

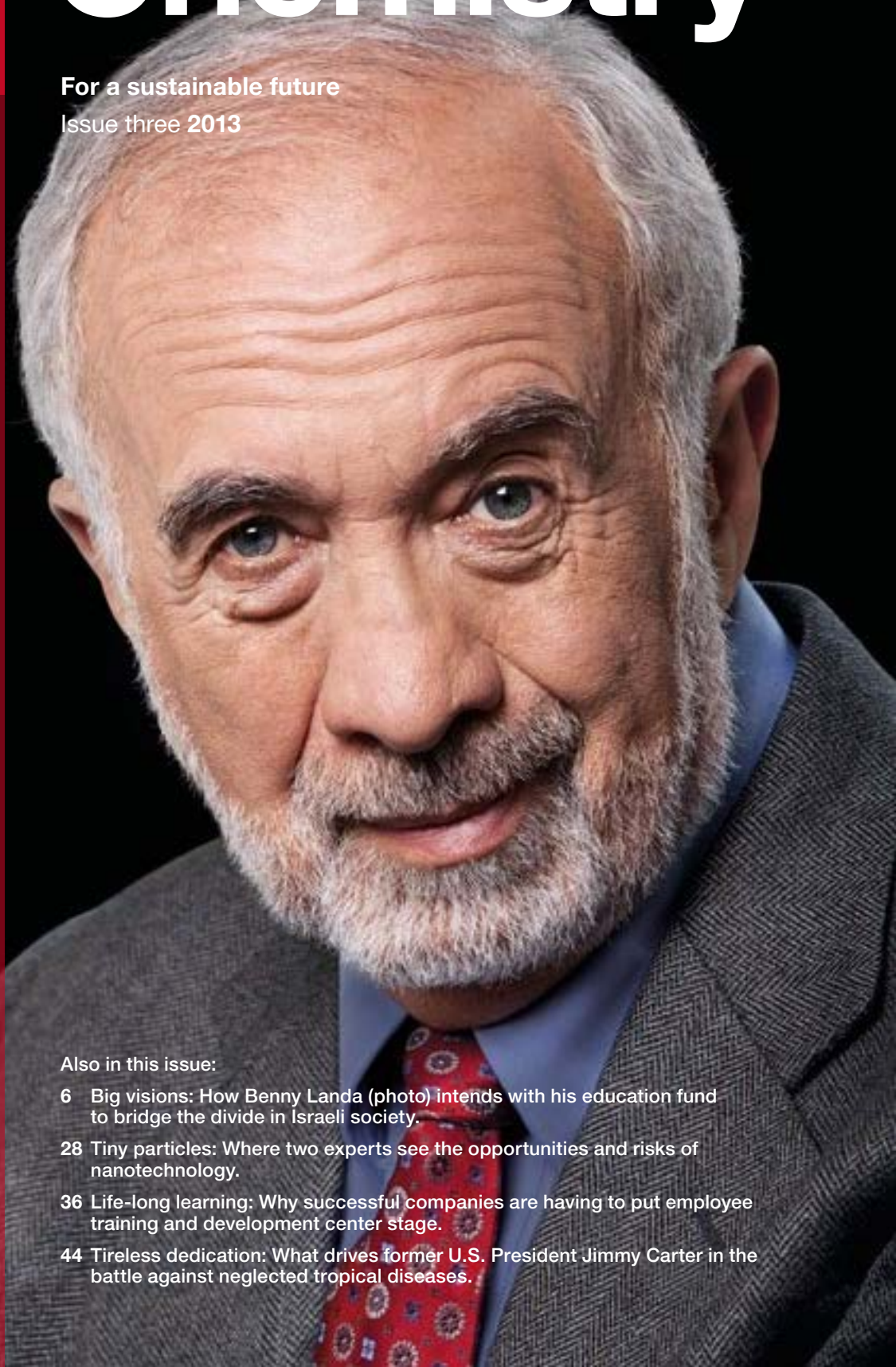


The Chemical Company

Creating Chemistry

For a sustainable future

Issue three 2013



The thirst of cities

More and more cities are running dry. How can we meet the challenges of urban water management?

