2/2023

EVONIK
Leading Beyond Chemistry

ELEMENTS

Research. Knowledge. The future.

Brain Drops

An issue about intelligent interaction with water

Water (H_2O)

A chemical compound consisting of hydrogen (H) and oxygen (O)

Water is made up of molecules, each of which consists of one oxygen atom and two hydrogen atoms. A water molecule is a dipole, which means that the oxygen and hydrogen atoms attract each other. As a result, individual molecules can interact with one another via hydrogen bonds. This gives water versatile and unique characteristics. One of them is water's high surface tension, which causes drops to form and enables lightweight objects and living creatures to move on the water's surface. In addition, water has the highest heat capacity of all liquids. In other words, a great deal of energy is needed to heat it up. Conversely, when water cools down it releases large amounts of energy in the form of heat. This effect helps to regulate the body temperature of living creatures and to stabilize the temperature of bodies of water.

Dipole A molecule with two opposite (positive and negative) poles.
Surface tension The interfacial tension of solids and liquids at an interface with a gas. This can be seen, for example, in the tendency of liquids to keep their surface area as small as possible.
Heat capacity (or heat storage capacity) The ratio between applied heat and the resulting change in the temperature of a body or a substance.

DEAR READERS,

When a human being is born, about three fourths of his or her body consists of water. Even though the proportion of water decreases with advancing age, H_2O molecules account for most of the content in the bodies of living creatures. Even our brains, which are so fascinating in their complexity, consist of about 73 percent simple water. And that's also true of our hearts. At the same time, the loss of only one or two percent of this water can throw the physical processes within our bodies off course.

If we shift to a global perspective, the situation is generally no different. Far more than two thirds of the earth's surface is covered by water. All the same, relatively small changes are sufficient to confront the human race with serious problems. Over thousands of years we have increasingly accelerated the cycle of water, especially freshwater, according to the hydrologist and UN consultant Johannes Cullmann (see the interview on page 32). We are now experiencing the consequences of this process, reinforced by climate change, in the form of severe droughts and floods covering entire regions.

All sectors have contributed to this situation: agriculture, drinking water production, power generation, and industry. But here's the good news: Solutions exist. Thanks to intelligent regulations, smart technology and, above all, determined implementation, these developments can be slowed down and perhaps even partially stopped. We present a number of these solutions in this issue.

We also talk about water itself as the solution. If fossil solvents used for chemical reactions could be replaced with the all-rounder H_2O, that would be a huge step toward greener chemistry. Sometimes a solution is very close at hand—in our brains, so to speak.

I wish you pleasant reading and new insights. If you have any questions, recommendations or criticisms, please write to me at elements@evonik.com

Jörg Wagner
Editor in Chief

All of the articles from the printed magazine, as well as additional current contents, are also available on the Internet at elements.evonik.com

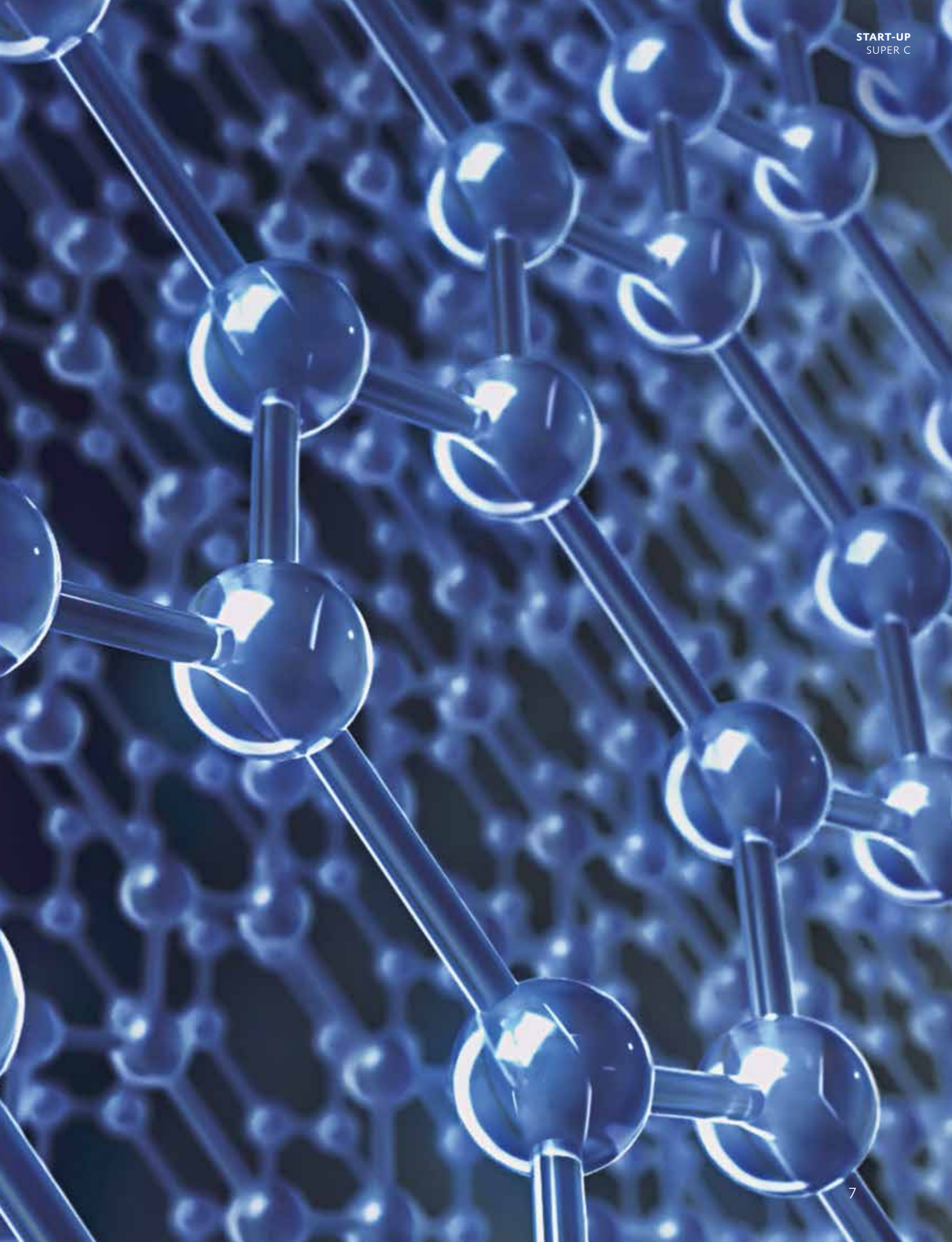
The elemental force of water, as seen here in the Huilo Huilo River in Chile, fascinates mankind. However, in many places the water cycle—from its source to the ocean and back—has been disrupted. What do we need to do in order to put the system back into balance?

In the USA, chlorine is generally used to remove bacteria from wastewater. But in Memphis, the city government uses peracetic acid from Evonik

To conserve water, Evonik uses a sophisticated process control system for the filtering step in the production of precipitated silica in Map Ta Phut, Thailand

DESIGNED FOR HIGH PERFORMANCE

The energy transition also requires more climate-friendly mobility. High-performance batteries—based, for example, on lithium ions—play a decisive role here. The Chinese company Super C, in which Evonik Venture Capital has held an investment since the end of 2022, is a battery specialist and a technological leader in the area of graphene materials. The company uses a process developed in-house to manufacture few-layer graphene (FLG)—a modified form of carbon with the carbon atoms arranged in sheets a few layers thick—which is used in making pastes for the electrodes of lithium-ion batteries. The addition of graphene increases the batteries' power, charging speed, and lifetime. Graphene also makes lithium-ion batteries less sensitive to high temperatures and so reduces the danger of fires. The technology is thus creating good conditions for boosting the performance of electric vehicles and so accelerating the energy transition. By acquiring a stake in Super C, Evonik is strengthening its growth strategy for battery solutions.



Going green

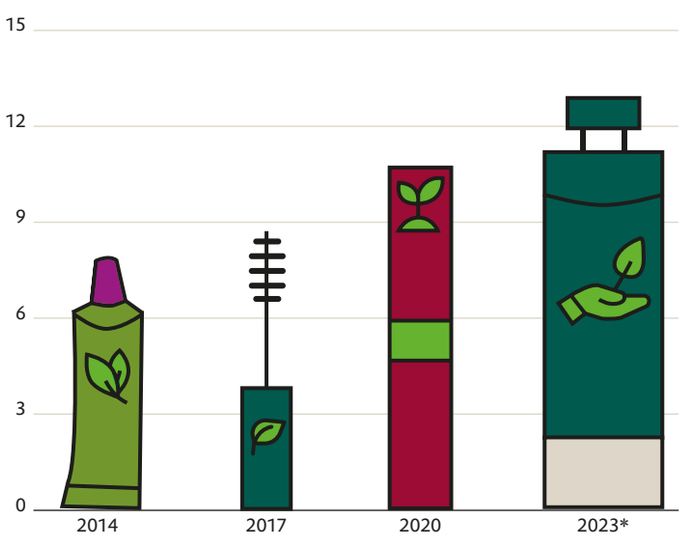
Ammonia used as a reducing agent could make steel production more sustainable

The steel industry is one of the world's biggest CO_2 emitters. This is mainly due to the smelting process, which takes place in blast furnaces. In this process, coal is used as a reducing agent to extract iron from iron ore. A German research team from the Max-Planck-Institut für Eisenforschung sees ammonia as a promising alternative to fossil reducing agents. When companies want to make steel production greener, they mostly rely on hydrogen instead of coal. However, green hydrogen is scarce, and its transport is costly and energy-intensive. Ammonia, on the other hand, is cheaper and more energy-efficient to transport, and can also be produced in a green manner. It was previously thought that ammonia had to be split into hydrogen and nitrogen before being used in a blast furnace. However, tests now show that when ammonia is fed directly into a blast furnace, around 98 percent of the iron ore is converted into metallic iron. This is possible because the hydrogen in the molecule splits off by itself at the temperatures used for smelting steel. The hydrogen is then freely available to reduce the heated iron ore. This cuts costs by 18 percent. Using ammonia as a hydrogen carrier could make it easier to start producing steel in a more climate-friendly way.

THAT'S BETTER

Nice growth

Sales of the natural cosmetics market worldwide, in US$ billion



Source: Statista Consumer Market Insights *Forecast

Certified natural cosmetic products do not contain petroleum-based ingredients, synthetic fragrances or microplastics. As a result, they are generally more degradable and thus more environmentally compatible. Sales of these products have almost doubled since 2014. Evonik is also active in this market and produces high-performance plant-based active ingredients for cosmetics in a resource-conserving way.

200

GIGABITS PER SECOND

That's the new speed record for wireless data transmission. It was achieved with the aid of a new type of microchip based on bipolar silicon germanium metal oxide transistors, in which the transmitter, receiver, and on-chip antennas are combined. A German research team developed the chip specifically for wireless communications and wants to use it to transmit high-frequency data, for example for future 6G applications.

LANMODULIN…

…is a small, disorderly-structured protein that can bind rare earths. Researchers in the USA are taking advantage of this property. Rare earths are essential for the energy transition, especially for high-tech applications such as wind turbine generators and batteries. However, metals such as lanthanum and neodymium are usually found in mixed form in ore deposits and are so chemically similar that they can only be separated from each other with great effort and expense. A new artificially modified protein based on lanmodulin is said to be able to efficiently separate rare earths. Thanks to the modification, the protein reacts so sensitively to differences in atomic diameter that it also reliably separates chemically similar rare earth metals from one another.

The heart of the matter

Molecular surgery accelerates the development of new drugs

A great deal of effort is needed to develop new drugs. Once the basic structure of a molecule is in place, chemists generate hundreds of variants with different side chains to test them for specific properties. The problem is that, with a few exceptions, it is difficult to subsequently move, remove, exchange, or add new atoms within the basic structure. The synthesis often has to start all over again. This may soon change, thanks to new molecular surgical methods that are being developed by researchers such as the chemist Mark Levin at the University of Chicago (Illinois, USA). In the future, a process known as skeletal editing will be used to optimize a molecule's "skeleton" in a targeted manner. This will reduce the number of reaction steps, reagents, and processing stages needed in drug development—and revolutionize the way organic chemists design molecules.

PEOPLE & VISIONS

"The product contains plant extracts that turn into volatile organic compounds upon contact with air"

THE PERSON

Deepak Rajmohan is a food biotechnologist, agricultural researcher, and company founder. He earned his bachelor's degree in agricultural engineering in India and then moved to the United States for his master's degree in food science. His work there included projects on food waste and loss. In addition, he worked on "active" packaging. This packaging contains components that extract certain substances from food or release substances themselves—the basis for the work of his startup GreenPod Labs. "Using science and technology to solve pressing problems thrills me every day," Rajmohan says.

THE VISION

Especially in warm countries such as India, food often spoils during storage or transport. Deepak Rajmohan found a solution for this in the natural defense mechanisms of fruits and vegetables. Together with his team, he has developed small packets that are enclosed with fruit or vegetables so that they can better survive long transport routes. "The product contains plant extracts that turn into volatile organic compounds upon contact with air. In fruits and vegetables, the specific mix of substances triggers an immune response." Thus armed against heat, high humidity or microbes, their shelf life is extended by 40 to 60 percent.

GOOD QUESTION

Ms. Uva, will we be making electronics from carrots in the future?

