Application examples

*Industrial water treatment*

- paper industry
- food industry
- oil refineries
- plastics industry

*Domestic water treatment*

- secondary clarification, if the activated sludge sediments very slow
- supplementing or replacing primary clarification

BASIC KNOWLEDGE

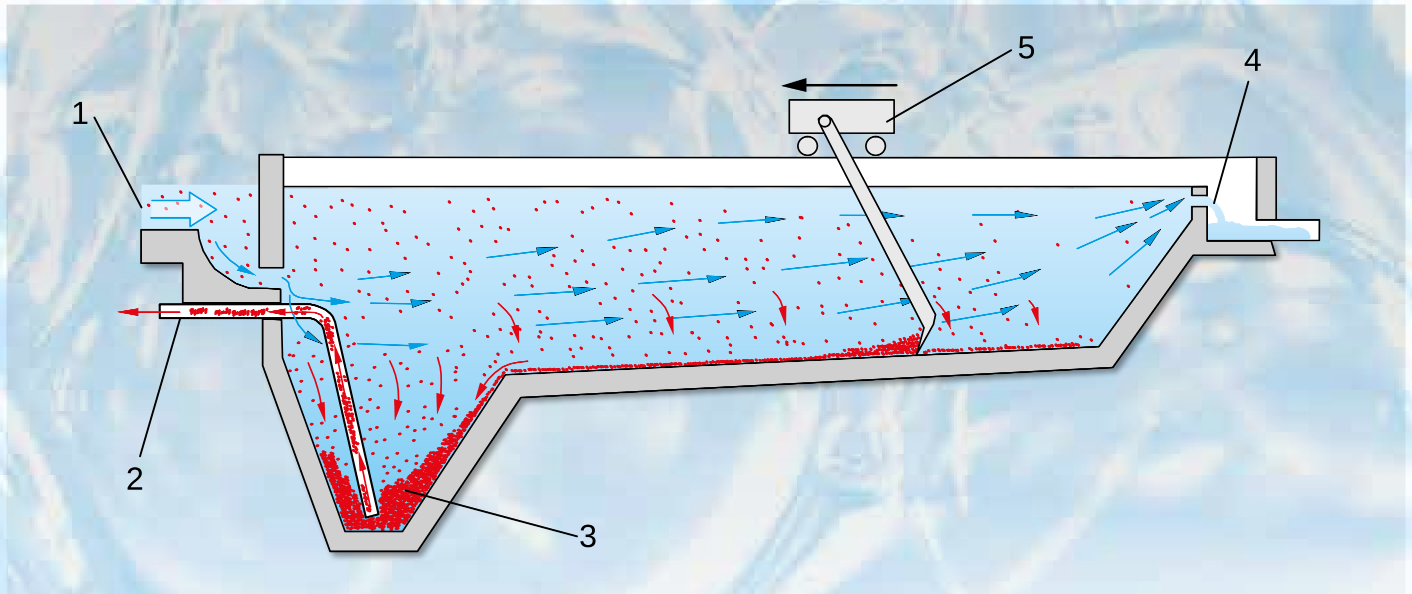
# SEDIMENTATION

Mechanical process engineering in many cases utilises gravity to separate different phases. Gravity can be used to separate a solid phase off from a fluid. When solid particles are suspended in a fluid, gravity causes them to sink. For this to happen, the density of the solid must be greater than that of the fluid. The process is termed sedimentation. Fluid is the umbrella term for gases and liquids. It is used because most physical laws apply equally to both.

In terms of the **separation of solids from gases** the phrase "dust separation" is also used. The solid phase may, on the one hand, be a usable material, on the other hand, it may be an unwanted material (gas purification). In gravity separators the gas flow is routed at slower velocity through a separator channel. On their way, the particles sink and are collected.

In practice the **separation of solid/ liquid mixtures** (suspensions) takes place in sedimentation tanks through which the suspension continuously flows. The shape of the base may be rectangular or circular.

In rectangular tanks the suspension flows in on one side and flows out over the rim on the opposite side. On the way, the solid particles sink to the bottom of the tank. The tank floor is positioned at an angle to aid discharge of the solid material. There are also devices by which the settled solid (sludge) can be cleared from the tank bottom. Sedimentation tanks are mostly used in water treatment.




*Sedimentation tank:*
***1** wastewater inlet, **2** sludge extractor, **3** sludge hopper, **4** clean water overflow*
***5** cart for sludge clearing*

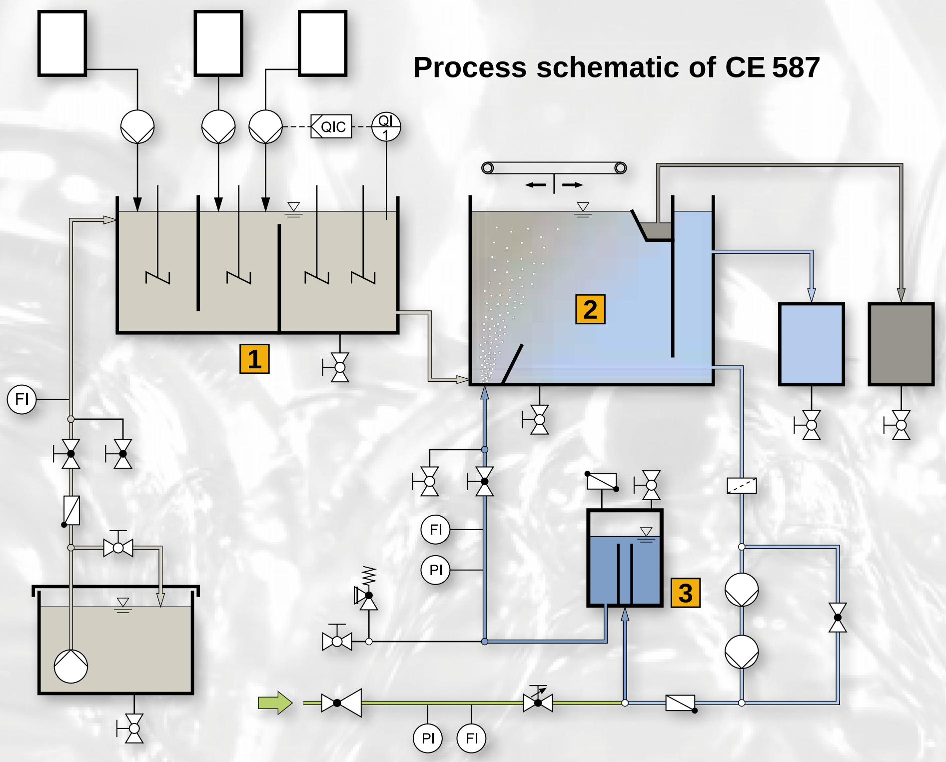
The *settling velocity* of the particles is the key variable in the design of sedimentation tanks and separator channels. It is directly related to the particle size, the particle shape (flow resistance) and the difference in density between the fluid and solid. If the particles in a suspension are very fine, or if the difference in density between the fluid and solid is slight, the settling velocity is very low. A technically useful separation by means of sedimentation is then not possible. Another variable influencing the settling velocity in liquids is the concentration of solid particles. At high concentrations, sedimentation is hindered. As the concentration increases, the so-called cluster settling velocity becomes less than the velocity of the single particles.

# CE 587 DISSOLVED AIR FLOTATION

**The flotation process most frequently used in water treatment is dissolved air flotation. CE 587 enables this process to be demonstrated clearly.**

- continuous and practical process
- conditioning of the raw water by flocculation
- flotation tank with electrically driven scraper
- control of pH value
- high quality instrumentation and control

**Process schematic of CE 587**




1 *Flocculation tank with stirring machines*

2 *Flotation tank with scraper*

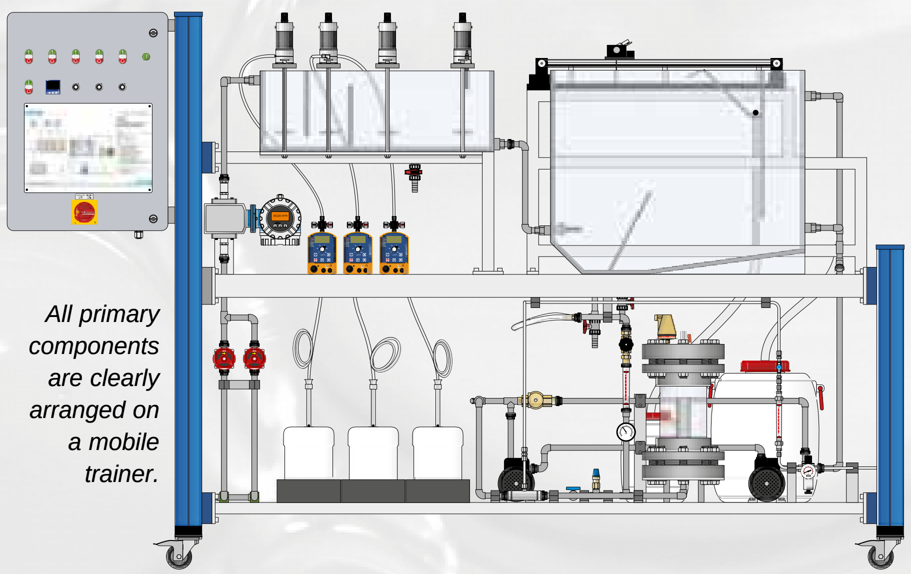
3 *Components to generate the bubbles*

*The electrically driven scraper clears the float from the surface of the water.*

You can find an interesting film of CE 587 on our 2E website **www.gunt2E.de**

*The recycle water enters the flotation tank: The sudden relief to atmospheric pressure causes the dissolved air to precipitate as a cloud of small bubbles.*

*Use of high quality components: Magneto-inductive flow rate sensor and metering pumps*



*All primary components are clearly arranged on a mobile trainer.*

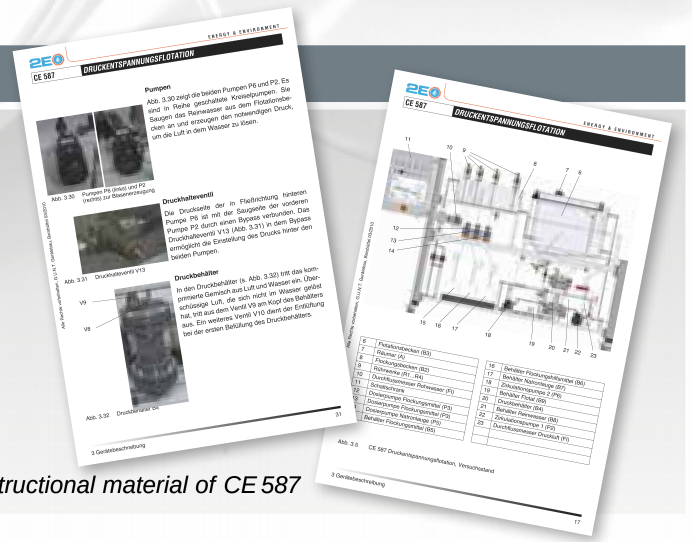
University of Applied Sciences in Münster (Germany)

**Be our next satisfied customer.**

## THE INSTRUCTIONAL MATERIAL

We have compiled a comprehensive range of instructional material for the CE 587 which will greatly assist you in getting to know the system and in preparing your lessons and laboratory experiments and exercises.

Materials delivered as paper printouts in a folder and additionally as PDF files on a CD.



*Instructional material of CE 587*

## CE 587 Dissolved Air Flotation

The illustration shows: Supply unit (left) and trainer (right)

*** Demonstration of dissolved air flotation**

*** Flocculation to condition the raw water**

*** Scraper to remove the float**

### Technical Description

CE 587 demonstrates the clarification of raw water containing solids using the dissolved air flotation process.

First, a suspension (raw water) is prepared in a tank. From here the raw water flows into a flocculation tank divided into three chambers. By adding a coagulant in the first chamber the repulsive forces between the solid particles are cancelled out. The solid particles combine into flocs. To create larger flocs a flocculant is added in the second chamber. The coagulant causes a drop of the pH value. By adding caustic soda the pH value of the water can be increased again. In the following third chamber of the flocculation tank low flow velocities are present to prevent any turbulence. Turbulence would impede the formation of flocs.

From the flocculation tank the raw water enters the flotation tank. A part of the treated water is removed from the flotation tank and saturated with air under pressure. This water (recycle water) enters via a relief valve so that it suddenly expands to atmospheric pressure. This creates minute air bubbles which attach to the flocs. This makes the flocs rise to the surface of the water. Using a scraper the floating flocs (float) can be moved into a collection channel.

Flow rates, pressures and pH values are masured. The pH value can additionally be controlled. The pressure of the recycle water can be adjusted.

Trivalent metallic salts are usually well suited as coagulants. Common flocculants are organic polymers. Powdered activated carbon can be used to produce the raw water.

The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

### Learning Objectives / Experiments

- functional principle of dissolved air flotation
- creation of a stable operating state
- effects of various parameters
  - * coagulant concentration
  - * flocculant concentration
- determination of the hydraulic loading rate (rising velocity)

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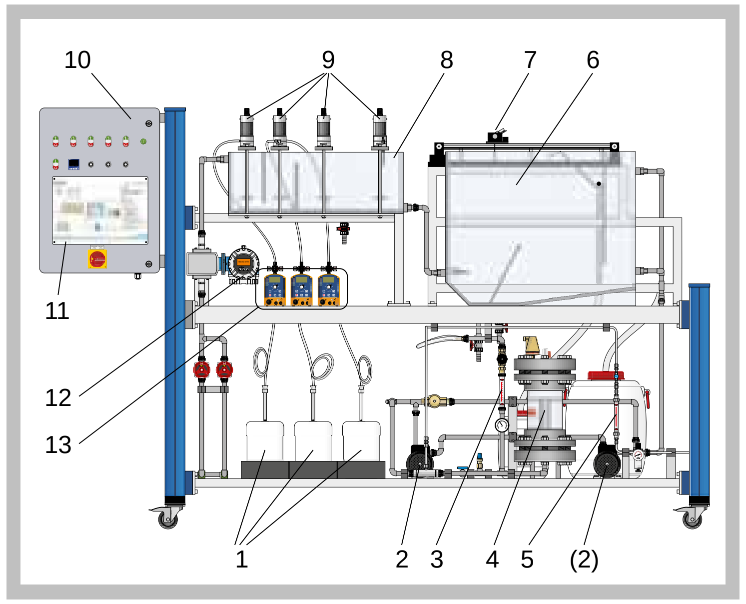
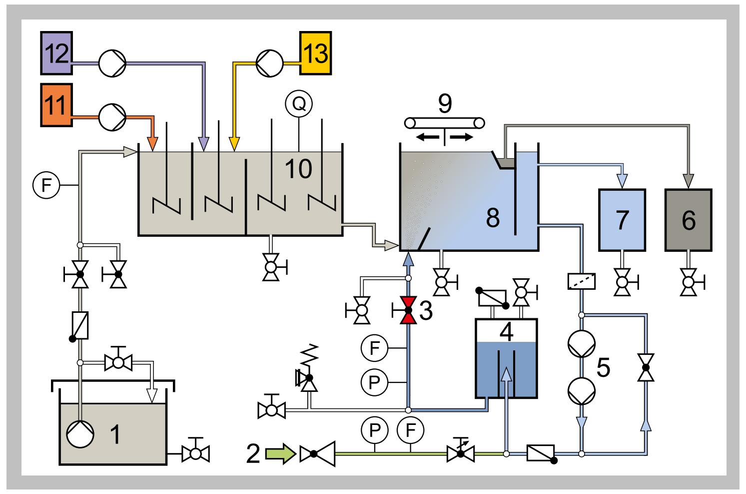
## CE 587 Dissolved Air Flotation




1 chemical tanks, 2 circulation pumps, 3 flow meter (recycle water), 4 pressure tank, 5 flow meter (air), 6 flotation tank, 7 scraper, 8 flocculation tank, 9 stirring machines, 10 switch cabinet, 11 process schematic, 12 electromagnetic flow rate sensor (raw water), 13 metering pumps




1 raw water, 2 compressed air, 3 relief valve, 4 pressure tank, 5 circulation pumps, 6 sludge (float), 7 treated water, 8 flotation tank, 9 scraper, 10 flocculation tank, 11 coagulant, 12 flocculant, 13 caustic soda; F flow rate, P pressure, Q pH value

### Specification

[1] removal of solids from raw water using dissolved air flotation
[2] conditioning of the raw water by flocculation
[3] 3 Metering pumps for chemicals
[4] flocculation tank with 3 chambers and 4 stirring machines
[5] flotation tank with electrically driven scraper
[6] pressure tank and 2 circulation pumps
[7] relief valve
[8] separate supply unit with tank and pump for raw water
[9] electromagnetic flow rate sensor
[10] measurement of flow rate, pressure and pH value
[11] control of the pH value

### Technical Data

Tanks
- flotation tank: 150L
- flocculation tank: 45L
- raw water: 300L
- treated water: 80L
- sludge (float): 15L

Raw water pump
- max. flow rate: 135L/min
- max. head: 7,0m

Circulation pumps
- max. flow rate: each 18L/min
- max. head: each 50m

Metering pumps
- max. flow rate: each 2,1L/h

Stirring machines
- max speed: each 600min$^{-1}$

Measuring ranges
- flow rate (raw water): 0...550L/h
- flow rate (recycle water): 30...320L/h
- flow rate (air): 20...360L/h
- pH value: 1...14
- pressure (recycle water): 0...6bar

### Dimensions and Weight

LxWxH: 1560x790x1150mm (supply unit)
LxWxH: 3100x790x1950mm (trainer)
Total weight: approx. 550kg

### Required for Operation

230V, 50/60Hz, 1 phase or 120V, 60Hz, 1 phase
Water connection, drainage, compressed air, caustic soda, iron(III) sulfate, flocculant, powdered activated carbon (recommendation)

### Scope of Delivery

1 supply unit
1 trainer
1 set of hoses
1 set of instructional material

### Order Details

083.58700 CE 587 Dissolved Air Flotation

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# HM 142 Separation in Sedimentation Tanks

*** Solid/liquid separation in a sedimentation tank**

*** Visualisation of flow conditions**

## Technical Description

In sedimentation tanks, solids are separated out of suspensions under the influence of gravity. For this, the density of the solid particles must be greater than that of the liquid.

With HM 142, the factors influencing the separation process in sedimentation tanks can be investigated. First a suspension of water and precipitated calcium carbonate is prepared in a tank. A pump delivers the suspension to the sedimentation tank. In the inlet area of the sedimentation tank the suspension intermingles with fresh water. The mixture flows over an inlet weir. On their way through the sedimentation tank the solids sink to the bottom. The treated water flows out by way of the weir at the sedimentation tank outlet.

The solid concentrations at the sedimentation tank inlet and outlet are determined by means of two Imhoff cones. The mass separated in the sedimentation tank can be determined from the difference between them. The flow rates of the suspension and the fresh water are adjusted by valves and indicated by flow meters. This enables the mixing ratio - and thus the solid concentration of the mixture - to be adjusted. In order to ensure a uniform mix of the suspension and prevent premature sedimentation, a portion of the suspension is fed back into the suspension tank by way of a bypass. To investigate the flow conditions, ink can be added with a piston burette to the fresh water stream as a tracer substance. The mixed-in volume of ink is entered using keys and indicated on a display. To provide enhanced observation of the flow conditions and settling processes, the sedimentation tank is made of transparent material.

A baffle plate can be positioned in the sedimentation tank to impede the flow. Its horizontal and vertical positioning in the sedimentation tank is adjustable. This enables the flow conditions and the efficiency of the separation process to be influenced.

The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

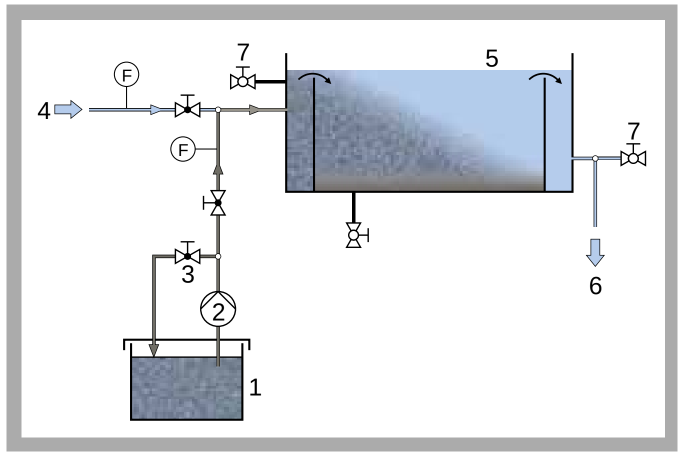
## Learning Objectives / Experiments

- learning the fundamental principle of separation of solids from suspensions in a sedimentation tank
- efficiency of the separation process dependent on
  - * solid concentration of suspension
  - * flow rate
  - * position of baffle plate
- investigation of flow conditions dependent on
  - * flow rate
  - * position of baffle plate



# HM 142 Separation in Sedimentation Tanks


1 suspension flow meter, 2 fresh water flow meter, 3 switch box, 4 bypass valve, 5 suspension pump, 6 suspension tank, 7 storage bin, 8 outlet, 9 sedimentation tank, 10 baffle plate, 11 fresh water/suspension mixing zone




1 suspension tank, 2 pump, 3 bypass valve, 4 fresh water inlet, 5 sedimentation tank, 6 treated water outlet, 7 sampling points; F flow rate

Determination of solid concentrations at sedimentation tank inlet and outlet by Imhoff cones

## Specification

[1] separation of suspensions by sedimentation in transparent sedimentation tank
[2] tank with pump to prepare and deliver a suspension comprising water and precipitated calcium carbonate
[3] bypass to tumble and homogenise the suspension
[4] mixing of the suspension with fresh water in sedimentation tank inlet zone
[5] adjustment of fresh water and suspension flow rate by valves
[6] precise piston burette for metering of ink to visualise flow conditions in the sedimentation tank
[7] influencing of flow conditions in the sedimentation tank with baffle plate that can be positioned
[8] determination of solid concentrations at sedimentation tank inlet and outlet by Imhoff cones

## Technical Data

Sedimentation tank
- LxWxH: 1000x400x230mm
- capacity: approx. 80L
- material: plexiglass

Suspension tank
- capacity: approx. 100L
- material: stainless steel

Pump
- max. flow rate: 75L/min
- max. head: 5m

Piston burette
- metering accuracy: 0,15% of nominal volume
- volume adjustment range: 0...20ml
- resolution: 0,01ml

Imhoff cones
- capacity: each 1000ml

Measuring ranges
- flow rate (fresh water): 60...640L/h
- flow rate (suspension): 0...1,9L/min

## Dimensions and Weight

LxWxH: 1900x670x1590mm
Weight: approx. 190kg

## Required for Operation

230V, 50/60Hz, 1 phase or 120V, 60Hz, 1 phase
Water connection (200...300L/h), drainage

## Scope of Delivery

1 trainer
1 piston burette
2 Imhoff cones
1 packing unit of precipitated calcium carbonate
1L ink
1 set of instructional material

## Order Details

070.14200 HM 142 Separation in Sedimentation Tanks

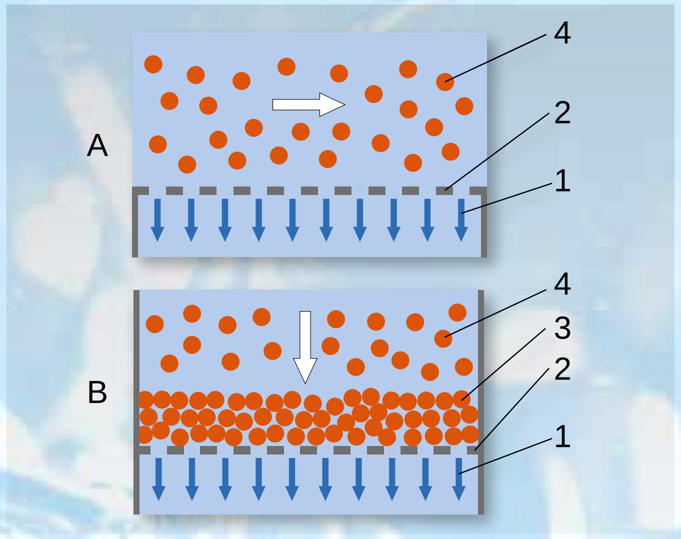
BASIC KNOWLEDGE

# FILTRATION

Filtration is used to remove solids. The fundamental principle is that the solids are captured and retained by a filter medium. The liquid phase of the raw water passes through the filter, and is termed filtrate. A fundamental distinction is made between depth filtration and surface filtration.

**Surface filtration**

Surface filtration is based on a screening effect. The solids do not penetrate the filter, but are held back on its surface. Therefore the pore width of the filter medium must be less than the size of the solid particles. Filter media used may be sieves, cloths, filter paper or membranes. If the flow is directed perpendicular to the surface, the term cake filtration is used. A filter cake builds up on the filter medium over time which reduces the flow rate of the filtrate. This is a disadvantage of this process. This problem is countered in cross-flow filtration by causing the raw water to flow parallel to the surface. Deposits on the filter are then largely removed by the flow. This principle is applied primarily in the membrane separation processes.

