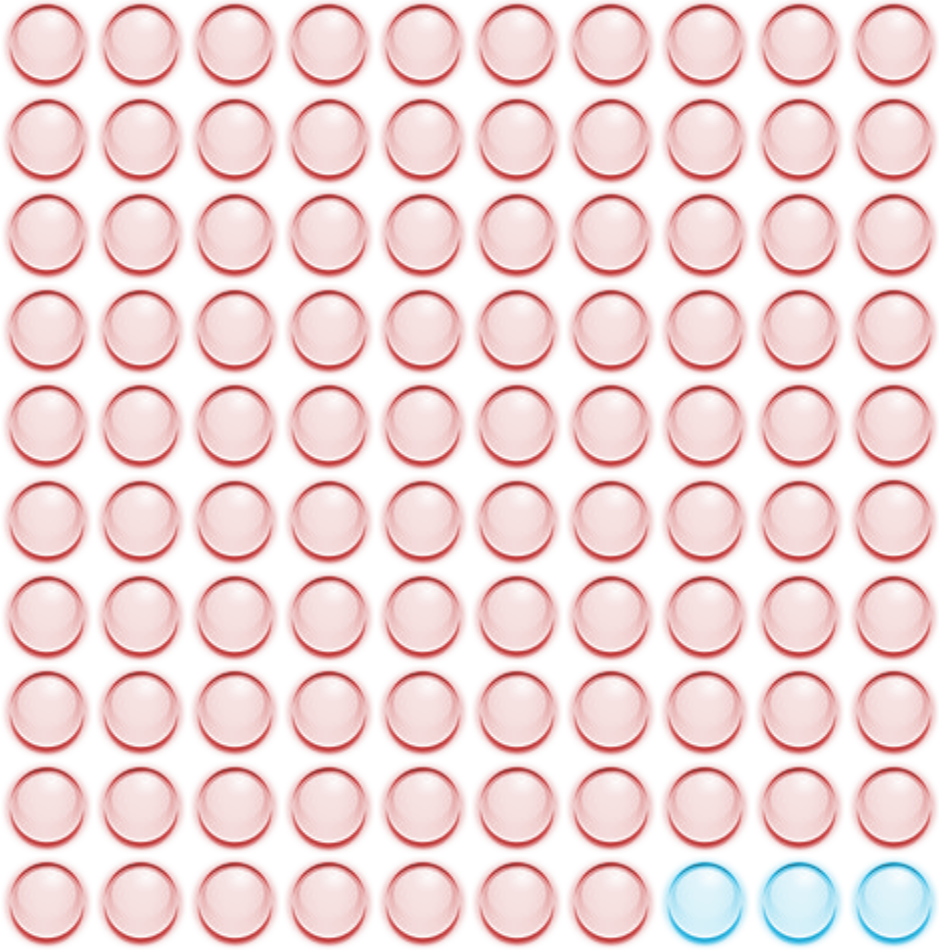
WATER ENERGIZED BY

LANXESS
Energizing Chemistry

Fact Book – Megatrend Water

97% of the world's available water is salt water...



...only **3%** is fresh water.

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1,400,000,000 km³

is the amount of available water, which covers 70% of earth.
But only 213,000 km³ of water is easily accessible, and 80% of our fresh water is frozen in the polar icecaps.

140 liters of water

is what it takes to produce a cup of coffee – what some experts refer to as “virtual water.”

0.0000010 mm

is the pore size of the reverse osmosis membrane marketed under LANXESS’ Lewabrane® brand. Only water molecules pass through, making it ideal for obtaining drinking water from seawater and brackish water.

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Agenda

1. **LANXESS protects water**
2. Water is becoming an increasingly valuable resource
3. Using water efficiently
4. LANXESS water treatment solutions

LANXESS – a global specialty chemicals player focused on technology and innovation

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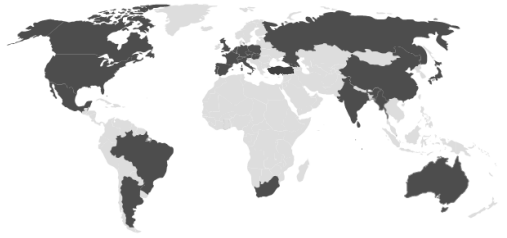
Energizing Chemistry



Specialty chemicals company

- Spun off from Bayer in 2004
- Listed in the DAX index* since 2012
- Focused on plastics, synthetic rubber, specialty chemicals and intermediates

Global success story

- Roughly 17,500 employees in 31 countries
- 52 production sites worldwide
- 2012 sales of EUR 9.1 billion

Strategy of targeted innovation

- Vital to LANXESS growth
- Emphasis on process and product innovation

* German stock market index.

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LANXESS is energizing chemistry

Premium quality

- Premium specialty chemicals company
- More than 5,000 products for a diverse range of applications
- High-quality solutions enabling customers to successfully meet current and future challenges

Technical expertise

- State-of-the-art materials, services and solutions that meet the most exacting standards
- Creating significant value for our customers, our company and the environment

LANXESS global mission

Sustainability

- Commitment to sustainable development
- Engineering solutions to meet the challenges of global megatrends
- Developing environmentally friendly technologies, resource-efficient processes and next-generation products

Innovation

- Targeted innovation designed to meet customer needs
- Pragmatic corporate culture drives product, process and outside-the-box innovation
- Highly effective innovation network, combining global reach with local expertise

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Solutions for global megatrends

Mobility

Urbanization

Agriculture

Water

LANXESS

LANXESS expertise – megatrend water

Premium quality

- Full-service provider of premium products for water treatment and purification

Innovations

- Development of innovative solutions for water treatment*

- Products and technologies from LANXESS enable more sustainable and responsible use of water

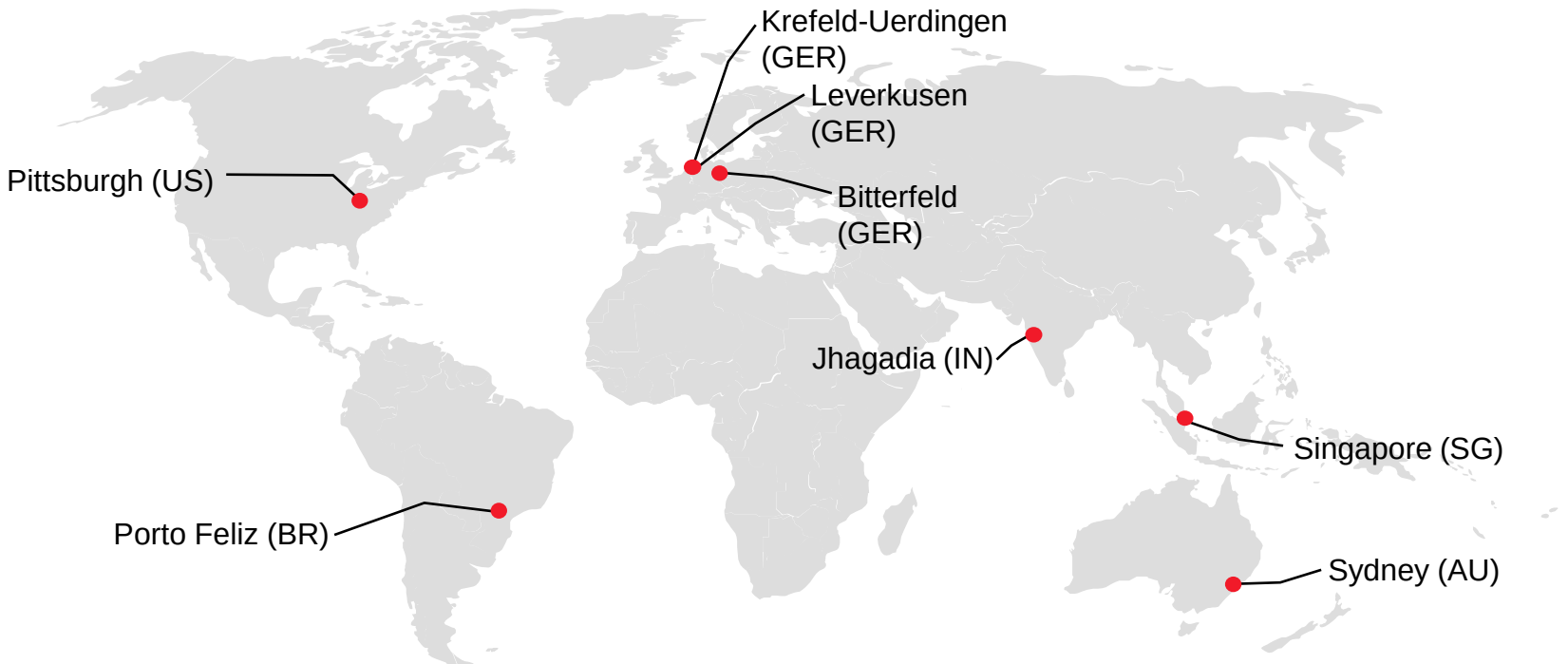
Sustainability

- LANXESS products and processes are used worldwide to treat water and to enable companies and communities to handle this resource efficiently

Global responsibility

* Prevention of water contamination, removal of harmful substances from contaminated water, and purification of existing water resources.