Yes, our initial research results show that we could use carotenoids from carrots to produce semiconducting materials for the manufacture of electronics. This could provide a much-needed solution to the growing problem of electronic waste. Carotenoids are pigment molecules that make carrots, pumpkins and autumn leaves orange. They contain alternating double and single carbon bonds, i.e. they are conjugated, which is useful for electronic conductivity. We incorporate the carotenoids into polymers by linking several individual carotenoid units into a longer chain. In this way, we create a polymer that breaks down into substances that can be reabsorbed by the environment. Put simply, we are using carotenoids to develop materials for compostable electronic devices.

Azalea Uva is a Ph.D. candidate in chemistry at the University of Toronto.

GO WITH THE FLOW

More and more often, entire regions are drying out—while other regions are being devastated by catastrophic floods. The uneven distribution of water is facing the human race with problems that were previously unimaginable. Good management and technology adapted to local needs can help in the search for a solution

TEXT **TIM SCHRÖDER**

Losing a lake: The Laguna de Aculeo in Chile used to be a popular getaway destination for water sports enthusiasts from the country's capital Santiago, which is about a two-hour drive away. But the lake has been dry since 2018 because of an unusually long period of drought and excessive water consumption in the region

The grass has dried up. A few ragged straws sway in the wind. The cattle breeders in the Magellan region of southern Chile are desperate. "The wind is getting stronger and drying everything out, and the grass isn't growing. This is the drama we're experiencing," they say. Here the fjords cut deep into the land. Some are covered with ice. The strong winds that are typical of this region are worsening the problem of sparse rainfall. In this region, 2022 was the driest year in more than half a century. There has been practically no rain this year either. Now the farmers no longer know how they can help their animals survive the winter without water.

The southern tip of South America is not the only place where weather anomalies are accumulating. Exceptions are becoming the rule. For example, the island of San Biagio in Lake Garda in Italy is normally completely surrounded by water. But this spring local people and vacationers were able to walk to it without getting their feet wet for the first time in decades. That's how low the water level had sunk in this lake, which is beloved by tourists, after months of extreme drought. Bodies of water are drying up in France and Spain as well. In May the Emilia Romagna region of northern Italy was suddenly hit by torrential rains. More than 20 rivers overflowed their banks and surged in the form of mudslides through villages and towns.

Similar disasters are happening in Asia and North America. Last year large regions of Pakistan were under water for several weeks after extremely severe monsoon rains. After three years of drought in California, so much rain fell this winter that there were floods in many districts. By contrast, in other regions it was unusually dry. Immense forest fires recently flared up in Canada. Their plumes of smoke could be measured as far away as western Europe. Today many scientists are saying that we have entered the Pyrocene epoch—the age of fire. However, the droughts and fires are basically developing this devastating force only because water is becoming increasingly scarce.

The situation is complicated. In some places there is too much water, in others not enough—and climate change is exacerbating this distribution problem to extremes. According to the Secretary-General of the United Nations, António Guterres, this situation is making the reliable and equitable supply of water an increasingly important task for mankind. "As humanity's most precious global common good, water unites us all," he said at the United Nations' Global Water Conference in March of this year. "That's why water needs to be at the centre of the global political agenda."

However, focusing only on water will not be sufficient, emphasizes the hydrologist and UN consultant Johannes Cullmann. "Climate change is always a pro-

Power struggles: The Grand Ethiopian Renaissance Dam in Ethiopia, which holds back the Blue Nile, has stirred up conflicts downstream with Sudan and Egypt. The first turbines of the associated power plant went into operation at the beginning of 2022

THE ANOMALY OF WATER

The volume of freshwater decreases down to a temperature of 4°C. That is its point of greatest density. If it is then either heated or cooled, its density decreases. That's why the temperature at the bottoms of lakes is about 4°C all year long, as a rule. Materials normally reach their greatest degree of density in a solid aggregate state

Extreme weather: Floods that pose an existential danger to human beings are increasing in frequency all over the world. For example, unusually heavy rainfalls in India in 2019 caused at least 200 deaths and left about a million people homeless

cess of water change as well," he explains. After pointing to the indissoluble connection between water issues and climate change, the topic that has so far been a stronger focus of public attention, he sounds an alarm: If the decision-makers still want to get the water crisis under control, they cannot wait as long as they did in the case of the measures against greenhouse gases (see the interview starting on page 32).

FRESHWATER IS BECOMING INCREASINGLY SCARCE

But where should we begin? The earth actually has vast reserves of water. Experts estimate that the global volume of water amounts to about 1.5 billion cubic kilometers. However, only about 2.5 percent of that amount is freshwater, and the biggest proportion of it is inaccessible. Just over two thirds of the freshwater is stored in glaciers in Greenland, the Antarctic, and other regions. Most of the remaining third is groundwater that lies so far under the earth's surface that it would be practically impossible to use it. Ultimately only about 37,000 cubic kilometers of renewable drinking water from rivers, lakes, and natural aquifers near the earth's surface are available to mankind (see the infographic on page 22).

And this amount is decreasing. That's because huge quantities of freshwater are lost year after year when they flow into the world's oceans without being replenished by corresponding reserves in the form of snow, ice or groundwater close to the earth's surface. Besides, the distribution of freshwater is extremely uneven. The inhabitants of arid zones in Africa and Asia have long been familiar with water scarcity. By contrast, the citizens of most industrialized countries in temperate climate zones have so far not had to deal with the question of where they get their water, as a rule. In these countries people are used to simply turning on the faucet to get a drink of water, take a shower or water the garden. But this situation is changing. A study conducted by the European Environment Agency (EUA) concludes that today 30 percent of Europeans are already directly affected by water stress in an average year.

This finding is obviously connected with climate change and the warming of the earth's atmosphere. Additional anthropogenic factors are aggravating the situation. At the United Nations' Global Water Conference, many experts pointed out the bad water management in many regions of the world. Often not enough money is being invested—or the financing flows into exactly those water management measures that ultimately →

Green fee: Golf players in Las Vegas are still free to play their sport. However, this casino metropolis in the Mojave Desert in the USA recently began to strictly regulate water consumption. Activities that waste water are penalized with fines

THE SCENT OF RAIN

When rain falls on dry soil, it generates a typical scent that is known as "petrichor." This term was coined by researchers in the 1960s. The scent is carried by oils that are released by plants during dry spells and by geosmin, a substance produced by soil bacteria

harm the overall system. Asit Biswas, a water expert at the Lee Kuan Yew School of Public Policy in Singapore, says that the latter problem is much more serious than scarce financing. "Lack of money, scarcity, and so on—of course all of them are excuses," he says indignantly. "Everywhere, the problem is bad management."

That's because today many countries are still primarily relying on megaprojects involving steel and concrete in order to supply their populations with drinking water and water for agriculture—by means of dams, for example. In the process, the responsible governments often think in terms of very national categories. One example of that is the construction of the Merowe Dam across the Nile in Sudan, which was completed in 2009. The turbines of the associated hydropower plant produce 1,260 megawatts of electricity, covering more than half of Sudan's power supply.

In addition, plans call for water to be channeled into the surrounding region through a canal system several hundred kilometers long so that agriculture can be practiced there. The project led to several thousand people losing their homes without receiving any compensation—but that's not all. Because of the gigantic surface of the reservoir, enormous volumes of water have been lost through evaporation ever since the dam was built. In addition, nutrient-rich sediments that would normally flow downstream and provide the farmers there with natural fertilizer are now accumulating in the reservoir. Structures such as the Merowe Dam and the Grand Ethiopian Renaissance Dam, which is just now going into operation in Ethiopia, always lead to tensions between the countries along the Nile, especially in periods of drought when the water becomes scarce. The situation along the Mekong River in Southeast Asia is similar.

WHEN RIVERS RUN DRY

All too often, the water supply is not comprehended as a system, says Lars Ribbe, a professor of spatial development and infrastructure systems at the Cologne University of Applied Sciences. Even today, in dry regions such as Burkina Faso and Mali people are digging wells without knowing how much groundwater will be replenished. The wells often dry up after a short period of time because the natural aquifers are emptying. Conversely, in some mountainous regions in South America highlands and forests are being overused and destroyed by herds of cattle. The damage affects crucial headwaters of streams and rivers that the inhabitants of villages and cities in the valleys depend on. "We need integrated water management that takes all of these factors into account. Above all, we have to regard water management as part of the overall technical and natural water cycle," Ribbe emphasizes.

Conflicts regarding water are also breaking out more and more frequently in industrialized countries as well. For example, in the state of Brandenburg in Germany, which has very little rain, a dispute over groundwater has been raging between the automaker Tesla and the local population ever since Tesla presented its plans for building a "gigafactory" just outside Berlin. The factory needs so much water that the region's permitted water supply rate is being drastically exceeded. Environmental organizations took legal action against the plan, with partial success. The factory's purified wastewater is also a focus of attention, because it could adversely affect the supply of drinking water in the Berlin metropolitan region. Other German industrial companies with high levels of water consumption are also subject to the criticism that their activities are having a negative effect on the groundwater.

Breakaways: Calving is a normal process for icebergs in the polar regions, like this one in western Greenland. Nonetheless, researchers are concerned, because the total ice mass is continuing to shrink—a process that is gradually causing a rise in sea levels

"Everywhere, the problem is bad management"

ASIT BISWAS, A WATER EXPERT AT THE LEE KUAN YEW SCHOOL OF PUBLIC POLICY, SINGAPORE

In regions where sufficient water was available in the past, water scarcity is leading to problems that were previously unknown. For example, in the summer of 2022 the water level of the Rhine sank so low that many ships could no longer pass through the river's shallowest stretch, which is near the famous Loreley rock. The Rhine is one of Europe's most important trade routes. For many companies, droughts of this kind mean that they can no longer transport their goods—but there's more. When the water level is low, industrial companies along the river must reduce the amount of water they use to cool down production facilities, for example.

Today Germany still does not have nationwide rules regulating how water is to be distributed in times of drought—simply because so far there has always been enough water. The German government has now, for the first time, drafted a "national water strategy," which would establish priorities regarding who may use how much water in the event of a future crisis. That also applies to agriculture, which currently needs much less water than the energy and industrial sector, and to private households, whose consumption of groundwater is rapidly increasing, especially during dry years. "If periods of drought and water scarcity continue to increase in Germany, we will need comprehensive water balances, which will be used to jointly manage the consumption of drinking water and the needs of industry and agriculture," says the Cologne water expert Lars Ribbe. →

CACTUSES INSTEAD OF ROLLED TURF

Examples from all over the world show what can be achieved even in the short term through good water management. For instance, in 2018 the inhabitants of Cape Town in South Africa were facing "Day Zero" after four years of drought. The water reserves in the major reservoirs had been completely used up. For certain periods of time, water consumption was limited to 50 liters per person per day. In addition, Cape Town residents were asked not to get their drinking water directly from the faucet but to fetch it from rivers and springs in the surrounding region. The price of water was also drastically increased in order to encourage private individuals and businesses to conserve water. Thanks to all of these measures, it was ultimately possible to avoid Day Zero.

The city of San Diego in southern California also succeeded in noticeably reducing water consumption by means of incentives and prohibitions. The city pays its residents subsidies if they switch to drought-resistant plants in their gardens. It also promotes water-conserving shower heads. Lawn watering is permitted only on two days per week. Furthermore, the city has set up an advice center that offers information about water management—for example, how to install cisterns for collecting rainwater and why it's worthwhile to switch on the short cycle of a washing machine. The city as a whole now consumes a third less water than it did before. A large seawater desalination plant ensures that the demand for water is reliably covered.

For many countries and regions, desalination plants are the most important technology for providing people with freshwater. In view of the gigantic reserves of seawater on the earth, they represent an obvious solution. At the same time, in many areas they are worsening the climate crisis. One example of that is Dubai. Today it has the world's largest desalination plant, which pro-

DENSE ICE

Researchers in England have created ice at a temperature of about -196° that is almost as dense as water. The water molecules in this ice do not lie in the orderly patterns of crystals, but instead are in a state of disorder, or amorphous. Experts assume that water in space generally occurs in an amorphous form

Switched off: In 2018 the reservoirs that supply water to the metropolis of Cape Town in South Africa were at risk of drying up. The city's residents were asked to use water from springs and rivers in the city's outlying districts

duces two million liters of drinking water per day—an amount that could cover the requirements of five large cities such as Berlin. However, the plant consumes vast quantities of oil and gas, thus making a huge contribution to CO_2 emissions, which in turn worsen the water problems in the long run. Only a small percentage of these plants worldwide are operated with electricity from renewable sources.

"HARD" OR "SOFT" MEASURES?

Moreover, these plants are extremely expensive. As a result, Singapore in Southeast Asia is relying only partially on seawater desalination. Almost five million people live in this city-state in an area smaller than the city of Berlin. In order to supply them with drinking water, Singapore has taken an unusual approach. In a three-step process called Newater, drinking water is extracted directly from wastewater. First, bacteria are removed from the pre-cleaned water by means of ultrafiltration. Next, reverse osmosis is used to remove tiny impurities such as viruses. In the third step, the water is disinfected with UV radiation.