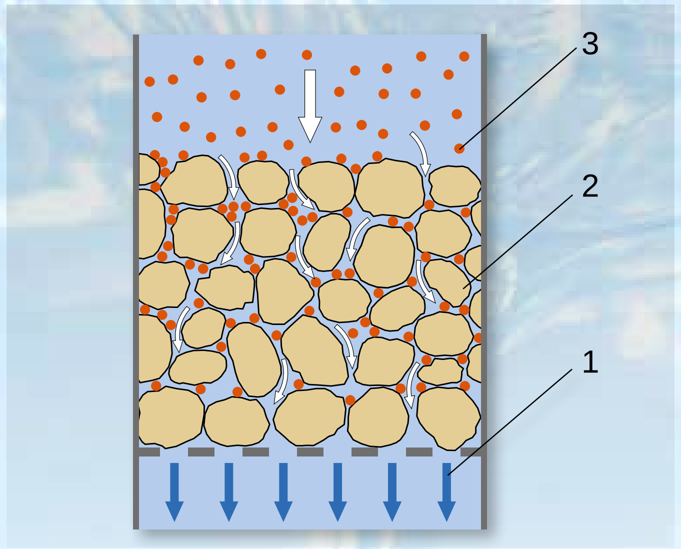



*Surface filtration:*
***A** cross-flow filtration, **B** cake filtration*
***1** treated water (filtrate), **2** filter medium, **3** filter cake*
***4** solids*

**Depth filtration**

In depth filtration, the raw water flows through a bed of granular material (filter bed) such as sand or gravel. As the raw water flows through the interstices between the grains of the filter medium, suspended solids are captured and retained. The treated water passes through the filter bed. Over time, more and more solids collect in the flow channels of the filter bed. This reduces the cross-sectional area of the flow channels increasing the hydraulic resistance of the filter to the flow. This resistance is expressed as a loss of pressure. The flow through the filter decreases, or it can only be maintained by increasing the pressure on the inflow side of the filter. The deposited solids can be removed by backwashing them. Consequently, the pressure loss is reduced by a backwash. This process usually takes place with treated water in the opposite flow direction.

The pressure trend over time in a filter bed can be depicted by filter resistance diagrams – also known as Micheau diagrams.

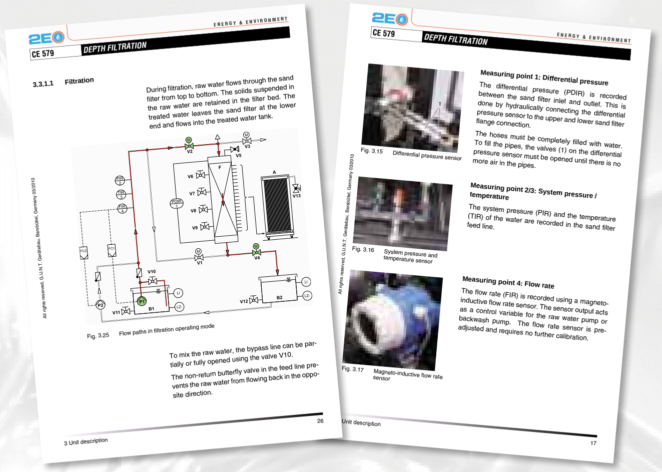



*Depth filtration:*
***1** treated water (filtrate), **2** filter medium, **3** solids*

# CE 579 DEPTH FILTRATION

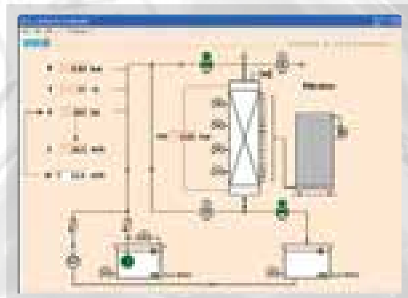
**The ideal way to teach and learn about depth filtration in all its aspects**

- filtration and backwash
- comprehensive range of instrumentation
- manometer panel to measure the pressures in the filter bed
- state-of-the-art software with control functions and data acquisition

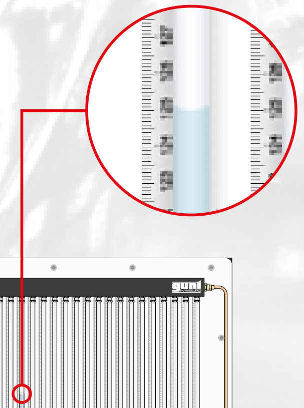


*The well-structured instructional material is delivered as paper printouts in a folder and additionally as PDF files on a CD.*

*Use of high quality components: Magneto-inductive flow rate sensor, backwash pump and ball valves with electric drive*



*GUNT software*



*Manometer panel* *Trainer*

## CE 579 Depth Filtration

The illustration shows: manometer panel (left) and trainer (right)

*** Removal of solids by depth filtration (sand filter)**
*** Pressure loss: plotting of Micheau diagrams**
*** Backwash of sand filters**

### Technical Description

Depth filtration with sand filters is a key unit operation in water treatment. CE 579 enables this process to be demonstrated.

Raw water contaminated with solids is pumped from above into a sand filter. The solids are captured and retained as the raw water flows through the filter bed. The water itself passes through the filter bed and emerges at the bottom end of the sand filter. The treated water (filtrate) flows into a tank. Over time, more and more solids are deposited in the filter bed which increases its flow resistance. This process is detectable by the increasing pressure loss between the sand filter inlet and outlet. The flow through the sand filter decreases. Backwashing with treated water cleans the filter bed and reduces the pressure loss again.

The sand filter is equipped with a differential pressure gauge. There are also several pressure measuring points along the filter bed. The pressures are transmitted to tube manometers via hoses and displayed there as water columns. This can be used to plot Micheau diagrams. The flow rate, temperature, differential pressure and system pressure are measured. The flow velocity in the filter bed (filter velocity) can be adjusted. Samples can be taken at all relevant points.

A software program is provided to control the operating states and measure data. A process schematic shows the current operating states of the individual components and the measured data. E.g. diatomite can be used to produce the raw water.

The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

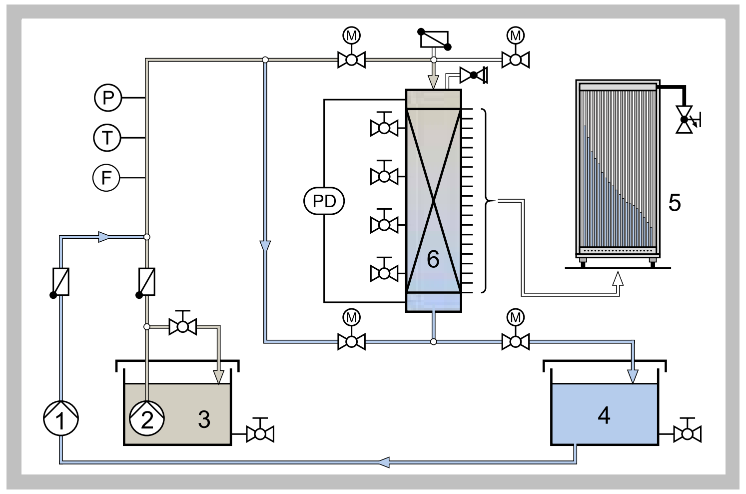
### Learning Objectives / Experiments

- learning the fundamental principle of depth filtration by sand filters
- observation of the pressure conditions in a filter bed
- determination of pressure losses
- plotting of Micheau diagrams
- principle of backwash



## CE 579 Depth Filtration


1 treated water tank, 2 raw water tank, 3 raw water pump, 4 switch cabinet, 5 backwash pump, 6 electromagnetic flow rate sensor, 7 temperature sensor, 8 ball valves with electric drive, 9 bleed valve, 10 sand filter




1 backwash pump, 2 raw water pump, 3 raw water, 4 treated water (filtrate), 5 manometer panel, 6 sand filter; F flow rate, P system pressure, PD differential pressure, T temperature

### Specification

[1] depth filtration with sand filter
[2] sand filter backwash possible
[3] 20 tube manometers to measure the pressures in the filter bed
[4] plotting of Micheau diagrams
[5] raw water and backwash pump
[6] electromagnetic flow rate sensor
[7] 4 ball valves with electric drive
[8] measurement of flow rate, differential pressure, system pressure and temperature
[9] filter velocity adjustable
[10] GUNT software with control functions and data acquisition via USB under Windows Vista or Windows 7

### Technical Data

Sand filter
- outer diameter: 200mm
- inside diameter: 150mm
- height: 1660mm

Raw water pump
- max. flow rate: 13m³/h
- max. head: 10m

Backwash pump
- max. flow rate: 3m³/h
- max. head: 37m

Tanks for raw water and treated water
- capacity: each 180L

Measuring ranges
- flow rate: 0...1300L/h
- tube manometers: 20x 0...1500mmWC
- differential pressure: -1...1bar
- system pressure: 0...4bar
- temperature: 0...100°C
- filter velocity: 0...70m/h

### Dimensions and Weight

LxWxH: 1590x900x2190mm (trainer)
LxWxH: 750x640x1900mm (manometer panel)
Total weight: approx. 250kg

### Required for Operation

230V, 50/60Hz, 1 phase or 230V, 60Hz/CSA, 3 phases
Water connection, drainage

### Scope of Delivery

1 trainer
1 manometer panel
1 set of hoses
1 packing unit of gravel
1 packing unit of diatomite
1 GUNT software CD + USB cable
1 set of instructional material

### Order Details

083.57900 CE 579 Depth Filtration

2E a division of G.U.N.T Gerätebau GmbH, P.O.Box 1125, D-22885 Barsbüttel, t +49 (40)67 08 54-0, f +49 (40)67 08 54-42, E-mail sales@gunt.de
We reserve the right to modify our products without any notifications. Visit our Websites: www.gunt.de | www.gunt2e.de

BASIC KNOWLEDGE

# AEROBIC PROCESSES

Biological processes enable dissolved biodegradable substances (organic matter) to be removed from wastewater. The organic matter provides a nutrient for microorganisms, and is converted under aerobic conditions into biomass, carbon dioxide and water. Aerobic microorganisms need oxygen for respiration.

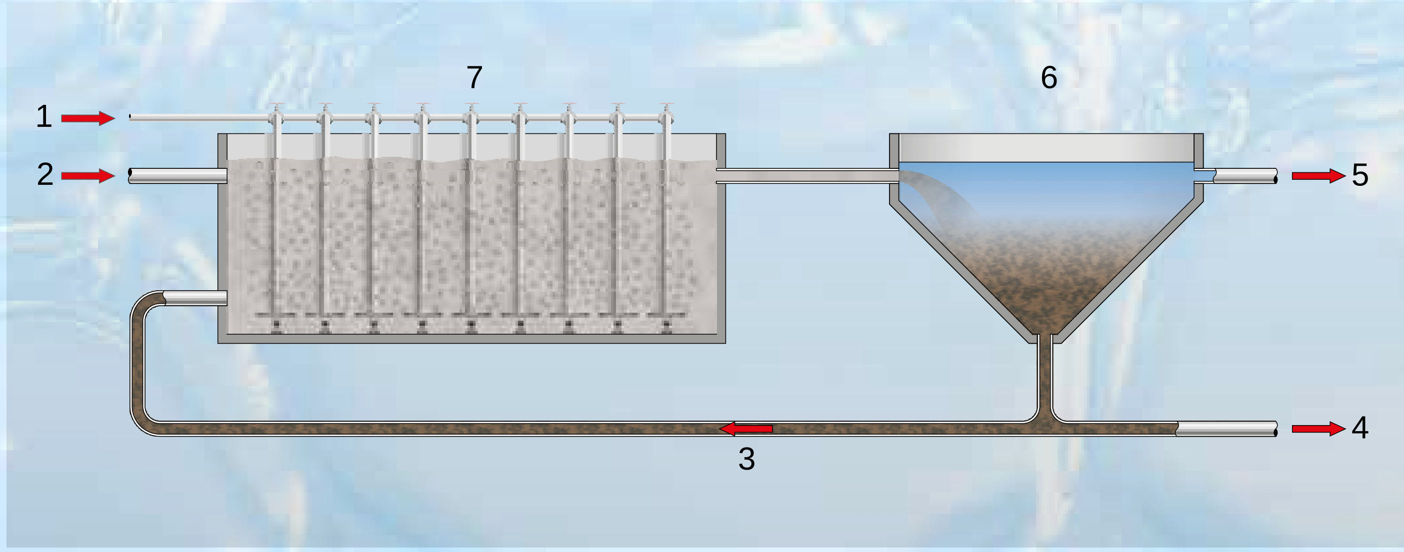
As well as organic matter, nitrogenous compounds such as ammonium and nitrate must usually also be removed from wastewater. Specific microorganisms convert ammonium initially into nitrate (nitrification). Another group of microorganisms then reduces the nitrate to nitrogen gas which escapes to the atmosphere (denitrification).

A distinction is made between biofilm and activated sludge processes.

## Activated sludge process

In this process, the microorganisms are suspended in the wastewater. Aeration of the wastewater in the aeration tank provides the aerobic microorganisms with oxygen. The metabolic process causes them to form into flocs – the so called activated sludge. This is separated from the wastewater by means of sedimentation (secondary clarification). More biomass is removed from the aeration tank than is produced in the same period of time. In order to balance out this loss of biomass in the aeration tank, part of the activated sludge is returned to the aeration tank (return sludge). The portion of the activated sludge which is not returned is termed surplus sludge and is a waste product of the process.

*Activated sludge*



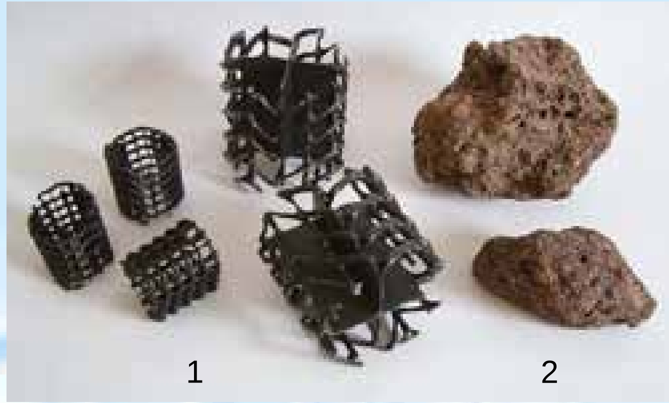

*Fundamental principle of the activated sludge process:*
*__1__ air, __2__ wastewater, __3__ return sludge, __4__ surplus sludge, __5__ treated water, __6__ secondary clarifier (sedimentation)*
*__7__ aeration tank*

## Biofilm processes

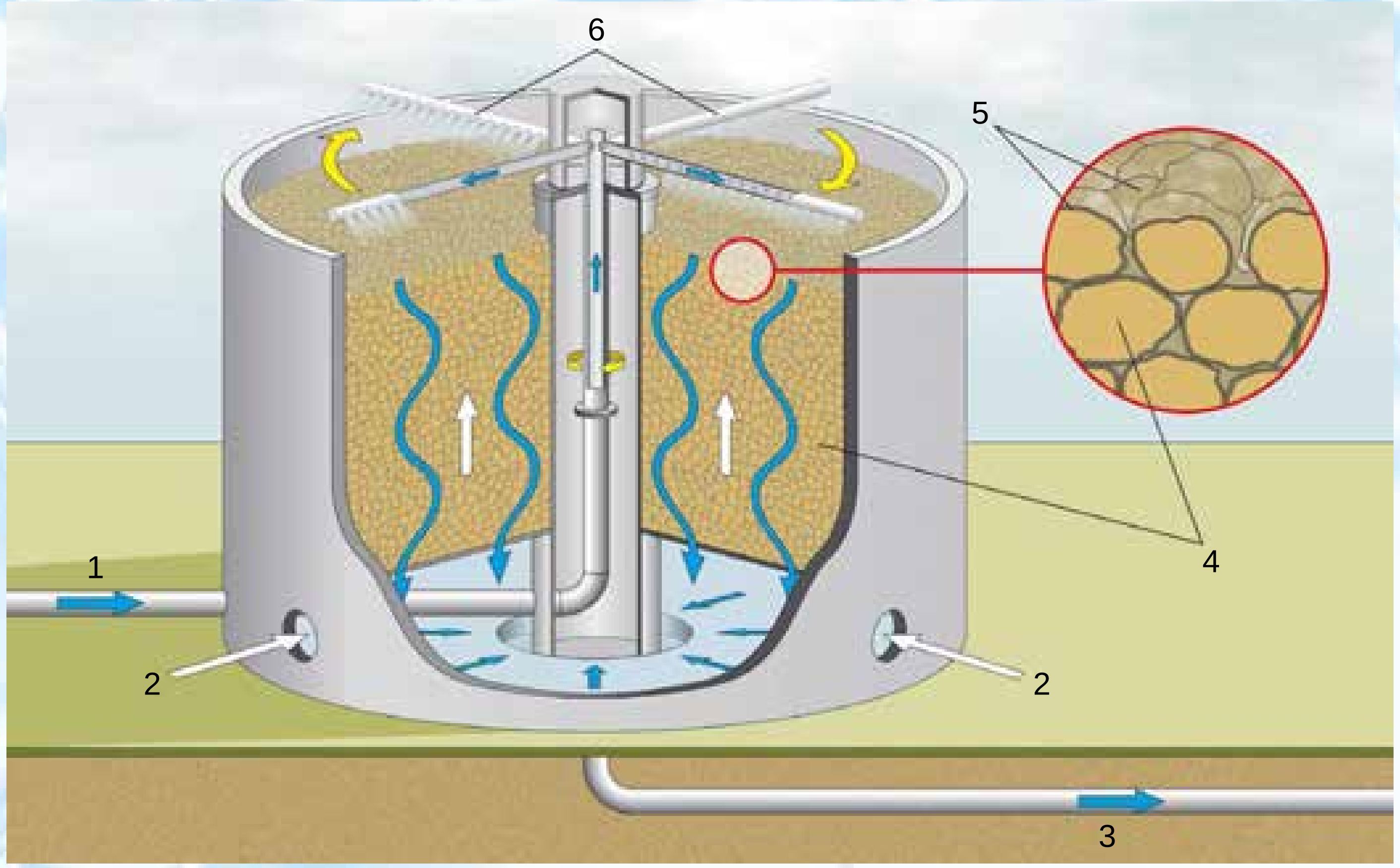
Biofilm processes are based on microorganisms settling on the surfaces of solids. The resulting layer of microorganisms is called a biofilm. The solids used in this process are called carrier material. This means the wastewater must be brought into contact with the biofilm affixed to the carrier material.

The most important version are **trickling filters.** Here the wastewater is trickled over a layer of carrier material (fixed bed) using a rotating distributor. Whilst the wastewater passes through the carrier material it is biologically cleaned by the microorganisms. Aeration of the trickling filter is normally via natural convection. This is based on the temperature difference between the outside air and the inside of the trickling filter.

Carrier materials have high specific surface areas (approx. 200 m²/m³). Carrier materials can be of natural origin (e.g. extrusive rocks) or be artificially produced.




*Carrier materials for biofilms:*
*__1__ artificial carrier material (plastic),*
*__2__ natural carrier material (e.g. extrusive rocks)*




*How a trickling filter works:*
*__1__ wastewater, __2__ aeration by natural convection, __3__ treated water, __4__ carrier material, __5__ biofilm, __6__ distributor*

## CE 701 Biofilm Process

The illustration shows: Supply unit (left) and trainer (right)

*** Aerobic biofilm processes: trickling filter**
*** Practical experiments in laboratory scale**
*** Concentration profiles**

### Technical Description

Fixed biofilm processes are used in the biological treatment of wastewater. Trickling filters are based on these processes.

A pump transports the wastewater from the supply unit to the upper end of the trickling filter. The wastewater drops down on the trickling filter using a rotary distributor. In the trickling filter there is a fixed bed consisting of special carrier material. On this carrier material there is a thin layer of microorganisms (biofilm). While the wastewater trickles through the fixed bed, the microorganisms clean the wastewater by biological processes. The degradation of organic substances preferably takes place in the upper region of the trickling filter. In the lower region on the other hand, the oxidation of ammonium to nitrate (nitrification) is the predominant process. Subsequently, the wastewater flows into a collecting tank. Two pumps deliver a portion of the collected wastewater to the rotary distributor again (recirculation).

In the lower region of the trickling filter there are openings to allow aeration by natural convection. Alternatively, aeration can take place with a compressor.

To produce the biofilm, the trickling filter is first filled with the carrier material, wastewater and activated sludge. The activated sludge continuously discharging from the trickling filter sediments into a secondary clarifier. A pump transports the activated sludge back to the trickling filter. The trickling filter is aerated by a compressor. Over time, microorganisms present in the activated sludge settle on the carrier material, thus producing the biofilm.

The following flow rates are recorded and can be adjusted: wastewater, recirculation, aeration (with compressor). The speed of the rotary distributor can also be adjusted. Sampling points on the trickling filter allow concentration profiles to be recorded.

Activated sludge from a wastewater treatment plant is required for the experiments. To analyse the experiments we recommend analytical equipment for determining the following parameters:
- biochemical or chemical oxygen demand
- ammonium concentration
- nitrate concentration

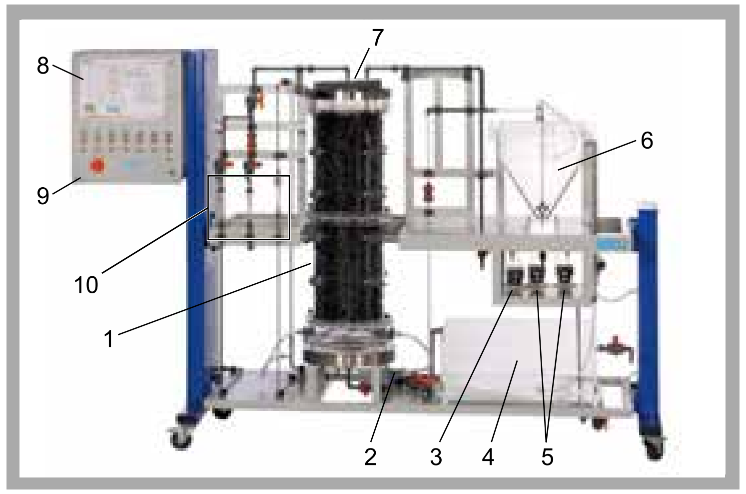
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

### Learning Objectives / Experiments

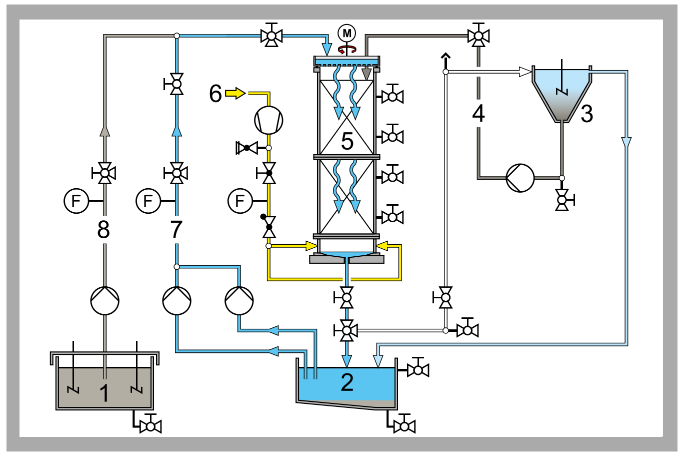
- functional principle of a trickling filter
- recording of concentration profiles
- creation of a stable operating state
- identification of the following influencing factors
  - * flow rate of recirculation
  - * volumetric loading of the trickling filter
  - * surface loading of the trickling filter
- comparison of various carrier materials



## CE 701 Biofilm Process




1 trickling filter, 2 compressor, 3 return sludge pump, 4 collecting tank, 5 circulation pumps, 6 secondary clarifier, 7 rotary distributor, 8 process schematic, 9 switch cabinet, 10 flow meter




1 wastewater tank, 2 collecting tank, 3 secondary clarifier, 4 return sludge, 5 trickling filter, 6 air, 7 recirculation, 8 wastewater; F flow rate

carrier material for biofilm

### Specification

[1] aerobic biofilm process for the degradation of organic substances and for nitrification
[2] transparent trickling filter with rotary distributor
[3] speed of the rotary distributor finely adjustable
[4] aeration of the trickling filter by natural convection or with compressor
[5] recording of concentration profiles is possible
[6] secondary clarifier with pump for transporting the return sludge
[7] all relevant flow rates finely adjustable
[8] separate supply unit with wastewater tank and two stirring machines
[9] two different carrier materials made of HDPE

### Technical Data

Trickling filter
- diameter: approx. 340mm
- height: approx. 1000mm
- capacity: approx. 90L

Rotary distributor
- max. speed: approx. $2min^{-1}$

Tanks
- wastewater tank: 300L
- collecting tank: 90L
- secondary clarifier: 30L

Flow rates
- wastewater pump: max. 25L/h
- circulation pumps: 2x max. 25L/h
- return sludge pump: max. 25L/h
- compressor: max. 600L/h

Carrier material
- specific surface: 180 or $300m^2/m^3$

Measuring ranges
- flow rate (wastewater): 2...25L/h
- flow rate (recirculation): 5...65L/h
- flow rate (aeration): 50...900L/h

### Dimensions and Weight

LxWxH: 1550x790x1150mm (supply unit)
LxWxH: 2870x790x1900mm (trainer)
Total weight: approx. 500kg

### Required for Operation

230V, 50/60Hz, 1 phase or 120V, 60Hz/CSA, 1 phase
Water connection, drainage, activated sludge and substances for preparation of artificial wastewater

### Scope of Delivery

1 trainer
1 supply unit
1 set of hoses
1 set of tools
1 cleaning brush
2 packing units of carrier material
1 set of instructional material

### Order Details

083.70100 CE 701 Biofilm Process

## CE 705 Activated Sludge Process

The illustration shows: Trainer (left) and supply unit (right)

* **Wastewater treatment plant in laboratory scale**
* **Aerobic biological degradation of organic substances**
* **Nitrification and pre-denitrification**

### Technical Description

The activated sludge process is the most important biological process in water treatment. CE 705 enables this process to be demonstrated.