LANXESS sites for water treatment products



Agenda

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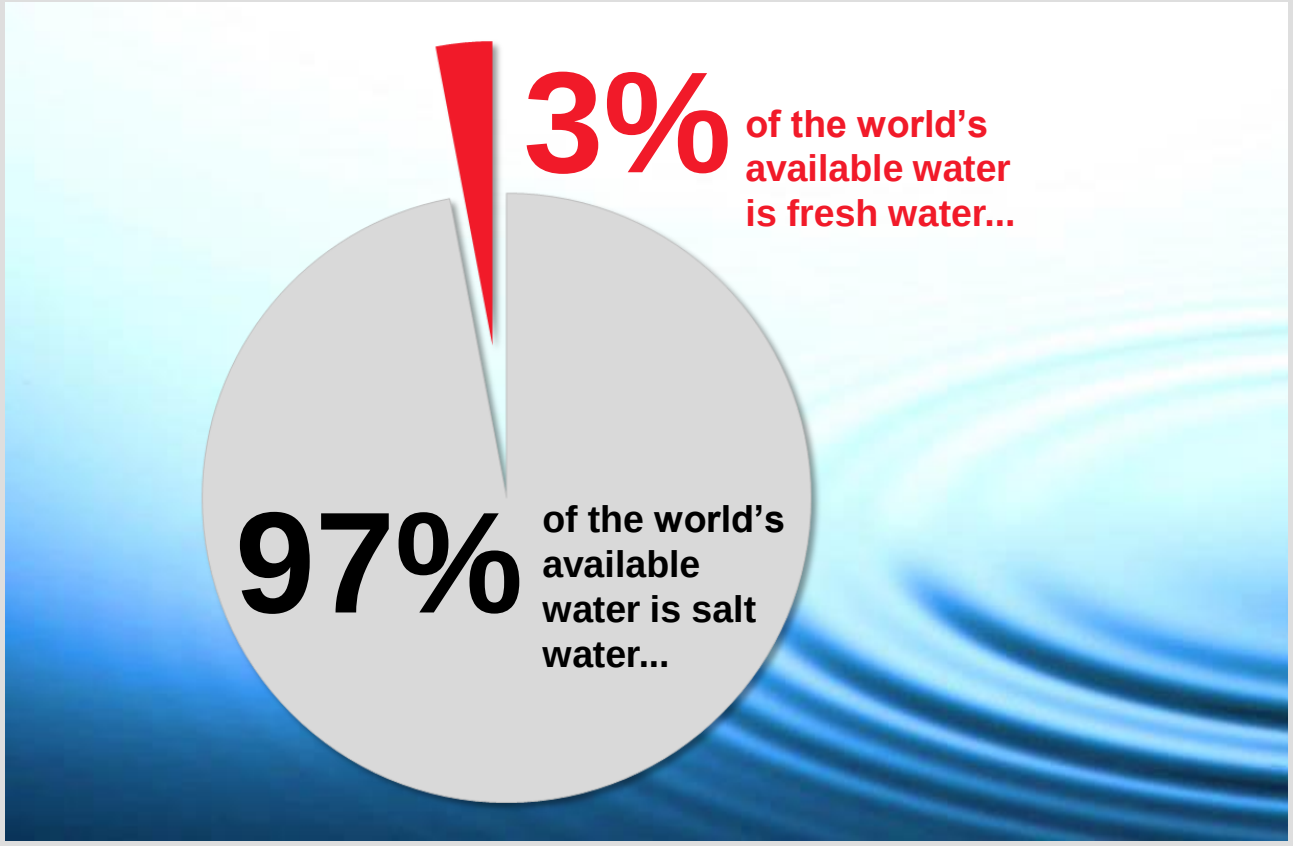
Water – elixir of life



- Worldwide, some 35 million km³ of fresh water is available. However, only around 213,000 km³ is easily accessible
- These 213,000 km³ can be found mainly in lakes, rivers and around 45,000 major reservoirs
- The majority (80%) of available fresh water is frozen in the polar icecaps

Less than 1% of the world's water is available for human use

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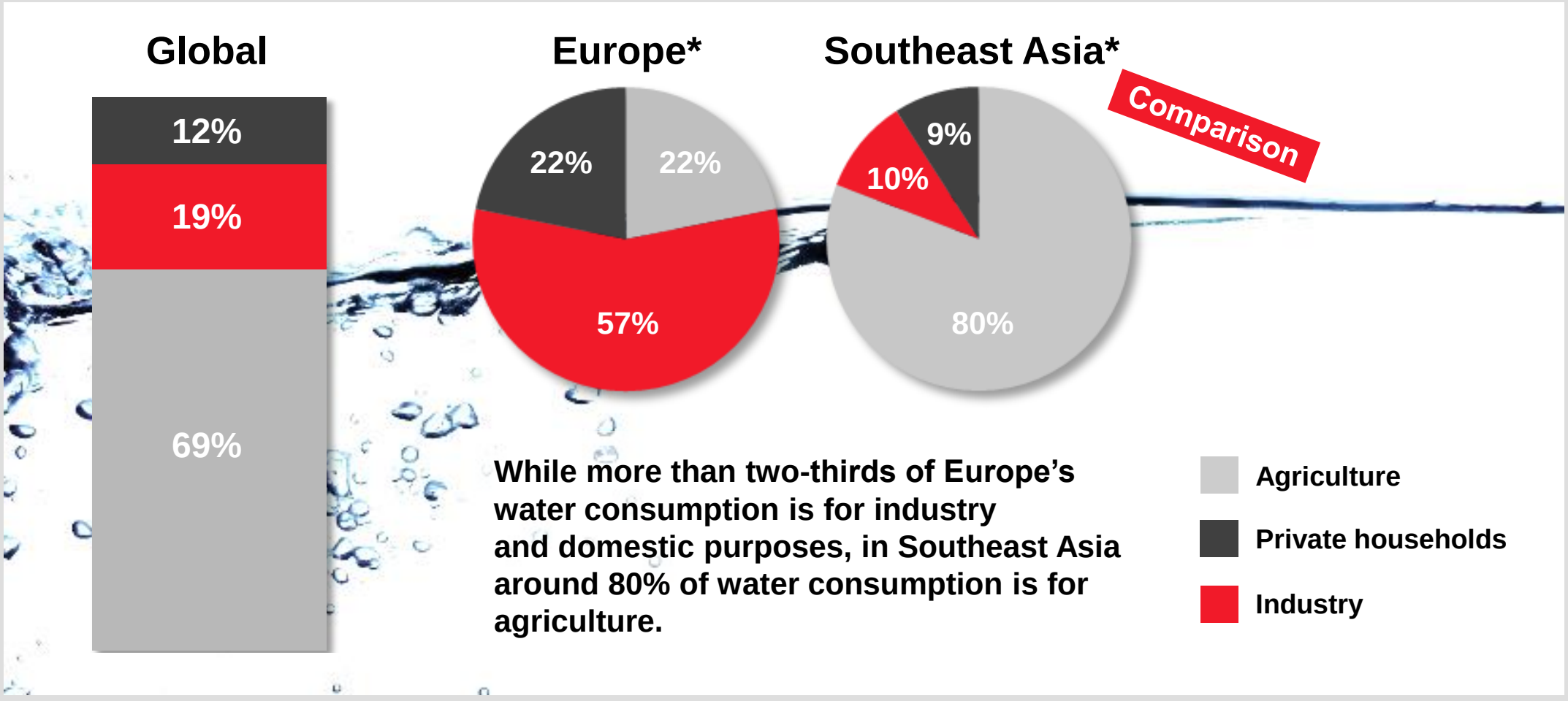
Three applications that account for global water consumption



Source: Food and Agriculture Organization of the United Nations (FAO) 2012; data from 2006
* Rounding differences.