For poorer countries, high-tech solutions like this one will continue to be prohibitively expensive. And in countries with low population densities, where many people live in small villages, central water treatment plants can be ruled out from the start. These areas have a smaller need for "hard" technology and a much bigger one for "soft" measures that supply people with water. In Ecuador, for example, with support from the environmental protection organization The Nature Conservancy it was possible to protect the catchment areas in the highlands and the mountain forests by organizing a round-table discussion between cattle owners from the mountain villages and residents of the towns in the valley. Together, the discussion participants decided to plant trees in the mountain forests from which the springs and riv- →

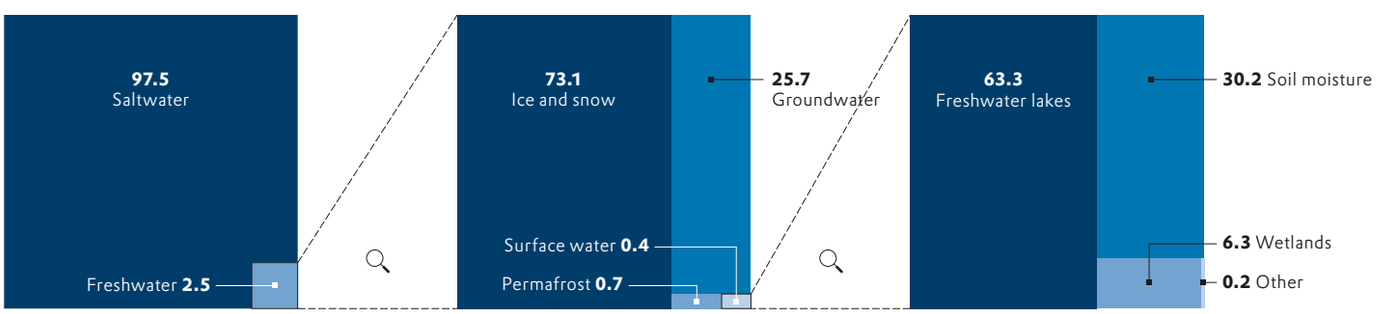
Thirsty work: Agriculture is the sector that consumes the largest amounts of water all over the world. The production of about a kilogram of cotton requires as much as 1,200 liters of water

THE WETTEST PLACE ON EARTH

The place on earth that receives the heaviest rainfall is Mount Wai'ale'ale on the island of Kaua'i in the Hawaiian Archipelago. On the eastern flank of this volcano, it rains on 335 days per year on average. About 12,000 millimeters of precipitation per year fall on every square meter of the mountain—compared to 800 millimeters in Hamburg

A SCARCE COMMODITY

The total volume of water on the earth is estimated to be just over 1.3 billion cubic kilometers. Freshwater that is available to humans is only a tiny fraction of this amount. All figures in percent



Source: USGS

Fire alert: On account of continuing drought, unusually large forest fires raged in British Columbia this summer. Simultaneously, rapid snowmelt caused several rivers in the southern part of this Canadian province to overflow their banks

ers draw their water. In addition, the cattle grazing was spread out more thinly. To compensate for this measure, the villages and towns are imposing a tax to help finance the cattle owners in the mountain region.

PARTICIPATION CREATES RESPONSIBILITY

Many people could benefit from good water management, says Philipp Günter from the German aid organization Misereor, which has already supported many projects in Africa and Latin America. "Over the years we've discovered that water can be a connecting element between people," he reports. When a village community works together to build cisterns for collecting rainwater to use in dry periods, small dams or a well, that strengthens its sense of solidarity. "The challenge consists of keeping the infrastructure going over a period of many years," Günter says, adding that part of the challenge is for the local people to participate in the financing and organization of the water project so that they feel responsible as a community.

Keeping an eye on the environment, technology, and people at the same time—that's still the real challenge facing water projects. And that's the factor that has sometimes been lacking in many countries, says Lars Ribbe. "There are still far too few water experts who are trained in this kind of networked thinking."

It's true that the overarching framework was already defined at the political level for a long time ago. In 2010, the General Assembly of the United Nations declared that "access to safe and clean drinking water" is a fundamental human right. But it won't be until the upcoming global climate conference in Dubai at the end of this year that water security is moved to the center of the global climate protection agenda—more than 40 years after the nations of the world met together for the very first time for a climate conference.

Tim Schröder is a science journalist who lives in Oldenburg

PRECIOUS WATER

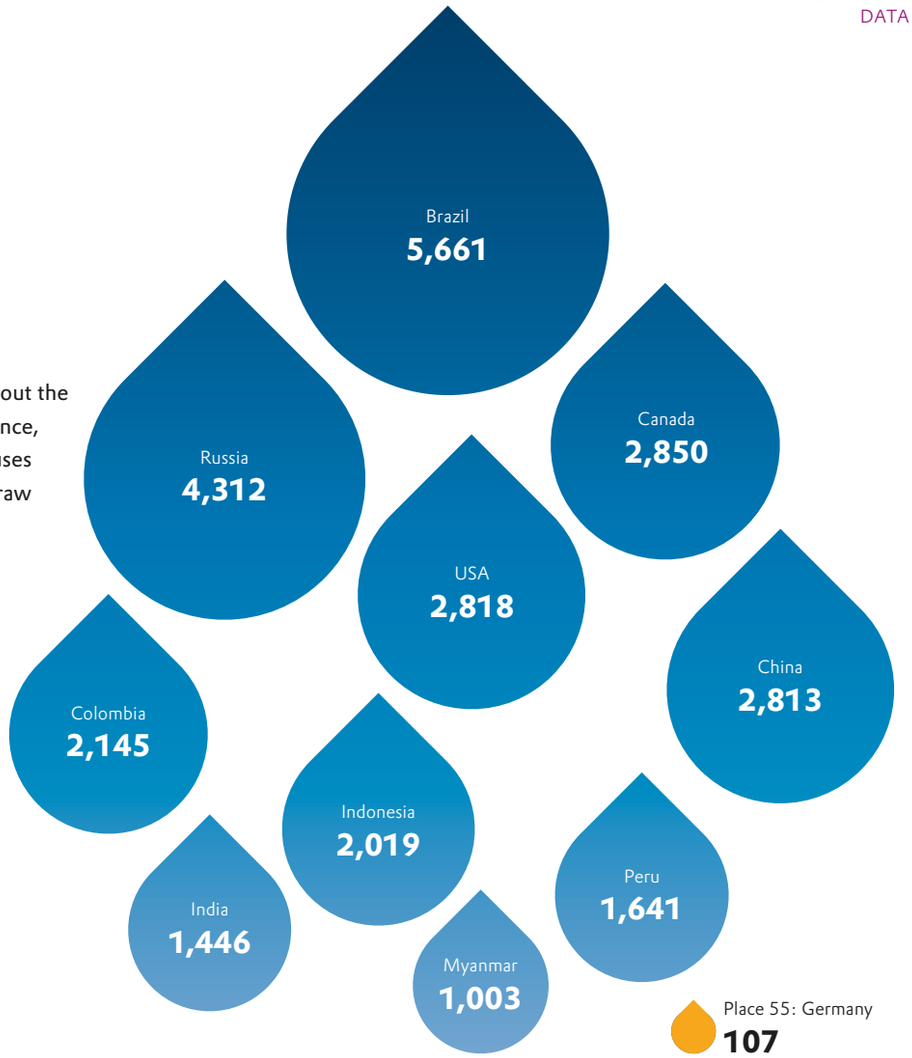
Water is distributed extremely unequally throughout the world. Where is this resource available in abundance, and where is it scarce? Who wastes it, and who uses it sparingly? And how much does this important raw material cost? A numerical overview

INFOGRAPHIC **MAXIMILIAN NERTINGER**

Water in abundance

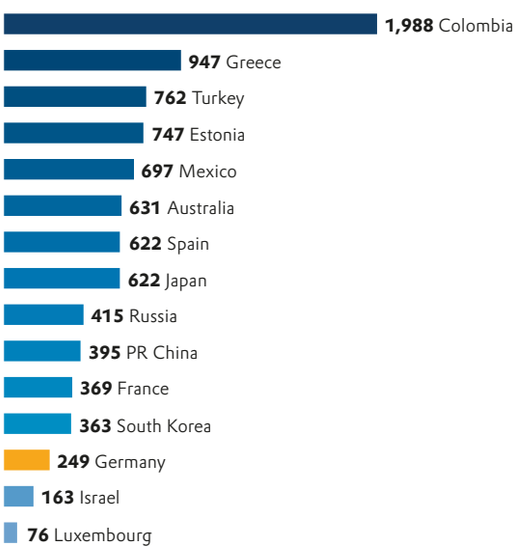
The ten countries with the biggest reserves of renewable freshwater* in 2020, in billions of cubic meters (compared with Germany)

* Balance of rainfall, evaporation, inflows and outflows



Wasting or saving

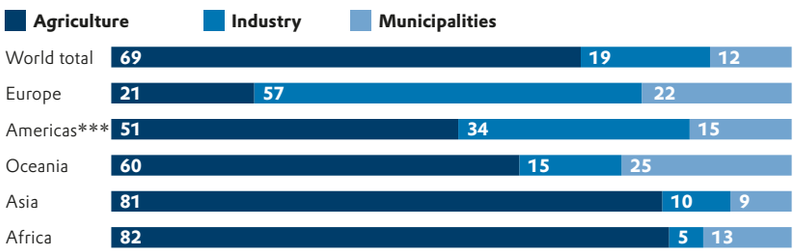
Annual per capita water consumption of selected countries in 2021** in cubic meters



** or last available year

Thirsty agriculture

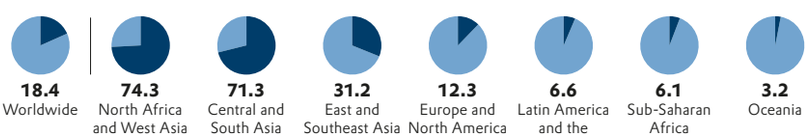
Water consumption by sector and continent 2015, in percent



*** North and South America

Where the water stress is highest

Proportion of the water abstracted from renewable water sources 2018, in percent

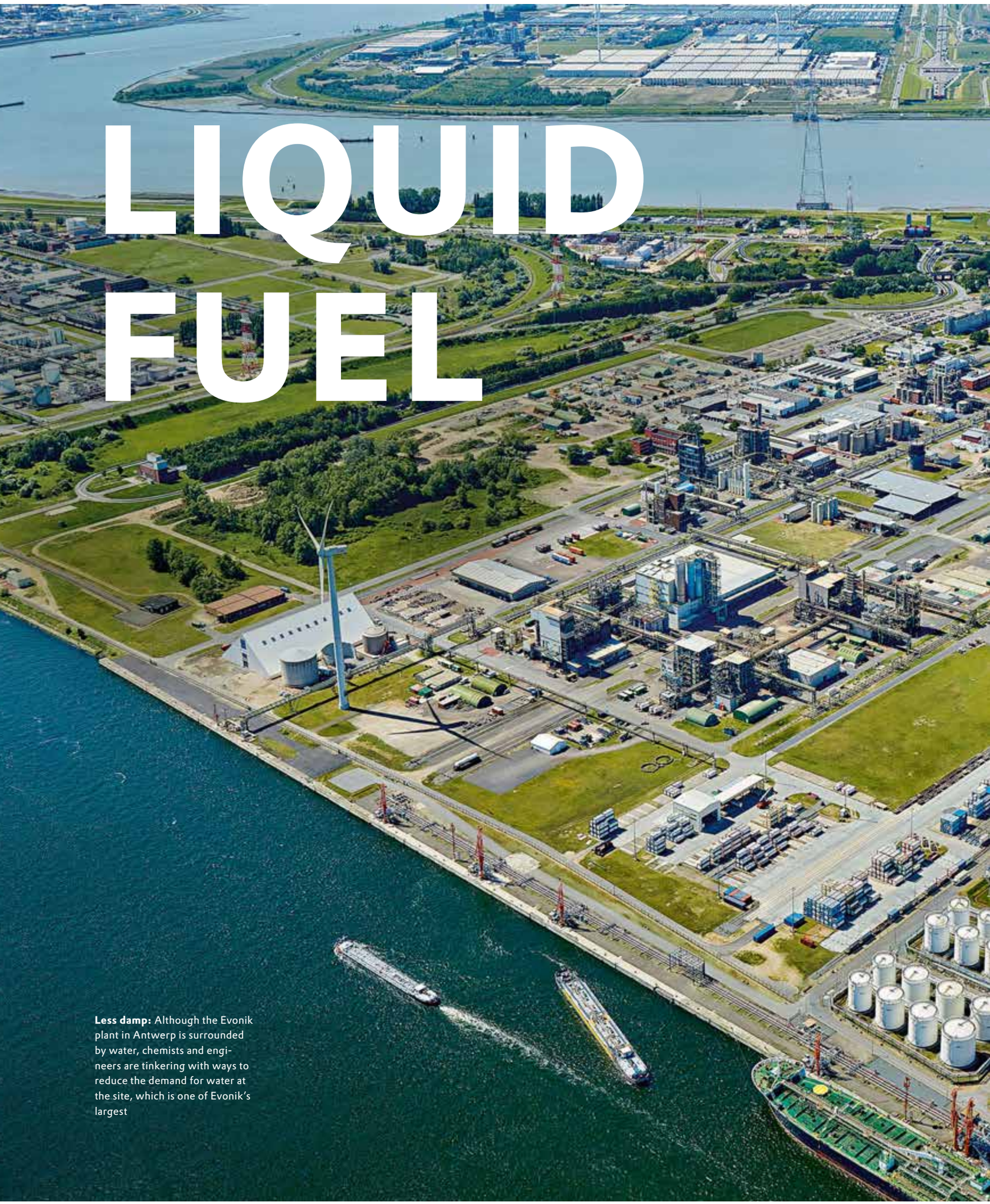


Various calculations

The price of tapwater in selected cities in 2020, in € per cubic meter

Sources: OECD, FAO, World Bank, holidu.de

LIQUID FUEL



Less damp: Although the Evonik plant in Antwerp is surrounded by water, chemists and engineers are tinkering with ways to reduce the demand for water at the site, which is one of Evonik's largest

Nothing can happen at Evonik without water, which is indispensable for cooling, for example. To secure supplies and conserve resources, different strategies are used depending on the location—from rainwater retention basins in South Africa to high-tech filters in Thailand and recooling systems in Germany. A look at sustainability around the world

TEXT **TOM RADEMACHER**
CONTRIBUTOR **BERND KALTWASSER**

Hot summers are stressful for Hannah Gerwing, who works for Evonik as an employee of the Logistics business line in Essen. That's because she keeps an eye on water level forecasts for the Rhine, which boasts numerous chemical factories along its banks. If the river threatens to drop to critical levels, Gerwing calls together the Low Water Task Force. "Last year I had to do this virtually every week from June through September," Gerwing says. Back then, the water shortage in the Rhine made headlines throughout Europe. As a result, cargo ships were only partially loaded or did not travel at all. Not only were raw materials and products left behind at Evonik or had to be transferred to road and rail, the low water level also threatened to cause difficulties for supplies and the cooling of production facilities. "If we don't take countermeasures in time, production has to be curtailed," Gerwing says.