A pump delivers raw water contaminated with dissolved organic substances (organic matter) into the aeration tank. Aerobic microorganisms (activated sludge) in the aeration tank use the organic matter as a source of nutrition, biodegrading it in the process. Since aerobic microorganisms need oxygen, the raw water is aerated in the aeration tank. The activated sludge is mixed with the raw water by stirring machines. In the secondary clarifier the activated sludge is then separated from the treated water by sedimentation. A portion of the activated sludge is returned to the aeration tank (return sludge). The treated water is collected in a tank.

It is also possible to convert ammonium into nitrate (nitrification) and nitrate into nitrogen (denitrification). For denitrification a zone without aeration can be created in the aeration tank by installing a partition wall.

The following flow rates are adjustable: raw water, return sludge, internal recirculation for pre-denitrification and air. Oxygen concentration, pH value and temperature can be contolled.

A software program is provided to display the operation states and measure data. A process schematic shows the current operating states of the individual components and the measured data.

Samples can be taken at all relevant points. Activated sludge from a wastewater treatment plant and analysis technology are required for the experiments. Recommended parameters are:
- $BOD_5$ (biochemical oxygen demand)
- COD (chemical oxygen demand)
- $NH_4$ (ammonium)
- $NO_3$ (nitrate)

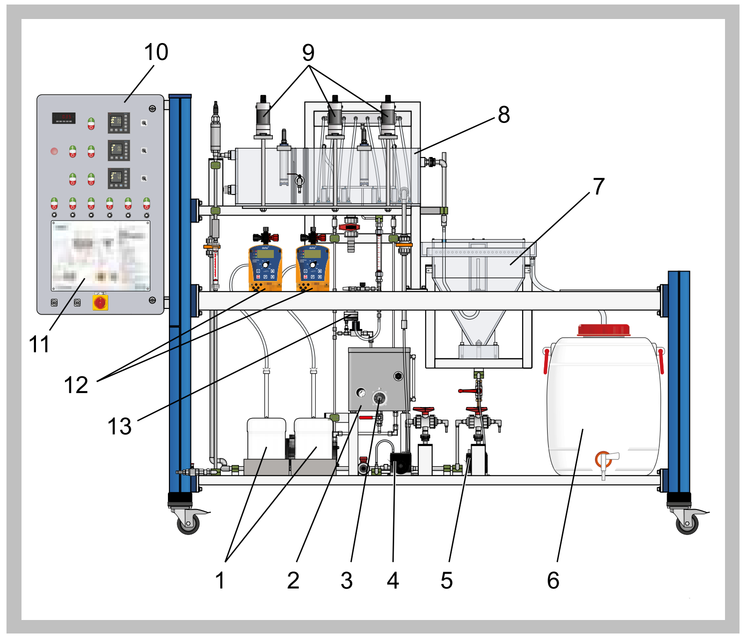
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

### Learning Objectives / Experiments

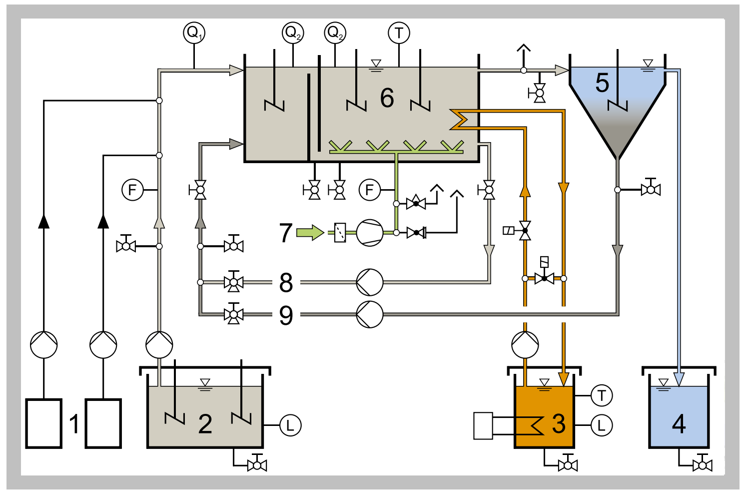
- learning the fundamental principle of the activated sludge process
- functional principle of nitrification and pre-denitrification
- creation of a stable operating state
- identification of the following influencing factors
  * return sludge ratio
  * return ratio of the internal recirculation
  * sludge age
  * sludge loading
  * volumetric loading
  * oxygen concentration, pH value and temperature
- efficiency of the pre-denitrification



## CE 705 Activated Sludge Process




1 tanks for acid and caustic, 2 heating water tank, 3 heater, 4 circulation pump, 5 return sludge pump, 6 treated water tank, 7 secondary clarifier, 8 aeration tank, 9 stirring machines, 10 switch cabinet, 11 process schematic, 12 metering pumps, 13 compressor




1 acid and caustic, 2 raw water, 3 heating water, 4 treated water, 5 secondary clarifier, 6 aeration tank, 7 air, 8 internal recirculation for pre-denitrification, 9 return sludge; F flow rate, L level, $Q_1$ pH value, $Q_2$ oxygen concentration, T temperature

### Specification

[1] biological wastewater treatment
[2] aeration tank with 3 stirring machines
[3] secondary clarifier
[4] nitrification and pre-denitrification
[5] separate supply unit with 2 stirring machines
[6] all relevant flow rates adjustable
[7] control of temperature, pH value and oxygen concentration
[8] measurement of flow rate, temperature, pH value and oxygen concentration
[9] GUNT software with display of the operation states and data acquisition via USB under Windows Vista or Windows 7
[10] visual inspection with webcam on PC

### Technical Data

Aeration tank
- capacity nitrification zone: approx. 34L
- capacity denitrification zone: approx. 17L

Tanks
- secondary clarifier: 30L
- raw water tank: 200L
- treated water tank: 80L

Flow rates
- raw water pump: max. 25L/h
- return sludge pump: max. 25L/h
- circulation pump: max. 25L/h

Speeds (stirring machines)
- secondary clarifier: max. $45min^{-1}$
- all others: each max. $600min^{-1}$

Measuring ranges
- flow rate (raw water): 2...25L/h
- flow rate (compressed air): 50...550L/h
- temperature: 0...40°C
- pH value: 0...14
- oxygen concentration: 0...10mg/L

### Dimensions and Weight

LxWxH: 1550x790x1150mm (supply unit)
LxWxH: 2830x790x1900mm (trainer)
Weight: approx. 450kg

### Required for Operation

230V, 50/60Hz, 1 phase or 120V, 60Hz, 1 phase
Water connection, drainage, activated sludge, substances for preparation of artificial wastewater, caustic soda, hydrochloric acid

### Scope of Delivery

1 trainer
1 supply unit
1 set of hoses
1 GUNT software CD + USB cable
1 webcam
1 measuring cup
1 stopwatch
1 beaker
1 set of instructional material

### Order Details

083.70500 CE 705 Activated Sludge Process

## A LOOK INSIDE OUR CUSTOMERS' LABORATORIES

**GUNT devices have been used by our satisfied customers for many years in hundreds of technical training institutes.**

**Highest requirements regarding conception and details: GUNT devices are ideal to convey knowledge through practical application.**

# CE 705 ACTIVATED SLUDGE PROCESS

ENERGY & ENVIRONMENT 2E

***The wastewater treatment plant in laboratory scale: Theory and practice of the activated sludge process***

- Biological Water Treatment
- Nitrification Denitrification
- Continuous Process
- Practical

## A LABORATORY SYSTEM FOR EDUCATION AND RESEARCH

# The Wastewater Treatment Plant

CE 705 clearly demonstrates the most important biological process in water treatment – the activated sludge process. The main field of application of this process is in the treatment of domestic wastewater by wastewater treatment plants. Knowledge of this process is therefore essential for budding engineers and specialists in the field of water treatment.


Bar screen


Grit chamber

In a wastewater treatment plant, domestic wastewater is treated to enable it to be discharged back into a watercourse. The treatment process is essentially divided into the following sections:

- mechanical treatment
- biological treatment

**Mechanical treatment**

In the first stage, suspended solids are mechanically removed from the wastewater. Initially, course materials such as pieces of wood, plastic bags and fabric are filtered out using a bar screen. Then the water flows into a grit chamber. In this sedimentation tank, mineral solids such as sand and gravel are separated by sedimentation. Organic solids have a much lower settling velocity than sand and, consequently, a low velocity sedimentation step is required to separate them. This process stage is termed primary clarification.

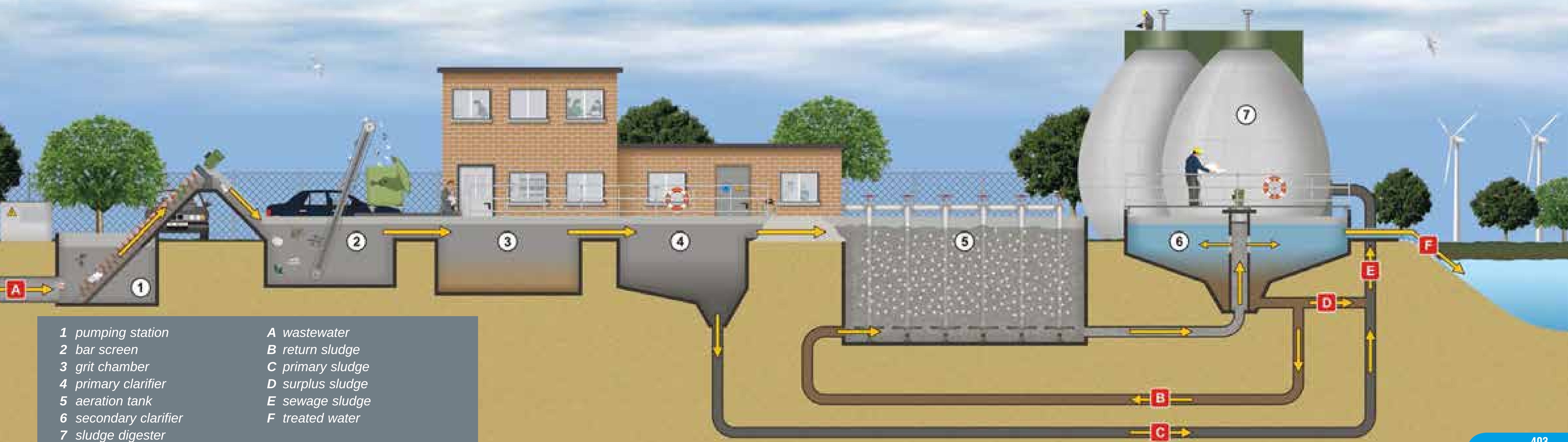

Aeration tank


Secondary clarifier

**Biological treatment**

Organic, biodegradable substances (organic matter) dissolved in wastewater provide nutrients for microorganisms. In this way, the wastewater is treated biologically. The microorganisms are suspended in the wastewater and are termed activated sludge. In the aeration tank the biological degradation of the organic matter takes place. Aeration of the wastewater provides the aerobic microorganisms with oxygen.

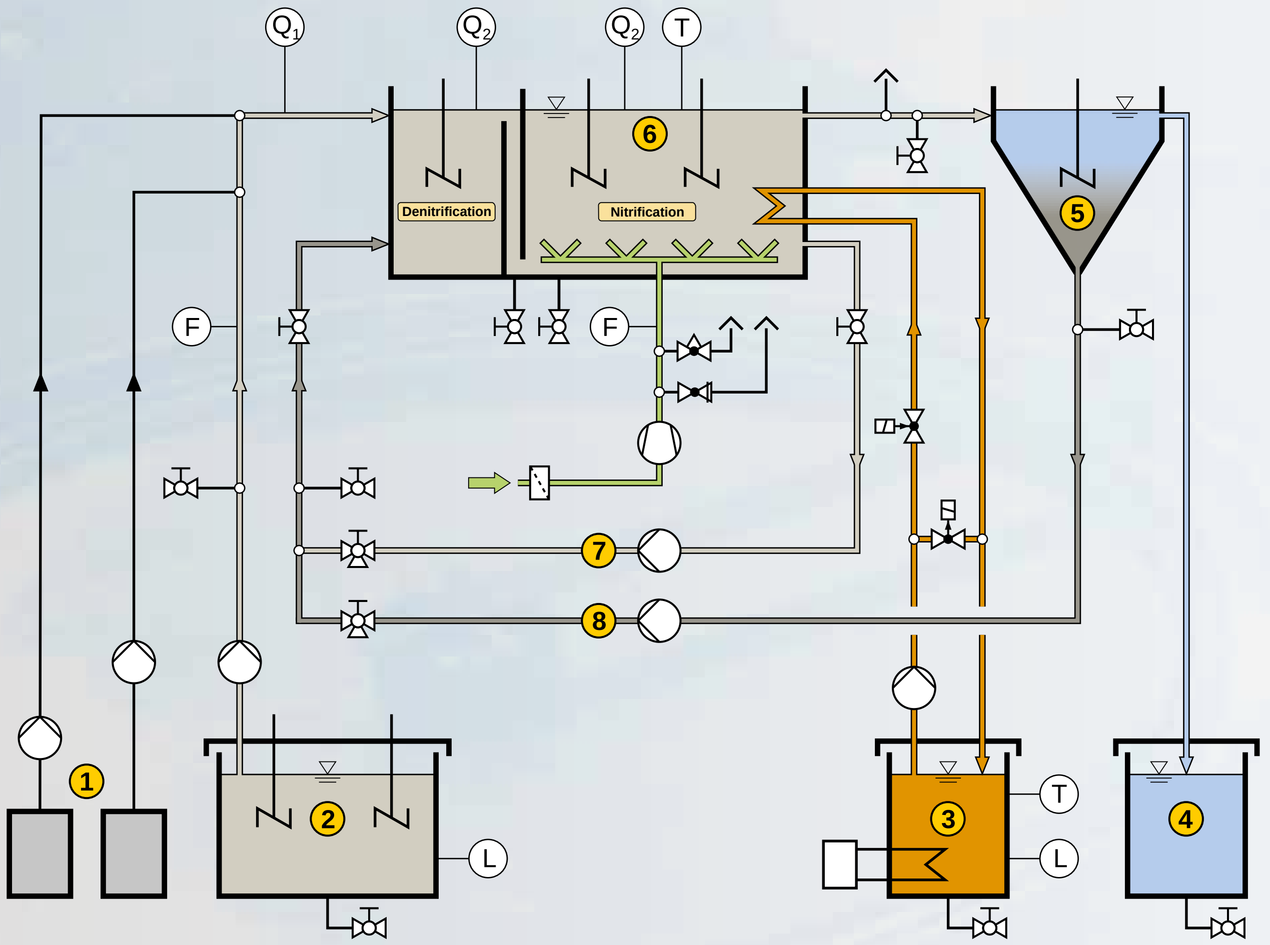
In the secondary clarifier the activated sludge is separated from the treated water by sedimentation. Part of the activated sludge is returned to the aeration tank (return sludge). The portion of the activated sludge which is not returned (surplus sludge) is a waste product of the process.




1 pumping station
2 bar screen
3 grit chamber
4 primary clarifier
5 aeration tank
6 secondary clarifier
7 sludge digester

A wastewater
B return sludge
C primary sludge
D surplus sludge
E sewage sludge
F treated water

## Concept




***Process schematic of CE 705:***
***1** acid and caustic, **2** wastewater, **3** heating water, **4** treated water, **5** secondary clarifier, **6** aeration tank, **7** internal recirculation for pre-denitrification, **8** return sludge*

***Sensors:***
***F** flow rate, **L** level, $Q_1$ pH value, $Q_2$ oxygen concentration, **T** temperature*

### Features

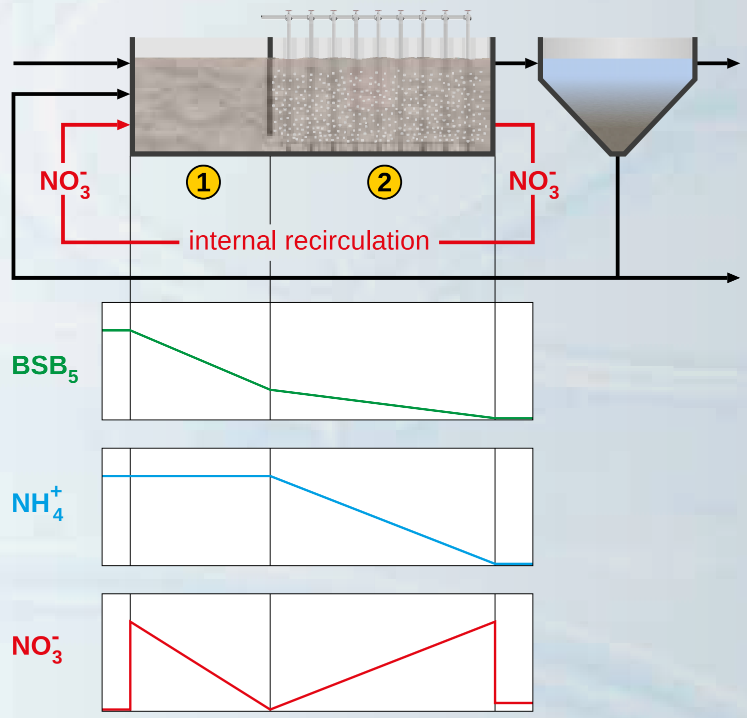
- wastewater treatment plant in laboratory scale
- continuous and practical process
- aeration tank with an anoxic zone for pre-denitrification
- supply unit with large wastewater tank
- comprehensive range of instrumentation and control
- GUNT software with control functions and data acquisition

*The CE 705 is part of our division*
***2E – ENERGY & ENVIRONMENT.***
*For further interesting informations about this device please step to **www.gunt2e.de.***

**NOTE**
For more technical details please visit our homepage **www.gunt.de** and select the data sheet of CE 705.

### Extensive range of learning objectives

- fundamental principle of the activated sludge process
- functional principle of nitrification and pre-denitrification
- creation of a stable operating state with nitrification and denitrification
- identification of the following influencing factors:
  - sludge age
  - volumetric loading
  - sludge loading
  - return sludge ratio
  - return ratio of the internal recirculation
- efficiency of the pre-denitrification
- influence of the following ambient conditions to the biological degradation
  - pH value
  - temperature
  - oxygen concentration



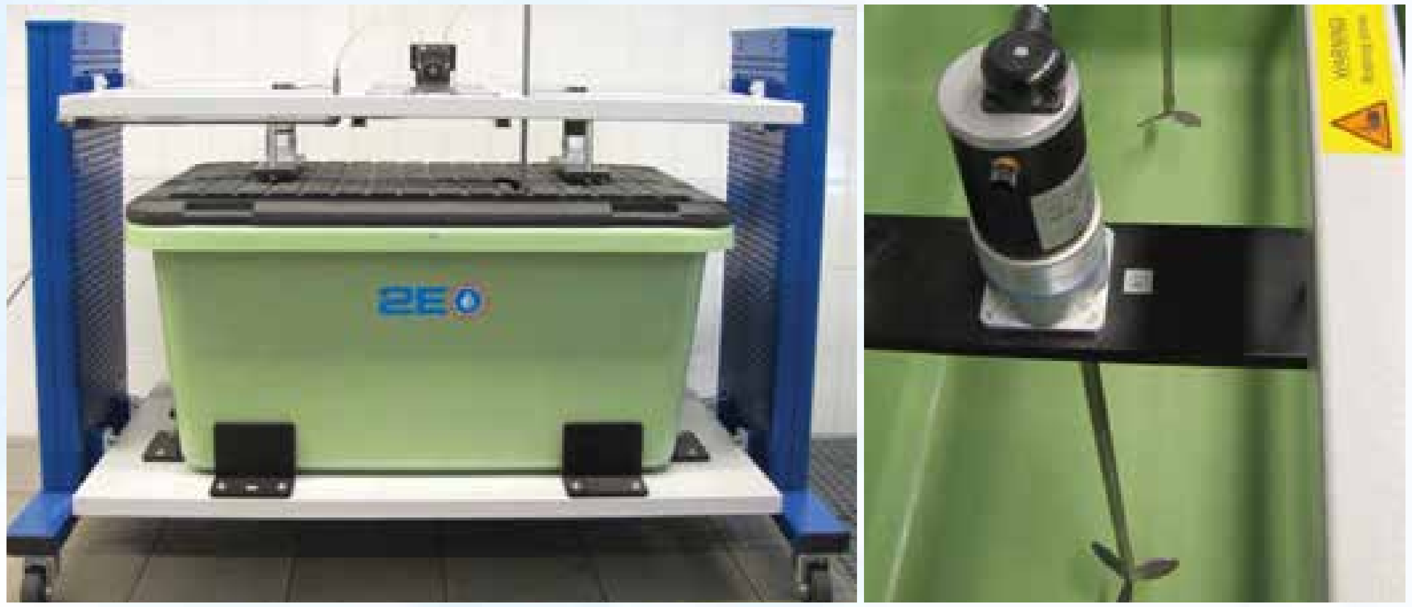

***Basic principle of pre-denitrification***

***1** anoxic zone (denitrification)*
***2** aerobic zone (nitrification)*

**The GUNT training systems are ideally suitable for students' group working, and of course for project-oriented working methods.**

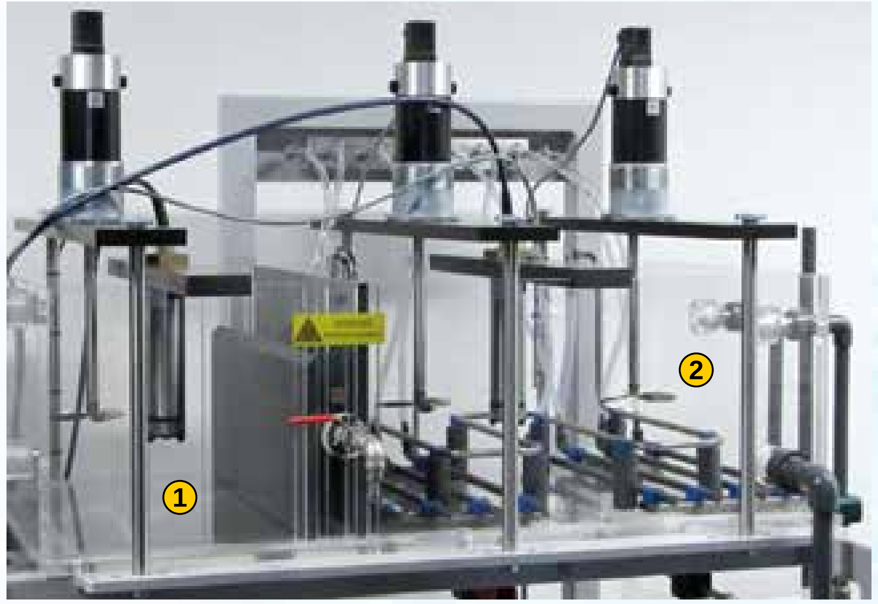
## Device Design

### SUPPLY UNIT

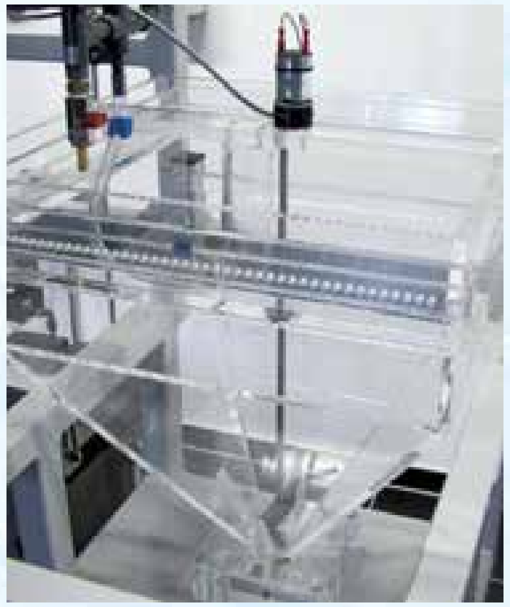



*Separate supply unit with large wastewater tank and two high-performance stirring machines*