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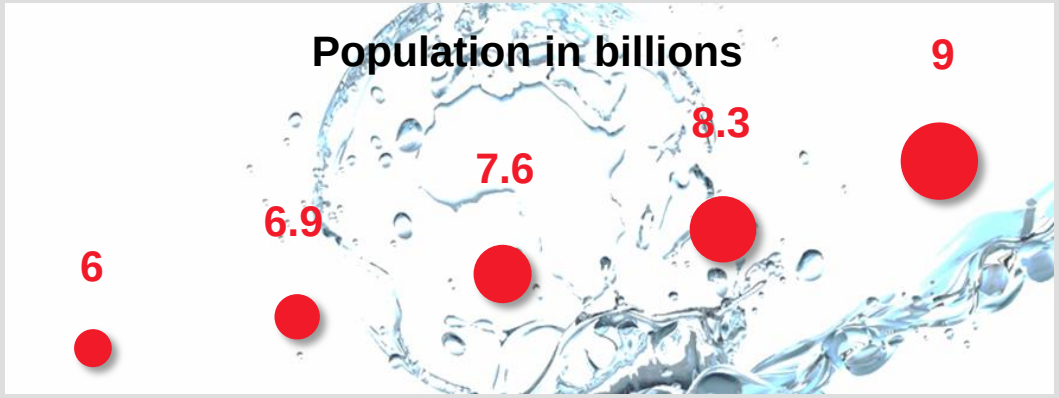
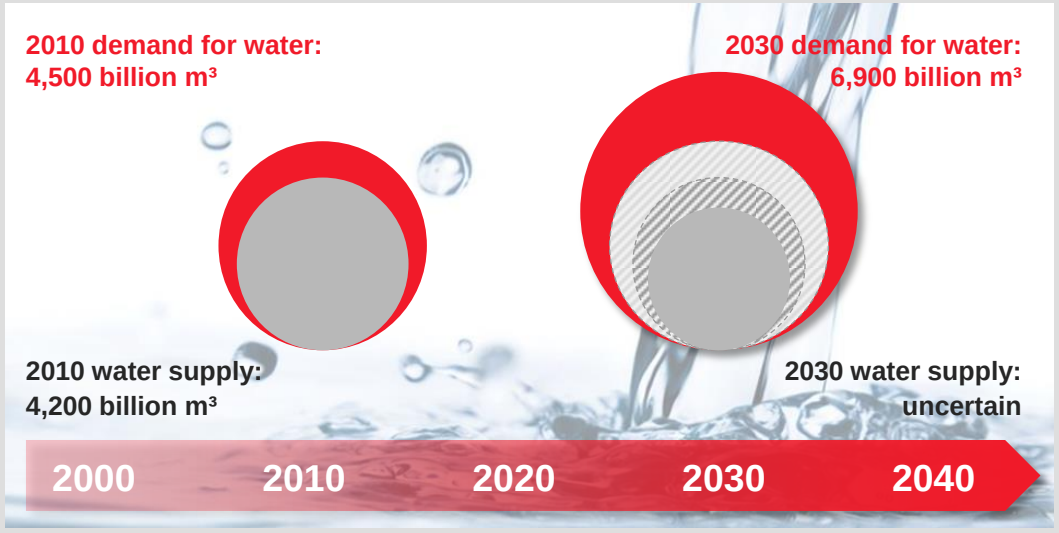
Global population growth is increasing the demand for clean water

- The world's growing population and increasing strains on the environment will further limit access to clean water
- Water consumption will continue to rise: As the global population will grow by roughly 80 million people per year, water consumption will annually increase by an estimated 64 million m³
- Local availability of water is already insufficient in many regions*
- In 2010, the United Nations declared the right to clean water as a human right – making the efficient use of water ever more important





Sources: UNESCO World Water Development Report 2009
* 884 million people have no access to an acceptable water supply by today's standards; 2.6 billion have no sanitation. Developing countries are particularly affected.

Water becomes increasingly scarce – global impacts to consider

Intensification of agriculture

Water use in everyday life

Population growth

Contaminated wastewater

Industrial water use

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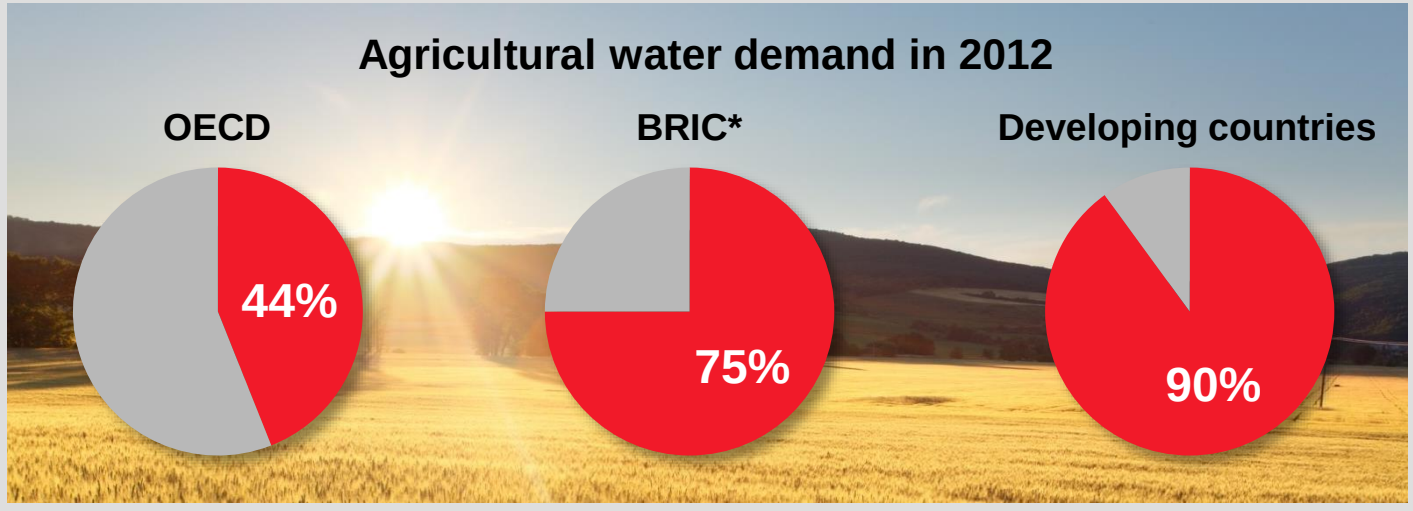
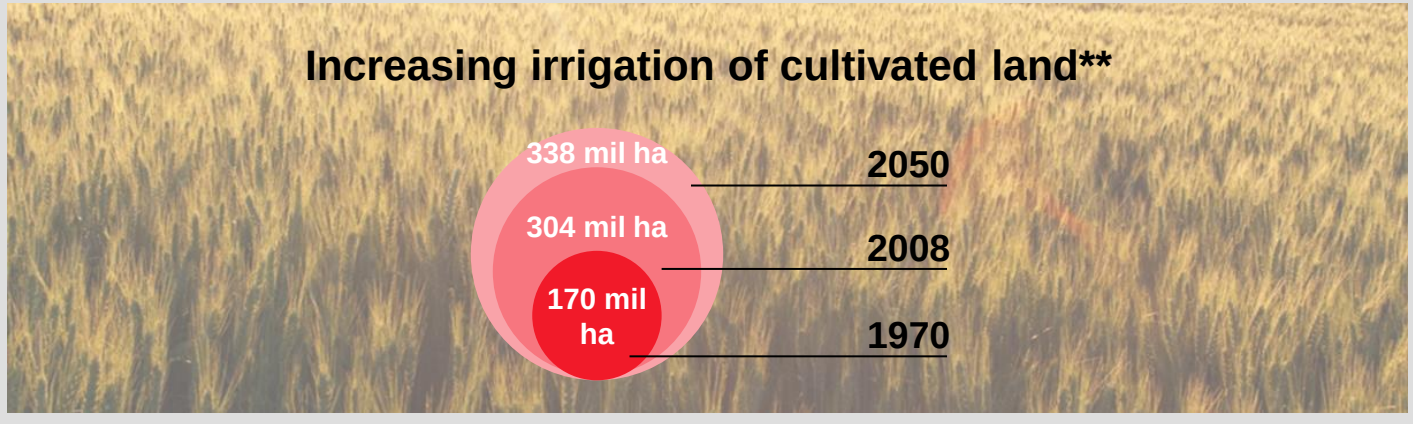
Global impacts – intensification of agriculture

- Agricultural water consumption is rising
  - By 2030, the demand for food will increase by 50%; by 2050, by 70%
  - Rising (meat) consumption requires more farmland
- Because water is essential to agriculture, water usage must become more efficient





Sources: United Nations Population Division / Food and Agriculture Organization of the United Nations (FAO), United Nations World Water Development Report 2012

* Significant differences exist between BRIC countries with regard to water supply used for agriculture, e.g., Russia: 20%, India: 87%.

** E.g., due to climate change.

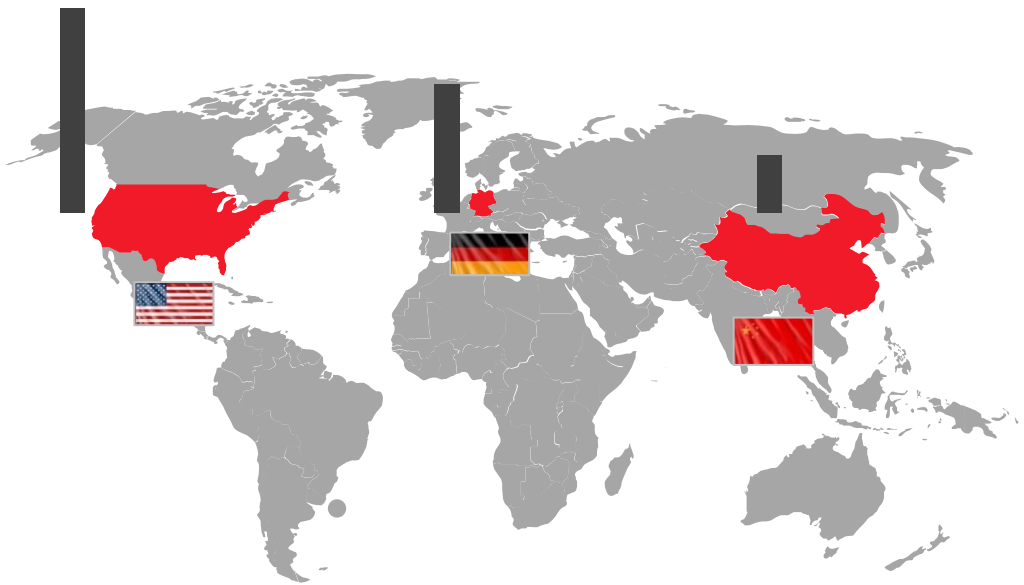
Global impacts – water consumption in everyday life