TOO LITTLE WATER OR TOO MUCH?

Low water levels affect production facilities in many ways: "Without water, nothing works," says Ulf Auerbach, who is responsible for water issues at Evonik. "We have to take this very seriously." The company analyzes the water situation at its sites worldwide in detail and has used the findings to forecast how it will change by 2030 and 2040, respectively. The results show that a quarter of all sites are threatened by water shortages. →

“Without water, nothing works. We have to take this very seriously”

ULF AUERBACH, SENIOR EXPERT ENERGY & CLIMATE AT EVONIK

“Shortage is only one of our problems. Elsewhere, floods are the greater risk, as are political and social conditions,” says Aurelie Wojciechowski, who works in the Sustainability Strategy unit at Evonik. To assess all this, Evonik plans to use the WWF’s Water Risk Filter in the future, a methodology that takes into account many other local factors in addition to impending scarcity. “Unlike CO_2, water is a variable that has a local impact and has to be evaluated in a very differentiated way from place to place,” Wojciechowski says.

EVERY LITER IS USED SIX TIMES

Chemistry needs water—lots of water. It is needed for chemical reactions, as a thinner and solvent, for washing and cleaning, and especially for cooling. According to the World Bank, of the approximately 3.9 trillion cubic meters of freshwater withdrawn globally each year, an average of 15 percent is used for industrial purposes. And the chemical industry is the thirstiest industry after the energy supply sector. In Germany, for example, it is the largest consumer of water in the manufacturing sector. According to the Federal Statistical Office, the German chemical industry uses around 2.6 billion cubic meters of water per year.

The good news is that chemical companies in Germany have largely been able to decouple their water needs from growth over the past three decades. Between 1991 and 2016, for example, the industry’s water abstraction fell by almost 40 percent, while production grew strongly at the same time. This is due to a major rethink. According to the German Chemical Industry Association (VCI), the industry today uses every liter of water almost six times before it is purified and released into the environment. Evonik too uses the principles of the circular economy when it comes to water. Globally, the company abstracted around 446 million cubic meters of water in 2022, just over half of it freshwater (see the chart on pages 30–31). Although the volumes of water used throughout Evonik are far greater, most of it circulates in closed systems and does not need to be constantly renewed.

At the same time, the company is constantly working to reduce specific water withdrawal—i.e. the amount of water per ton of product produced. The new water management strategy aims to reduce freshwater consumption by another three percent by 2030. Where appropriate, saltwater is used instead of freshwater. For example, Evonik cools its methionine production in Singapore entirely with seawater. This is possible because the city-state’s administration treats this important resource and the Evonik plant was built with particularly corrosion-resistant materials. Thus, each site must find a solution that’s appropriate to local conditions, says Auerbach.

However, one rule applies worldwide: “Energy and water consumption are very closely related because about 90 percent of our water use is for cooling,” Auerbach says. Wherever waste heat is used to save energy, less cooling water is needed in one place and less steam for heating in another. As part of a global technology program, Evonik is currently investing up to €700 million in improving energy efficiency at locations around the world in order to reduce CO_2 emissions. If this also reduces the water requirement, the investment is all the more worthwhile. In order to raise awareness of this further, Evonik is developing its own water policy, which encompasses group-wide instructions and also includes customers and suppliers. “Water is actually too cheap, but the risks aren’t,” says Wojciechowski. “All over the world, we have to take into account the specific locally threatening scenarios so that we can then quickly take correct countermeasures if necessary.”

Water recycling
Evonik operates eleven plants in Antwerp, including one of the world's largest production facilities for the essential amino acid methionine. The use of wastewater is expected to reduce the annual demand for freshwater by 2.5 million cubic meters

ANTWERP
COOLING WITH WASTEWATER

COUNTRY	Belgium
LOCATION	51°18′ N, 4°18′ E
CLIMATE	warm temperate
AVERAGE TEMPERATURE	11 °C
ANNUAL PRECIPITATION	816 mm
DAYS OF RAIN	120

Water is never far away: Evonik's large production site in Antwerp, Belgium, is squeezed onto a narrow strip of land between a canal and the Scheldt River, which widens to a width of one kilometer or more behind Europe's second-largest seaport before flowing into the North Sea. Nevertheless, the people in charge of the site have been scratching their heads for a long time about how the water supply will continue in the long term. That's because Evonik's plants need a lot of liquid for cooling, steam, and processes.

Because the tides mix saltwater and freshwater in the Scheldt to a brackish mixture, it is not usable for all purposes. Even the water from the somewhat less salty canal cannot be used indefinitely. "For a long time we were able to cover our cooling needs by using the canal water for once-through cooling," explains Dirk Goossens, Sustainability Coordinator at the site. However, the construction of two large plants some years ago caused the site to reach its limits. "Especially in summer, we cannot and must not release unlimited amounts of heat into the canal," says Goossens. The ecological balance would be disturbed if the water were to get too warm. Evonik therefore cools all new plants with cooling towers that circulate water and release heat into the air. "But we need very clean freshwater for this," says Jorn Walscharts, the energy and wastewater operations manager at the site. Around 1.4 million cubic meters must be fed in each year in order to compensate for the evaporated amounts and prevent calcification of the system over the long term. At present, this water still comes from the public drinking water network, but things will soon change. "The idea is to treat municipal wastewater from the city of Antwerp so that we can use it directly for cooling," says Walscharts.

In cooperation with several technology companies, Antwerp's municipal water utility is planning to set up a kind of cooling water factory on the site of a former Opel plant. In the future, the new facility will treat the wastewater from 600,000 households—around 20 million cubic meters per year. "The water has already passed through the normal treatment plant and would currently be discharged into the river," Walscharts explains. Instead, it will be pressed through a special membrane once again in a process known as reverse osmosis, thus removing the remaining impurities and salts. "The result is recycled water that contains less salt than drinking water," Walscharts says. "That's a big advantage for us."

In Antwerp, Evonik will thus no longer need valuable drinking water for cooling or for steam generation and chemical processes—in total around 2.5 million cubic meters per year. It also reduces the workload for the site's desalination plants. "This reduces our water needs by a further ten percent and also lets us dispense with additional chemicals," says Goossens. The facility is scheduled to go into operation in three years.

MAP TA PHUT
SAVING WATER WITH FILTER TECHNOLOGY

COUNTRY	Thailand
LOCATION	12° 42′ N, 101° 6′ E
CLIMATE	tropical
AVERAGE TEMPERATURE	27.2 °C
ANNUAL PRECIPITATION	1,807 mm
DAYS OF RAIN	155

Thailand is used to extreme weather. In fact, the entire country depends on water being held back in reservoirs during the rainy season to prevent flooding. In the dry season, these reservoirs then enable a secure supply of water and electricity generated by means of hydropower. “Proper management of these reservoirs is extremely important, but is complicated by climate change,” says Surasak Photia, who heads Evonik’s site in Map Ta Phut. Here, the Silica business line produces precipitated silica, which is used in products ranging from car tires to toothpaste. The production process requires a lot of water. The product is precipitated from the liquid as a white powder and then separated and dried in filter presses. “Depending on how you conduct this process, a lot of water can be saved,” Photia explains. His technicians proved this in 2020, when water once again became a major political issue in Thailand following a number of extreme weather incidents. Without any investment, the site was able to reduce water demand by ten percent by changing filter settings.

Knowing how: A sophisticated filtration and drying process helps to reduce the amount of water required in the production of precipitated silica

Well prepared: Collected rainwater is already being used in the South African province of KwaZulu-Natal, where Evonik produces hydrogen peroxide

UMBOGINTWINI
OSMOSIS INSTEAD OF DISTILLATION

COUNTRY	**SOUTH AFRICA**
LOCATION	30° 0′ S, 30° 54′ E
CLIMATE	warm temperate
AVERAGE TEMPERATURE	20.5 °C
ANNUAL PRECIPITATION	887 mm
DAYS OF RAIN	89

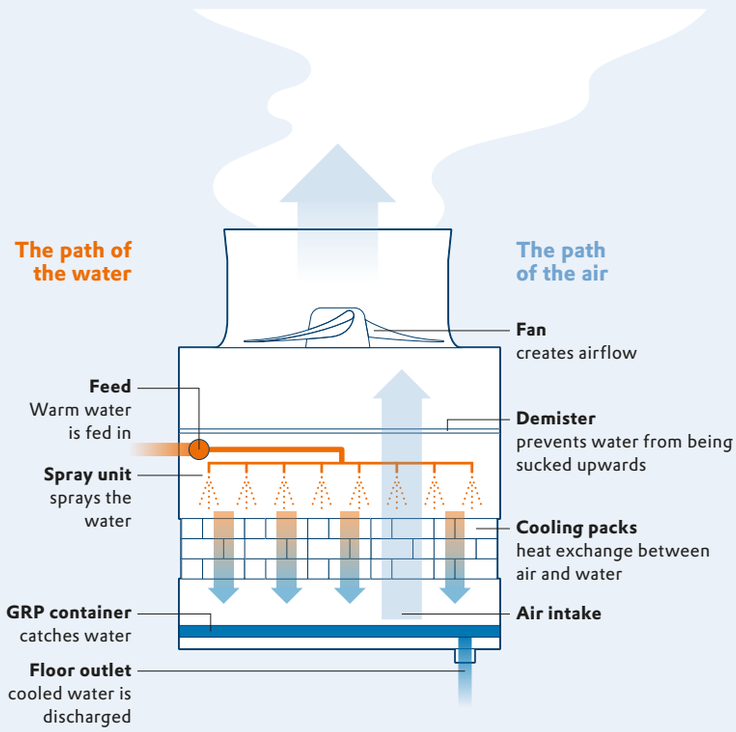
The Umbogintwini Industrial Complex owes its name to the nearby Mbokodweni river and is located slightly more than one kilometer from the Indian Ocean. Accordingly, there should be water in abundance. Nonetheless, the people at this chemical park are concerned. The park, where Evonik produces hydrogen peroxide, is located south of the South African megacity of Durban. Extreme weather conditions are on the rise. The site has been identified as a moderately water-scarce site. “We save water in keeping with our sustainability due diligence and to reduce the impact on our environment,” says Surie Govender, the Sustainability ambassador at the location. “Every drop helps.” The measures are manifold. For example, currently collected rainwater is supplied to the changeroom sanitary facilities. In the future, this will be extended to the warehouse for use in the cleaning of returned drums. But the plans in Umbogintwini go even further: In the future, cooling water could be treated and used in production and logistics. And instead of bringing the hydrogen peroxide to a certain concentration by means of distillation, it’s also possible to use reverse osmosis, which our project team is working on. This would save steam energy, cooling requirements, and thus water.

WESSELING
RELIEF FOR THE RIVER

COUNTRY	Germany
LOCATION	52° 48′ N, 7° 18′ E
CLIMATE	warm temperate
AVERAGE TEMPERATURE	10.7 °C
ANNUAL PRECIPITATION	847 mm
DAYS OF RAIN	115

In Wesseling, two state-of-the-art cooling towers ensure that silica production can run without seasonal interruption. After the treated wastewater has been used to rinse filter presses it is cooled in a particularly energy-efficient manner. The Rhine benefits from the lower discharge temperature.

Warm in, cool out
Schematic diagram of a cooling tower



MARL
COOLING WATER CIRCUIT

COUNTRY	Germany
LOCATION	51° 42′ N, 7° 6′ E
CLIMATE	warm temperate
AVERAGE TEMPERATURE	10.6 °C
ANNUAL PRECIPITATION	884 mm
DAYS OF RAIN	197

The Marl Chemical Park uses around 600 million cubic meters of water per year. Nevertheless, the site here on the northern edge of the Ruhr region is considered "dry." For one thing, the chemical park is not located on any major river, as the Rhine is more than 20 kilometers distant as the crow flies. The site's thirst for water could never be quenched by the tranquil Lippe River, which meanders past to the north of the site, and the Wesel-Datteln Canal right next to the industrial site.

Covering six square kilometers (three times the area of Monaco), the Marl Chemical Park is home to three power plants and around 100 production facilities operated by more than 20 companies. Water is in demand practically everywhere—as process water, fire-fighting water, washing water or drinking water, but above all as a means of cooling and generating steam. Over the decades, it has been possible to largely decouple the demand from the surrounding waters. Instead of using river water for once-through cooling, water is now circulated in recooling systems.