### TRAINER



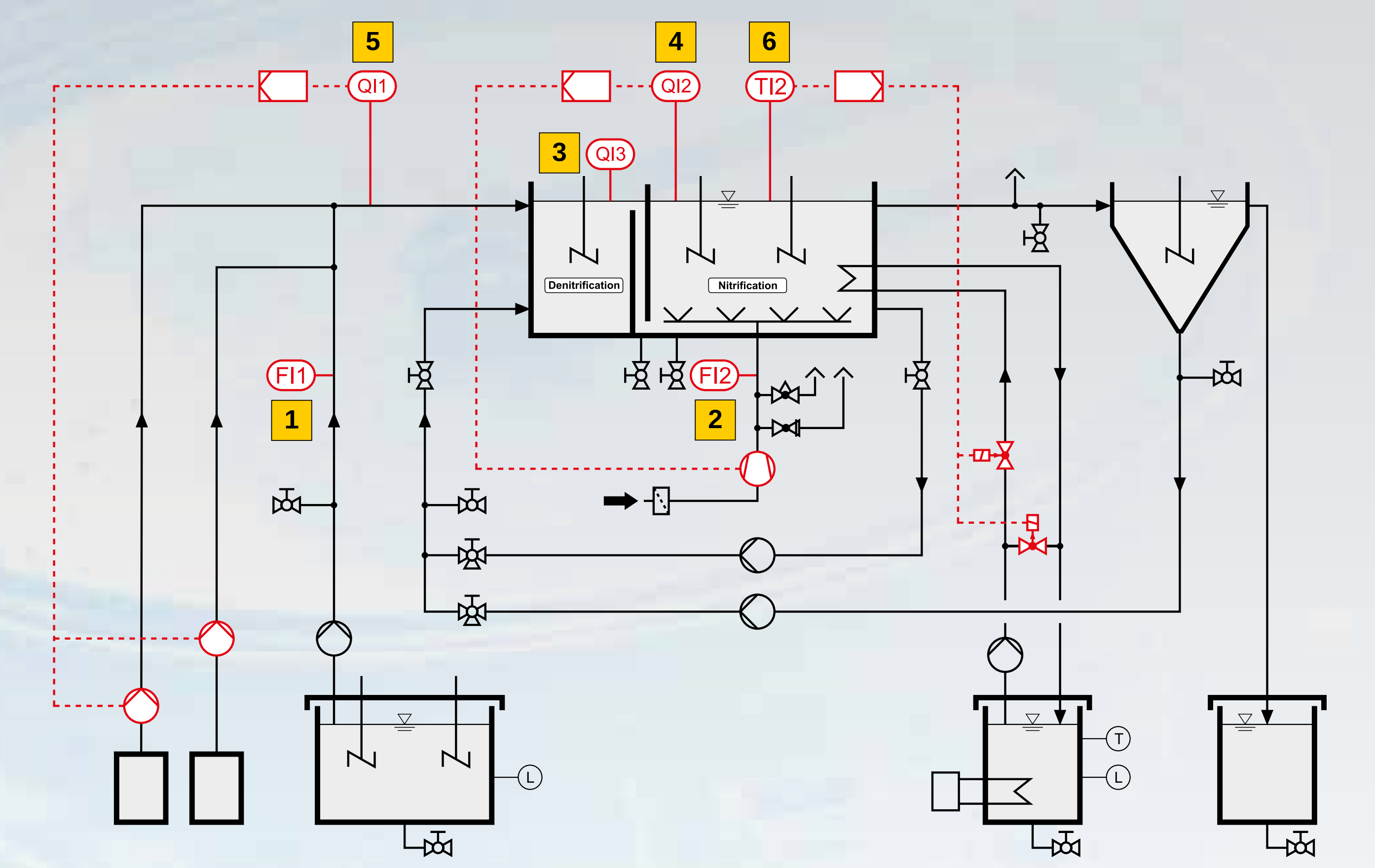

*Aeration tank with an aerobic zone **(2)** and an anoxic zone for pre-denitrification **(1)***



*Secondary clarifier for separation of activated sludge*

## Instrumentation and Control

| | PARAMETER | | MEASUREMENT | CONTROL |
|---|---|---|---|---|
| 1 | flow rate | wastewater | ✓ | |
| 2 | | aeration | ✓ | |
| 3 | oxygen concentration | aeration tank (anoxic zone) | ✓ | |
| 4 | | aeration tank (aerobic zone) | ✓ | ✓ |
| 5 | pH value | wastewater | ✓ | ✓ |
| 6 | temperature | aeration tank (aerobic zone) | ✓ | ✓ |




### 1 2 FLOW RATE

### 3 OXYGEN CONCENTRATION


*In the anoxic denitrification zone the oxygen concentration is measured and indicated digitally.*

| SENSORS | CONTROLLERS | ACTUATORS |
|---|---|---|

### 4 CONTROL OF OXYGEN CONCENTRATION

*Oxygen sensor*


*Digital industrial controller*

*High-performance compressor*

### 5 CONTROL OF pH VALUE

*pH sensor*


*Digital industrial controller*

*Professional metering pumps*

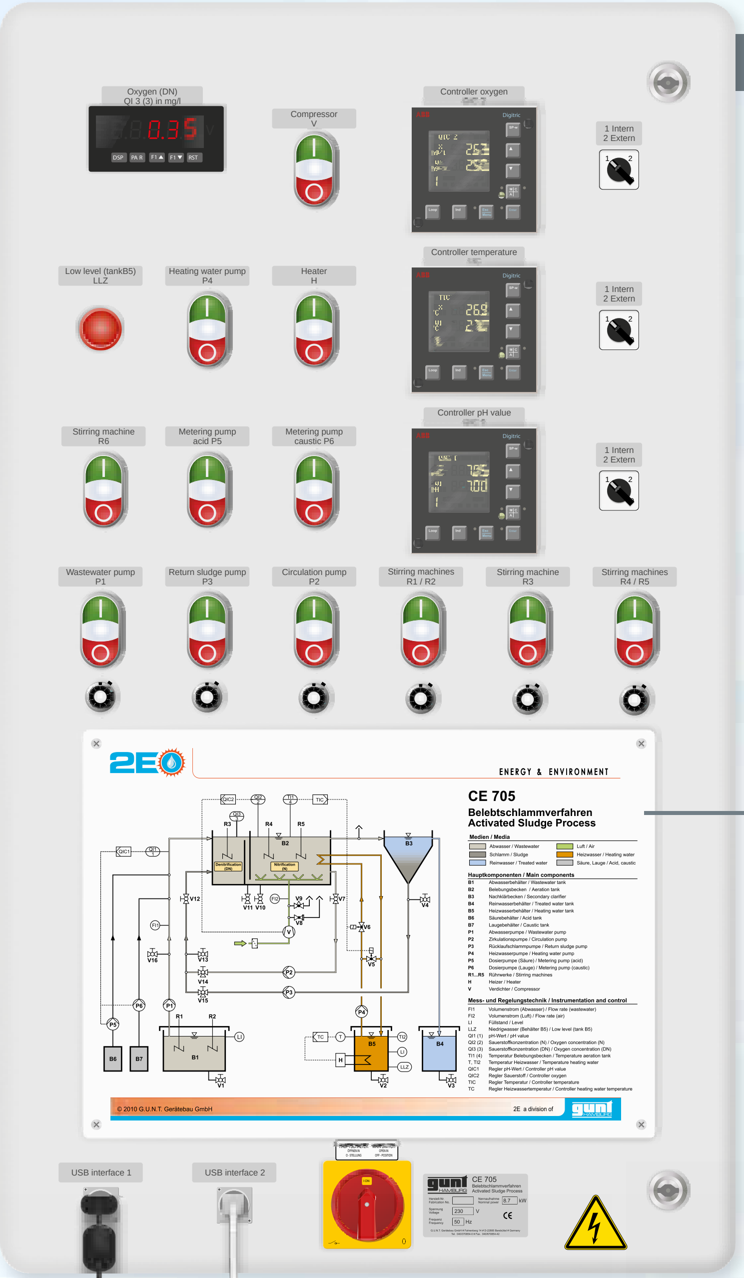
### 6 CONTROL OF TEMPERATURE

*Temperature sensor*


*Digital industrial controller*

*Solenoid valves in heating water circuit*

## Operation and Software




### SWITCH CABINET

- controls of all primary components:
  - pumps
  - stirring machines
  - compressor
- controls arranged very clearly
- potentiometer to adjust:
  - flow rates of the pumps
  - rotation speed of the stirring machines
- digital controllers for control loops
- digital display of measured values
- transducers for the sensors

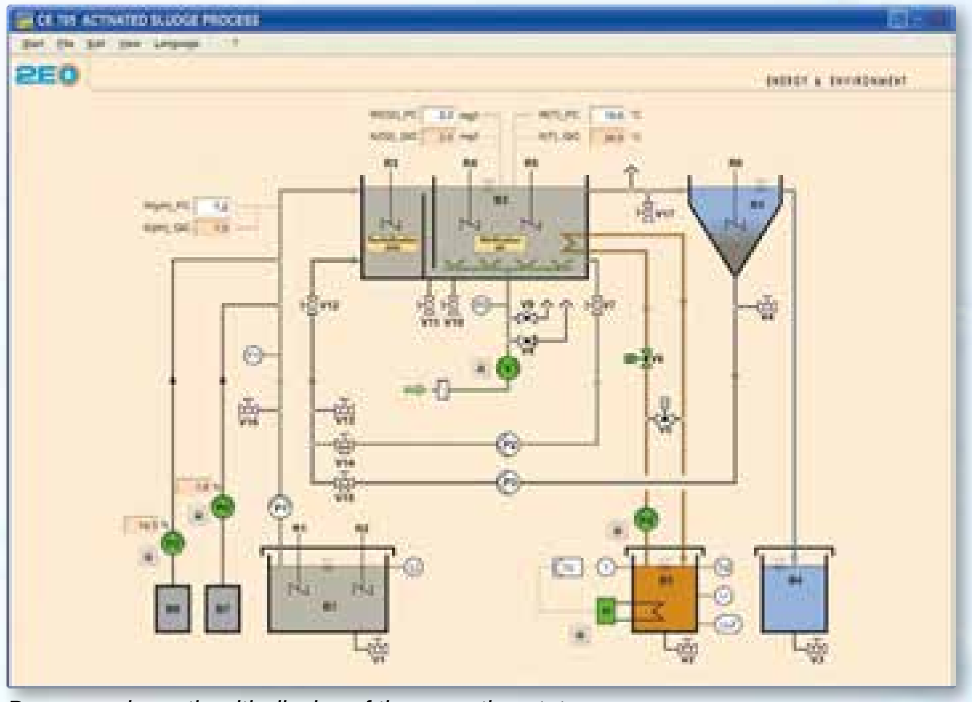
*A large, clear process schematic on the switch cabinet makes it easy to assign all the components.*

***Visual inspection with webcam on PC***

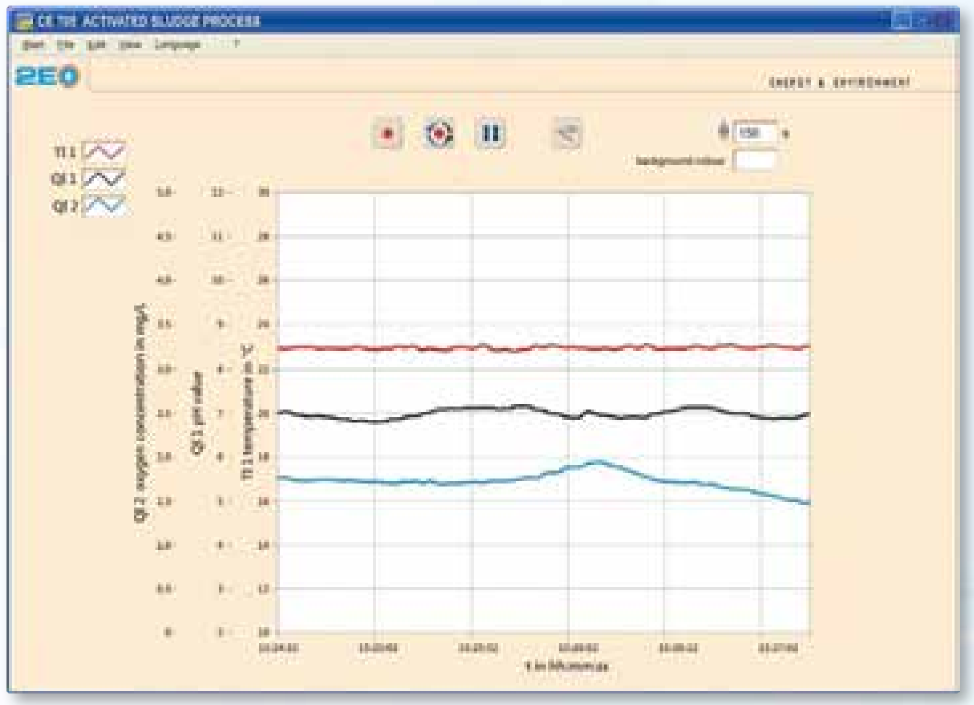
### SOFTWARE AND DATA ACQUISITION

#### GUNT Software

- state-of-the-art software with display of the operation states and data acquisition
- control of the control loops
- storage of the measured data
- representation of time functions
- visual inspection with webcam on PC
- language selectable




*Process schematic with display of the operation states*




*Representation of time functions of the measured data*

***Certainly in four languages – as you already know from GUNT.***

# The Instructional Material

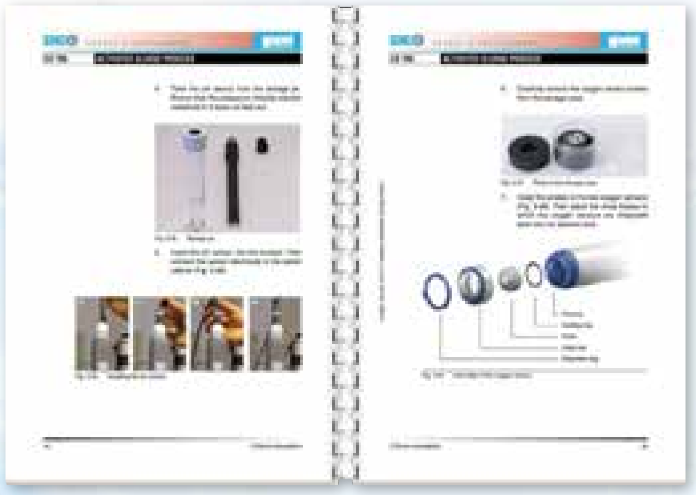
## EXPERIMENT INSTRUCTIONS

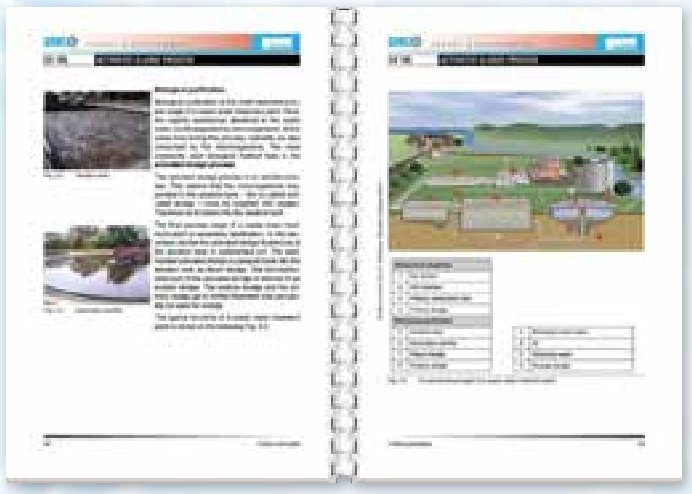

We have developed an extensive range of instructional material for the CE 705 which will greatly assist you in getting familiar with the trainer, in preparing your lessons, laboratory experiments and exercises.

### The experiment instructions comprises:

- detailed description of the device
- detailed operating instructions
- design and function of the components used described very detailed
- fundamentals of the activated sludge process
- detailed description of the experiments
- work sheets for the experiments

*Certainly in four languages – as you already know from GUNT.*



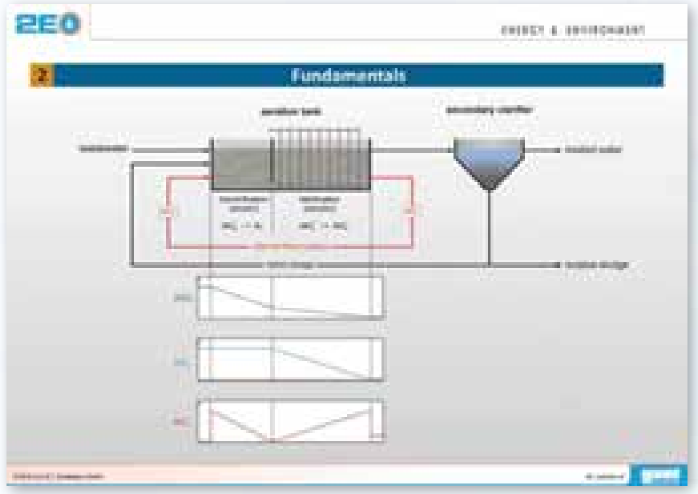


Materials delivered as paper printouts in a folder and additionally as PDF files on a CD. **An extract of the experiment instructions is available on our 2E homepage www.gunt2e.de.**

**Updates**

When any updates or additions to the CE 705 are made – in particular with regard to the instructional material and the software – you, as a GUNT customer, will be notified accordingly.

## PRESENTATION





### The perfect way to get into the topic:

- fundamentals of biological wastewater treatment and the activated sludge process
- design and concept of the CE 705
- clearly and illustrative

**The presentation is part of the instructional material.**

## VIDEO


The instructional material also includes a video. The video clearly demonstrates all essential aspects necessary for the preparation and execution of the experiments.

The video enables to practical and easily get into the topic. Of course, the video is also available on our homepage www.gunt2E.de.

## Commissioning and Training

A staff member of GUNT explains the fundamental principle of the activated sludge process.

The commissioning and training is carried out by high-qualified staff members of GUNT. As well as testing the products supplied, this includes instruction for the customer in the operation of the equipment. The possibilities of the system are demonstrated in detail. This enables you to quickly incorporate this training system into your own teaching programme.

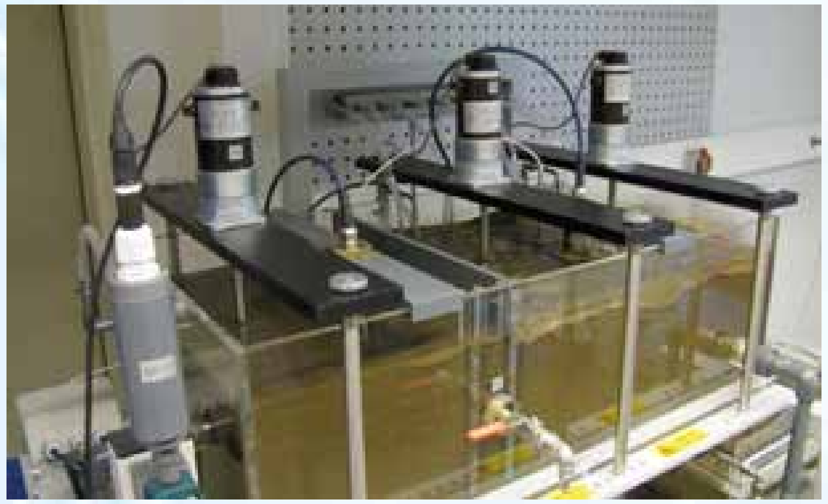
**If you require installation or training services, we will be glad to help.**

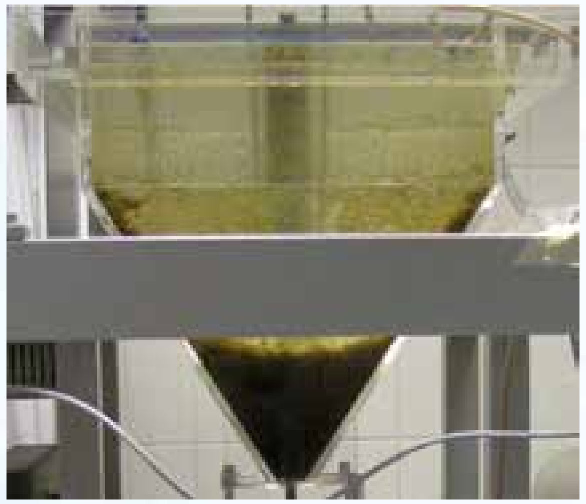
Many domestic and international customers are already successfully using our CE 705 training system.

**Examples:**

- Vocational School of Stockerau (Austria)
- University of Karlsruhe (Germany)
- University of Deggendorf (Germany)
- University of Regensburg (Germany)
- Training Centre of Agip kco (Kazakhstan)
- Technical University of Monterrey (Mexico)

*Activated sludge is taken from a wastewater treatment plant during a training.*





*During the training the operation of the CE 705 is demonstrated under real conditions with activated sludge.*

DEGGENDORF INSTITUTE OF TECHNOLOGY

Modern and practice-oriented education – supported by high-grade devices of GUNT

*A staff member of GUNT explains the operation of the CE 705 to Mrs. Prof. Dr.-Ing. Deininger from the University of Deggendorf (Germany).*

# WE TAKE QUALITY SERIOUSLY

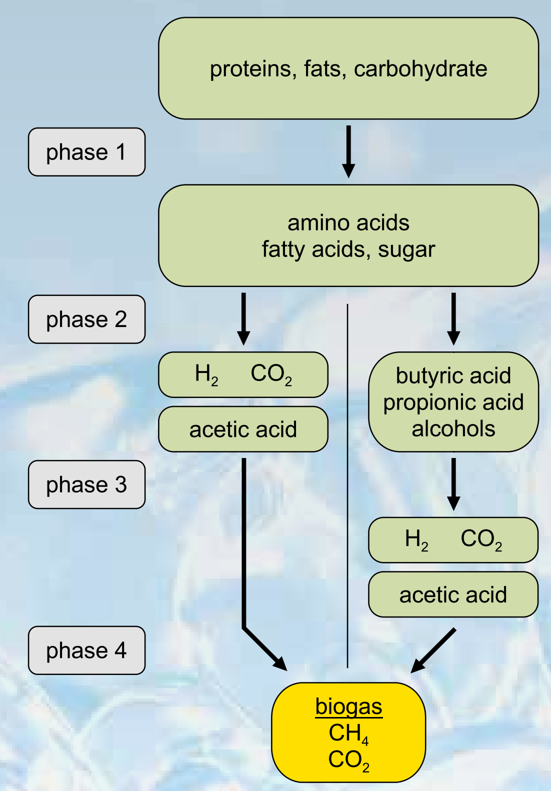

**Our quality management system has been certified since 1998.**

## BASIC KNOWLEDGE

# ANAEROBIC PROCESSES

In contrast to the aerobic processes, the anaerobic degradation of organic substances takes place in the absence of oxygen. The anaerobic microorganisms use the organic substances as a source of nutrition, and so degrade them. This produces biogas, mainly comprised of methane (60%) and carbon dioxide (35%). Biogas can be used as an energy source. The complex processes involved in anaerobic degradation can be simplified by dividing them into four phases (illustration). The metabolism is carried out in eech phase by different microorganisms.

Anaerobic processes are suitable for wastewater with very high concentrations of organic substances, such as occur in the food and paper industries. They are also often employed upstream of an aerobic process such as the activated sludge process.




*Fundamental principle of anaerobic degradation*

■ **Phase 1: Hydrolysis**

Long-chain, often undissolved substances such as proteins, fats and carbohydrates are converted into dissolved species such as amino acids, fatty acids and sugar.

■ **Phase 2: Acidification**

Acid-forming microorganisms convert the hydrolysed substances into short-chain organic acids such as butyric acid, propionic acid and acetic acid. Small quantities of hydrogen and carbon dioxide are also produced.

■ **Phase 3: Acetic acid formation**

Methane ($CH_4$) can be produced by methane bacteria using acetic acid or hydrogen and carbon dioxide. Therefore acids and alcohols produced in phase 2 first have to be converted into acetic acid.

■ **Phase 4: Methane formation**

Methane bacteria produce methane using hydrogen, carbon dioxide and acetic acid.

The microorganisms of the individual phases place different demands on the ambient conditions. This relates especially to the pH value and the temperature. Accordingly, the first two and last two phases are each consolidated into one stage (table).