- Water consumption in everyday life is influenced by two factors:
  - Direct water consumption
  - Indirect water consumption (“virtual water”)*
- The total amount of water a person uses is their “water footprint”
- The world’s growing population means that water must be handled carefully

Average water footprint**

- Global average: 1,240 m³
- USA: 2,483 m³
- Germany: 1,545 m³
- China: 702 m³

Countries’ average water footprint



Source: www.wasserfussabdruck.org

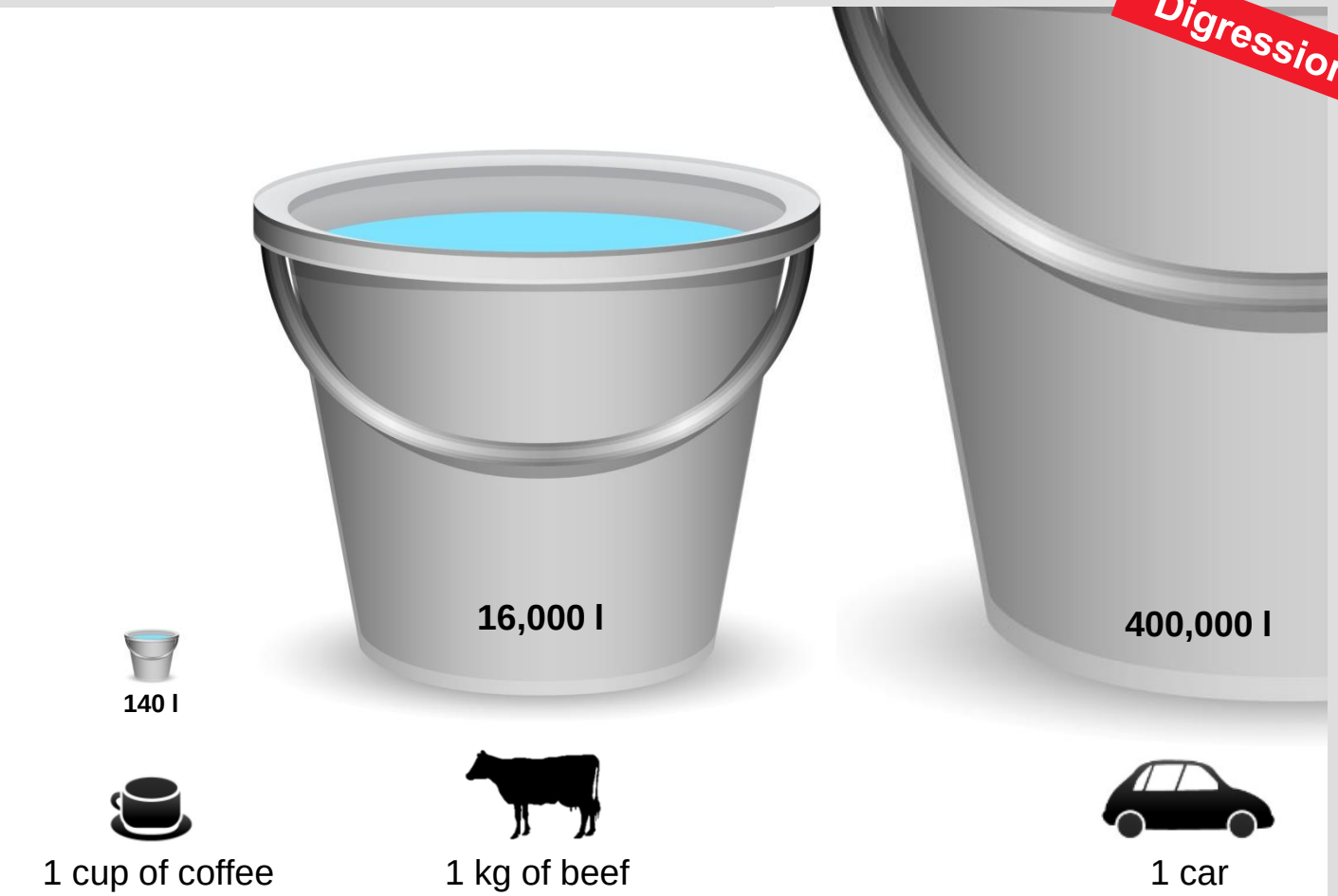
* See page 17.

** Consumption per capita per year.

In focus: “virtual water” – how much water is needed for what?

- British scientist John Anthony Allan researched the hidden quantities of water consumption and coined the term “virtual water”
- Water used for the manufacture, packaging and transport of products* is taken into account

Digression



Source: http://virtualwater.eu/
* Water used in one country for exported goods is allocated to the importing country.

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Global impacts – industrial water usage

- The growth of industry requires more clean water,* e.g.:
  - In power plants: for energy production
  - In mining: for recovering and purifying rare earths**
  - In the electronics industry: to create ultra-pure water for the manufacture of semiconductors
  - In the paper industry: as a lubricant and binding agent for paper fibers
  - In the food industry: as a component of food and beverages
  - In medicine: for the manufacture of pharmaceuticals
- A special issue in developing countries
  - Many countries have not yet adopted technologies for advanced water purification and treatment processes
  - Regulations regarding water abstraction, water quality and wastewater treatment are often disregarded

* Water is used for many purposes in industry, including the cooling systems of production plants and as a transport agent.
** Rare earths are metals used for the manufacture of polishes, special glass, plasma and LCD screens, energy-saving lamps and radar units.

Global impacts – wastewater contamination

- Increasing wastewater contamination due to population growth and increasing industrialization:
  - Global wastewater production is around 1,500 km³ per year
  - Current wastewater contamination is estimated at 12,000 km³* per year
- Improper disposal of wastewater
  - Around the world, around 80% of municipal wastewater flows back into watercourses untreated
  - In developing countries, 90% of wastewater is fed back into watercourses untreated

Source: UNESCO World Water Development Report 2009
* Assuming that 1 liter of wastewater can pollute 8 liters of fresh water.

The four challenges of water supply

Efficient water use for **agriculture**

Proper conservation of **water in daily life**

Population growth

Proper treatment of **wastewater**

Clean water and efficient treatment for **industrial use**

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Agenda

1. LANXESS protects water
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Clean water is extremely important for the sustainable development of our planet

Households, agriculture and **industry** all depend on an adequate supply of clean water.
Different standards of water quality and purity are required depending on the application.

Only through **state-of-the-art treatment** and the efficient use of **water**, this vital resource can be secured for future generations.

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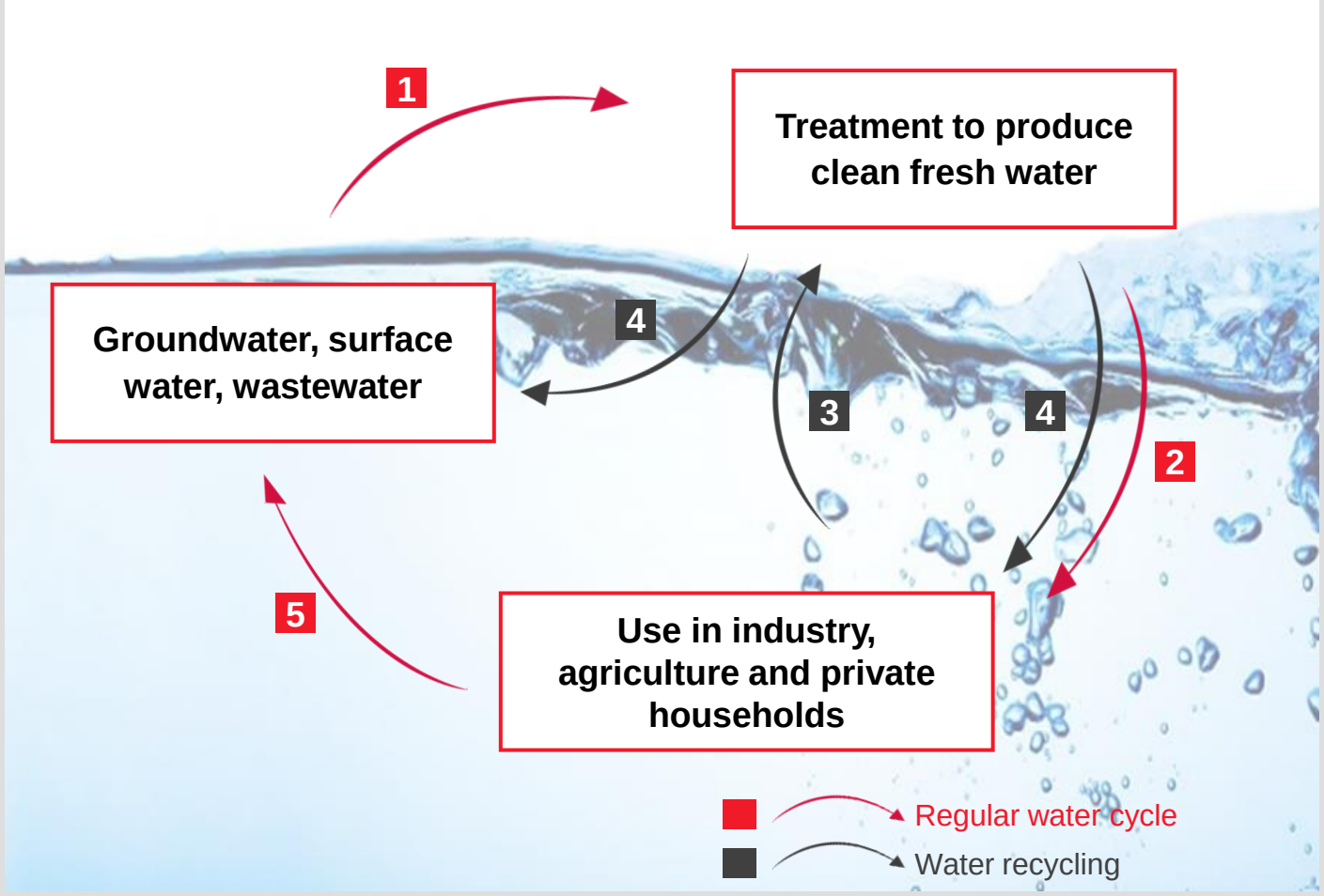
What does water treatment mean?