A total of around 80 such cooling cells are spread across 18 recooling plants distributed throughout the chemical park. In these cells, water is trickled onto evaporative bodies while a large fan pulls air through the system from above. In this way, the warm water releases evaporation energy into the air. The water, which has been cooled to a target temperature of 20 degrees, is piped to customers in the park, who use it to cool their processes and then return it warmed by a maximum of ten degrees Celsius. Only from one to one and a half percent of the cooling water evaporates in the recooling system and has to be replaced with treated water from the Wesel-Datteln Canal.

In the future, this demand is expected to decrease further. To achieve this, plants will use more of their waste heat themselves or transfer it to where process heat is needed. Hot water at up to 80 degrees Celsius flows from plant to plant in a dedicated waste heat network. "It's more complex than the cooling cycle. We have to balance the feeders and consumers precisely with one another so that the system operates stably," explains Johannes Offer, who is responsible for projects in the Utilities unit at Evonik. But the effort is worthwhile. Up to 60 megawatt hours can already be exchanged, which corresponds to the heating needs of about 6,000 single-family homes. Another 50 megawatt hours would

be possible, Offer says. “We could save a corresponding amount—not only in energy, but also in water for cooling and for steam generation.”

For the renaturalized Lippe, a popular recreational area in the region, the inflow of water is as important as the abstraction. The Marl Chemical Park discharges around 15 million cubic meters of water a year—over three times as much as it withdraws. A large part comes from the Chemical Park’s own wells as well as from rainwater and groundwater. “Everything that rains on our plants and our land or passes through our soil has to be collected and treated in case it has been contaminated,” explains Jörg Gisselmann, who heads Evonik’s Marl environmental operations. The wastewater is treated by bacteria in a biological wastewater treatment plant. In large pools, the bacteria eliminate chemical compounds of carbon, nitrogen or phosphorus.

Evonik recently installed a Fenton plant to cope with the growing wastewater load as a result of expanding production capacities. This is used to pre-treat more polluted wastewater to make it “digestible” for the bacteria. What is special about this system is that hydrogen peroxide, which Evonik produces itself, can also be used to break down complex carbon compounds in an environmentally friendly way. The hydrogen peroxide itself is additionally activated by iron salts. It produces hydroxyl radicals, which break down organic constituents of wastewater. In this way, even wastewater that is difficult to purify can be treated biologically to keep the Lippe clean.

“The ZLD system enables us to reduce our fresh water consumption by around two thirds”

SURESH PILLAI, MANAGING DIRECTOR
OF EVONIK CATALYSTS INDIA

DOMBIVLI
PRODUCTS FROM PROCESS WATER

LAND	India
LOCATION	19° 12′ N, 73° 6′ E
CLIMATE	tropical
AVERAGE TEMPERATURE	26.7 °C
ANNUAL PRECIPITATION	1,439 mm
DAYS OF RAIN	91

Suresh Pillai is the managing director of Evonik Catalysts India. In 2022 the company put a zero liquid discharge (ZLD) system into operation at its Dombivli location. The system purifies wastewater and transforms material previously classified as waste into a saleable product.

What does the zero liquid discharge system do?
We use our ZLD system to purify our process water. This is water that we have used to produce metal catalysts, for example. Our system treats about 550 to 600 cubic meters of wastewater per day. This is equivalent to 25 to 30 tanker truck loads. We can reuse more than half of this water directly in our production process. We use the rest as cooling water.

Why is this important?
For us and our customers, it is by no means just about ecology—this topic is an important growth driver for our business. This is where the ZLD system comes into play. It shows that we take this issue seriously. Specifically, it enables us to reduce our consumption of freshwater by around two thirds. In addition, the process produces about ten to 15 tons of sodium sulfate and certain mixed salts that can be sold as commercial products.

How widespread is the ZLD concept in India?
The idea of avoiding liquid waste is not entirely new. It is important, especially here in the state of Maharashtra, where summers are hot and dry and water is precious. But our project is also exemplary for other reasons. As far as I know, we are one of the first companies in this region to use ZLD not only for a selected process flow or plant section but for all the process water. In this way we’re demonstrating how systematic resource conservation can be implemented.

MOBILE
CLEAN THANKS TO MARSH PLANTS

LAND	USA
LOCATION	20° 30′ N, 88° 6′ W
CLIMATE	warm temperate
AVERAGE TEMPERATURE	19.9 °C
ANNUAL PRECIPITATION	1,396 mm
DAYS OF RAIN	96

Roundhead bulrush (*Scirpoides holoschoenus*) and southern cattail (*Typha domingensis*) plants have an important job to do. These marsh plants grow in a basin filled with limestone gravel on the edge of Evonik's Mobile location. "It was a real novelty in the early 2000s, when the basin was added to keep up with our growing production. Scientists at NASA had spent years working on the idea," says Trey Laubenthal, who is responsible for all wastewater treatment at the location. Here in the US state of Alabama, the company relies on a wastewater treatment method that is particularly close to nature and handles around 4.5 million liters a day. Before being discharged into the nearby Theodore Industrial Canal, the water passes through several stages of treatment. The last stage is the so-called constructed wetland, a basin that is slightly larger than a soccer field. The plants in it form a dense network of roots with which they extract almost all the remaining carbon, nitrogen, and phosphorus compounds from the water. Otherwise these compounds could cause damage to the natural habitat of the canal. Meanwhile, in the basin the plants are thriving so well that they are swarming with insects, small animals, and snakes. "The water we're discharging into the canal is a cleaner version than the canal water itself," says Laubenthal. As a result, the Theodore Industrial Canal itself—a sort of cul-de-sac in Mobile Bay—is popular with amateur anglers, Laubenthal says. The only thing to watch out for are the alligators.

Sumps are trumps: 4.5 million liters of wastewater are treated daily at the Mobile location. Before the water is discharged into a canal, it passes through a constructed wetland (on the left in the photo)

Tom Rademacher is a freelance journalist based in Cologne. He writes about scientific and industrial topics, among others.

Everything flows

A huge amount of water passes through Evonik's plants every year. By far the largest part of it is recirculated, and practically all of the rest is returned to the bodies of water from which it originates. Almost no water is lost

INFOGRAPHIC **MAXIMILIAN NERTINGER**

USE

The amount of water used is approximately equal to the content of Lake Ammer in Bavaria (1,750 million cubic meters).

1,810
million cubic meters

ABSTRACTION

About a quarter of Evonik's water requirements is newly supplied each year.

446
million cubic meters

RAINWATER

Captured rainwater and recycled water from neighboring companies.

POTABLE WATER AND GROUNDWATER

Freshwater from local water supply and wells.

SURFACE WATER

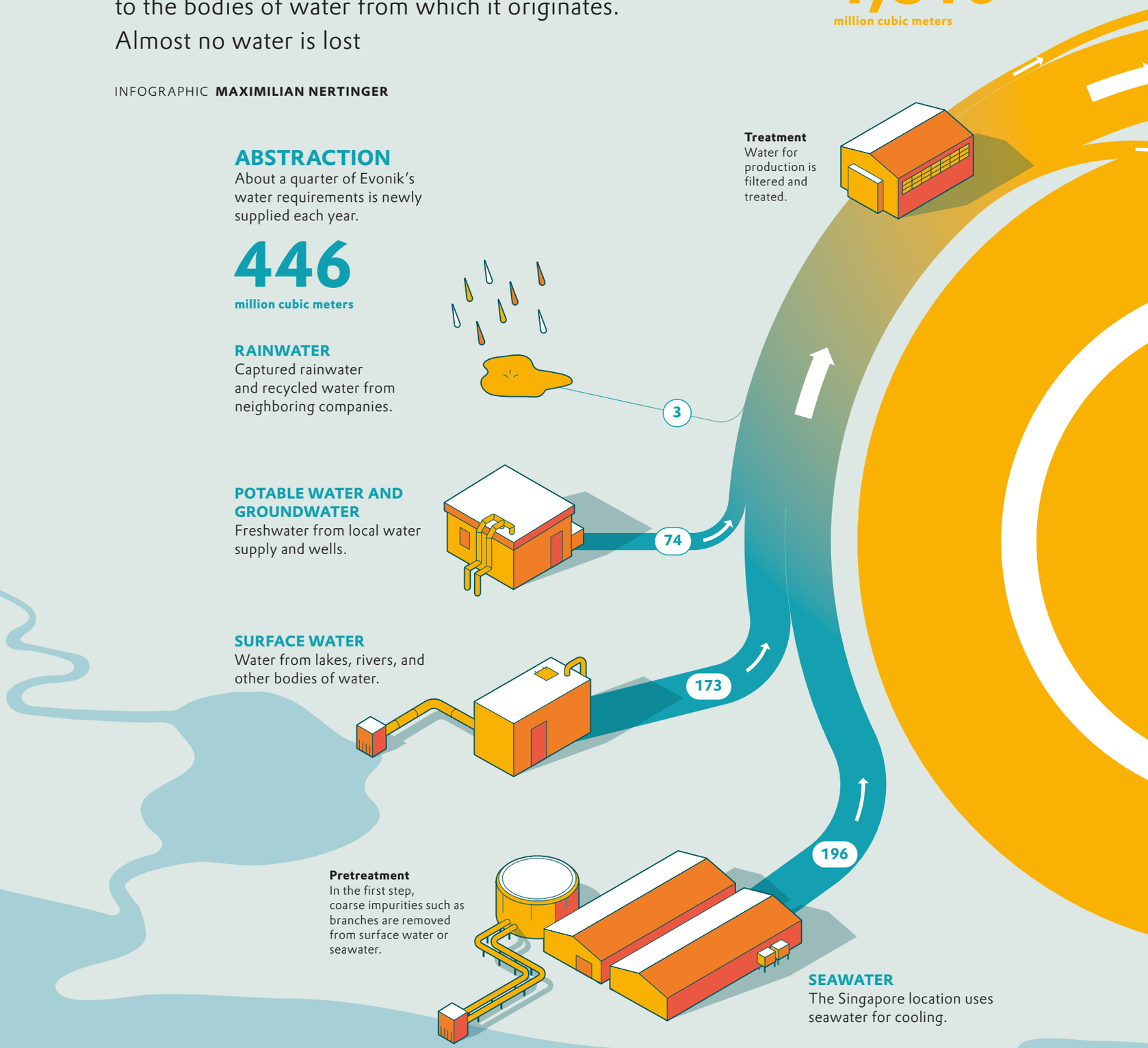
Water from lakes, rivers, and other bodies of water.

Treatment
Water for production is filtered and treated.

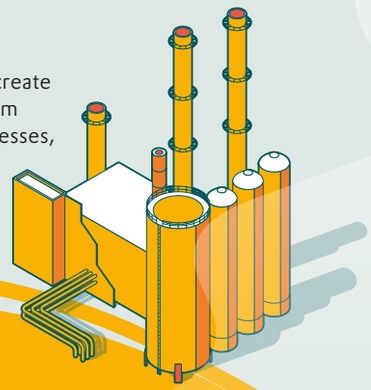
Pretreatment
In the first step, coarse impurities such as branches are removed from surface water or seawater.

SEAWATER

The Singapore location uses seawater for cooling.



PRODUCTION
Water is used to create steam, as a medium for chemical processes, and for sanitary purposes.



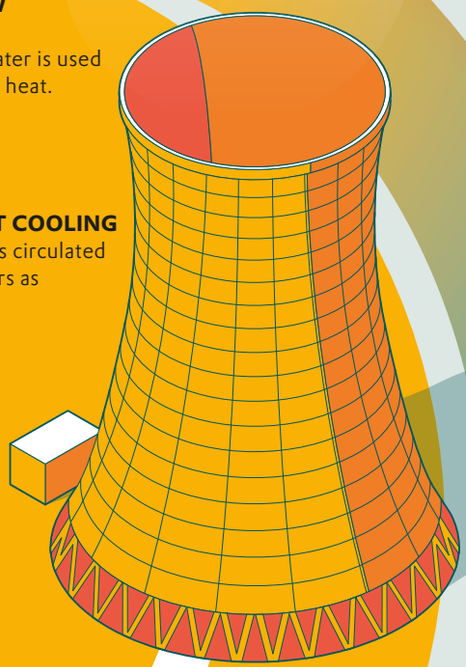
45

381

THROUGH-FLOW COOLING
Freshly supplied water is used to dissipate process heat.

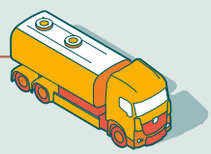
1.384

CLOSED-CIRCUIT COOLING
Most of the water is circulated and cooled in towers as required.



LOSSES
Small amounts of water evaporate or are used to dilute products.

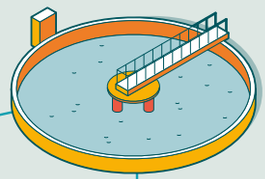
7
million cubic meters



7

RETURN
The used water is almost completely discharged into bodies of water.

439
million cubic meters



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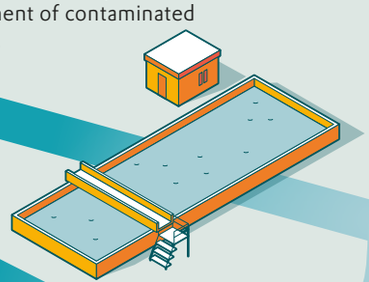
EXTERNAL WASTEWATER TREATMENT PLANTS
Contaminated water is partially discharged to municipal wastewater treatment plants.

INTERNAL WASTEWATER TREATMENT PLANTS
At many of its locations, Evonik operates its own plants for the treatment of contaminated water.