Ideally, therefore, the process should take place in stages, in two separate reactors. All four phases can also, in principle, take place in a single stage in one reactor. A compromise must then be found with regard to the ambient conditions, resulting in a lower degradation rate. The microorganisms of the first two phases can undergo metabolic processes both with and without oxygen. The microorganisms of the third and fourth phase, by contrast, are strictly anaerobic, and react very sensitively to oxygen and fluctuating pH values.

| parameters | stage 1<br>phase 1 + 2 | stage 2<br>phase 3 + 4 |
|---|---|---|
| pH value | 5,2 ... 6,3 | 6,7 ... 7,5 |
| temperature | 25 ... 35 °C | 35 ... 60 °C |

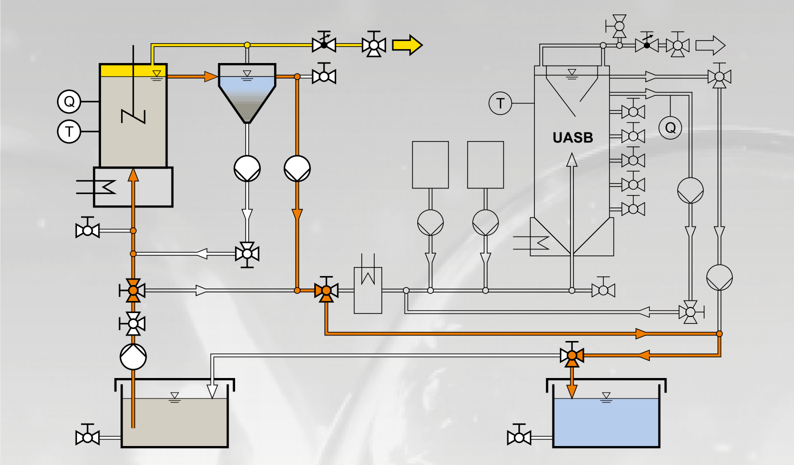
# CE 702 ANAEROBIC WATER TREATMENT

## A laboratory system for education and research

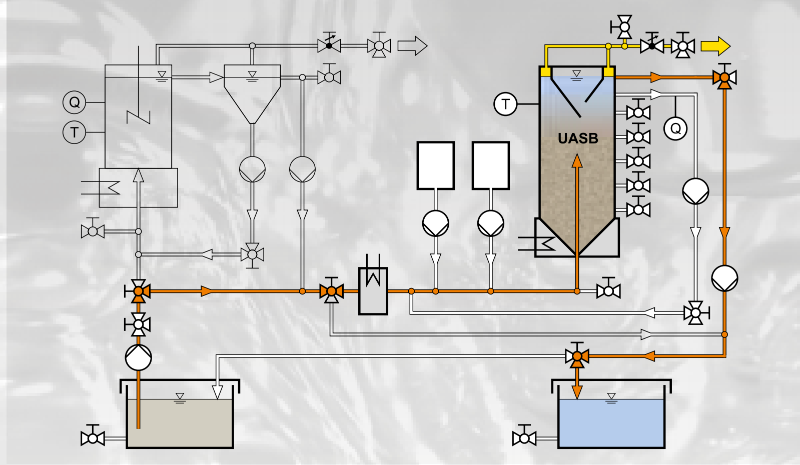
- two different types of reactors with temperature control
- three different operation modes
- UASB reactor with control of pH-value
- GUNT software for data acquisition

Stirred tank with secondary clarifier

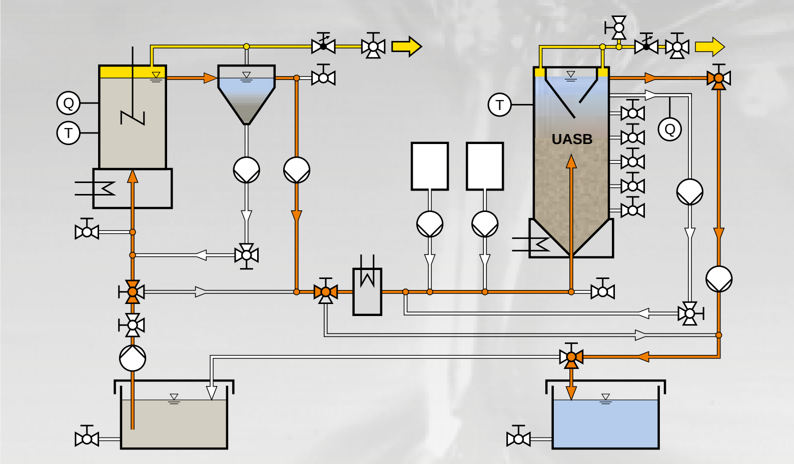
UASB reactor




*Operation mode 1 (1 stage):*
- ☑ *Stirred tank with secondary clarifier*
- ☐ *UASB reactor*




*Operation mode 2 (1 stage):*
- ☐ *Stirred tank with secondary clarifier*
- ☑ *UASB reactor*




*Operation mode 3 (2 stages):*
- ☑ *Stirred tank with secondary clarifier*
- ☑ *UASB reactor*


## THE UASB PRINCIPLE

### Upflow Anaerobic Sludge Blanket

The UASB reactor is a reactor type that is frequently used in anaerobic water treatment.

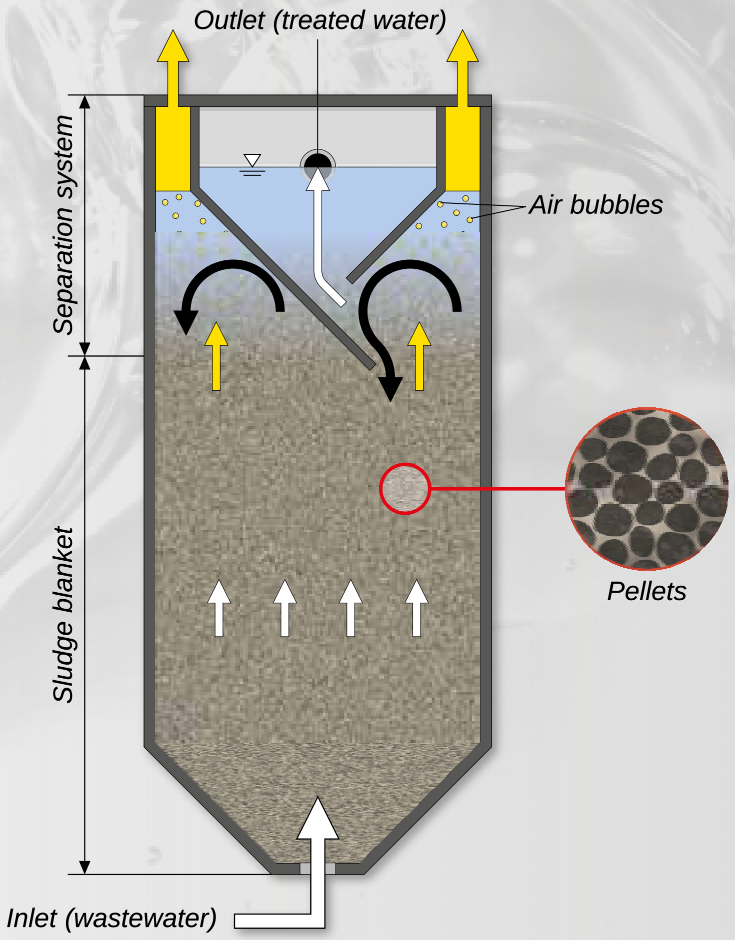
The reactor contains a sludge blanket which consists of anaerobic micro-organisms in the form of pellets. These pellets are an essential characteristic of the UASB principle. The reactor is flowed through from the bottom to the top.

Biogas which mainly consists of methane and carbon dioxide is produced during the anaerobic degradation. A separation system is installed at the top of the UASB reactor. It separates biogas from treated water. In addition it guarantees that the pellets (biomass) remain in the reactor.

Biogas

Sludge blanket

Treated water



## CE 702 *Anaerobic Water Treatment*

The illustration shows: Supply unit (left) and trainer (right)

*** Anaerobic degradation of organic substances in the stirred tank and UASB reactor**

*** 3 different operation modes**

### Technical Description

CE 702 demonstrates the biological anaerobic water treatment. The trainer consists basically of two units:
- stirring tank with secondary clarifier
- UASB reactor

Both units can be used separately or in combination. This allows both a single stage and a dual stage operation mode. In the dual stage operation a pump first transports the raw water into a stirred tank. In this tank the acidification of the organic substances dissolved in the raw water takes place. Here, anaerobic microorganisms convert the long-chain organic substances into short-chain organic substances. In a secondary clarifier the biomass discharged from the stirred tank is separated from the water. The separated biomass is pumped back into the stirring tank.

From the secondary clarifier the raw water pretreated in this manner reaches a UASB reactor (UASB: Upflow Anaerobic Sludge Blanket). Here the final step of the anaerobic degradation takes place. The previously formed short-chain substances are converted by special microorganisms into biogas (methane and carbon dioxide). Flow through the UASB reactor is from the bottom to the top. At the top of the UASB reactor there is a separation system. This separates the generated gas from the treated water. It also ensures that the biomass remains in the reactor. The gas can be discharged externally or collected. The treated water exits at the top end of the reactor and is collected in a tank.

To adjust the flow velocity in the UASB reactor a of the treated water can be recirculated.

The temperatures in the stirred tank and the UASB reactor can be controlled. The pH value in the stirred tank is measured. In addition, the pH value in the UASB reactor can be controlled. A software and webcam are available for data acquisition and visual inspection.

Anaerobic biomass and analysis technology are required to perform the experiments. Recommended parameters are: COD (chemical oxygen demand), nitrogen and phosphor.

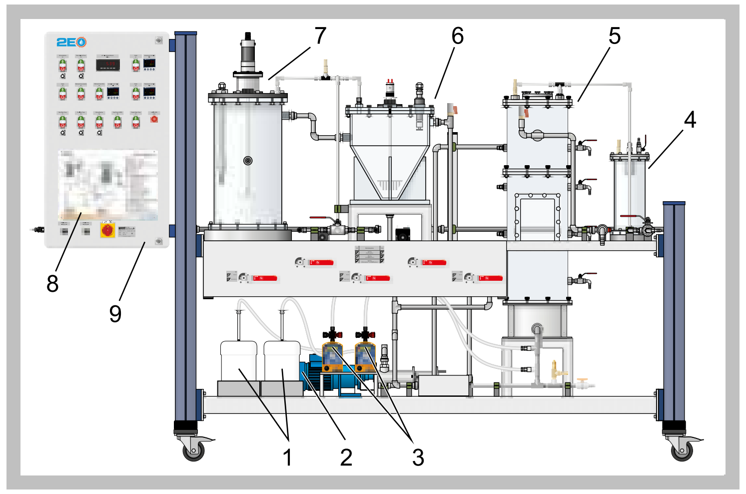
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

### Learning Objectives / Experiments

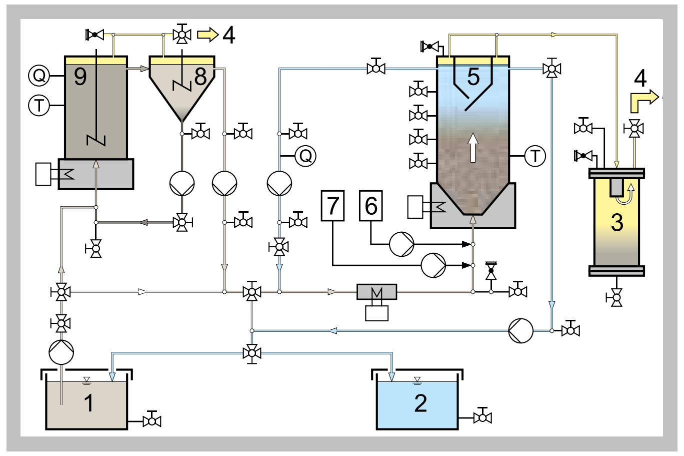
- familiarisation with anaerobic water treatment
- effects of temperature and pH value on anaerobic degradation
- functional principle of a UASB reactor
- comparison of single stage and dual stage operation mode
- monitoring and optimisation of the operating conditions
- identification of the following influencing factors
  * sludge loading
  * volumetric loading
  * flow velocity in the UASB reactor



## CE 702 *Anaerobic Water Treatment*




1 chemical tanks, 2 circulation pump, 3 metering pumps, 4 foam separator, 5 UASB reactor, 6 secondary clarifier, 7 stirred tank, 8 process schematic, 9 switch cabinet




1 raw water, 2 treated water, 3 foam separator, 4 gas, 5 UASB reactor, 6 acid, 7 caustic, 8 secondary clarifier, 9 stirred tank; T temperature, Q pH value

UASB reacor during experimental operation

### Specification

[1] anaerobic degradation of organic substances
[2] stirred tank with secondary clarifier
[3] UASB reactor with separation system
[4] separate supply unit with tanks for raw water and treated water
[5] single stage or dual stage operation mode
[6] temperatures in the stirred tank and the UASB reactor can be controlled
[7] control of the pH value in the UASB reactor
[8] GUNT software for data acquisition via USB under Windows Vista or Windows 7
[9] visual inspection with webcam

### Technical Data

Tanks
- stirred tank: 30L
- secondary clarifier: 30L
- UASB reactor: 50L
- tank for raw water: 180L
- tank for treated water: 180L

Flow rates (max.)
- raw water pump: 25L/h
- return sludge pump: 25L/h
- circulation pump: 100L/h
- metering pumps: 2x 2,1L/h

Measuring ranges
- pH value: 0...14
- temperature: 0...100°C

### Dimensions and Weight

LxWxH: 1550x790x1150mm (supply unit)
LxWxH: 2830x790x1900mm (trainer)
Weight: approx. 520kg

### Required for Operation

400V, 50/60Hz, 3 phases or 230V, 60Hz/CSA, 3 phases
Water connection, drain, sewage sludge, pellets from an UASB reactor, substances for preparation of artificial wastewater, caustic soda, hydrochloric acid

### Scope of Delivery

1 trainer
1 supply unit
1 set of hoses
1 stopwatch
1 set of tools
1 GUNT software CD + USB cable
1 webcam
1 set of instructional material

### Order Details

083.70200 CE 702 Anaerobic Water Treatment

2E a division of G.U.N.T Gerätebau GmbH, P.O.Box 1125, D-22885 Barsbüttel, t +49 (40)67 08 54-0, f +49 (40)67 08 54-42, E-mail sales@gunt.de
We reserve the right to modify our products without any notifications. Visit our Websites: www.gunt.de | www.gunt2e.de

# THE BRAND FOR TECHNICAL TRAINING SYSTEMS IN ENERGY AND ENVIRONMENT

## 2E is an abbreviation for ENERGY & ENVIRONMENT

Energy and environment are essential for sustainable development.

*"The next 10 years will be critical for the future of our planet. Radical measures must be taken both on climate change mitigation and adaption before we are locked into potentially irreversible, catastrophic climate transformation, whose impacts are expected to substantially change the environment and our lives on this planet."*

United Nations Development Programme:
"Charting a new Low-Carbon Route to Development"
Yannik Glemarec

Engineers, scientists, technicians and skilled workers have to play an important role in this transition process...

**...and it begins with education and training.**

GUNT is pioneering innovative technical training systems in clean-energy technologies.

The importance of water to human and ecosystem health is addressed in a complete range of technical training equipment for water treatment.

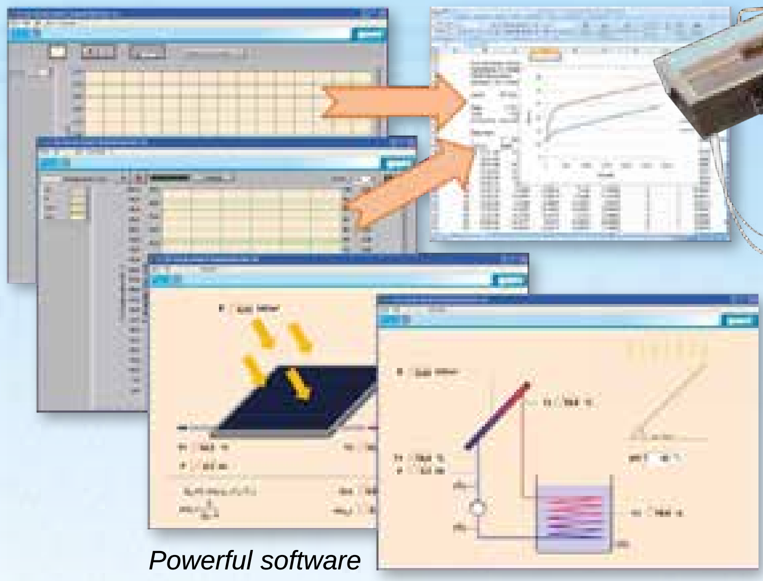
## ENERGY

We offer a wide range of technical training equipment for energy efficiency and renewable energy technologies:

- Solar Energy
- Hydropower and Ocean Energy
- Wind Power
- Biomass
- Geothermal Energy
- Energy Systems
- Energy Efficiency in Building Services Engineering

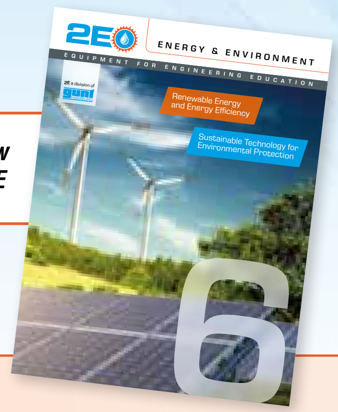
*ET 202 Principles of Solar Thermal Energy*

**As an example:**



*Powerful software for data acquisition and self-paced learning sequences.*

**Ask for our new catalogue of 2E**



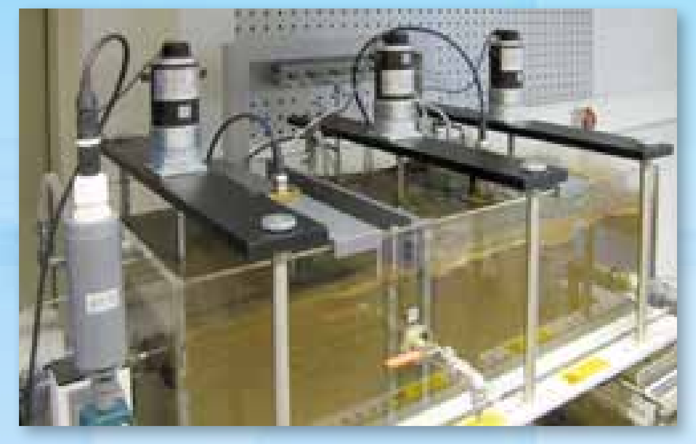

## ENVIRONMENT

2E provides you with a wide product range for education in the field of Environment. Experts distinguish between the following areas:

- Water
- Air
- Soil
- Waste

**A wide range of technical training equipment for water treatment**

*A laboratory scale plant for training and research in water treatment: Activated sludge process*



*CE 705 Activated Sludge Process*

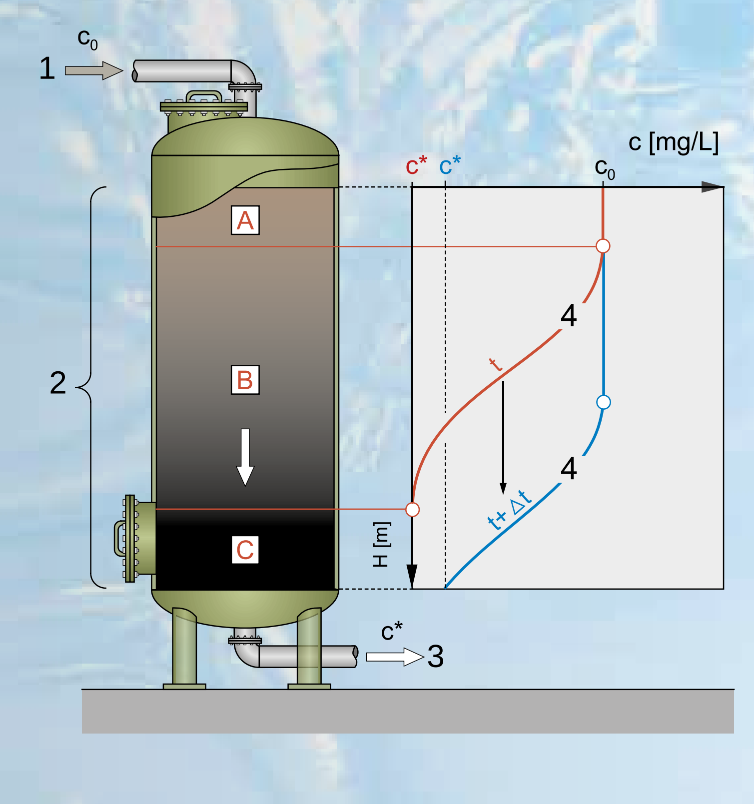
Visit our 2E website
**www.gunt2E.de**

BASIC KNOWLEDGE

# ADSORPTION

One method of removing dissolved substances from water is adsorption. This method is based on physical or chemical interaction between dissolved substances and a solid phase. The dissolved substances are bound to the solid phase.

The solid phase is referred to as the adsorbent, and the dissolved substance as the adsorbate. If adsorbent is brought into contact with adsorbate for long enough, an adsorption equilibrium is established. The adsorbent is then fully charged, and can absorb no more adsorbate. The adsorbent in most widespread use is activated carbon. Activated carbon has a very distinct pore system. One gram of activated carbon has a pore surface area of approximately 1000 m².




*Concentration profiles in an adsorber:*
***1** raw water, **2** fixed bed of activated carbon*
***3** treated water, **4** concentration profiles*
***H** fixed bed height, **t** time, **c** adsorbate concentration*
*$c_0$ adsorbate concentration in inlet*
***c*** adsorbate concentration in outlet*

In water treatment, adsorption is mainly implemented with continuous-flow adsorbers. In this case, the concentration profile marked in red on the illustration is established after the time ***t***. It corresponds to the trend of the adsorbate concentration in the water along the fixed bed.

This concentration profile is divided into three zones:

- Zone A

The adsorbent is fully charged and can absorb no more adsorbate. So the adsorption equilibrium has been reached. The adsorbate concentration in the water corresponds to the inlet concentration ($c_0$).

- Zone B

The adsorption equilibrium has not yet been reached, so adsorbate is still being adsorbed. This zone is known as the **mass transfer zone**.

- Zone C

Since the adsorbate has been fully removed from the water in zone B, the adsorbent is still non-charged here, so the adsorbate concentration is zero.

Over time, the concentration profile moves through the fixed bed in the direction of the flow. At the time ***t* + Δ*t*** it corresponds to the blue curve. There is no longer any non-charged adsorbent remaining in the fixed bed. The adsorbate concentration in the outlet (***c****) is greater than zero. This state is termed the breakthrough, and the trend over time of the adsorbate concentration in the outlet is termed the breakthrough curve. The shape of the concentration profile indicates how well the capacity of an adsorbent is utilised before the breakthrough is reached. The narrower the mass transfer zone, the more effectively the capacity is utilised.

**Applications**

Adsorption on activated carbon is suitable primarily for non-polar dissolved organic substances with low water solubility. Examples include the chlorinated hydrocarbons DDT and lindane. These toxic substances often accumulate in ground water. To prevent them from entering the food chain, they must be removed in the course of remediation processes and treatment to meet drinking water quality.

BASIC KNOWLEDGE

# MEMBRANE SEPARATION PROCESSES

Compared to filtration, membrane separation processes remove much smaller substances, such as viruses and dissolved ions, from the water. The driving forces of the separation process are for example differences in concentration or pressure between the two sides of the membrane. The following membrane separation processes are used in water treatment:

1. Microfiltration
2. Ultrafiltration
3. Nanofiltration
4. Reverse osmosis

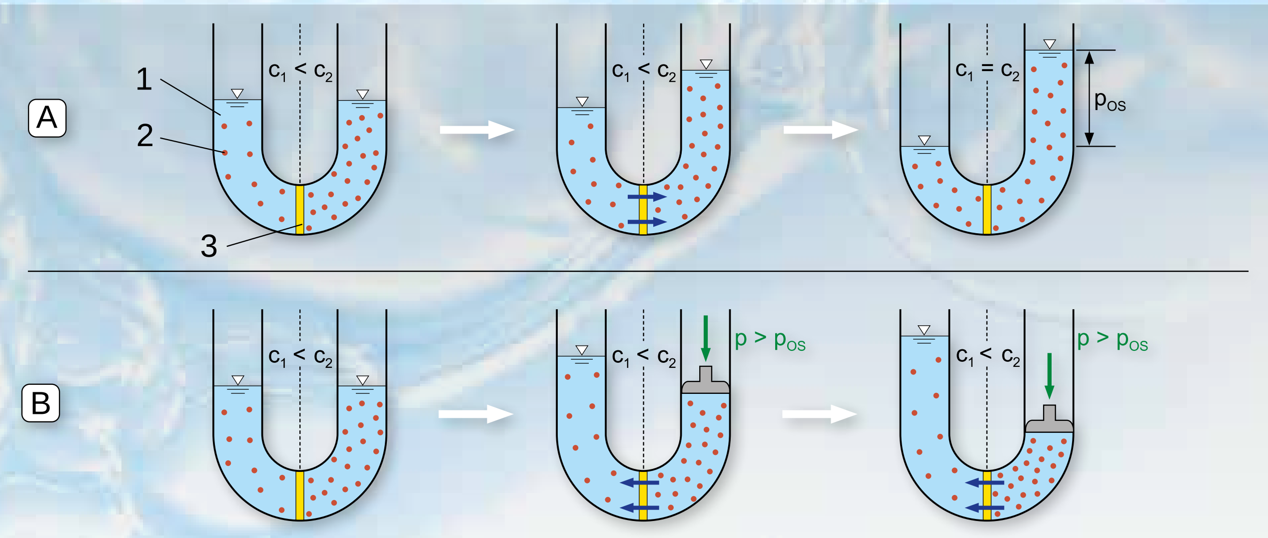
The pressure difference – the so-called transmembrane pressure – increases in the sequence indicated above. At the same time the separation limit – that is, the size of the smallest separable substances – decreases. The treated water is termed permeate, and the retained portion of the raw water is retentate.

**Reverse osmosis**

Reverse osmosis is particularly important. This unit operation enables high purity water to be produced. It is often required for many different processes in industry and for desalination of sea water.

To understand the reverse osmosis, the osmosis first has to be explained by an example (illustration). Two salt solutions with differing concentrations are separated by a semi-permeable membrane. The membrane is only permeable to water molecules. In trying to equalise concentrations on either side, water flows from left to right through the membrane. The water level rises on the right side until a state of equilibrium is established, the – so called – osmotic equilibrium. The same salt concentration now prevails on both sides of the membrane. The resultant hydrostatic pressure difference between the two sides of the membrane is termed the osmotic pressure.

To reverse the direction of flow of the water (reverse osmosis), the osmotic pressure must be overcome. To do so, a pressure greater than the osmotic pressure is applied to the right side of the membrane. The water then flows from right to left through the membrane. The retentate is produced on the right hand side, and the permeate on the left. In the applications mentioned transmembrane pressures up to 100 bars can be required.