Cover story from page 8

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Welcome



The water issue

It is colorless, odorless and has no taste. Everyone knows H₂O. Dihydrogen monoxide, on the other hand, sounds more mysterious, maybe even threatening – but water, whatever you may call it, is a fascinating chemical compound. Humans, animals and plants all need water to survive. Water cools, cleans and dissolves. As steam, it produces electricity in power plants.

More than 70% of the Earth is covered in water. Nevertheless, there are some areas where water supplies are not sufficient to meet demand. Almost one billion people do not have access to clean drinking water. Water is not only scarce in developing countries. Cities such as London, Barcelona, Mexico City, Houston, Sydney and Singapore also do not have enough (page 8). And sometimes there is enough water, but it is of poor quality: It is unsuitable for drinking and can even make people ill.

Every day, 3,000 children die as a result of contaminated water and lack of hygiene. The charitable foundation BASF Stiftung and UN-HABITAT, the United Nations Human Settlements Programme, are working together to support the right to water. For instance, children in Mangalore, India, are learning how to use water responsibly and test water quality (page 20).

The work of former U.S. President Jimmy Carter is also a success. Since 1986, his organization, The Carter Center, has been fighting to eradicate Guinea worm, which can infect people who drink from stagnant water sources. The worm, which can cause serious illness, has nearly disappeared – also thanks to the larvicide Abate® (page 44). This is one of the many BASF products that improve people's quality of life, demonstrating how "We create chemistry for a sustainable future."

By the way, our magazine *Creating Chemistry* is now also available online – for desktop computers, tablets and smartphones. This makes reading our magazine convenient, whether you are at home or on the move.

I hope you enjoy diving into this issue.

Sincerely,

A handwritten signature in black ink, appearing to read "Kurt Bock".

Dr. Kurt Bock
Chairman of the Board of Executive Directors
BASF SE

The world in figures

-50%

Organic light-emitting diodes (OLEDs) based on nanotechnology have the potential to reduce energy consumption by as much as 50% compared to today's energy-saving light bulbs.¹

See **Nanotechnology – a science under discussion** on page 28.



Quality of life

1 millionth of a millimeter

A nanometer is just one-millionth of a millimeter. The size of a nanoparticle compared to a soccer ball is like the size of a soccer ball compared to the Earth.



-99%

Thanks to a development aid project spearheaded by former U.S. President Jimmy Carter, the potentially deadly Guinea worm disease could soon be eradicated. The number of cases of the disease, previously 3.5 million per year, has fallen by more than 99% since 1986.²

See **Shining a light on hidden diseases** on page 44.

Food and nutrition

\$267 million*

In Colombia alone, the cost of treating the neglected tropical disease Chagas is \$267 million per year. Using targeted insecticides to control the insects that spread the disease would cost \$5 million.³



* In this issue, the \$ symbol always refers to U.S. dollars. The conversion of euros to U.S. dollars is based on the average exchange rate on December 31, 2012, when €1 cost \$1.32.

30 billion metric tons

More than 30 billion metric tons of CO₂ are produced by humans worldwide each year.⁴

See **CO₂ – from exhaust gas to raw material** on page 50.



Resources, environment and climate

0.4%

110 million metric tons of CO₂, or 0.4% of global CO₂ emissions, are used by industry each year as chemical feedstock.⁵

CO₂

July 28, 2010

This was the day the United Nations explicitly recognized the human right to clean drinking water and sanitation.⁶

See **The thirst of cities** on page 8.



Resources, environment and climate

2060

By 2060, Singapore wants to meet up to 55% of its water demand with wastewater purified to bring it up to drinking water quality.⁷



Food and nutrition



250 kilometers

Producing one kilogram of beef releases 36 kilograms of CO₂ and has nearly the same impact on the environment as driving a car for 250 kilometers.⁸

Quality of life

70:20:10

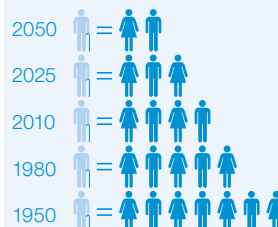
According to the 70:20:10 model, 70% of all learning results from on-the-job experience, 20% is due to interactions with others and only 10% results from formal training or education.⁹



8.3 million

In Europe, the number of workers retiring currently exceeds the number joining the workforce by 200,000. This labor gap is expected to grow to 8.3 million people by 2030.¹⁰

Ratio of pensioners to the labor force in OECD* countries¹¹



* The OECD (Organisation for Economic Co-operation and Development) includes 34 member countries from around the world which are committed to democracy and market economies.