236

SURFACE WATER
Treated water and uncontaminated cooling water is returned to lakes and rivers.

196

SEA
The uncontaminated cooling water in Singapore is discharged back into the sea.

“We need to slow down the water cycle”

Today a large proportion of our freshwater is disappearing unused into the ocean, causing additional rising of the sea level. The hydrologist Dr. Johannes Cullmann works as a scientific advisor for the United Nations. He believes that the water challenge can still be solved at the global level—if the steps are implemented at a faster rate than climate change

INTERVIEW **JÖRG WAGNER** & **CHRISTIAN BAULIG**

Watching the water: For Johannes Cullmann, it's only a short walk from his office at the World Meteorological Organization to the shore of Lake Geneva. Just under 60 percent of the lake belongs to Switzerland, and just over 40 percent to France. With an average volume of 89 cubic kilometers, it holds more water than any other lake in central Europe

Dr. Cullmann, the media are devoting more and more space to water shortages and water surpluses—in reports on events ranging from forest fires in the Rocky Mountains to sinking water levels in the Rhine and floods in Pakistan. Is this topic currently receiving the attention it deserves?

JOHANNES CULLMANN I think it's basically a good thing that the media have become attentive to the topic of water, because the entire debate about sustainability and resilience is strongly connected to water. About 80 percent of all natural disasters are related to water. Climate change is always a process of water change as well. Our societal and economic resilience also depends on water. How can we continue to engage in agriculture? Who is suffering the greatest long-term damage as a result of hydrological changes? Unfortunately, the media generally focus on spectacular events. These are unavoidable, and they will increase in the next 60 to 100 years. But droughts and floods are only one part of the overall picture.

Where should we look more closely instead?

At the causes that underlie these catastrophes—and at the consequences that ensue. First of all, we need to slow down the water cycle. As a result of human beings' shaping of our landscape, the water cycle has been accelerated more and more by construction measures. That started to happen as long ago as the Roman Empire. For a long time, we've been trying to keep water away from our direct surroundings, either because we're afraid of floods or because we want to use the land for agriculture, for example. When there are periods of no rain, the increased rate of drainage heightens the risk of droughts. At the same time, flooding situations are dangerously exacerbated because too much water is flowing at once to the same point.

So, slowing down—what else should we be doing?

The second important point is that we need to reintroduce more water into our overall system. With the help of satellites, the US-German space mission Grace is monitoring the places where we are losing freshwater all over the globe. To a large extent, this is in the form of snow and ice, which are melting and flowing into the oceans. But this is also happening in warmer regions where there is no snow and ice, such as Brazil and parts of the USA. Here we are losing groundwater because agriculture is expanding without any regard for the natural resources. In Germany as well, the amount of water that is lost from our system every year is greater than the amount of water that Germans drink. All of these factors thus contribute to the proportion of the rise in the sea level that is not due to thermal expansion, which is defined as the expansion of the ocean water that already exists. We need to create additional reservoirs in order to compensate for these losses, whether it's through biosystems and in the groundwater or by means of new infrastructure.

1,400
LITERS
of water are needed to produce half a pound of butter

In the case of climate change we have realized that it can mainly be traced back to the excessive emission of greenhouse gases. In the case of the hole in the ozone layer, we knew at some point that we would have to give up our use of CFCs. Why is it so difficult for us to acknowledge the connections in the case of water?

Because it still does not represent an urgent problem for most people. The ozone hole seemed directly dangerous to people because they were afraid of getting skin cancer. People are at least vaguely aware of the fact that climate change is an existential issue affecting their future. We still haven't reached that point with regard to water. For most people, water is still affordable and available in practically unlimited quantities. But here we're ignoring the fact that our water consumption far exceeds the amount that comes out of our faucets at home every day. Our total consumption is many times larger if we look at how much water is contained in all the food and other goods that we consume. This is what we call our water footprint.

What needs to be done in order to raise people's awareness of this fact?

For example, we have to provide people with more information about the conditions under which the inexpensive roses we buy in a discount store are grown in Kenya. The water that is needed for these roses is not available to the local population. We have to explain that the production of half a pound of butter requires about 1,400 liters of water, and that margarine may be a better alternative. We shouldn't lay down any rules about who can consume what and when, but everyone ought to know what consequences result from their behavior.

When people consume goods more consciously, they deserve praise. But wouldn't it be more important to regulate water consumption in ways that reward frugality and punish wastefulness?
We can certainly achieve a great deal through subsidies and taxes—for example, if the government generally supports processes in which water is reused. That could also have an effect on municipal sewage treatment plants, most of which have until now simply channeled the purified water into rivers. The purified water could also be used to re-irrigate land or replenish groundwater—in other words, to slow down the water cycle and create reservoirs. No municipality does that of its own accord, because it costs more than the practices that prevail today. The difference in costs has to be offset in financial terms.

It was only the pricing of carbon dioxide that led to a significant change in people's behavior. Shouldn't water also have a price that gives us an incentive to be frugal? Why should people in Saudi Arabia limit their consumption of water if a cubic meter of water from the faucet costs only three cents?
You're right. There should be a global agreement to re-evaluate water as an economic commodity. At the same time, we need international agreements to prevent consumers from switching to products from neighboring countries where water is cheaper or even free of charge. However, making water more expensive across the board without enacting reasonable regulations would be dangerous, because this always affects the poorest people rather than the large-volume consumers. The situation for carbon dioxide is different. If you increase the price of CO_2, you're not putting a disproportionate burden on lower-income groups.

3
CENTS
is the price of a cubic meter of drinking water in Riyadh, the capital of Saudi Arabia

How realistic is the concept of such a global agreement? In view of the urgency of the problems, we haven't got much time for negotiations.
Together with the UN Climate Secretariat, in 1992 we succeeded in installing a mechanism in which all the countries of the world work together to limit global warming. The most important result of that was the Paris Agreement of 2015, in which 195 states committed themselves to limit climate change and restructure the global economy in climate-friendly ways. At the UN Water Conference this spring, the participants launched a process that will lead, among other things, to a committee in which the UN member states talk with one another and develop guidelines. However, we clearly cannot once again take 23 years to reach a consensus, as we did in the case of the climate agreement.

Agriculture is the sector that consumes the most water all over the world. What would a more frugal use of water look like?
Having fewer monocultures would be a start. For some plants, it's also smarter to simply confront them with a bit of water stress during their maturity phase instead of constantly watering them, because the fruit then becomes better. You might get one, two or three tons less yield per hectare, but you'll be able to sell your crop for a higher price. For high-quality agricultural products, it can make sense to install smart irrigation systems, even though they're slightly more expensive. →

"We're ignoring the fact that our water consumption far exceeds the amount that comes out of our faucets at home every day"

And what can be done by industry, which is among the biggest water consumers in most of the prosperous countries?
Today there are still many unsustainable processes that date back to a time when people didn't have to think about the frugal use of water. They simply regarded water as a remainder in economic terms. You can save a lot of water by using it in a cycle. That also helps to reduce heat pollution. As a result of human activities, the Rhine is as much as four degrees warmer in the winter than it was before the age of industrialization. Through practices like these we are heating up our environment, and the heat that is produced through so much effort is lost. It's as though we were holding an immersion heater in the river—it just doesn't make sense. And instead of channeling the purified process water from manufacturing industries into rivers, it would be better to use that water for agriculture or landscape maintenance.

Industry causes problems. But to what extent can it also be part of the solution by facilitating developments that promote water conservation?
Thanks to innovations, the purification of wastewater from industry and elsewhere has improved so much that the resulting water can be used without any risks today. That's a giant step forward. I think there will be lots of potential in the desalination of ocean water if we use less climate-damaging alternatives instead of fossil energy sources. The products and processes in the agriculture sector also harbor tremendous opportunities for using water in smarter ways—such as drip irrigation. All of these are innovation fields in which industry and science play a major role and which offer tremendous benefits for humanity.

689
MEASURES
are to be implemented worldwide as the result of the most recent UN Water Conference

In addition to these approaches, there are some ideas in circulation that sound like science fiction. They involve tapping freshwater resources under the ocean bed or towing glaciers to regions where water is scarce. Do projects like these have a future?
There may be a good applications for them somewhere in the world, but I would always prioritize improving something that I know I can improve.

Do we have sufficient resources to finance a comprehensive global restructuring of our water management?
When I look at how much money we've made available for combating the COVID-19 pandemic, I think it can certainly be financed. Some people say that we need several trillion US dollars in order to solve the water problem at the global level. The money is available. We only need to have the determination to spend it in the right way.

You're talking about tax money. What about the capital market?
Governmental financial instruments alone won't be sufficient to get this problem under control—especially because a large proportion of water use affects private companies. That's why we also need the capital market to participate in this refocusing process. I think the problem is not the lack of financing options but the shortage of smart implementations of transformational programs.

"Making water more expensive across the board without enacting reasonable regulations would be dangerous"

At the UN Water Conference this spring, you celebrated it as a success when the participants voluntarily committed themselves to 689 measures for combating the water crisis. In view of the dimensions of the problem, is this voluntary commitment really moving us forward?
Voluntary commitments are an important step that generates involvement. They are a good mechanism for clearly showing people where opportunities exist to make things better.

As a scientist, you know that we have to find and implement solutions quickly. But as a member of a political organization, you need to participate in tough decision-making processes. Do you sometimes feel despair?
Of course I would like to see things moving faster. However, in my experience the past two years have been extremely positive, because I'm finally seeing people's willingness to deal with the issue of water—and to reach agreements. This willingness did not exist 15 years ago. At the same time, this topic is often treated as being off limits in terms of security policy. Today the private sector is realizing that water is a resource, recognizing its value, and developing sustainable solutions. That's why I'm confident that we can make progress relatively quickly.

This may sound cynical, but do events that hit the headlines all over the world—such as low water levels in the Rhine, forest fires in the Rocky Mountains, and floods in Asia—help to keep up the pressure on public opinion?
People accomplish relatively little on the basis of pure reason. And the existing system is extremely beneficial for many people in the world. As long as this mentality is firmly embedded in our society, change won't happen without moments of shock such as these. Unfortunately, this is what things look like: We set our alarm clock every morning so that we can get to work on time. And in the same way, we need a small catastrophe once in a while in order to understand that sustainable development doesn't automatically happen on its own.

Prof. Johannes Cullmann, 50, has been a scientific advisor to the President of the UN General Assembly since 2022. In this capacity he coordinates issues related to sustainable development. He previously headed the water and climate-related activities of the World Meteorological Organization (WMO) in Geneva for eight years. In his function as a head of division at the Federal Institute of Hydrology, he represented Germany on the International Commission for the Hydrology of the Rhine. He was one of the organizers of the first analysis of the impact of climate change on the Rhine. In his capacity as a hydrologist, from 2012 to 2014 he was a Senior Advisor for the water-related activities of the WMO and the President of the UNESCO's Intergovernmental Water Council.

CLOUD WARRIORS

Welcome to Aotearoa! In the language of New Zealand's original inhabitants, the Māori, this name means "the land of the long white cloud"—a reference to a special cloud formation that is said to have guided Polynesian seafarers here a long time ago. This island group in the Pacific Ocean features a breathtaking natural environment that has a spiritual meaning for the Maōri and also shapes the country's economy.

TEXT **PAULINE BRENKE**

Milford Sound unfurls its spectacular beauty especially after a rain. That's when hundreds of small waterfalls surge down from the mountains, really bringing this fjord panorama to life. Milford Sound is part of Fiordland National Park, which covers more than 12,600 square kilometers in the southwest corner of South Island. It's also part of the Te Wahipounamu World Heritage Area. New Zealand offers many spectacular landscapes like this one, with broad beaches, volcanoes, and impressive forests that are not only beautiful to look at but also provide resources for the country's significant lumber industry.

They stamp their feet, stick out their tongues, pound their bodies rhythmically, and sing loud—that's how the members of the All Blacks, New Zealand's rugby team, welcome their competitors on the playing field. Before every match, the team dances the "Ka Mate" haka, which was composed in 1820, in order to demonstrate their unity and strength and challenge their rivals. "Haka" is the Māori word for the dances through which they express their passion, strength, and identity. Evonik is also a presence on the rugby field. The players' shoes contain VESTAMID E®, a polyamide-12 elastomer from Evonik. It provides elasticity, so that the shoe soles effectively absorb impacts and protect the players' ankles.


AIG
adidas

Te Puke, the self-proclaimed "Kiwi Capital of the World," lies along the Bay of Plenty on the eastern coast of North Island. Its warm, humid climate and fruitful soil provide ideal conditions for fruit growing, the region's most important industry. The kiwi fruit with its furry coat originated in China, and that's why it's also known as the Chinese gooseberry. The vegetation phase of the kiwi can take as long as 240 days. To shield the plants from pests and damage during this long period of time, fruit growers depend on plant protection products. Evonik provides them with BREAK-THRU® additives, which make the product effective even in small quantities.

The area around Morrinsville, not far from Auckland, is one of the most important regions of New Zealand's dairy industry. The art project "Herd of Cows" brings together the town's commercial sector with its growing creative scene. Each of the 60 life-sized cow sculptures is sponsored by a local business and represents part of the history of Morrinsville. Cow Number 10, named Betty (see photo), was created by the Maōri sculptor Zena Elliott. Evonik also has a special relationship with this small town: Morrinsville is the location of the company's only facility in New Zealand. There's also an Evonik cow: Number 9, Kiwiana.