*Fundamental principle of osmosis (A) and reverse osmosis (B):*
***1** water, **2** salt ions, **3** semi-permeable membrane, **p** pressure, $p_{OS}$ osmotic pressure*
*$c_1$ salt concentration on the left side of the membrane, $c_2$ salt concentration on the right side of the membrane*

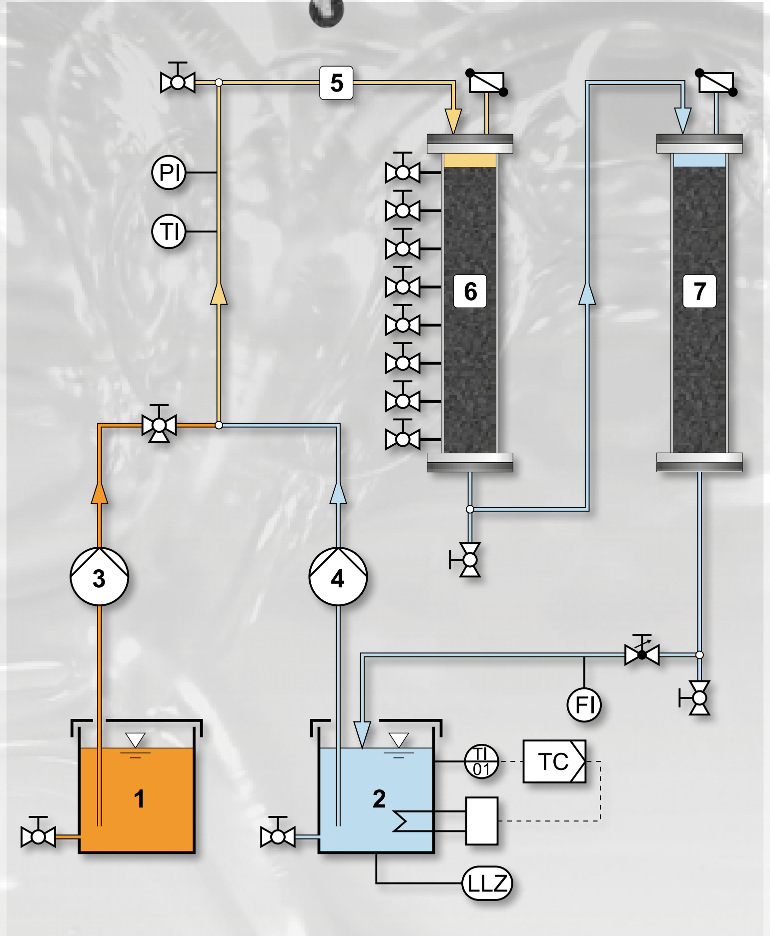
# CE 583 ADSORPTION

*All components are clearly arranged on a mobile trainer.*

## The ideal way to teach and learn about adsorption in all its aspects

One method of removing dissolved substances from water is adsorption. In water treatment, adsorption is mainly implemented with continuous-flow adsorbers. The adsorbent in most widespread use is activated carbon.

- continuous process
- two adsorbers with activated carbon filling
- reuse of the treated water (closed water circuit)
- control of water temperature




*Process schematic of CE 583:*
*1 concentrated adsorbate solution, 2 treated water, 3 metering pump, 4 treated water pump, 5 raw water, 6 adsorber, 7 safety adsorber*

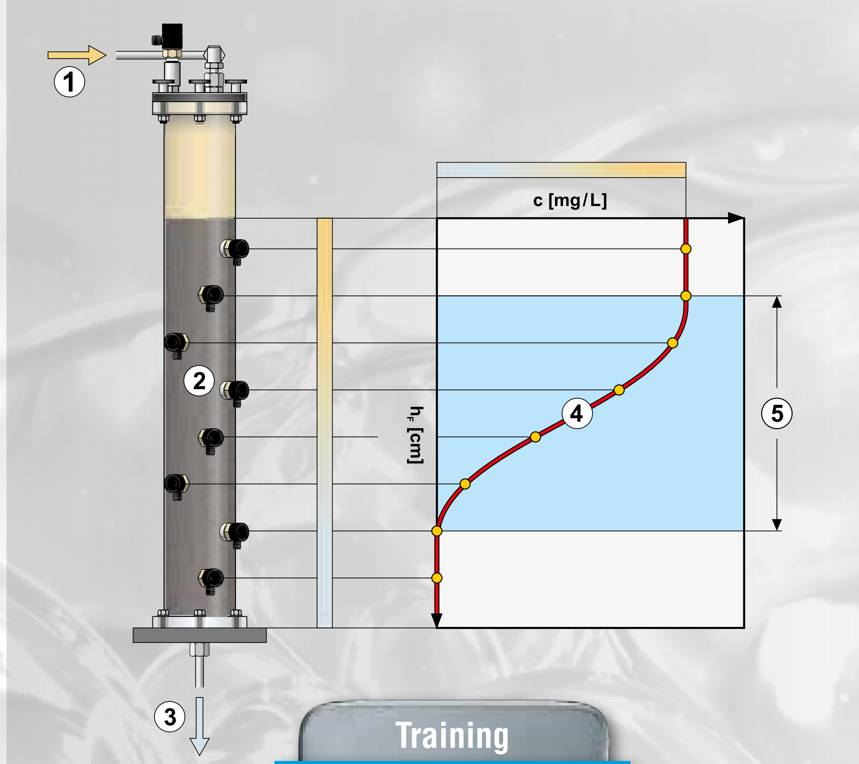
*Precise adjustment of the adsorbate concentration in the raw water using high quality pumps*

*Tanks for adsorbate solution and treated water made of stainless steel*

*Primary component of CE 583: adsorber with sampling points*

## EXTENSIVE RANGE OF LEARNING OBJECTIVES

- recording of concentration profiles
- recording of breakthrough curves
- relationship between concentration profiles and breakthrough curves
- determining the mass transfer zone
- an adsorber's mass balance
- an adsorber's efficiency
- predicting breakthrough curves
- scale-up of the results to industrial scale
- detection of the following influencing factors
  - contact time
  - temperature
  - mode of operation




*Plotting of concentration profiles with CE 583: 1 raw water, 2 adsorber with sampling points, 3 treated water, 4 concentration profile, 5 mass transfer zone*

**Training**

**If you require installation or training services, we will be glad to help.**

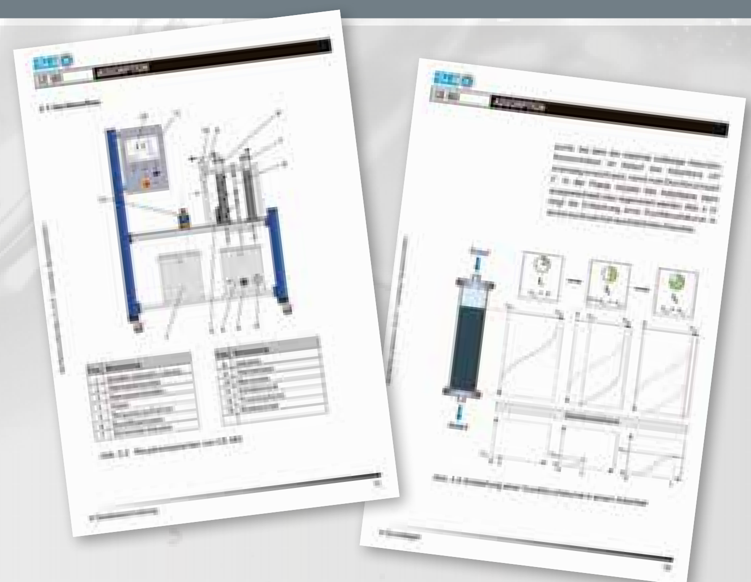
## THE INSTRUCTIONAL MATERIAL

We have compiled a comprehensive range of instructional material for the CE 583 which will greatly assist you in getting to know the system and in preparing your lessons and laboratory experiments and exercises.

The instructional material comprises

- detailed representation of the fundamentals
- description of the device
- detailed description of the experiments
- worksheets for the experiments
- performed reference experiments

Materials delivered as paper printouts in a folder and additionally as PDF files on a CD.



*Instructional material of CE 583*

## CE 583 Adsorption

* Adsorption of dissolved substances on activated carbon
* Concentration profiles and breakthrough curves
* Determination of the mass transfer zone
* Influence of the temperature and the contact time on adsorption
* Practical experiments in laboratory scale

### Technical Description

CE 583 demonstrates the removal of dissolved substances by adsorption. During adsorption the substances dissolved in the raw water are called adsorbate.

A pump transports the water from a tank in a circuit with two adsorbers filled with activated carbon. The pump transports treated water to the first adsorber. A concentrated adsorbate solution is added to the treated water flow using a metering pump. The raw water produced in this way enters the adsorber and flows through the activated carbon fixed bed. Here the adsorbate adsorbs on the activated carbon. To remove any quantities of adsorbate still present from the water, the water then flows through a second adsorber (safety adsorber). The treated water is returned to the feed line of the first adsorber where concentrated adsorbate solution is added once again. This creates a closed water circuit.

The flow rates of both pumps can be adjusted. Thereby the following parameters can be varied:
- concentration of the adsorbate in the raw water
- contact time of the raw water with the activated carbon

The water temperature can be controlled. This allows for the temperature effect of the adsorption to be investigated. Flow rate, temperature and pressure are continuously measured. Sampling points are arranged in such a way that breakthrough curves and concentration profiles can be plotted.

Analysis technology is required to evaluate the experiments. The choice of analysis technology depends on the adsorbate used. Methylene blue can e.g. be used as adsorbate. The concentration of methylene blue can be determined using a photometer.

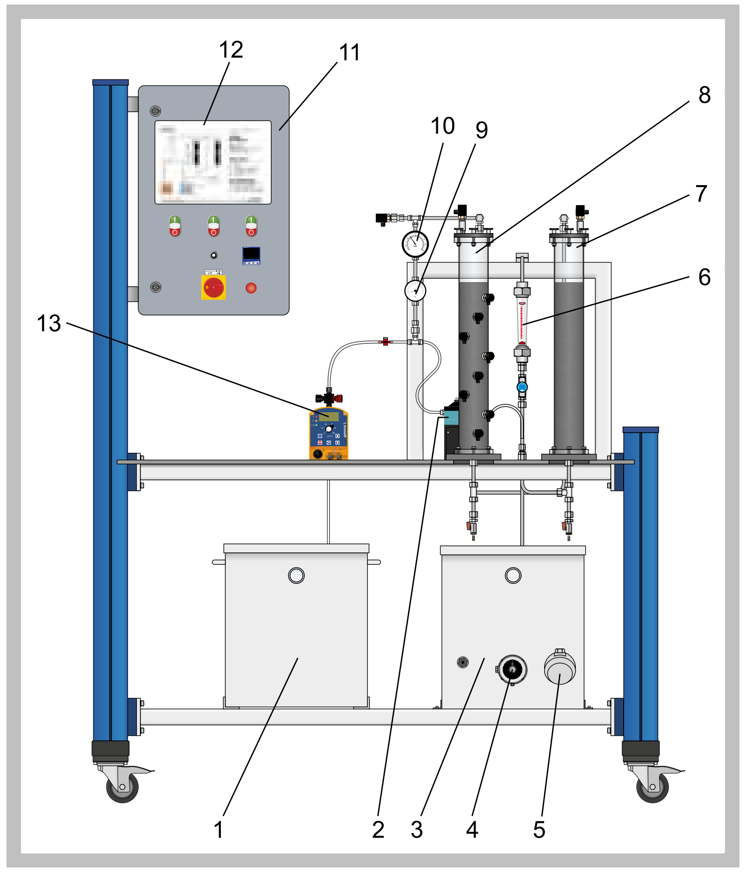
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

### Learning Objectives / Experiments

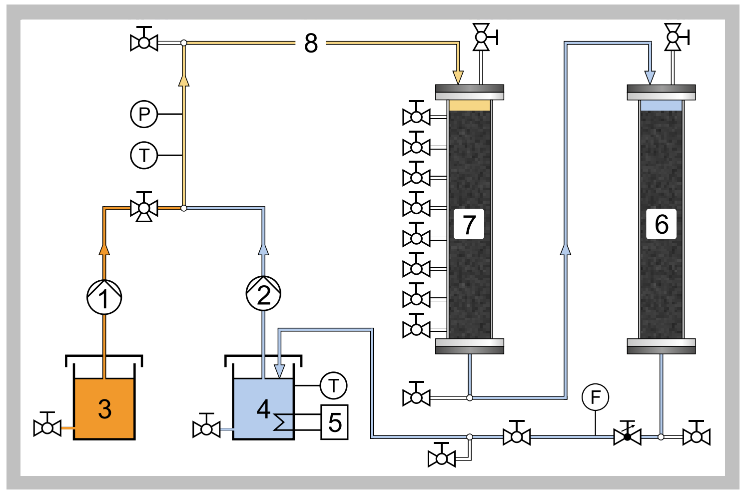
- recording of concentration profiles
- recording of breakthrough curves
- relationship between concentration profiles and breakthrough curves
- determining the mass transfer zone
- an adsorber's mass balance
- an adsorber's efficiency
- predicting breakthrough curves
- scale-up of the results to industrial scale
- detection of the following influencing factors
  * contact time
  * temperature
  * mode of operation



## CE 583 Adsorption




1 adsorbate solution tank, 2 circulation pump, 3 treated water tank, 4 heater, 5 temperature sensor, 6 flow meter, 7 safety adsorber, 8 adsorber, 9 thermometer, 10 manometer, 11 switch cabinet, 12 process schematic, 13 metering pump




1 metering pump, 2 circulation pump, 3 concentrated adsorbate solution, 4 treated water, 5 heater, 6 safety adsorber, 7 adsorber, 8 raw water; F flow rate, P pressure, T temperature

### Specification

[1] 2 adsorbers with activated carbon filling
[2] adsorber with 8 sampling points
[3] safety adsorber for closed water circuit
[4] continuous process
[5] metering pump for concentrated adsorbate solution
[6] pump for recirculating the treated water
[7] water temperature control
[8] digital temperature indication
[9] flow rate adjustable
[10] change of adsorbate concentration and contact time

### Technical Data

Adsorber and safety adsorber
- inside diameter: each 60mm
- height: each 600mm
- capacity: each 1700cm³

Tanks
- treated water: 45L
- adsorbate solution: 45L

Circulation pump
- max. flow rate: 180L/h
- max. head: 10m

Metering pump
- max. flow rate: 2,1L/h
- max. head: 160m

Heater
- max. power: 500W

Measuring ranges
- flow rate: 0...60L/h
- temperature: 0...60°C
- pressure: 0...2,5bar

### Dimensions and Weight

LxWxH: approx. 1500x790x1900mm
Weight: approx. 180kg

### Required for Operation

230V, 50/60Hz, 1 phase or 120V, 60Hz/CSA, 1 phase
Water connection, drainage,
methylene blue (recommendation)

### Scope of Delivery

1 trainer
1 packing unit of activated carbon
1 set of test tubes
1 set of tools
1 set of instructional material

### Order Details

083.58300 CE 583 Adsorption

## CE 530 Reverse Osmosis

The illustration shows: supply unit (left) and trainer (right)

*** Membrane separation process for obtaining solvent from a salt solution**

*** Spiral wound membrane module for separation**

*** Example application: sea water desalination**

### Technical Description

This trainer has been developed in cooperation with the **Institute for Thermal Process Engineering at the TU Hamburg-Harburg**. A solution of NaCl in a defined concentration is mixed in a tank complete with a stirring machine. A pump delivers the solution to the spiral wound membrane module. The pump generates the necessary pressure for separation.

The spiral wound membrane module consists of multiple membrane envelopes. A membrane envelope is made up of two membranes with a porous spacer between them. The membrane envelope is sealed on three sides and on its fourth, open, side is connected to the perforated permeate collecting tube. There are other spacers between the envelopes to ensure axial flow of the salt solution. The spacers together with the membrane envelopes are wound spirally around the permeate collecting tube. The salt solution arrives at the front face of the module and flows axially between the envelopes. The semi-permeable membrane is permeable to water (permeate) but not to dissolved NaCl. The applied pressure forces the water through the membrane into the envelopes. In the envelopes the water flows spirally towards the permeate collecting tube and exits the module in an axial direction. As a result of the water being removed, the solution is concentrated as it travels through the module. It exits the module as retentate and is returned to the raw water tank.

The permeate is collected in a separate tank. Another tank containing distilled water is provided to flush through the spiral wound membrane module.

The pressure and flow rate can be adjusted by valves. In order to check the success of the separation, salt concentrations in the raw water, retentate and permeate are recorded by measuring the respective conductivity values.

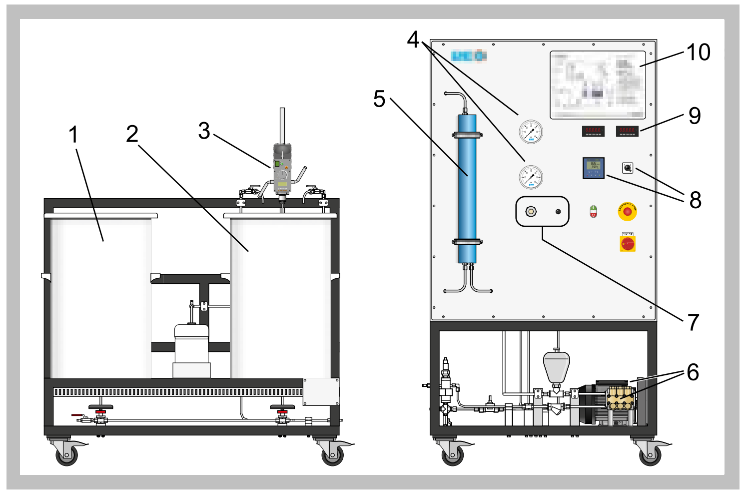
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

### Learning Objectives / Experiments

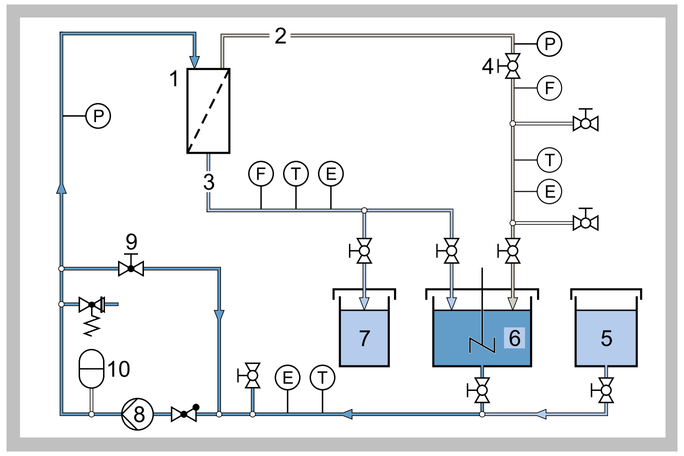
- assembly, cleaning and conservation of membrane modules
- fundamental principle of reverse osmosis
  * Van't Hoff's law
- permeate flow rate and retention dependent on
  * pressure
  * salt concentration in raw water
  * yield
- determination of diffusion coefficients



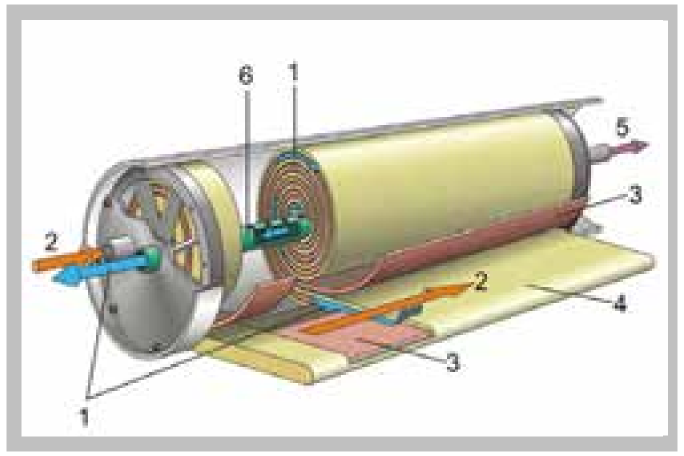
## CE 530 Reverse Osmosis




1 tank for distilled water, 2 raw water tank, 3 stirring machine, 4 manometer, 5 spiral wound membrane module, 6 pump with motor, 7 valves, 8 conductivity display and selector, 9 flow rate display, 10 process schematic




1 spiral wound membrane module, 2 retentate, 3 permeate, 4 retentate valve, 5 distilled water, 6 raw water (salt solution), 7 permeate, 8 pump, 9 overflow valve, 10 pulsation damper; P pressure, F flow rate, T temperature, E conductivity




Spiral wound membrane module: 1 permeate, 2 raw water, 3 spacer, 4 membrane envelope, 5 retentate, 6 permeate collecting tube

### Specification

[1] removal of solvent from a salt solution using reverse osmosis
[2] polyamide spiral wound membrane module
[3] piston pump with pulsation damper for pressure generation
[4] overflow valve to adjust the pressure upstream of the membrane module
[5] valve to adjust the retentate flow rate
[6] raw water tank with stirring machine to prepare a salt solution
[7] tank for distilled water to flush through the spiral wound membrane module
[8] tank to collect the permeate
[9] safety cutout to protect the pump against dry running

### Technical Data

Spiral wound membrane module
- active area: 1,2m²
- raw water flow rate: max. 23L/min
- length: approx. 500mm
- diameter: approx. 60mm

Piston pump
- max. flow rate: approx. 425L/h
- max. head: approx. 700m

Max. operating pressure: 60bar

Stirring machine
- power consumption: 140W
- speed: 30...1000min$^{-1}$

Tanks
- raw water (salt solution): approx. 110L
- distilled water: approx. 110L
- permeate: approx. 5L

Measuring ranges
- retentate flow rate: 0,2...6,0L/min
- permeate flow rate: 0,05...1,8L/min
- temperature: 3x 0...50°C
- pressure: 2x 0...120bar
- conductivity: 3x 0...200mS/cm

### Dimensions and Weight

LxWxH: 1250x1050x2100mm (trainer)
LxWxH: 1500x1050x1400mm (supply unit)
Weight: approx. 290kg (in total)

### Required for Operation

230V, 50/60Hz, 1 phase or 120V, 60Hz, 1 phase
Water connection, drainage, sodium chloride, distilled water, sodium disulfite (conservation of the membrane module), caustic soda, hydrochloric acid

### Scope of Delivery

1 trainer, 1 supply unit, 1 membrane, 1 conservation tank, 1 set of tools, 1 set of hoses, 3 conductivity sensors
1 set of instructional material

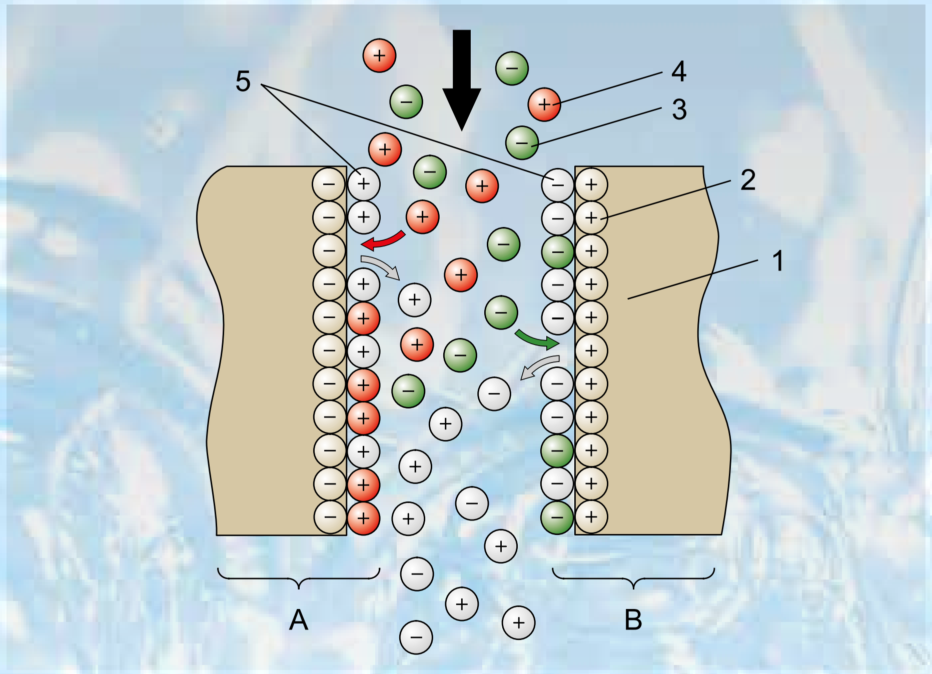
### Order Details

083.53000 CE 530 Reverse Osmosis

BASIC KNOWLEDGE

# ION EXCHANGE

Ion exchange is a physical/chemical process in which a solid absorbs ions from a liquid and, in exchange, discharges an equivalent amount of identically charged ions to the liquid. Positively charged ions are known as cations, and negatively charged ions are known as anions. Ion exchangers may be natural materials (such as zeolites) or synthetic resins (such as polystyrene or polyacrylate).




*Fundamental principle of ion exchange*
***A*** *cation exchanger,* ***B*** *anion exchanger*
***1*** *matrix,* ***2*** *permanently bonded ions,* ***3*** *anions,* ***4*** *cations,* ***5*** *counterions*

An ion exchanger consists of a matrix with permanently bonded ions and oppositely charged counterions. The counterions are exchanged with the ions being removed from the water.