Resources, environment and climate

14%

By 2025, 14% of the world's population – that is 1.1 billion people – will get their drinking water from the seas. Currently, around 72 million people do so, or 1% of the global population.¹²



768 million

768 million people do not have access to clean drinking water. In addition, nearly 2.5 billion people lack adequate sanitation facilities.¹³

1. VCI (German Chemical Industry Association), *The Chemical Industry's Contribution to Climate Protection and the Energy Turnaround* ("Beiträge der chemischen Industrie zum Klimaschutz und zur Energiewende"), May 15, 2013; 2. The Carter Center; 3. World Health Organization (WHO); 4. German Federal Ministry of Education and Research, *Technologies for Sustainability and Climate Protection – Chemical Processes and Use of CO₂*, May 2013; 5. German Chemical Society (GDCh), *News from Chemistry* ("Nachrichten aus der Chemie"), Issue 58, December 2010; 6. United Nations; 7. Singapore's national water agency PUB; 8. Spiegel Online, *Climate Footprint: One Kilogram of Meat Causes 36 Kilograms of Carbon Dioxide* ("Klimabilanz: Ein Kilo Fleisch verursacht 36 Kilogramm Kohlendioxid"), July 19, 2007; 9. Michael M. Lombardo / Robert W. Eichinger, *The Career Architect Development Planner*, 2000; 10. Ernst & Young, *Tracking Global Trends*, 2011; 11. Organisation for Economic Co-operation and Development (OECD), *Pensions at a Glance 2011. Retirement-Income Systems in OECD and G20 Countries*, March 17, 2011; 12. Global Water Intelligence (GWI); 13. UNICEF

The bridge builder

Israel is a country riven with social and economic differences. But an education fund set up by the entrepreneur Benny Landa and his wife Patsy aims to bring about positive change. By offering underprivileged young people the chance to study, Landa hopes to foster greater understanding among the different communities that make up this vibrant land.

A visionary inventor who holds more than 700 patents, Benny Landa loves the tiny details that go into achieving big things.

A new printing process devised by his company, Landa Corporation, uses ink made of pigment particles only a few nanometers across – compared to around 100,000 for a human hair. This nanotechnology printing stands to be as revolutionary as digital offset color printing, something Landa's first company, Indigo, pioneered in the 1990s.

When he is not fine-tuning systems in Landa Corporation's high-tech compound near Tel Aviv, the restless entrepreneur pursues a very different big dream: the bridging of socio-economic gaps in Israeli society. "When you grow up poor like I did, it has a profound effect on you," says the Canadian-bred Landa. "You appreciate the contrast between having the freedom to do things, and having to make do."

Born to Holocaust survivors in Wrocław, Poland, after the end of the Second World War, Landa emigrated with his parents to Edmonton, Canada, in 1948. His father, a carpenter, bought a tobacco shop and added a little studio to make passport photos. It was equipped with a camera

that was remarkable for the time because it captured images directly on paper, rather than film – giving the young Benny a life-long appetite for innovation.

One country, two societies

After studying in Israel and England, Landa left Canada with his wife Patsy and moved to Israel permanently in 1974. For many years, Landa says he was so deeply immersed in running his business, Indigo, that he did not think about much else. "When I sold the business to Hewlett-Packard in 2002, I finally got my head above water and was actually quite shocked by what I saw – an Israeli society with great social injustices, great inequalities," he says.

The very same year, Landa and his wife founded the Landa Fund for Equal Opportunity Through Education, which channels a yearly donation through Israel's seven universities and a number of non-profit organizations. The fund aims to narrow socio-economic gaps by helping young people with "privileged minds and underprivileged means" get a higher education. In so doing, it also aims to promote civic equality between Israel's Jewish and Arab citizens.

Benny Landa and his wife have expended about \$50 million

through the fund thus far, and their commitment is ongoing. The fund also sponsors non-governmental organizations including Merchavin ("open spaces"), which promotes values of shared citizenship and runs the fund's Arabic teaching program, and Kav Mashveh ("equalizing line"), a professional placement program for Israeli Arab university graduates. To date, the fund's activities have enabled thousands of talented, underprivileged youth to get university degrees.