New Zealand is renowned for its enormous sheep population. The island nation is home to about 26 million sheep—but only five million people. That amounts to five sheep per inhabitant. The Waikato region, located south of Auckland, is one of the many areas where sheep like to roam. In addition to its subterranean caves and black-sand beaches, it's mainly famous because of its lush, extensive pasture land, which is known from the films "The Lord of the Rings" and the Hobbit trilogy. Sheep's wool is one of the country's most important export goods. Before it can be processed further in the textile industry, the wool is usually bleached with hydrogen peroxide, one of the items in Evonik's product portfolio.

THE H_2O_2 PIONEER

Since 1998, Evonik Peroxide has operated New Zealand's only hydrogen peroxide plant, which is located three kilometers from the town center of Morrinsville in the Waikato region of North Island. Hydrogen peroxide (H_2O_2) is an environmentally friendly oxidation and bleaching agent that is primarily used in the manufacture of cellulose and paper, the textile industry, ore extraction, and food production. The plant also produces peracetic acid, a high-quality derived product that is used as an industrial disinfection agent.

Evonik locations
1 Morrinsville

At

1

location Evonik has

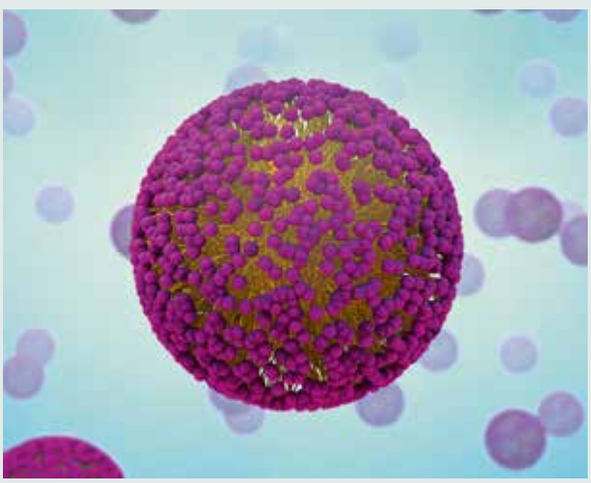
25

employees

Chemistry in Water to the Rescue

If synthetic organic chemistry is to survive, the transition from its dependence on petroleum products and organic solvents, in particular to nature's reaction medium, water, must happen quickly

by Prof. Dr. Bruce Lipshutz



The combination of hydrophilic heads (purple) and lipophilic tails (yellow) ensures that micelles dissolve in water

Do you know anyone ...anyone who would claim that we have an infinite supply of oil on planet Earth? Probably not. So how is it that the development of modern organic chemistry has been essentially tied to the availability of petroleum and the downstream products? For over 200 years, society's dependence on these products has been growing. From the pharmaceuticals that keep us alive to the herbicides and pesticides that enable food production that feeds a growing population, they are produced primarily in petroleum-based organic solvents, which must be disposed of properly when they are spent. What exactly does this mean? To the extent that a very healthy percentage of this organic, and therefore carbon, waste is burned, the result is CO_2. Yes, CO_2, and a lot of it! So, is chemistry a big contributor to climate change? Shhhh... yes!

It's not that hard to change this. In fact, if "change" is based solely on science, then we are already there, in harmony with biology, which is water-based. And the payoff is substantial, replete with bonuses reflecting much more than minimizing pollution and ensuring that planetary resources are available to future generations. Put another way, going green is a win-win on all levels.

SEARCHING FOR THE APPROPRIATE REACTION VESSEL

The secret to doing organic chemistry in water is no secret at all; rather, it has been hidden in plain sight, perhaps for billions of years. Nature itself provides the answer: Life could not exist without the synthesis of complex, water-insoluble biomolecules such as polypeptides or vitamins under aqueous conditions. The power of "chemistry in water" is actually something we experience at first hand every day. On a large scale, "chemistry in water" can also be observed when oil companies clean up marine spills. It's obvious: The know-how is already there, at least conceptually. So why has organic synthesis been so slow to adapt?

The challenge lies in finding the appropriate "reaction vessels" for water-insoluble biomolecules. Throughout evolution, nature's reaction "flasks" for water-insoluble biomolecules have been, and still are, a variety of membranes, vesicles, and micellar arrays, in water. Could it be that simple?

Yes and no. The good news is that, in principle, organic synthesis should be possible in these reactors; the reactants would be accommodated, as well as the catalysts that speed up these reactions. Making all sorts of products would then be feasible because, unlike enzymes, these particular biomolecules are "brain-dead"; they have no biases and no recognition of what's coming in to react and what products are being formed.

"Micellar catalysis is becoming rich with a growing toolbox of technologies that enable just about any reaction to be run in water"

As one of the pioneers of green chemistry, Prof. Bruce Lipshutz (71) was awarded the Presidential Green Chemistry Challenge Award by the US Environmental Protection Agency (EPA) in the Academics category in 2011. Lipshutz began teaching at the University of California, Santa Barbara, in 1979 and has been on the faculty ever since. The focus of his research group is organic synthesis using catalysts. He is particularly interested in micellar catalysis, which makes it possible to carry out organic reactions in water instead of in organic solvents. For this purpose he develops customized surfactants. Evonik's Health Care Business Line offers the Chemistry in Water technology developed by Prof. Lipshutz for the production of pharmaceutical intermediates and active ingredients on an industrial scale.

The bad news is that a nanoreactor must be identified that is suitable for organic synthesis; it must be capable of accommodating many different types of chemistry, such as that routinely used by the fine chemical industry (especially pharmaceutical and agrochemical companies). This has been the "valley of death" that has remained unfilled for centuries: It is the difference between recognizing the need and creating the technologies that make organic synthesis "in water" possible. Let's understand that it's the nanoreactors that are "in water"; the actual chemistry involving water-insoluble reactants and catalysts takes place within the inner cores, which serve as the "solvent" for various reactions.

Nature, with its membranes, vesicles and micelles, has likely relied on these concepts over the millennia for its chemistry in water involving insoluble educts. Molecules of interest within the fine chemicals industry tend to be rather complex, so the tools needed to make them in water need to be equally sophisticated. Therefore, new surfactants to be used in an aqueous medium, present in very limited amounts, must not only be "benign by design" but must also allow many reactions to be run efficiently. Did someone just ask, "What about palladium chemistry?"

To apply such guidelines to modern synthesis, and especially to transition metal-catalyzed reactions, these processes must subscribe to many of the twelve Principles of Green Chemistry. Does the literature on micellar catalysis provide any hints, background, or precedent to help organic chemistry make the switch to water? Unfortunately, no, no, and no.

That's not to say that there isn't considerable prior knowledge about micellar catalysis; there is. But its use by the fine chemicals industry has been, at best, hit or miss. Over the past 15 years, however, a lot of trial and error has led to a much better understanding of surfactant design, leading to micellar catalysis which today is becoming rich with a growing toolbox of technologies that enable just about any reaction to be run in water.

The leading "designer" surfactant to date is TPGS-750-M, which contains the MPEG-750-containing hydrophilic group. It is divided into three parts. The hydrophilic section facing outward in water contains the building block methoxy polyethylene glycol 750 (MPEG 750). The inner, or lipophilic, portion consists of the commodity chemical vitamin E. The two building blocks are connected by a succinic acid linker. Each portion of this designer surfactant is innocuous and, due to the vitamin E present, even by itself, healthy!

ENVIRONMENTAL AND ECONOMIC BENEFITS

This micelle-forming amphiphile, TPGS-750-M, can be used to affect many different reaction types, especially those of particular interest to pharmaceutical and agrochemical companies. Key reactions, including those catalyzed by palladium, amide/peptide bond formations, and Nucleophilic Aromatic Substitution reaction (SNAr) processes that have traditionally been run in organic solvents can be accommodated.

In addition to the environmental and associated economic benefits to be realized, the higher concentrations of substrates and catalyst localized within the inner micellar cores not only lead to faster reactions but also provide opportunities to use precious metal catalysis at ppm loadings.

Since most targets are water-insoluble solids, they precipitate from the aqueous medium and need only be filtered for isolation purposes. How's that for a "work-up"? And what about the filtrate, the aqueous medium that often contains the catalyst? It's recycled. Boom!

Do we really have a choice? If we already have the know-how to stretch our limited planetary resources, what's the downside to doing more with less? Perhaps the bigger question is: Do we have the resolve in the chemical industry to make these changes? Let's hope so. Sustainability is not just a buzzword; it has tremendous implications. Indeed, it is our future.

BACTERIA UNDER ATTACK

The City of Memphis wanted to improve the quality of its wastewater discharge to the Mississippi River. Evonik is helping with an innovative approach to disinfection

TEXT **NORBERT KULS**

Some of the famous sons of Memphis, Tennessee are known by just two letters. A bronze statue on Beale Street honors blues legend W.C. Handy, and the late guitarist B.B. King opened the first of his eponymous clubs on that very street more than three decades ago. Lesser known among the tourists that flock to the birthplace of rock'n'roll—500,000 people yearly make a pilgrimage to Elvis Presley's home Graceland—is M.C. Stiles. Still, in the 1970s and 1980s, Maynard C. Stiles was considered one of the most powerful officials in Memphis' city government besides the mayor. Stiles served first as the sanitation director and later as the head of the Memphis Public Works department.

Stiles also has a monument of sorts in Memphis, and it is one befitting a legend of sanitation. One of the city's two wastewater plants is named after him. The M.C. Stiles Wastewater Treatment Facility sits only a short drive north of downtown Memphis on the banks of the Wolf River, one of the many tributaries of the mighty Mississippi. →

Memphis, located on Mississippi River in southwest Tennessee, became the birthplace of rock'n'roll in the 1950s. The city's wastewater treatment didn't begin until the late 1970s

Robert Knecht, Memphis' Director of Public Works, is trying to shape the city's environmental history with wastewater disinfection at the M.C. Stiles facility

Memphis wastewater is disinfected with peracetic acid from Evonik in the disinfection channels of the M.C. Stiles facility before flowing into the Mississippi River

While not as flashy and entertaining as Graceland or the music clubs of Beale Street, the site's raw sewage pumps and circular water clarifiers play a significant part in the city's history. Completed in 1977, the M.C. Stiles plant was only the second attempt to clean the wastewater of Memphis' businesses and citizens. It followed the completion of T.E. Maxson—named after an influential city engineer—two years earlier. Before that, millions of gallons of Memphis wastewater were simply dumped into the city's rivers, creeks, and ditches.

Robert M. Knecht is Stiles' heir as the current director of Memphis' Public Works Division. The former Air Force computer specialist, twenty years with the city and almost ten years in his current role, also wants to shape the city's environmental history—with the help of Evonik. "I am trying to improve water quality, since we have such a big influence on that. I like to fish, and as someone who uses the river, I want to make sure I have done what I can for the ecosystem," Knecht says during a visit to the M.C. Stiles facility, where Evonik has operated a peracetic acid plant since 2019.

A LONG-TERM INVESTMENT

Evonik's Wolf River plant supplies peracetic acid to M.C. Stiles and T.E. Maxson, the two largest users of this bacteria killer for municipal wastewater disinfection in the world. It constitutes an innovative approach for municipalities that traditionally rely on other disinfection methods like chlorine or ultraviolet treatment. "It's a huge long-term investment," says Knecht as he stands on a walkway above the disinfectant channels of the Stiles facility, a stone's throw from the slow-moving Mississippi River. "With costs of $24 million a year, it is the largest investment in Operations & Maintenance we have made in a long time."

An Evonik employee is taking a wastewater sample at Memphis' T.E. Maxson wastewater treatment facility

Peracetic acid, or PAA, is a powerful organic acid with a strong oxidation potential—perfect for killing bacteria like *E. coli* in human or animal waste. PAA is produced through the reaction between hydrogen peroxide (Evonik is one of the world's largest producers of that cleaning agent), acetic acid (vinegar), water, and a catalyst. "As it breaks down, its oxidative properties are attacking the bacteria," explains Greg Conrad, Director of Water Treatment Solutions at Evonik's Active Oxygens business, during a tour of the company's Memphis site.

PAA is already widely used as a disinfectant in the poultry industry and in beverage processing. About 30 percent of the production from the Wolf River Plant is sold to poultry producers in the neighboring states of Arkansas and North and South Carolina. However, PAA's use in wastewater disinfection is still relatively new despite its apparent advantages. "The great thing about peracetic acid is that it breaks down into environmentally benign products: vinegar, oxygen, and water," explains Conrad.

A worker prepares to offload hydrogen peroxide for the production of the disinfectant peracitic acid at Evonik's Wolf River plant

Greg Conrad, Evonik's Director of Water Treatment Solutions at Active Oxygens, has dedicated his entire career to water

Tennessee didn't require the disinfection of its sewage until the 2010s. When the state started considering more stringent regulations, Memphis tested other established disinfection methods like chlorine and ultraviolet treatment. But chlorine leaves a residual in the water—which contains carcinogenic by-products and requires costly dichlorination. Ultraviolet treatment involves a lot of capital investment and has high maintenance costs. In addition, UV treatment is not a good alternative for cities like Memphis, which have a vast share of industrial waste with organic components that turn the water brown, making it impenetrable to UV rays. This high proportion of industrial waste—about 60 to 80 percent of Memphis wastewater comes from industries like pulp or paper producers—differentiates the city from many other municipalities. Also, manufacturing plants in Memphis don't have to treat their own wastewater before it enters the municipal system. In other words, wastewater treatment is a herculean task for Memphis.