Ion exchange is based on the principle that the higher the valence (ionic charge), the more strongly the ions are bonded to an ion exchanger. This means divalent ions are capable of being exchanged for monovalent counterions. Ion exchangers can only exchange a certain quantity of ions. When the exchange capacity is exhausted, the ion exchanger is regenerated. This utilises the fact that ion exchange depends not only on the valence of the ions involved, but also on their concentration. So a large number of ions with a low valence can displace ions with a higher valence. In regeneration therefore, the exhausted ion exchanger is converted back to its original form by a high concentration of the original counterions. In the case of cation exchangers this is done with acids, and in the case of anion exchangers with caustic.

### Applications

- Desalination

When removing salt (sodium chloride: NaCl), $Na^+$ ions are exchanged for $H^+$ ions by a cation exchanger. In an anion exchanger, the $Cl^-$ ions in the salt are then exchanged for OH- ions. The released $H^+$ and $OH^-$ ions combine to form water ($H_2O$).

- Softening

When hard water is heated, lime deposits form. These can lead to damage in pipes and equipment (for example steam generation and in households). In the softening process, calcium ions ($Ca^{2+}$) and magnesium ions ($Mg^{2+}$) are removed from the water by cation exchangers

- Detoxification

Industrial wastewater can contain toxic substances such as heavy metals, cyanides and chromates. These substances are normally present in the form of ions, and can be removed from the wastewater by ion exchange.

BASIC KNOWLEDGE

# PRECIPITATION / FLOCCULATION

Precipitation and flocculation are two different processes, though in practice they are often combined. In precipitation, dissolved substances are converted into undissolved solids by a chemical reaction. This is achieved by adding a precipitant.

The solids can then be removed by means of mechanical processes such as sedimentation. However, the resultant solids (precipitation products) usually have a low density and sediment very slow. The object of flocculation is to produce larger solids with better sedimentation properties.

An important area of application for precipitation and flocculation is the removal of dissolved metals (e.g. iron).

### Precipitation

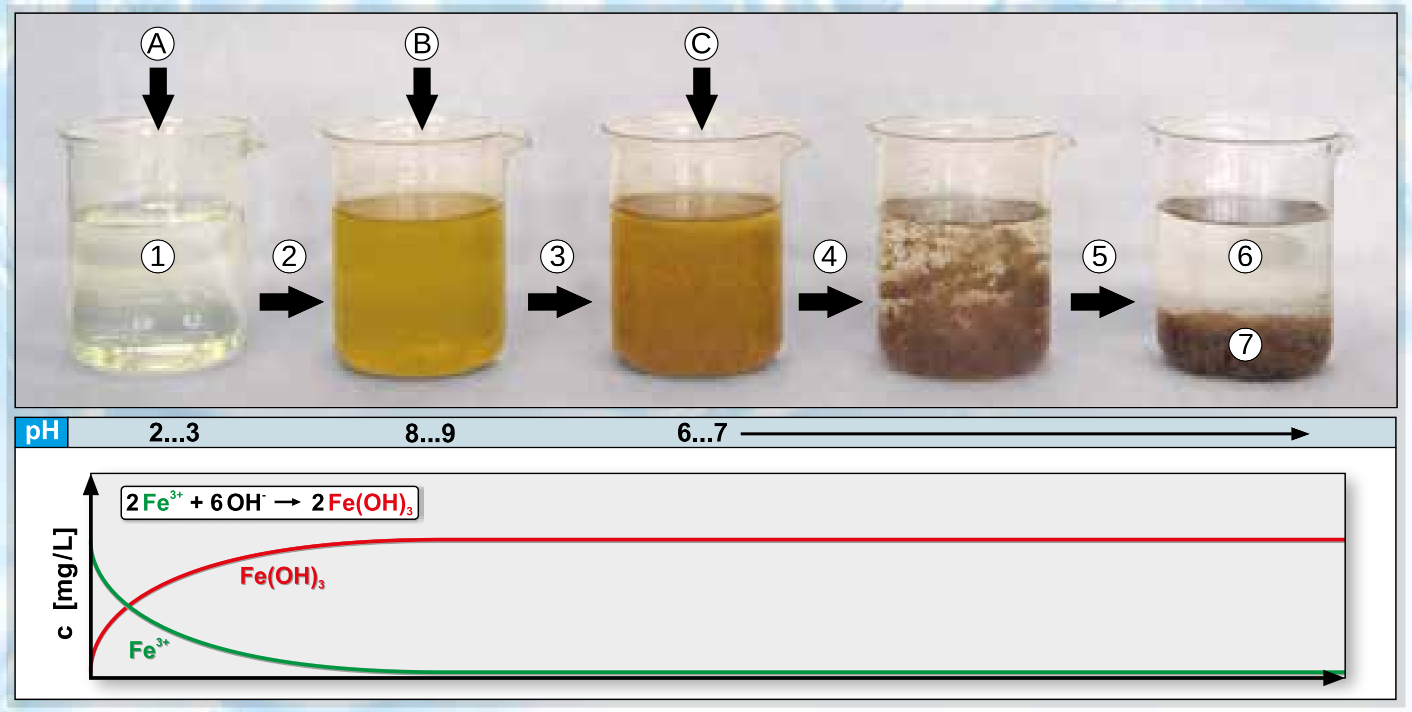
A frequently used form of precipitation is **hydroxide precipitation.** This makes use of the fact that the solubility of many metals diminishes with increasing pH value. A common precipitant for hydroxide precipitation is caustic soda (NaOH). Hydroxide precipitation can be illustrated simplified in the following example:

Wastewater to be treated contains trivalent dissolved iron ($Fe^{3+}$) and has a pH value of approx. 2 to 3. $Fe^{3+}$ ions are only soluble at very low pH values. By adding caustic soda (precipitant) the pH value is increased to approx. 8 to 9. The OH ions (hydroxide ions) of the caustic soda react with the $Fe^{3+}$-ions and form insoluble iron hydroxide: $Fe(OH)_3$.

### Flocculation

The particles often are charged identically and repel each other. Therefore the particles can't aggregate into larger flocs (coagulate). Consequently, the electrostatic repulsive forces between the particles must first be eliminated. This is done using inorganic coagulants, such as metal salts. The individual particles can then aggregate into micro-flocs. This first phase of the flocculation process is termed **coagulation.**

In the second phase – the actual **flocculation** – flocculants are added into the wastewater. These agents are organic polymers. They adhere to the micro-flocs, enabling them to be interconnected. The resultant flocs are termed macro-flocs.




*Hydroxide precipitation of dissolved iron ($Fe^{3+}$) followed by flocculation:*
***1*** *wastewater,* ***2*** *precipitation,* ***3*** *coagulation,* ***4*** *flocculation,* ***5*** *sedimentation,* ***6*** *treated water,* ***7*** *iron hydroxide $Fe(OH)_3$*
***A*** *precipitant (NaOH),* ***B*** *coagulant,* ***C*** *flocculant*

## CE 300 Ion Exchange

* Softening and desalination of water by ion exchange
* Regeneration of ion exchangers
* Cation and anion exchanger

### Technical Description

Ion exchangers are used in water treatment primarily for desalination and softening. CE 300 enables these processes to be demonstrated with the aid of cation and anion exchangers.

The raw water is pumped from the tank into the top of the cation exchanger. In the softening process the water flows from there back into the collecting tank. To desalinate the raw water, it is then additionally routed through the anion exchanger. From there the treated water passes into the collecting tank. In the regeneration process, acid or caustic is fed into the ion exchangers from below using the same pump. The acid and caustic used is collected in the collecting tank.

The flow rate of the pump is adjustable, and can be read from a flow meter before it enters the first ion exchanger. For continuous evaluation of the process, a conductivity sensor is installed upstream of the inlet into the collecting tank. The measured values can be read from a conductivity meter. Samples can be taken at all relevant points. Tap water can be used as raw water.

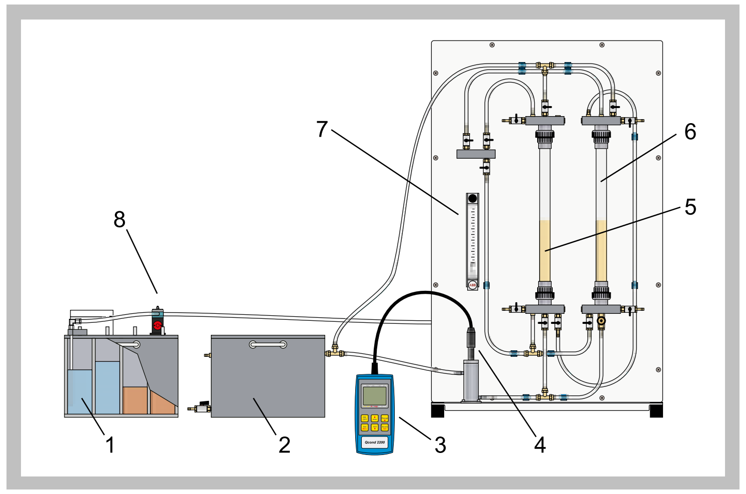
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

### Learning Objectives / Experiments

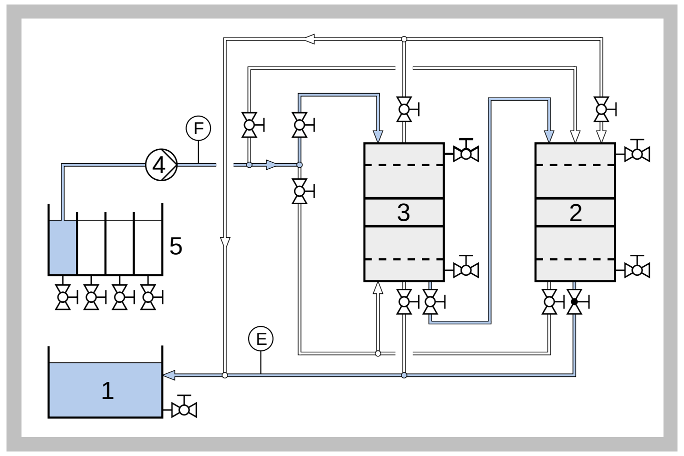
- learning the fundamental principle of softening and desalination by ion exchange
- identification of the different modes of operation of cation and anion exchangers
- combined use of cation and anion exchangers for desalination
- exchanging capacities and regeneration
- verification of the theoretically calculated regeneration time



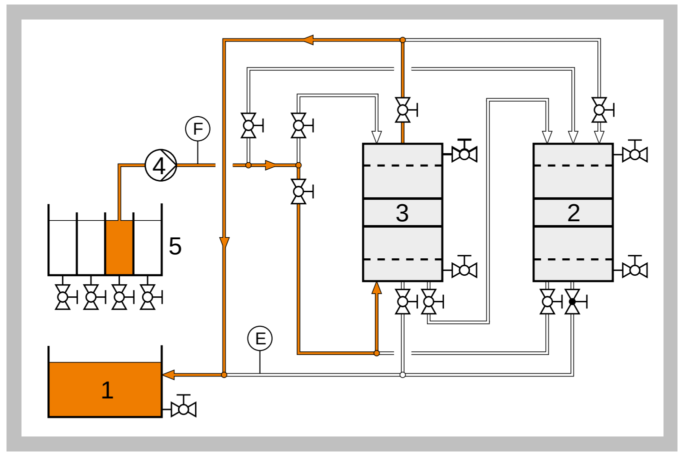
## CE 300 Ion Exchange




1 tank for raw water, rinsing water, acid and caustic, 2 collecting tank, 3 conductivity meter, 4 conductivity sensor, 5 cation exchanger, 6 anion exchanger, 7 flow meter, 8 pump




Flow path with the two ion exchangers configured in series (desalination):
1 collecting tank, 2 anion exchanger, 3 cation exchanger, 4 pump,
5 raw water tank; E conductivity, F flow rate




Flow path with cation exchanger regeneration:
1 collecting tank, 2 anion exchanger, 3 cation exchanger, 4 pump,
5 acid tank

### Specification

[1] softening and desalination with ion exchange
[2] cation and anion exchangers usable separately and in combination
[3] regeneration of ion exchangers
[4] tank with 4 chambers for raw water, rinsing water, acid and caustic
[5] diaphragm pump to transport raw water, rinsing water, acid and caustic
[6] collecting tank for treated water, rinsing water, acid and caustic
[7] continuous measurement of conductivity and flow rate

### Technical Data

Ion exchanger
- material: network polymer
- cation exchanger: $H^+$ form
- anion exchanger: $OH^-$ form

Diaphragm pump
- max. flow rate: 300mL/min
- max. head: 10m

Tank
- 4 chambers
- capacity: each approx. 5L
- material: PVC

Collecting tank
- capacity: approx. 20L
- material: PVC

Measuring ranges
- flow rate: 20...270mL/min
- conductivity: 0...2000µS/cm

### Dimensions and Weight

LxWxH: approx. 610x510x1010mm (experimental unit)
LxWxH: approx. 350x480x310mm (tank, 4 chambers)
LxWxH: approx. 440x540x230mm (collecting tank)
Weight: approx. 46kg

### Required for Operation

230V, 50/60Hz, 1 phase or 120V, 60Hz/CSA, 1 phase
Water connection, caustic soda, hydrochloric acid, distilled water

### Scope of Delivery

1 experimental unit
2 tanks
1 conductivity sensor
1 conductivity meter
1 packing unit of cation exchanger
1 packing unit of anion exchanger
1 set of hoses
1 set of instructional material

### Order Details

083.30000 CE 300 Ion Exchange

# CE 586 PRECIPITATION AND FLOCCULATION

## Practical Education in Water Treatment

Precipitation and flocculation is a physical/chemical process in water treatment. The removal of dissolved metals is one of the main applications of this process. It is often required for the production of drinking water and for treatment of contaminated ground water.

CE 586 enables this process to be teached very practically.


## CONTINUOUS AND PRACTICAL PROCESS

**1** Precipitation tank

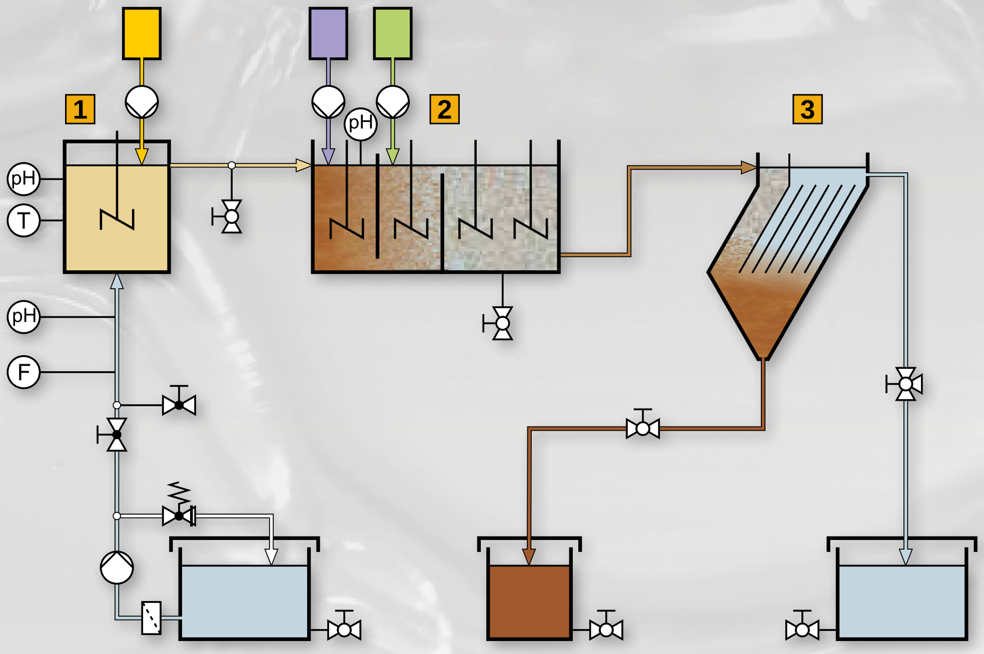
*Precipitation of dissolved substances*

**2** Flocculation tank

*Formation of flocs by coagulation and flocculation*

**3** Lamella separator

*Separation of the flocs by sedimentation*




Metering pumps

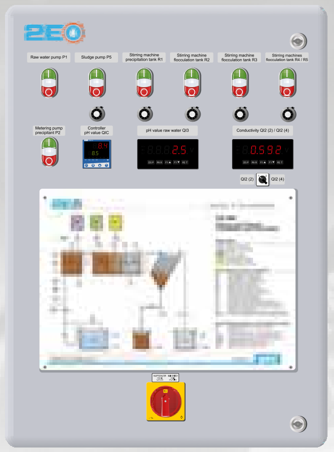
*Precise addition of chemicals by use of industrial metering pumps*

## INSTRUMENTATION AND CONTROL

- use of high quality instrumentation
- flow rate sensor
- conductivity sensor
- temperature sensor
- control of pH value in the precipitation tank

You can find an interesting film of CE 586 on our 2E website
**www.gunt2E.de**

## SWITCH CABINET



- controls of all primary components
- controls arranged very clearly
- digital displays for measured values
- digital controller for pH value

A large, clear process schematic on the switch cabinet makes it easy to assign all the components.

## THE INSTRUCTIONAL MATERIAL

The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments. Materials delivered as paper printouts in a folder and additionally as PDF files on a CD.

**Updates**
When any updates or additions to the CE 586 are made – in particular with regard to the instructional material – you, as a GUNT customer, will be notified accordingly.

*Instructional material of CE 586*

BUE The British University in Egypt الجامعة البريطانية في مصر
Department of Civil Engineering

*A staff member of the British University in Egypt (Cairo) explains how CE 586 works.*

## CE 586 Precipitation and Flocculation

The illustration shows: Supply unit (left) and trainer (right).

*** Removal of dissolved substances (e.g. iron) by precipitation and flocculation**

*** Sedimentation of the flocs in the lamella separator**

### Technical Description

CE 586 demonstrates the removal of dissolved substances by precipitation and flocculation with subsequent sedimentation.

First, raw water is produced in a tank to contain dissolved metal (e.g. iron). A pump transports the raw water to the precipitation tank. Here the precipitant is added (e.g. caustic soda). Due to the reaction of the dissolved metal ions with the precipitant, insoluble metal hydroxides form (solids). From here the water flows into a flocculation tank divided into three chambers. The purpose of flocculation is to improve the sedimentation properties of the solids. By adding a coagulant in the first chamber the repulsive forces between the solid particles are cancelled out. The solid particles aggregate into flocs (coagulation). To generate larger flocs, a flocculant is then added (flocculation). In the third chamber low flow velocities are present to prevent any turbulence. Turbulence would impede the formation of flocs. The now well sedimentable flocs are then separated from the treated water in a lamella separator. The treated water and the sedimented flocs (sludge) are collected in two tanks.

Flow rate, temperature and the pH value are measured. In addition, the pH value in the precipitation tank can be controlled. For measuring the conductivity an external meter is available. Samples can be taken at all relevant points.

Analysis technology is required to analyse the experiments. The choice of analysis technology depends on the substances used. Trivalent metallic salts are usually well suited as coagulants. Common flocculants are organic polymers.

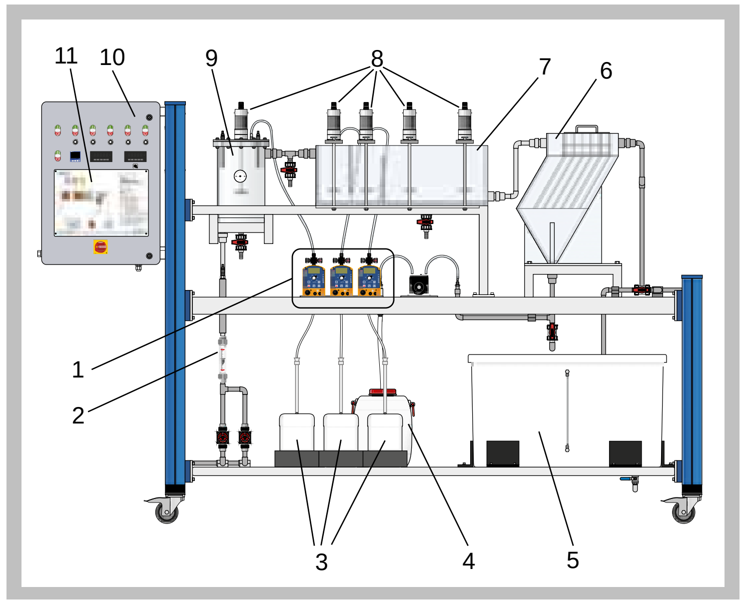
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

### Learning Objectives / Experiments

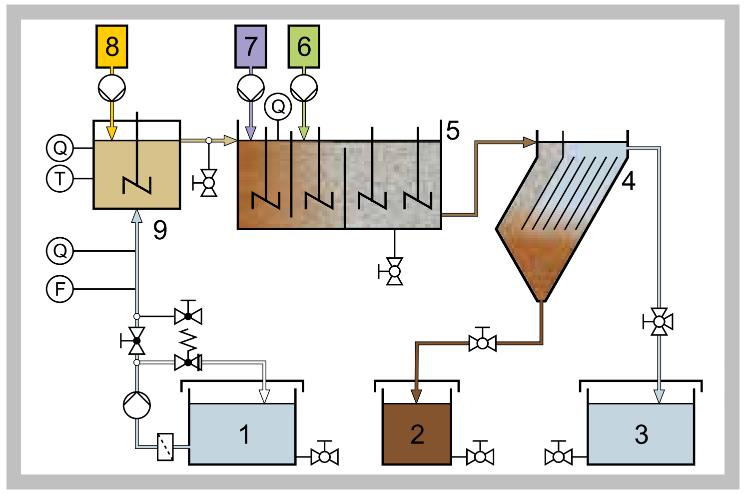
- familiarisation with precipitation and flocculation
- effect of the pH value on precipitation
- creation of a stable operating state
- determination of the required metering quantities (precipitant, coagulant, flocculant)
- functional principle of a lamella separator



## CE 586 Precipitation and Flocculation




1 metering pumps, 2 flow meter, 3 chemicals tank, 4 sludge tank, 5 treated water tank, 6 lamella separator, 7 flocculation tank, 8 stirring machines, 9 precipitation tank, 10 switch cabinet, 11 process schematic




1 raw water, 2 sludge, 3 treated water, 4 lamella separator, 5 flocculation tank, 6 flocculant, 7 coagulant, 8 precipitant, 9 precipitation tank; F flow rate, Q pH value, T temperature

### Specification

[1] precipitation and flocculation of dissolved substances (e.g. iron)
[2] separate supply unit with tank and pump for raw water
[3] precipitation tank with stirring machine
[4] flocculation tank with 3 chambers and 4 stirring machines
[5] 3 metering pumps for chemicals
[6] sedimentation of the flocs in the lamella separator
[7] measurement of flow rate, temperature and pH value
[8] control of the pH value in the precipitation tank
[9] conductivity meter

### Technical Data

Tanks
- raw water and treated water: each 300L
- precipitation tank: 10L
- flocculation tank: 45L
- sludge tank: 15L

Lamella separator
- number of lamellas: 6
- angle of inclination of lamellas: 60°

Raw water pump
- max. flow rate: 180L/h
- max. head: 10m

Metering pumps
- max. flow rate: each 2,1L/h
- max. head: each 160m

Stirring machines
- max speed: each 600min$^{-1}$

Measuring ranges
- flow rate: 15...160L/h
- pH value: 0...14
- temperature: 0...60°C
- conductivity: 0...2000µS/cm

### Dimensions and Weight

LxWxH: 1550x790x1150mm (supply unit)
LxWxH: 3100x790x1950mm (trainer)
Total weight: approx. 435kg

### Required for Operation

230V, 50/60Hz, 1 phase or 120V, 60Hz, 1 phase
Water connection, drainage, iron(III) chloride, iron(III) sulfate, flocculant, caustic soda, hydrochloric acid

### Scope of Delivery

1 trainer
1 supply unit
1 conductivity meter
0,5L calibration solution (potassium chloride)
1 set of hoses
1 set of instructional material

### Order Details

083.58600 CE 586 Precipitation and Flocculation

# INSTRUCTIONAL MATERIAL AND SOFTWARE

**GUNT's policy is:**

High-quality hardware and clearly laid-out instructional materials ensure the teaching and learning success of an experimental unit. The core elements of the instructional material provided to accompany the units are reference experiments conducted by ourselves. The description of the experiment incorporates the detailed set-up, through to interpretation of the results obtained. A group of experienced engineers devise and maintain the accompanying instructional material.

Our software – in our context meaning computerised data acquisition programs – always comes with comprehensive online help to explain the features offered the detailed use of the program. GUNT software is developed and written in-house by another group of experienced engineers.


## BASIC KNOWLEDGE

# CHEMICAL OXIDATION

Industrial wastewaters or contaminated ground waters often contain non-biodegradable organic substances. These include, for example, chlorinated hydrocarbons. These substances can be chemically oxidised and so removed from the water. There are always two components involved in oxidation: the substance being oxidised and the oxidant. The oxidant absorbs electrons and is reduced. The substance being oxidised gives off electrons in return.

Organic substances are oxidised in stages, with intermediate products being formed along the way. Where organic substances are fully oxidised, they are converted into the inorganic end products water and carbon dioxide.