1. Water often needs to be purified or treated before use
2. It is then available to households, agriculture and industry
3. After use, the water may be contaminated and thus needs further treatment
4. The water can then be reused or returned to open water-courses and groundwater
5. Clean water may be discharged without treatment after use



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Processes for treating water

Examples

Adsorption and absorption processes*

- Ion exchange resin adsorption
- Adsorption with oxides
- Activated-carbon adsorption
- Extraction

Mechanical processes

- Sieving
- Filtration
- Membrane processes (e.g., reverse osmosis)

Chemical processes

- Precipitation
- Oxidation
- Water treatment with biocides
- Water softening

Thermal processes

- Distillation
- Incineration
- Thermolysis

Biological processes

- Biochemical oxidation
- Biochemical reduction
- Sludge digestion

* Adsorption refers to the enrichment of substances from gases or liquids at the surface of a solid body. Absorption describes the take-up or “dissolving” of atoms, molecules or ions in a phase.

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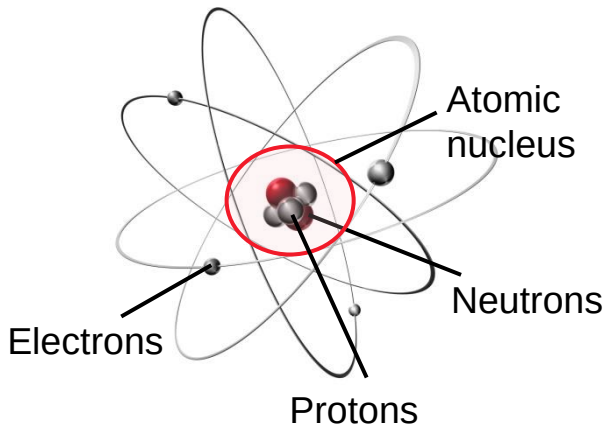
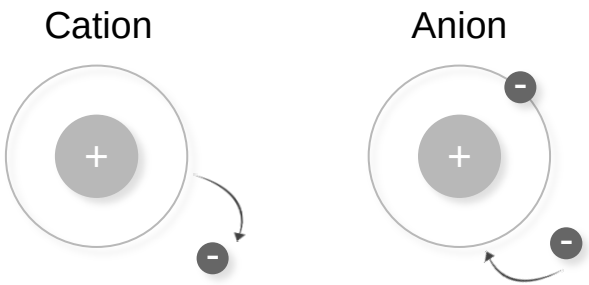
Example: ion exchange resin adsorption (1/3)
What are ions?

An ion is an electrically charged atom

- Atoms are the smallest components of a material – they consist of an atomic nucleus and an atomic shell
  - The atomic nucleus is made up of protons (positively charged particles) and neutrons (neutral particles)
  - Electrons (negatively charged particles) orbit the atomic nucleus on different paths*
- In their neutral state, atoms have an equal number of electrons (negatively charged particles) and protons (positively charged particles)
- An ion is produced if an atom has more or fewer electrons than in the neutral state**
  - Positively charged ions are called cations
  - Negatively charged ions are called anions

Structure of an atom





* The electrons in the inner orbit are usually firmly bound to the atomic nucleus; the electrons of the external orbits are less fixed given the distance from the nucleus.
** If there are too many electrons, the ion takes on electrons and is therefore negatively charged; if there are too few electrons, it emits electrons and is therefore positively charged.

Example: ion exchange resin adsorption (2/3)
How it works

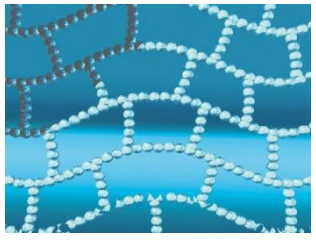
What are ion exchange resins?

- Small, porous polystyrene beads that are insoluble in water and organic solvents, or acrylic resins with a functional group*
- Diameter of 0.25 to 1.3 mm

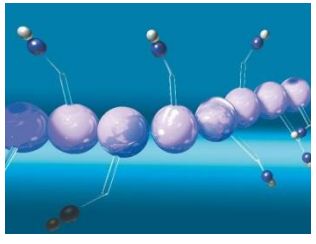
What can ion exchange resins do?

- Remove certain ions from liquids
- To do so, they emit ions with the same charge into the solution

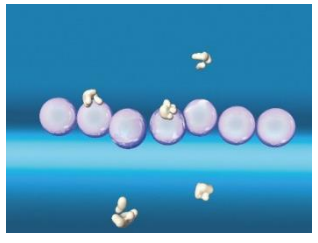
How does ion exchange resin adsorption work?



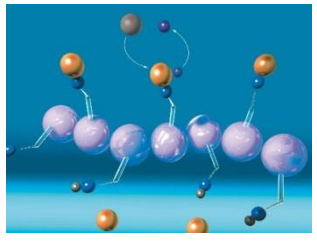
The small beads are constructed from a network of polymer threads with a large number of cavities.



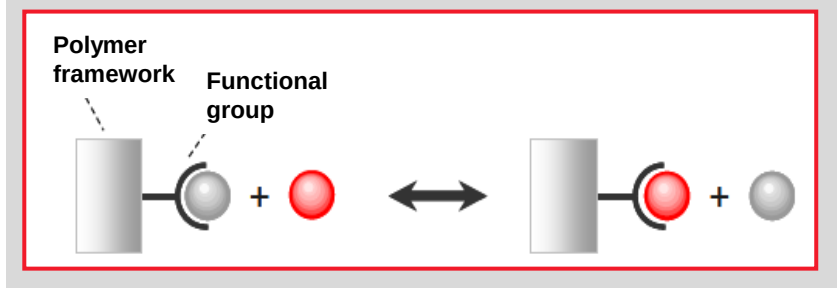
Functional groups are applied to the polymer chains.



These chemical substances take on anions or cations and …



… can exchange these for other ions like tentacles.



* The functional group is key to the chemical functioning of the ion exchange resins. It is also termed “anchor group.” It gives the exchange resin its characteristics as an ion exchange resin type. A functional group may be, for instance, a sulfonic-acid group, a carboxyl group or an amine.

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Example: ion exchange resin adsorption (3/3)
Application examples

Areas of application for ion exchange resins in the industry

- In power plants: treatment of raw water and condensate for steam generation
- In the semiconductor, solar and pharmaceutical industry: production of ultra-pure water
- Wastewater treatment in all industrial processes where metals are processed or refined

Ion exchange resins enable the extraction of metals

- Metals are extracted from ores at high temperatures under pressure with the help of acids
- By using ion exchange resins, the metals can be recovered from these acidic solutions

Ion exchange resins decarbonize* drinking water

- Ion exchange resins can be used to treat drinking water by removing unwanted substances that impair taste and smell**

* Decarbonization means the partial softening of the water.
** In some cases, these unwanted substances may also be harmful to health.

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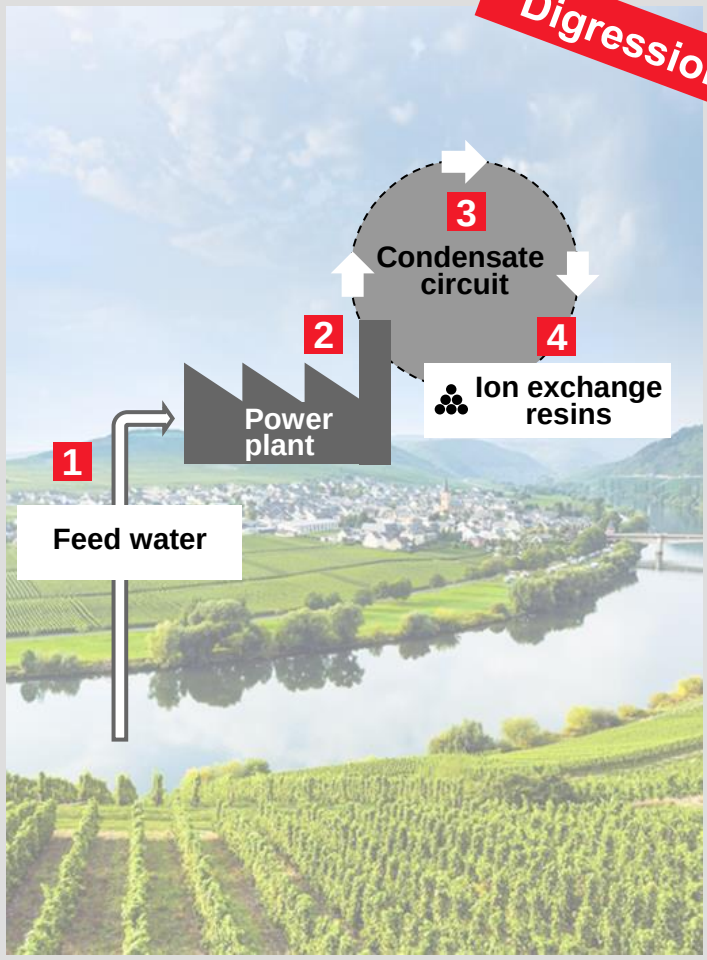
In focus: water recycling in the power plant with ion exchange resins

1. For use in power plants, water is taken from watercourses and treated as feed water* using ion exchange resins
2. The treated feed water is then fed into the condensate circuit of the power plant
3. Within the circuit, the water is vaporized, used to generate electricity and recondensed
   - During the process sequence, the water may become contaminated with particles or soluble substances
4. This means it needs to be retreated with ion exchange resins before the next vaporization cycle (recycling)

Digression



* For example, demineralized water that is fed into a steam generator from feed water containers in power plants.