After several tests and a pilot program, Memphis opted for PAA and an 18-year contract—including the option for two five-year extensions—with the PAA producer PeroxyChem starting in 2018. Two years later, Evonik acquired PeroxyChem for $640 million.

The contractual agreements with the city were as unique as the disinfection method. The company leased the land from the city and built its peracetic acid production plant on the site of the Stiles facility. A plant close to the site cuts down on transportation costs. "It is unique for suppliers to have the ability to work with a municipality to bring value to them beyond just the chemistry, to provide additional services and create jobs," says Conrad.

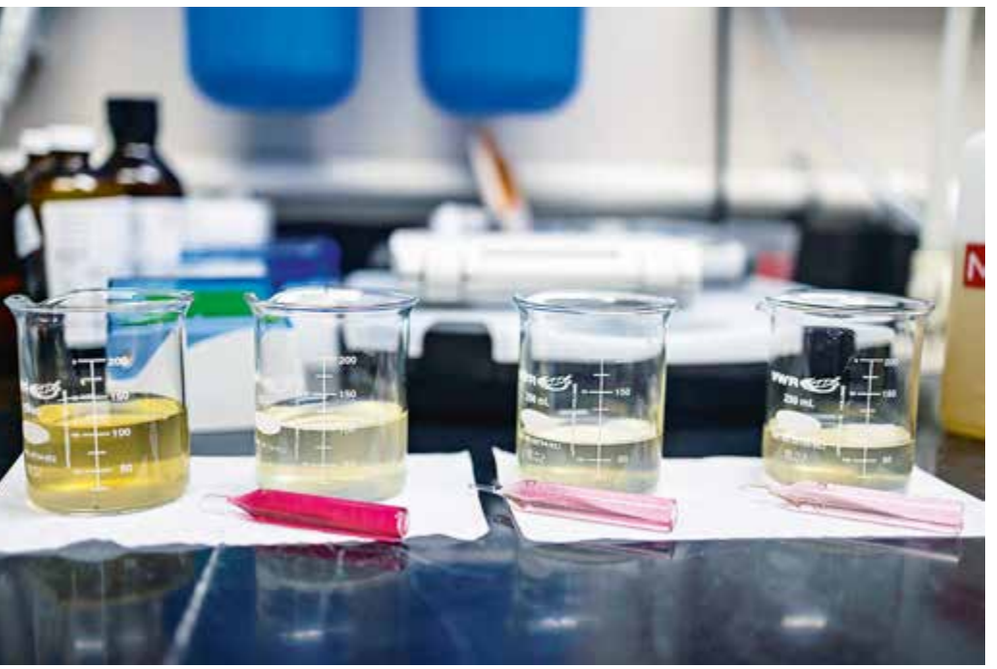
A peracetic acid (PAA) monitor is used to determine the amount of PAA residual remaining in the wastewater

"A LOT OF SKIN IN THE GAME"

In the plant's parking lot, double-walled stainless steel Isotainer trucks sit lined up. The tanks are refrigerated to control temperature and prevent any potential for decomposition when the PAA is transported to Evonik customers in the region. "We are the only company with the authority to haul PAA in bulk," says Conrad.

For the transport to the Stiles plant, Evonik opted for a more direct solution than truck delivery. An underground pipeline, double-walled, resistant to chemical corrosion, and a quarter-mile long, carries the PAA from the gleaming Wolf River tanks along a fence to the Stiles' disinfectant channels.

Robert Knecht is also happy with these arrangements. "I was very optimistic that we were going to get more than just a supplier—a long-term partner," he says. "I wanted a company to actually come to Memphis, bring new jobs to our city, and build a facility close by, because we were going to be one of the country's largest users of peracetic acid," he says. →



Samples of Memphis wastewater in Evonik's Wolf River plant before (left) and after being disinfected with different concentrations of peracetic acid. As the PAA is consumed by the organic matter and bacteria in the disinfection channels, the wastewater color gets lighter. The pink vials show the residual concentration dropping as the PAA reacts with the contaminants

"I use the Mississippi River to fish, and I try to improve its water quality"

ROBERT M. KNECHT, DIRECTOR OF PUBLIC WORKS, CITY OF MEMPHIS

As part of its service, Evonik also ensures that the bacteria level doesn't exceed the permitted level. "If the bacteria level rises above a certain amount, we would be responsible for the fines from the Environmental Protection Agency," says Conrad. "We have a lot of skin in the game."

Evonik engineers also developed a unique approach to determine the correct dosage of PAA for the Stiles plant. Most suppliers determine the amount of PAA needed to reduce the bacteria to the desired level on the basis of the incoming wastewater's flow rate and a predetermined dosage. At the end of the process, plant operators test the water for disinfectant traces to ensure that the bacteria are significantly reduced or gone. Evonik workers also check up on these residuals—but the check-up doesn't determine potential adjustments to the PAA levels.

Evonik adjusts the dosage parameters at the beginning of the process on the basis of the changes in water quality. "We wanted to reduce the amount of PAA we use," says Conrad. "You don't always need the same amount if the water quality is better." Critical to analyzing and measuring the water's quality is its color. "The wastewater color constantly changes," he explains. "One day, it could look like a cup of tea; the next, it could look like espresso. It all depends on what is coming into the water." Conrad and his team found that the water's color indicates its pollution level. The results of this color analysis are then fed into an algorithm that determines the level of needed PAA.

Pipettes used for lab analysis of raw materials and final product tests

TAILOR-MADE DISINFECTION

Things run a little differently at Memphis' second wastewater facility, T.E. Maxson, which serves the southern part of the city. There is no pipeline connecting it to the Wolf River plant. Instead, Evonik uses its Isotainer trucks to deliver the disinfectant and fill the peracetic acid tanks next to the contact channels.

Because the wastewater quality in the southern half of Memphis is different, Evonik doesn't use color analysis but instead analyzes the Chemical Oxygen Demand (COD) of the wastewater at Maxson—a yardstick of the oxygen required to break down organic compounds in water. The COD test is typically used to determine the effectiveness of wastewater treatment processes and to monitor the levels of organic pollutants in water. "COD is the organic loading of the water—how dirty the water is," says Conrad. "When the organics are high, we use more PAA."

Evonik engineer Jon Watson is preparing disinfected wastewater samples in the Wolf River plant's lab

Wastewater treatment is a particular challenge for Memphis, Tennessee, because most of the wastewater comes from industry

Conrad, who lives in Oklahoma and started his first business when he was 20 years old, also pioneered PAA for treating wastewater used in oil extraction with hydraulic fracturing—fracking. "It has been my passion to find green and sustainable solutions," he says. "I have dedicated my entire career to water."

The disinfection of the wastewater with PAA at the Stiles facility is the last step before the water is released into the Mississippi. Still, it doesn't look like drinking water as it flows over a concrete wall towards the river. It's more like the color of tea, albeit considerably lighter than before. But the water is disinfected and gets diluted enough when it enters the massive stream. The health risks are negligible.

Due to its relative novelty, Evonik is still working on the broader acceptance of PAA in wastewater treatment in several states. "People are not used to it," says Conrad. "We are still in the infancy of the use of PAA, but it is catching on very quickly." In Tennessee and Arkansas, it is gaining acceptance, and slowly also in Texas, Ohio, and Kentucky. "But it might not always be the best fit for a city. In smaller applications and where there is fairly clean water without much industry, UV might be a better option," he cautions.

Evonik will also approach the industrial plants to help them clean their own wastewater before it enters the city system in Memphis. That would lower the companies' bills from the city and make it easier for Evonik to treat the wastewater at Stiles and Maxson. "We want to make the water cleaner by treating it first at industry facilities upstream," says Conrad. He glances at the M.C. Stiles pools with the bubbling sewage and gets into his SUV to drive back to Oklahoma. "We make a living killing bacteria," he says.

Norbert Kuls is Evonik's Communications Manager in North America and a former US correspondent for German newspapers

OCEAN TREASURE

TEXT **BJÖRN THEIS**

In densely populated South Korea, plots of land are scarce. Plans are now afoot to build a floating city for 12,000 inhabitants offshore from the port metropolis Busan

Water is the wellspring of innovation. But progress often results in additional consumption. "Soft innovations" demonstrate that this precious resource can also be used responsibly

Our history is a history of water. Many cultures have developed along the earth's major rivers. Thanks to waterways such as the Euphrates and the Tigris in Mesopotamia, the Nile in Egypt, and the Yellow River in China, these "hydraulic cultures" had a surplus of drinking water and food. The water economy gave rise to countless innovations. Agriculture and the construction of dikes, ships, and locks were optimized, and chemistry, hygiene, physics, and mathematics also reaped the benefits.

Thousands of years later, industrialization launched an era during which the innovative power of mankind grew by leaps and bounds. Simultaneously, water consumption increased. According to estimates, the volume of water that is used worldwide could increase tenfold between 1900 and 2025. It seems clear that innovation uses (up) water.

THE SOFT PATH

This could change in the future. For a long time, the human race depended on "hard" water-related innovations such as canal systems, reservoirs, and seawater desalination plants to satisfy its increasing need for water. However, today more and more universities and startups are choosing a "soft" innovation path and placing their bets on developments aimed at using water responsibly. An innovative rediscovery of water is in full swing.

One example of such a transformation comes from California. This is where the project development firm Solar Aquagrid is now working to optimize the most important components of the "hard" water infrastructure. Together with the state government, the project developers are planning to cover California's 6,000-kilometer-long open canal system with a roof consisting of solar modules. This would reduce evaporation and make about 13 gigawatts of solar power available year after year. That would be enough to supply 9.8 million of California's 13 million households with power. Under the name Project Nexus, the construction of an initial test stretch has already begun.

By contrast, the Oceanix firm would like to open up new habitats for human beings. Together with the United Nations, Massachusetts Institute of Technology, and the Bjarke Ingels Group architecture firm, Oceanix is working on a project for building floating cities. The construction of the first prototype will begin this year under the name Oceanix Busan. This first floating city is being built off the coast of Korea. Plans call for it to offer a climate-positive home for about 12,000 people on an area of six hectares.

DRINKING WATER FROM VAPOR

Meanwhile, researchers at the University of Illinois Urbana-Champaign are aiming to use the natural water cycle and transform the water vapor from the surface of the oceans into drinking water. In contrast to existing desalination plants, this system would need hardly any energy to vaporize the water. As a result, it's considerably more cost-effective. In a study, the team investigated a total of 14 cities including Abu Dhabi, Barcelona, and Los Angeles and came to the conclusion that between 38 and 78 billion liters of drinking water could be extracted annually per plant, depending on local conditions [BL1].

In December 2022, Ruhr University Bochum presented a brand-new use for water. Researchers at the university had developed a water-based computer switch that is an entire order of magnitude faster than semiconductors. The scientists succeeded in doing this by dissolving sodium iodide in water, then spraying the solution as a flat jet a few micrometers thick, and bombarding it with a laser. They were able to demonstrate that the very short laser pulse releases electrons from the iodide ions, making the water electrically conductive so that it can thus act as a switch.

These examples show that even in the 21st century, water still offers a veritable ocean of innovation opportunities. That's a good reason for the Creavis Foresight team to pay particular attention to the topic of water-related innovations as part of the new Foresight focus theme GameChanger 2040.

Björn Theis heads the Foresight department at Evonik's innovation unit Creavis

“I’m reaching for the stars”

LOG **GESA-MARIE ZIENERT**

Dr. Andrea “Annie” Kritcher is a nuclear engineer and physicist on the National Ignition Faculty at Lawrence Livermore National Laboratory in California. For the December 2022 experiment, she designed the capsule that contained the deuterium and tritium fuel

I’ve always wanted to do something that benefits humanity, and Lawrence Livermore National Laboratory is where I found the opportunity. Nuclear fusion is considered the holy grail of the quest to generate potentially unlimited amounts of clean energy. My team and I have recently come one decisive step closer to this vision.

Nuclear fusion reactions cause stars like the sun to radiate energy. So in our experiments, it’s a bit like igniting a miniature sun in the lab. Late last year, we fired 192 lasers at a peppercorn-sized capsule filled with a fuel composed of the hydrogen isotopes deuterium and tritium. The material was heated to 140 million degrees Celsius—ten times hotter than the interior of the sun. The heat causes the fuel capsule to collapse further and further in on itself. The resulting pressure is so enormous that the hydrogen nuclei fuse together to form helium. This all happens in fractions of a second and releases huge amounts of energy.

What’s special about our experiment is that, for the first time, the fusion of atomic nuclei has succeeded in releasing more energy than was needed to trigger the reaction. This means that fusion power plants have the potential to reduce our dependence on fossil fuels. In addition, they do not release greenhouse gases. There are also no supply bottlenecks: Deuterium is found in large quantities in seawater, and tritium can be produced in the fusion reactor.

When I was a child, I never thought I would literally reach for the stars. The fact that I can do this today is mainly thanks to my parents, who have always supported me in pursuing my goals. The task now is to further increase the efficiency of nuclear fusion in order to come another step closer to creating a sustainable nuclear fusion reactor.

Masthead

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“We forget that the water cycle…

…and the life cycle are one,” as Jacques-Yves Cousteau (1910–1997) once said. The famous French marine explorer not only produced fascinating underwater documentaries but also dedicated himself to protection of the oceans.

Cousteau understood that oceans and glaciers, seas and groundwater reservoirs form a fragile system that is closely connected with our life. Droughts and floods, for example, are clear symptoms of the climate crisis, which has been caused by human activities. However, intelligent water management and technical solutions offer us an opportunity to protect this valuable resource and bring about a positive transformation.