Internationally, Israel enjoys the reputation of an economic powerhouse with a well-trained workforce and vibrant start-up culture. But when Landa took a closer look, he discovered a tale of two societies. "Part of Israel is like Denmark – very advanced, well-educated, a high GDP per capita and a high standard of living. But we have a second economy which is more like El Salvador – poor, large families, less education and a much lower income."

Statistics confirm that most of the disadvantaged citizens are Israeli Arabs, who make up one-fifth of the country's population, and immigrants from countries as diverse as Russia and Ethiopia. "This situation is not sustainable. No country can leave large segments of its own society behind," Landa adds.

Under the Landa Fund programs,



Milestones of Benny Landa's career

1946

Benny Landa is born in Wrocław, Poland.

1971

He co-founds the company Imaging Technology (Imtec) located in the United Kingdom.

1977

Landa founds Indigo in Rehovot, Israel. The company develops and manufactures digital offset printing presses.

1994

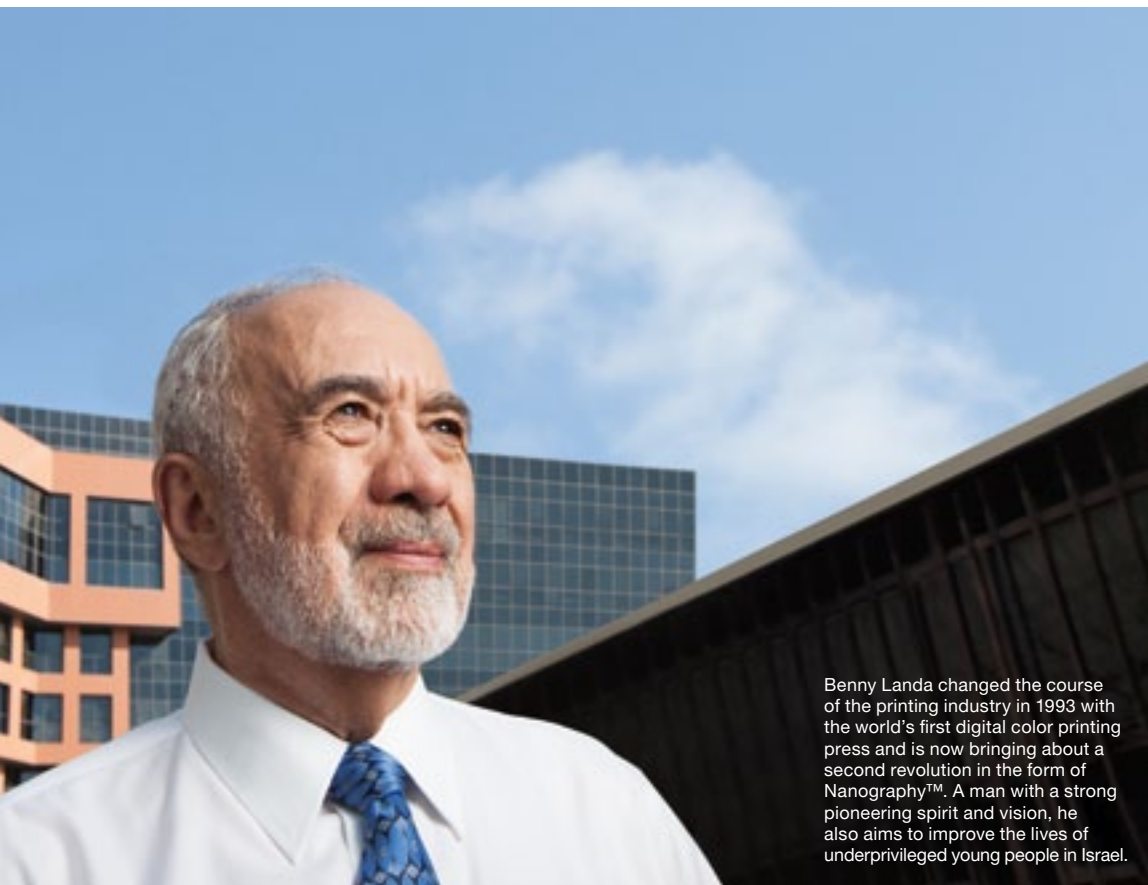
Indigo is listed on NASDAQ.