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Example: water treatment by adsorption with oxides

What are oxides?

- Oxides are chemical compounds that contain metals and oxygen: *metal* + oxygen = *metal* oxide

Oxides for the treatment of drinking water and wastewater

- Iron oxides are especially well suited to the removal of arsenic, phosphates and other substances from drinking water and wastewater due to their high adsorption capacity*
- The grainy iron oxide granulate (adsorbent**) is used in a filter bed (solid carrier material in reactors)
- On flowing through the filter bed, the unwanted substances react with the surface of the iron oxide particles and form a compound that is insoluble in water

* Arsenic has a high affinity with iron oxide; in the first half of the 19th century, Robert Bunsen discovered that iron hydroxide precipitated from iron salts using lime relieves symptoms of arsenic poisoning.

** Adsorbents are solids that enable the accumulation of substances due to their suitable surface.

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In focus: arsenic removal from drinking water

Digression

What is arsenic?

- Arsenic is an odor and flavor-neutral metalloid

Why is arsenic so dangerous?

- Arsenic is one of the most dangerous contaminants of drinking water
  - In many regions of the world, the groundwater from which drinking water is taken is contaminated with arsenic
- The WHO* sets down threshold values: arsenic concentration in drinking water may not exceed 10 micrograms per liter

Global arsenic concentration

* World Health Organization

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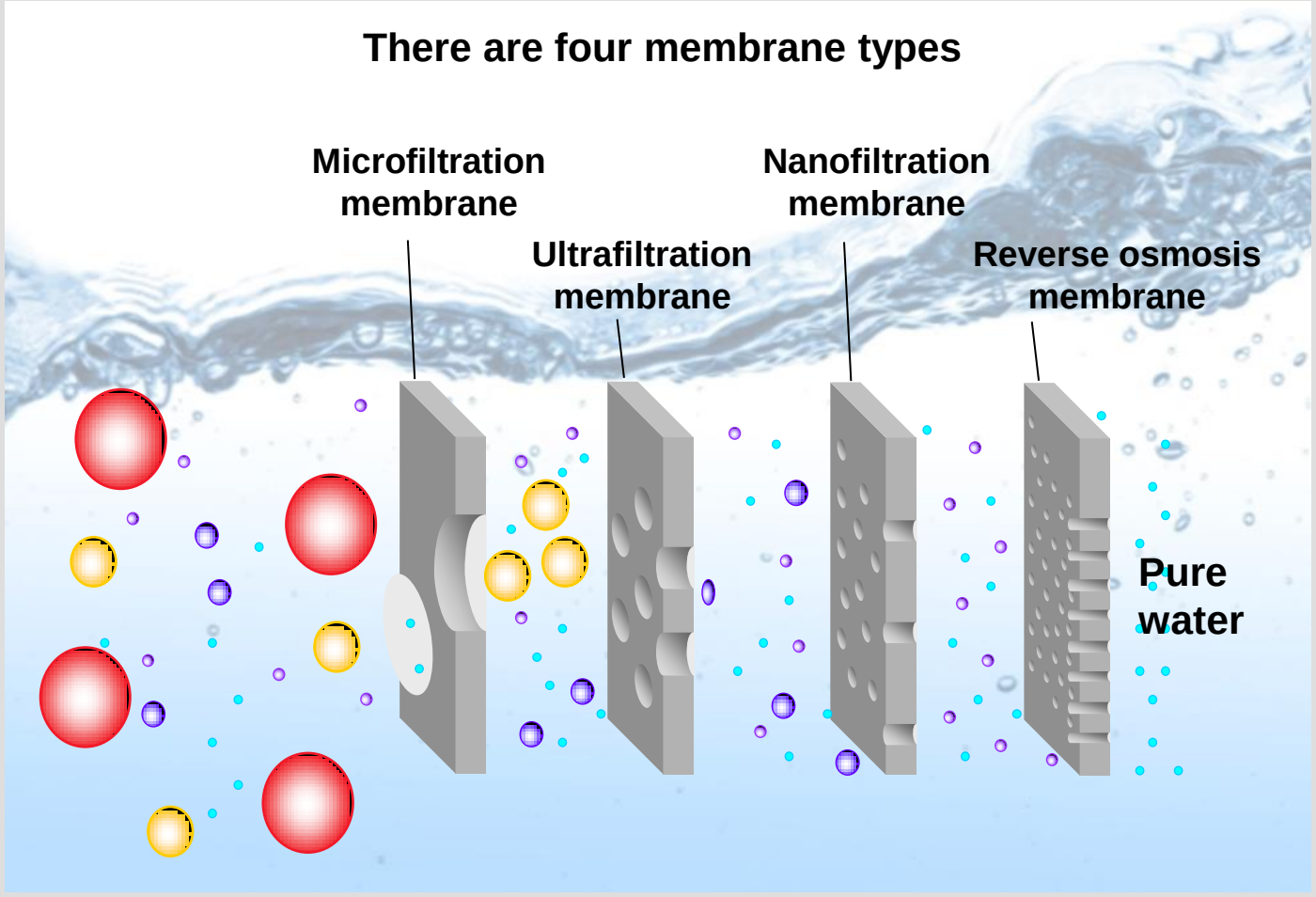
Example: membrane technologies



What are membranes?

- Membranes are selective barriers that allow certain substances to pass through while others are blocked
- Four membrane technologies are differentiated depending on their pore size
  - Microfiltration (0.1-1 µm)
  - Ultrafiltration (0.01-0.1 µm)
  - Nanofiltration (0.001-0.01 µm)
  - Reverse osmosis (< 0.001 µm)

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Example: water treatment by reverse osmosis

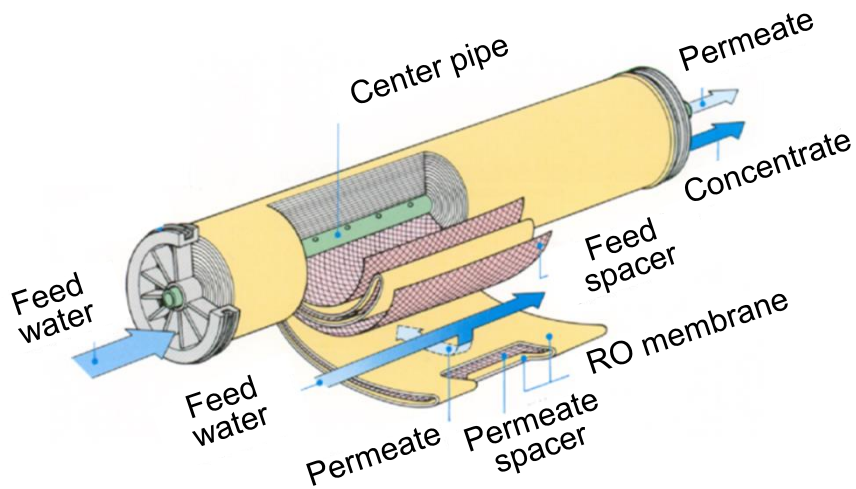
How does reverse osmosis (RO) work?

- Reverse osmosis is a technique whereby unwanted, dissolved substances are removed from fluids*
- The fluid being purified is forced through a semipermeable (partially permeable) membrane at high pressure

Areas of application of reverse osmosis

- Industrial water treatment
  - Desalination of process, feed and wastewater
- Municipal water treatment
  - Desalination of drinking water (e.g. sea water)
  - Wastewater treatment
- Remediation and regeneration of groundwater*

Structure of a reverse osmosis membrane element



* As part of groundwater remediation, the water is usually pumped off through wells and purified in various systems.