### Advanced oxidation processes

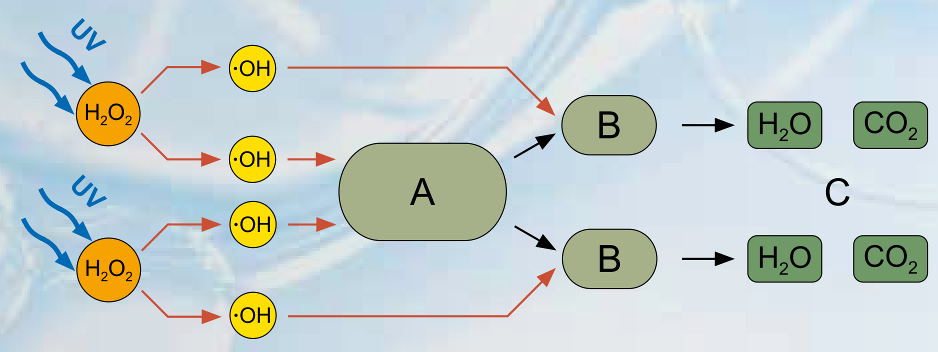
Oxidation processes are termed advanced when hydroxyl radicals (OH radicals) are used as the oxidants. The basic feature of radicals is the presence of a single free electron in place of an electron pair. This is indicated in the formula by a dot (·OH). This electron provides the OH radical with a very high reactivity. OH radicals are very strong oxidants, and are capable of oxidising virtually any organic substance.

One method of producing OH radicals is to irradiate hydrogen peroxide ($H_2O_2$) with UV light. Hydrogen peroxide absorbs the UV radiation, splitting into two OH radicals (photolysis). In this way, two OH radicals can be obtained from one hydrogen peroxide molecule.

### Application in water treatment

This process is applied in practice by adding hydrogen peroxide to the water being treated and then irradiating the water with UV lamps. The efficacy of this process depends to a large degree on the quantity of OH radicals produced. Their number rises with the quantity of source material and the intensity of the UV radiation. However, the high energy consumption of UV lamps means that increasing the radiation intensity at will is not economically viable.

Advanced oxidation can also be combined with biological processes. Then, organic substances are first chemically oxidised until biodegradable intermediate products are created.




*Fundamental principle of advanced oxidation with hydrogen peroxide and UV radiation:*
***$H_2O_2$** hydrogen peroxide, **·OH** hydroxyl radical*
***A** non-biodegradable organic substance, **B** organic intermediate products, **C** inorganic end products*

## CE 584 Advanced Oxidation

### Technical Description

In water treatment oxidation processes are used to remove organic substances which are not biodegradable. If the oxidation is by hydroxyl radicals (OH radicals) it is called "advanced oxidation". A common method for forming hydroxyl radicals is the irradiation of hydrogen peroxide with UV light. CE 584 demonstrates this process using a discontinuous falling film reactor.

The falling film reactor consists of a transparent tube which is open at the bottom. At the top of the tube there is a circular channel. Using a pump the raw water enriched with hydrogen peroxide is transported from a tank into the channel. From here the water flows as a thin falling film along the inside wall of the tube back into the tank. This creates a closed water circuit. At the centre of the tube there is a UV lamp. By irradiation of the falling raw water with UV light hydroxyl radicals form from the hydrogen peroxide molecules. The hydroxyl radicals oxidate the organic non-biodegradable substances in the raw water. As protection against the radiation the UV lamp is fitted with a protective tube.

The flow rate and temperature of the water are continuously measured. The temperature is indicated digitally in the switch cabinet. Samples can be taken at the tank.

E.g. triethylene glycol dimethyl ether can be used to produce the raw water. Analysis technology is required to evaluate the experiments.

The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

### Learning Objectives / Experiments

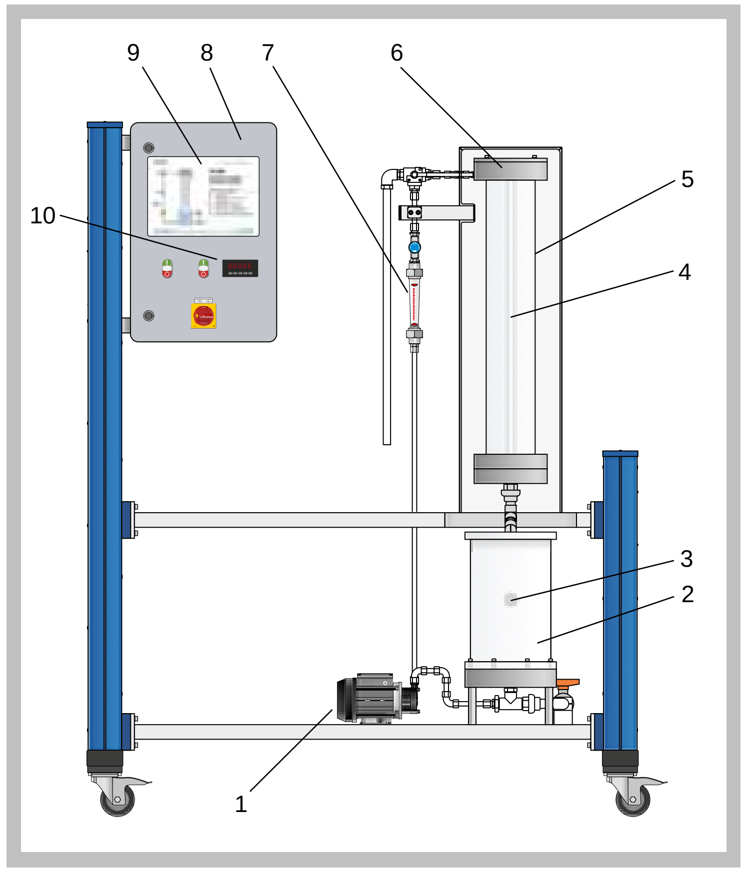
- familiarisation with oxidation with hydrogen peroxide and UV light
- recording of degradation curves for the investigation of reaction kinetics
- influence of the hydrogen peroxide quantity on the process

*** Oxidation of organic substances with hydrogen peroxide ($H_2O_2$) and UV light**

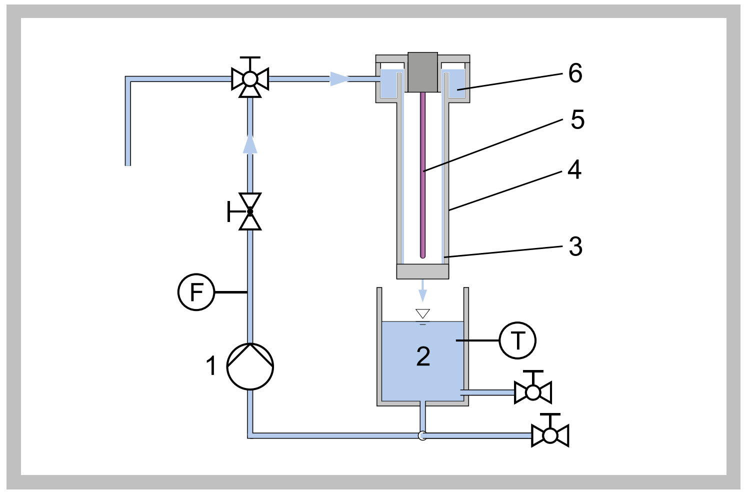
*** Discontinuous operation with falling film reactor**



## CE 584 Advanced Oxidation




1 pump, 2 tank, 3 temperature sensor, 4 UV lamp with protective tube, 5 falling film reactor (tube), 6 channel, 7 flow meter, 8 switch cabinet, 9 process schematic, 10 digital temperature display




1 pump, 2 tank, 3 falling film, 4 falling film reactor (tube), 5 UV lamp, 6 channel; F flow rate, T temperature

### Specification

[1] advanced oxidation process
[2] use of hydrogen peroxide and UV light
[3] formation of hydroxyl radicals (OH radicals)
[4] falling film reactor with UV lamp
[5] discontinuous operation
[6] flow rate adjustable
[7] measurement of temperature and flow rate
[8] digital temperature indication
[9] protection device against UV radiation

### Technical Data

Falling film reactor (tube)
- diameter: 130mm
- height: 1000mm
- material: glass

UV lamp
- emitted wavelength: 254nm
- power: 120W

Pump
- max. flow rate: 360L/h
- max. head: 9m

Tank
- capacity: 10L

Measuring ranges
- flow rate: 30...320 L/h
- temperature: 0...50°C

### Dimensions and Weight

LxWxH: 1510x790x1900mm
Weight: approx. 170kg

### Required for Operation

230V, 50/60Hz, 1 phase or 120V, 60Hz, 1 phase
Water connection, drainage, hydrogen peroxide, triethylene glycol dimethyl ether (recommendation)

### Scope of Delivery

1 trainer
2 buckets
2 beakers
1 set of instructional material

### Order Details

083.58400 CE 584 Advanced Oxidation

BASIC KNOWLEDGE

# COMBINED PROCESSES

Wastewater usually contains large numbers of substances with different properties. Consequently, a single unit operation is not usually sufficient to treat the water. That is why water treatment plants always combine several individual unit operations. The unit operations are selected primarily based on the properties of the raw water and the treated water quality requirements. One treatment target can often be achieved with different combinations. The question of which combination is most suitable must be investigated for each application. Economic factors are often the key to this decision.

Areas of application for water treatment plants:

- drinking water purification
- treatment of communal and industrial wastewater
- production of process water within industry
- treatment of contaminated ground water (remediation of contaminated sites)

For many industrial processes water with specific properties is required (e.g. hardness, pH value, salt content). At the same time heavily contaminated wastewater is produced in many production processes which cannot be discharged directly into a wastewater treatment plant. Therefore, a water treatment plant is integrated into many production processes. The treated wastewater can then either be discharged into the sewer or reused for the production process.

Such production processes occur, for example, in the following industries:

- food industry
- textile industry
- paper industry

The figure shows by way of example a multi-stage water treatment plant (A) integrated into an industrial production process (B). First the wastewater is treated mechanically. This protects the downstream plant components (e.g. pumps and pipes) against potential damage and clogging. Coarse solids are removed in a lamella separator (2) by sedimentation. Next, non-sedimentable solids are separated in a sand filter (4) by depth filtration. The thus mechanically cleaned wastewater contains no more solids and is then treated using physical/chemical processes. Dissolved organic substances (e.g. chlorinated hydrocarbons) are removed by adsorption in activated carbon in an adsorber (5). In the final stage an ion exchange takes place (6). This can e.g. be used to remove heavy metals from the wastewater or desalinate the wastewater.

The treated water is collected in a collector tank (7). The treated water can now either be discharged into the sewer (8) or returned to the production process (9). This creates a closed water circuit within the production process reducing the costs of wastewater disposal.


*Example of an industrial water treatment plant:*

***1*** *wastewater*
***2*** *lamella separator (sedimentation)*
***3*** *collecting tank*
***4*** *sand filter*
***5*** *adsorber (activated carbon)*
***6*** *ion exchanger*
***7*** *collecting tank for treated water*
***8*** *discharge of the treated water into the sewer*
***9*** *reuse of the treated water*

***A*** *water treatment plant*
***B*** *production*

## CE 581 Water Treatment Plant 1

The illustration shows: Supply unit (left) and trainer (right)

*** Example of a water treatment plant**
*** Depth filtration: removal of undissolved substances**
*** Adsorption: removal of dissolved substances**
*** Ion exchange: softening and desalination**

### Technical Description

Depth filtration, adsorption and ion exchange are key unit operations in water treatment. CE 581 enables these three operations to be demonstrated.

The raw water is pumped from above into a gravel filter and then routed into a sand filter. In the process, suspended solids are removed from the raw water. The filtered water then flows into the second treatment stage. There dissolved substances are removed by adsorption on aluminium oxide and on activated carbon. Then the water passes on to the third treatment stage. In this stage unwanted ions are removed from the water by ion exchange. First the water is softened by cation exchange. The water is then desalinated in a mixed bed ion exchanger containing cation and anion exchangers.

The separate supply unit includes pumps and tanks for the raw water and treated water. The raw water tank can be aerated. This ensures the raw water is mixed through. It also enables dissolved substances (such as iron) to be precipitated so as to then filter them. A connection to backwash the sand filters is provided.

The flow rate, temperature, conductivity, differential pressure and system pressure are measured. Samples can be taken at all relevant points. A software program is provided to control the operating states and measure data. A process schematic shows the current operating states of the individual components and the measured data.

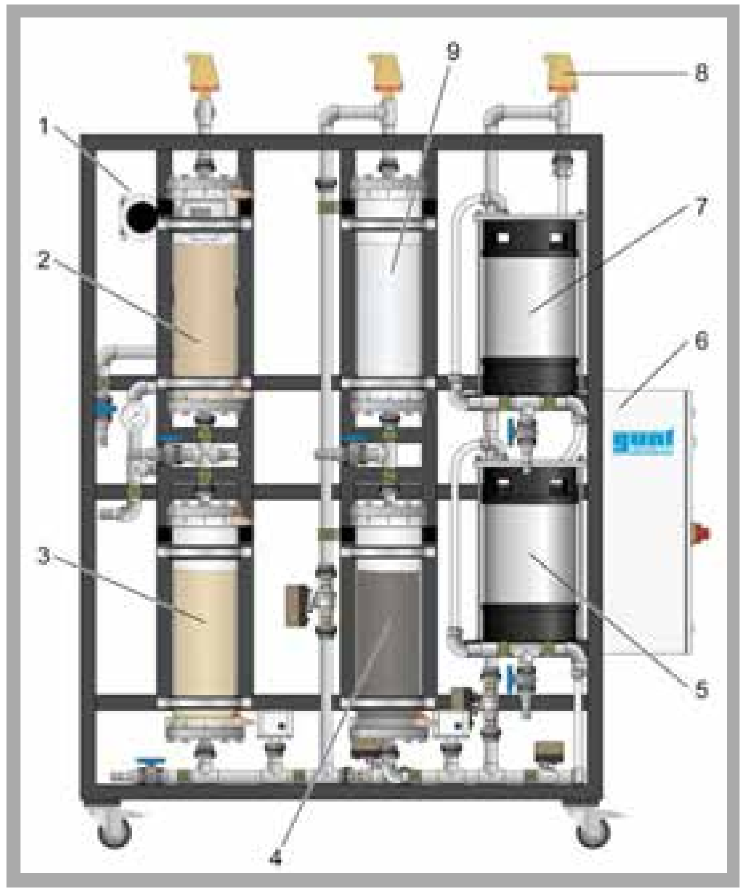
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

### Learning Objectives / Experiments

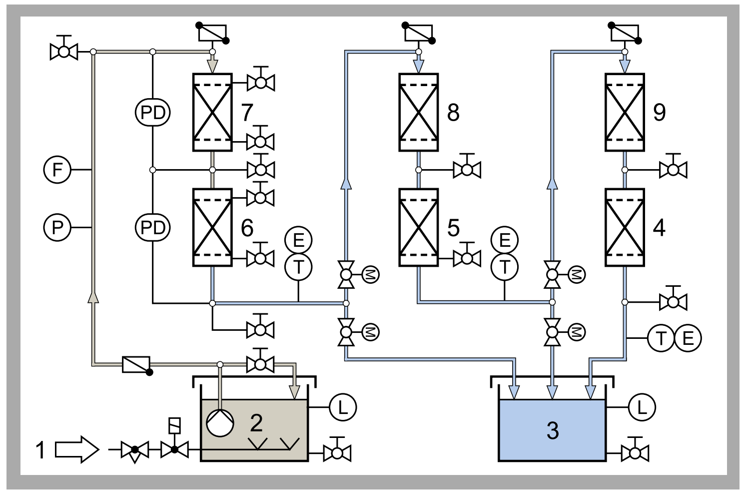
- learning the fundamental principle of the unit operations depth filtration, adsorption and ion exchange
- observation and determination of the pressure loss in depth filtration
- plotting of breakthrough curves (adsorption)
- comparison of various adsorption materials
- familiarisation with the fundamental principle of ion exchange



## CE 581 Water Treatment Plant 1



1 electromagnetic flow rate sensor, 2 gravel filter, 3 sand filter, 4 adsorber (activated carbon), 5 cation exchanger, 6 switch cabinet, 7 mixed bed ion exchanger, 8 bleed valve, 9 adsorber (aluminium oxide)



1 external compressed air supply, 2 raw water, 3 treated water, 4 mixed bed ion exchanger, 5 adsorber (activated carbon), 6 sand filter, 7 gravel filter, 8 adsorber (aluminium oxide), 9 cation exchanger; E conductivity, F flow rate, L level, P system pressure, PD differential pressure, T temperature

### Specification

[1] 3 unit operations in water treatment: depth filtration, adsorption, ion exchange
[2] gravel filter, sand filter, aluminium oxide adsorber, activated carbon adsorber, cation exchanger, mixed bed ion exchanger
[3] separate supply unit with tanks for raw water and treated water
[4] raw water tank with possibility of aeration
[5] gravel filter and sand filter with differential pressure measurement
[6] flow rate measurement of raw water
[7] measurement of conductivity and temperature after each treatment stage
[8] GUNT software with control functions and data acquisition via USB under Windows Vista or Windows 7

### Technical Data

Raw water pump
- max. flow rate: 25m³/h
- max. head: 20m

Gravel filter, sand filter and adsorbers
- diameter: each 200mm
- height: each 650mm

Ion exchanger tank
- diameter: each 240mm
- height: each 410mm

Tanks for raw water and treated water
- capacity: each approx. 180L

Measuring ranges
- flow rate: 0...1300L/h
- system pressure: 0...4bar
- differential pressure: 0...2.5bar
- conductivity: 0...600µS/cm
- temperature: 0...100°C

### Dimensions and Weight

LxWxH: 1300x800x950mm (supply unit)
LxWxH: 1680x800x2135mm (trainer)
Total weight: approx. 270 kg

### Required for Operation

230V, 50Hz, 1 phase
Water connection, drainage, compressed air (recommendation), substances for preparation of the raw water

### Scope of Delivery

1 trainer
1 supply unit
1 packing unit of sand
1 packing unit of gravel
1 packing unit of aluminium oxide
1 packing unit of activated carbon
1 set of hoses
1 GUNT software CD + USB cable
1 set of instructional material

### Order Details

083.58100 CE 581 Water Treatment Plant 1

## CE 582 Water Treatment Plant 2

The illustration shows from left to right: manometer panel, trainer, supply unit.

*** Example of a water treatment plant**
*** Depth filtration and ion exchange**
*** Backwash of sand filters and regeneration of ion exchangers**

### Technical Description

Depth filtration with sand filters and ion exchange are key unit operations in water treatment. CE 582 enables these two operations to be demonstrated.

The raw water is pumped from above into a sand filter. Solids are captured and retained as the raw water flows through the filter bed. The filtered water emerges from the bottom end of the sand filter and then flows through two ion exchangers (cation and anion exchangers). In the process, unwanted ions are exchanged for hydrogen and hydroxide ions. The raw water is softened and desalinated. The sand filter and the two ion exchangers can be used in combination or separately. The solids deposited in the sand filter result in an increase in pressure loss. Backwashing cleans the filter bed and reduces the pressure loss. The ion exchangers can be regenerated with acid or caustic.

The sand filter is equipped with a differential pressure measurement. There are also several pressure measuring points along the filter bed. The pressures are transmitted to tube manometers via hoses and displayed there as water columns. This can be used to plot Micheau diagrams. The flow rate, temperature, conductivity, differential pressure and system pressure are measured. The flow velocity in the filter bed (filter velocity) can be adjusted. Samples can be taken at all relevant points. E.g. diatomite can be used to produce the raw water.

A software program is provided to control the operating states and measure data. A process scematic shows the current operating states of the individual components and the measured data.

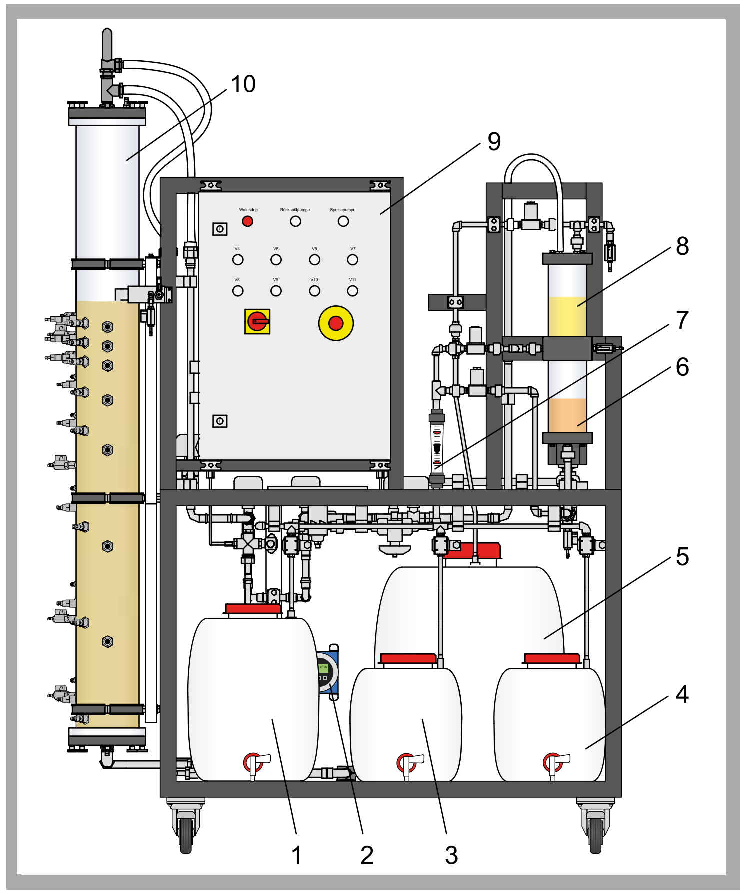
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

### Learning Objectives / Experiments

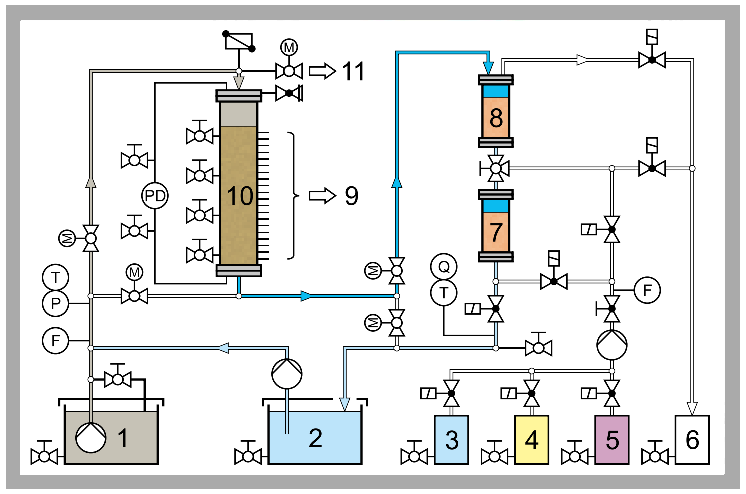
- learning the fundamental principle of the unit operations depth filtration and ion exchange
- observation and determination of pressure losses in a sand filter
- plotting of Micheau diagrams
- principle of backwash
- identification of the different modes of operation of cation and anion exchangers
- regeneration of ion exchangers



## CE 582 Water Treatment Plant 2




1 rinsing water tank, 2 electromagnetic flow rate sensor, 3 acid tank, 4 caustic tank, 5 collecting tank, 6 cation exchanger, 7 flow meter, 8 anion exchanger, 9 switch cabinet, 10 sand filter




1 raw water, 2 treated water, 3 distilled water, 4 caustic soda, 5 hydrochloric acid, 6 collecting tank, 7 anion exchanger, 8 cation exchanger, 9 manometer panel, 10 sand filter, 11 water from backwashing; E conductivity, F flow rate, P system pressure, PD differential pressure, T temperature

### Specification

[1] water treatment with depth filtration and ion exchange
[2] sand filter, cation and anion exchanger
[3] all processes usable separately or in combination
[4] backwash of sand filter
[5] regeneration of ion exchangers
[6] differential pressure measurement of sand filter
[7] 20 tube manometers to measure the pressures in the filter bed
[8] plotting of Micheau diagrams
[9] measurement of flow rate, temperature, conductivity, differential pressure and system pressure
[10] filter velocity adjustable
[11] GUNT software with control functions and data acquisition via USB under Windows Vista or Windows 7

### Technical Data

Raw water pump
- max. flow rate: 25m³/h
- max. head: 20m

Backwash pump
- max. flow rate: 3m³/h
- max. head: 37m

Tanks for raw water and treated water
- capacity: each approx. 180L

Measuring ranges
- flow rate (raw water): 0...1300L/h
- flow rate (regeneration): 2...25L/h
- differential pressure: -1...1bar
- system pressure: 0...4bar
- tube manometers: 20x 0...1500mm
- conductivity: 0...600µS/cm
- temperature: 0...100°C
- filter velocity: approx. 0...70m/h

### Dimensions and Weight

LxWxH: 1550x920x2200mm (trainer)
LxWxH: 1300x800x1150mm (supply unit)
LxWxH: 750x640x1840mm (manometer panel)
Total weight: approx. 320kg

### Required for Operation

230V, 50Hz, 1 phase
Water connection, drainage, caustic soda, hydrochloric acid, distilled water

### Scope of Delivery

1 trainer
1 supply unit
1 manometer panel
1 packing unit of gravel
1 packing unit of diatomite
1 packing unit of cation exchanger
1 packing unit of anion exchanger
1 set of hoses
1 GUNT software CD + USB cable
1 set of instructional material

### Order Details

083.58200 CE 582 Water Treatment Plant 2