2002

Hewlett-Packard acquires Indigo. Landa Corporation and the Landa Fund for Equal Opportunity Through Education are founded.

2012

Landa unveils his nanographic printing systems at drupa trade fair.



Benny Landa changed the course of the printing industry in 1993 with the world's first digital color printing press and is now bringing about a second revolution in the form of Nanography™. A man with a strong pioneering spirit and vision, he also aims to improve the lives of underprivileged young people in Israel.

each participating university is required to track students, report how they do compared to others, and to monitor the drop-outs. The institutions that get the best results are rewarded with greater resources. "We run it like an investment, in every way," Landa says. Overall, the results have been "outstanding" with most students on the roster performing above the scholastic average.

Social investment

"We don't call it philanthropy. We call it social investment," says Landa. "The payback isn't in dollars or euros, it's in intangibles, but it's the best investment in town."

It has, for example, changed the life of Mahmud Mahamid, an Israeli Arab studying materials engineering at Ben-Gurion University, who at one time could not even afford the bus fare to school. Luana Gutman, a Russian Jewish immigrant enrolled in medical laboratory sciences, endured great personal privation before winning a Landa scholarship. "For these kids, it's like a gift of life," enthuses Landa. "They are so motivated to show that the faith we have in them is well-placed."

Sharing culture and values

Landa is ambitious in his aims and, although the fund has attracted much praise, he is still not satisfied with its achievements. He is therefore broadening its focus to include "existential and cultural gaps" between Israeli Arabs and Jews. Through Technion, the prestigious Israel Institute of Technology, the Landa Equal Opportunities Project provides health services as well as academic preparation to Israeli Arab high school students in the north. The fund also sponsors programs to teach Israeli children Arabic. Landa reasons that only if you speak the same language can you grasp the culture and values of others – something that will foster compassion and understanding between the country's Jews and Arabs.

"Many people think the biggest threat to Israel is exogenous. I don't think that at all," says Landa. "Societies fragment from a lack of equal opportunity, not from an outside threat." ■

“
We don't call it philanthropy.
We call it social investment. The payback isn't in dollars or euros, it's in intangibles, but it's the best investment in town.”

Benny Landa, entrepreneur and founder of the Landa Fund for Equal Opportunity Through Education



BASF Stiftung improves business perspectives for Africa's youth

Sun-kissed Kenya boasts some of East Africa's most gorgeous landscape. The economy, on the other hand, is failing to live up to its potential. A staggering 80% of all those unemployed are young people aged between 15 and 34, according to a recent UN Development Programme report.

Better education is part of the solution. A joint project, Student Training for Entrepreneurial Promotion (STEP), teaches aspiring entrepreneurs how to start and run their own business. The initiative is supported by the German Commission for UNESCO, the University of Lüneburg, Germany, and BASF Stiftung, a charitable foundation based in Ludwigshafen, Germany.

Last year, more than 200 students at Kenyatta University in the capital, Nairobi, took STEP courses in management, accounting, marketing and business law. Similar training was given to 200 students in Uganda.