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In focus: desalination of water through reverse osmosis

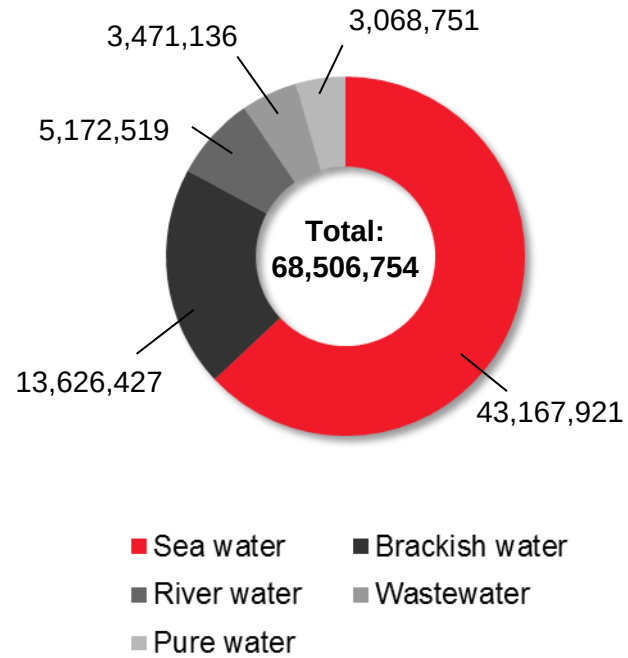
Digression

Why does water need to be desalinated?

- Depending on the application, industry needs water with a very low salinity to avoid incrustation or corrosion
- For use as drinking water, because water is only potable below a certain salinity*
- Desalination is also important for regions with affected watercourses, for instance through agriculture

Naturally occurring categories	**Sea water****	15,000–50,000 mg/l TDS
	Brackish water	1,500–15,000 mg/l TDS
	River water	500–3,000 mg/l TDS
Categories after desalination	**Drinking water**	< 600 mg/l TDS
	Pure water	< 500 mg/l TDS
	Ultra-pure water	< 1 mg/l TDS

Water desalinated per day worldwide using reverse osmosis (in m³)



* This is regulated, for example, via the German Drinking Water Ordinance (TVO); similar statutory provisions apply in other countries.

** The salinity of water determines its water category: Salinity is measured by the sum of salts dissolved in the water (total dissolved solids, in mg/l). The higher the salinity, the harder the desalination process using reverse osmosis.

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Example: water treatment with biocides

Why is it necessary to treat water with biocides?

- Biocides are used to control the growth of microorganisms (e.g., bacteria, fungi or algae) in industrial water cycles

Why is water treatment with biocides so important?

- Large quantities of water are used in industrial processes, e.g., in cooling systems or paper production
- At warm temperatures and with steady exposure to air, this water can provide optimal conditions for the growth of microorganisms
- Biocides can prevent the growth and spread of these microorganisms and ensure that facilities continue to function properly
- Biocides lower the risk of production downtime

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Example: water softening as an effective purification process

What is water softening?

- Water softening prevents lime deposits in water
  - The formation of certain salts* is prevented

Where does water softening play a part?

- In industrial cleansing processes, such as the rinsing of bottles in beverage production
- In water-dependent cleaning equipment in private households**

Why is water softening important for cleansing processes?

- The lime that is dissolved in water supplies reduces the performance of many cleaning agents (surfactants)
- Surfactants perform optimally in softened water
  - Softening thus makes it possible to reduce the use of fresh water, cleaning agents and detergents

* Calcium and magnesium ions dissolved in water can form calcium or magnesium salts that may result in lime deposits.
** E.g., laundry machines, dishwashers.

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Agenda

1. LANXESS protects water
2. Water is becoming an increasingly valuable resource
3. Using water efficiently
4. **LANXESS water treatment solutions**

Tailor-made solutions for the efficient use of water – Energized by LANXESS

Products from LANXESS …

... make **water** available for use in private households and as clean drinking water

... make it possible to produce pure and ultra-pure water for industrial processes

... promote the efficient use of **water** in agriculture

... enable sustainable **water management** through innovative recycling methods

LANXESS products, services and innovations enable us and our customers to create progressive and efficient solutions for the use of water resources.

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Focus on the development of innovative and sustainable solutions

Research and development	▪ LANXESS supports the development of efficient agents to enable our water resources to meet the needs of the world's growing population	
Product efficiency	▪ LANXESS offers technically sophisticated, extremely powerful products to produce high-quality water at an affordable cost	
Sustainability and responsibility	▪ LANXESS is committed to conserving the valuable resource of water – which plays a part in both its commercial activities and its social commitments	

LANXESS processes for water treatment

Examples

Adsorption and absorption processes

Ion exchange resin adsorption

Adsorption with oxides

Activated-carbon adsorption

Extraction

Mechanical processes

Sieving

Filtration

Membrane processes, such as

Reverse osmosis

Chemical processes

Precipitation

Oxidation

Water treatment with biocides

Water softening

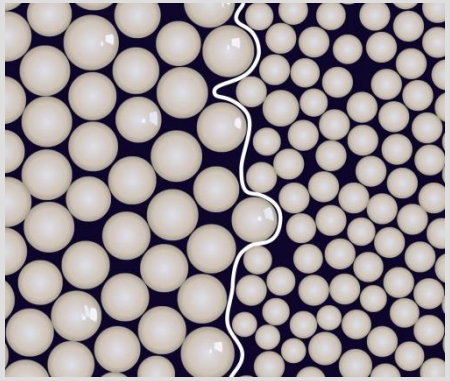
LANXESS

Adsorption with innovative ion exchange resins

Solutions for …

- The removal of substances from water

Lewatit®



Areas of application

- Groundwater
- Drinking water*
- Food production
- Process water
- Wastewater

LANXESS polymer beads for reliable and economical water purification

- Diverse range of heterodisperse and monodisperse products**
- Purification with low energy consumption due to low pressure loss of the resins
- Longer service life and reliable adsorption of substances in the water due to inner and outer homogeneity of the beads***
- Efficient regeneration (retreatment) of the resins reduces the use of chemicals

* Ion exchange resins are also used in private households: in cartridge water filter systems e.g. in drinking-water filters, coffee machines and electric kettles.
** Heterodisperse ion exchange resins have polymer beads of different sizes; monodisperse ion exchange resins, conversely, have polymer beads of uniform size.
*** The beads form a homogenous bed structure that is similar to a crystal lattice. This produces channels of an equal size that enable uniform water throughput.

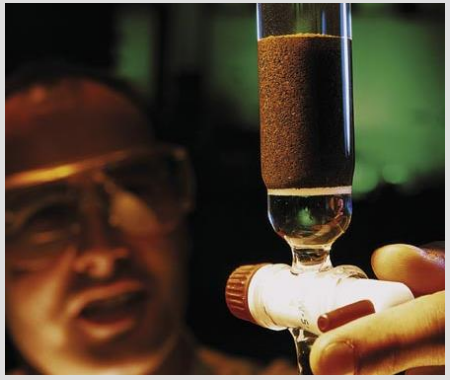
LANXESS

Adsorption with effective iron oxide granulate

Solutions for …

- Arsenic removal*

Bayoxide®



Areas of application

- Drinking water
- Wastewater

LANXESS iron oxide granulate Bayoxide® E33 satisfies individual needs in the field of arsenic removal

- A range of product grades serving different requirements and areas of deployment
- Stable granulate that does not disintegrate in water
- A particularly safe and cost-effective way to reduce arsenic concentrations in tap water**

* Lewatit® FO 36, a hybrid adsorber by LANXESS made up of anion exchangers and iron oxide, also removes arsenic from water.
** Using Bayoxide® E33 HC, a product co-developed by LANXESS and Severn Trent (a UK-based water technology company).

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Reverse osmosis with high-performance membrane elements

Solutions for …

- Desalination of water

Lewabrane®

Areas of application

- Production of feed water for power plants
- Desalination and particle removal for industrial processes
- Drinking-water treatment*

Membrane elements from LANXESS for efficient desalination

- The membrane elements consist of spiral-wound, thin-film composite membranes specially developed for water treatment
- Low salt passage**
- Improved rejection of organic compounds
- Good mechanical and chemical stability of membrane

* Treatment of drinking water from brackish or sea water often requires a certification from NSF International or a corresponding permit certifying that the manufacturing processes for reverse osmosis elements have been approved for drinking-water applications. LANXESS received this certificate for Lewabrane® in June 2013.

** The rejection is usually > 99.7% under standard conditions.

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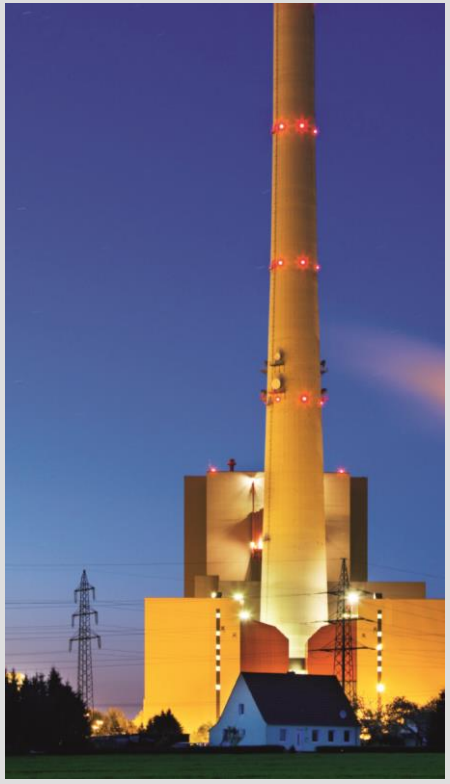
Water treatment in cooling cycles

Solutions for …

- Efficient water cycles

Veriguard® Preventol®



Areas of application

- Prevents the formation of surface scum
- Restricts growth of bacteria, algae and fungi

LANXESS biocides – innovative products and expert advice

- High effectiveness enables stable plant performance
- Continuous innovation thanks to state-of-the-art research labs in several locations
- Large biocide portfolio and customized technical advice: make it possible to select the optimum product at the right dosage
- Broad expertise to secure compliance with statutory provisions

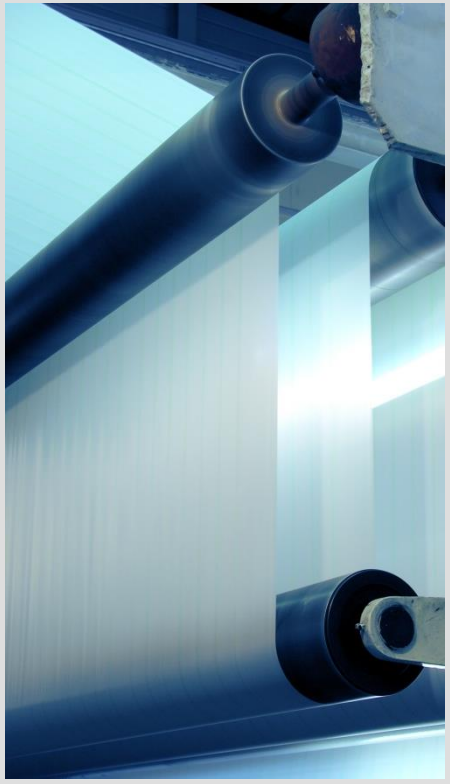
LANXESS

Water treatment in paper mills

Solutions for …

- Powerful paper mills

Veriguard® Preventol®



Areas of application

- Prevents spread of microorganisms in wet pulp
  - This is necessary because paper mills provide an optimal environment for bacteria and fungi due to warm temperatures and a steady supply of air
  - Additives used in paper production are also nutrients that foster the growth of microorganisms

LANXESS biocides support reliable paper production

- Keep the water clean during production process
- Provide effective control of the microorganisms that lead to the formation of scum in papermaking machines
- Offer protection against system compromise and downtime during production

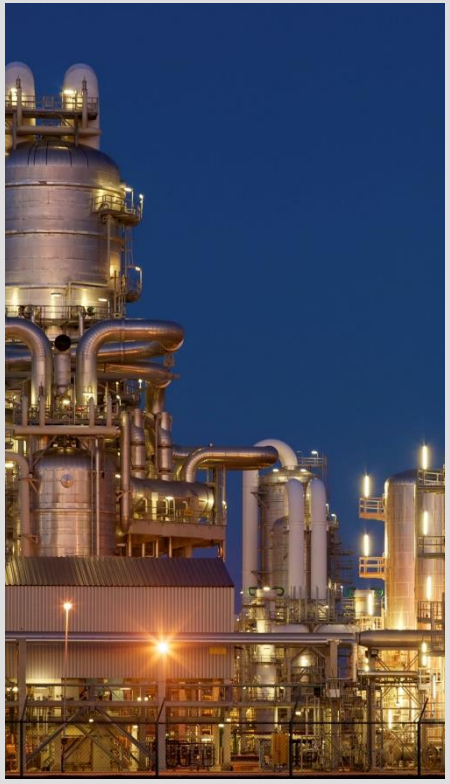
LANXESS

Water softening with effective scale inhibitors* (1/2)

Solutions for …

- Water treatments that optimize the effectiveness of cooling-water additives and detergents

Bayhibit®



Areas of application in industry

- Cooling-water systems and industrial cleaning processes
- Detergents

LANXESS water treatment agents improve the cleaning power of water and reduce water consumption in cooling circuits

- Improve performance in industrial processes such as cleaning bottles: scale formation is effectively inhibited**
- Prevent the formation of non-soluble salt deposits in water circuits
- Avoid corrosion

* Scale inhibitors are additives that prevent the precipitation of non-soluble calcium salts and their deposits on surfaces.
** Even under difficult conditions (e.g., high temperatures, very high pH values, high water hardness).

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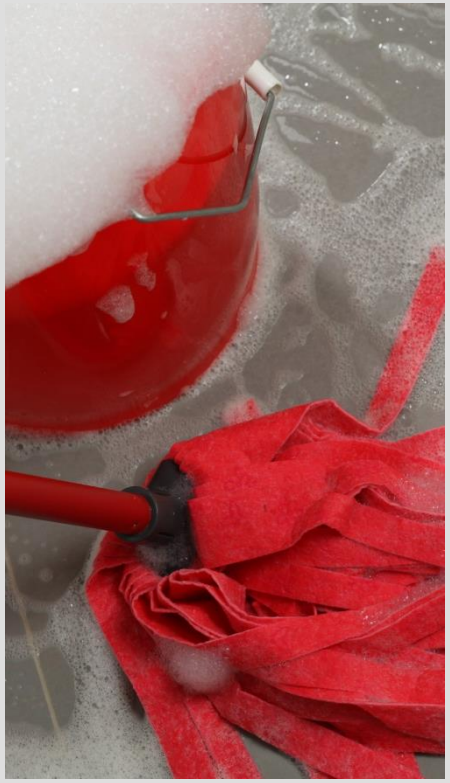
Water softening with effective scale inhibitors (2/2)

Solutions for …

- Water treatments that optimize the effectiveness of washing and cleaning agents

Baypure®



Areas of application

- Washing agents and detergents
- Surface cleaners in household and industrial uses

LANXESS water treatment agents for the environmentally friendly optimization of washing and cleaning agents

- Improve cleaning power of washing agents by binding disruptive metal ions that can destroy bleaching agents, for example
- Prevent lime deposits by binding calcium and magnesium ions that are dissolved in the water*
- Good biodegradability: no known effect on wastewater and low environmental impact

* E.g., Baypure® DS 100 prevents the formation of gray film on the item being washed by binding loose dirt particles and preventing them from being redeposited.

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Innovative LANXESS planning tool enables more efficient handling of the resource of water

Solutions for …

- Planning and simulation of water treatment systems that make use of reverse osmosis and ion exchange resins

LewaPlus™

Areas of application

- Demineralization with ion exchange resins / mixed-bed ion exchange resins
- Inspection of existing demineralization filter systems
- Desalination of brackish water using reverse osmosis

The software offers a number of advantages

- Combines planning and simulation of plants that use LANXESS reverse osmosis membranes and ion exchange resins
- Input screen for water analysis data, suitable for both ion exchange resins and reverse osmosis applications
- Automatic calculation of a recommended reverse osmosis system configuration
- Provides instant calculations of key data* and offers a clear summary in the reverse osmosis module

* System performance including pump pressure and water flow quality.

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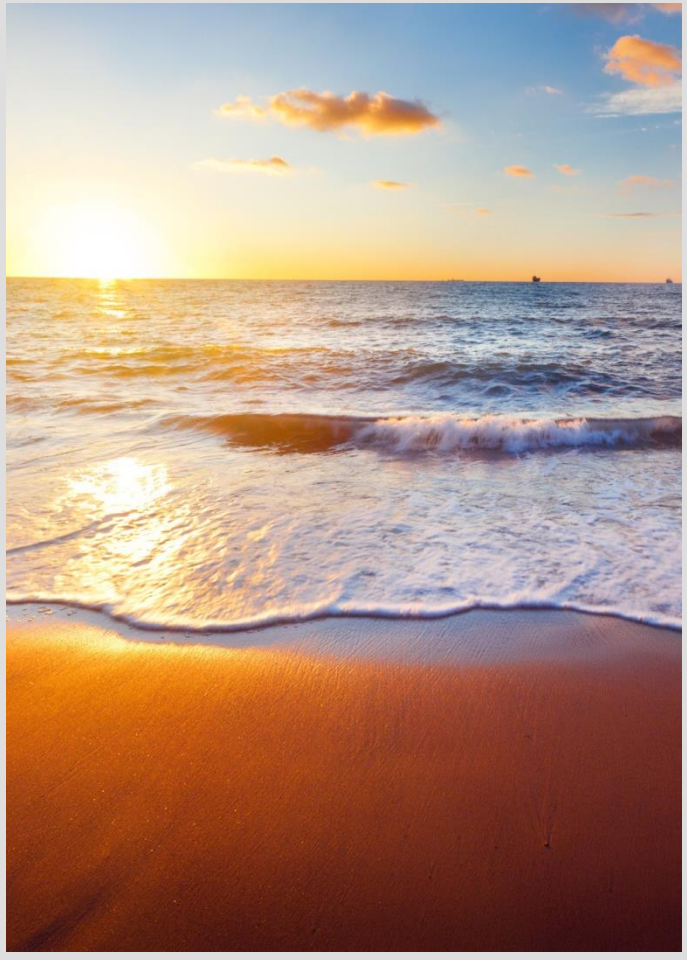
LANXESS supports the efficient use of water resources

Modern water management needs to meet the rising demand for clean water and promote the sustainable use of water resources.

Chemical agents play a key part in this process by enabling the treatment and recycling of water, thus making the use of water more efficient.

With its products and comprehensive expertise, LANXESS contributes to effective and sustainable water usage. Water Energized by LANXESS.



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Energizing Chemistry

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LANXESS AG
LANXESS Tower
Kennedyplatz 1
50569 Köln
Germany

www.lanxess.com

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