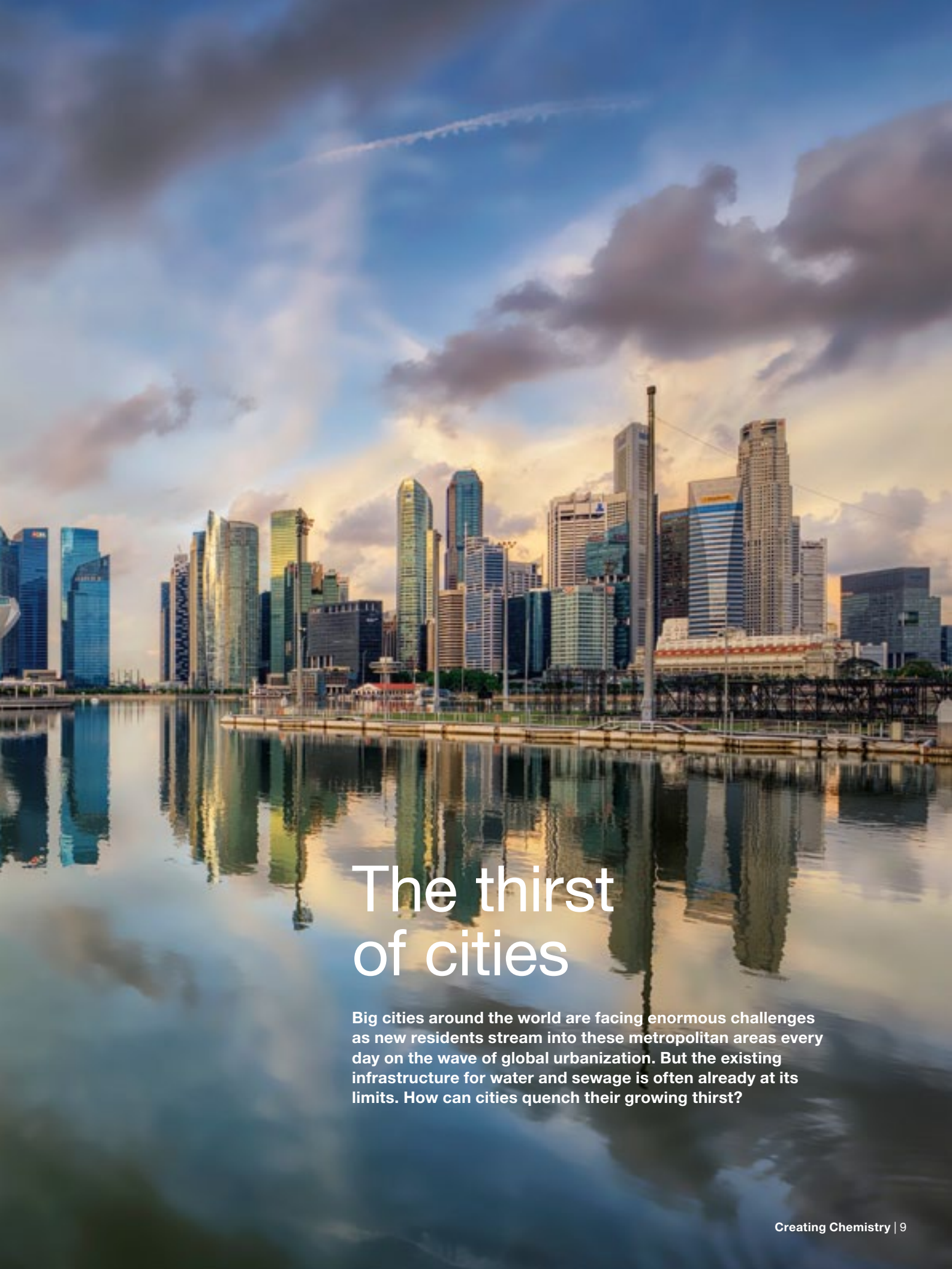
"It is impressive to see how much energy and creativity the students put into their business," says Peter van den Hoek, Managing Director of BASF East Africa in Nairobi. "This entrepreneurial spirit will ensure markets continue to develop in Africa." In future, universities in Kenya and Uganda will conduct the program themselves.



To find out more, visit:
www.unesco.org



Singapore's successful model: The modern island state is a leader in terms of water treatment and water management.



The thirst of cities

Big cities around the world are facing enormous challenges as new residents stream into these metropolitan areas every day on the wave of global urbanization. But the existing infrastructure for water and sewage is often already at its limits. How can cities quench their growing thirst?

Necessity is the mother of invention and, after years of drought, the Californian city of San Diego was certainly in need. Between 1900 and 1916, barely a drop of rain fell in the city and the municipal water reservoirs were almost empty. In desperation, the city council offered the 'rainmaker' Charles Hatfield \$10,000 if he could get the clouds to shed their tears with his rainmaking method. He started work in January 1916 – and soon thereafter the city experienced one of its worst floods of the 20th century. Facing death threats, Hatfield left the city and the council began looking for other sources of water. In late 1946, San Diego joined the Metropolitan Water District of Southern California and, in so doing, gained access to the Colorado River.

Since then, expensive water imports have been the main pillar of San Diego's water management, according to the authors of a recent U.S. study*. Four-fifths of the city's water comes from the Colorado River and the Bay-Delta; the water is transported into the city through aqueducts. The consequences of this strong dependency are already foreseeable.

Impediment to growth

Where will cities draw their water from in the future? How can cities ensure

that their residents will have sufficient water for drinking, cooking, washing and hygiene ten, 20 or 50 years from now? Water is also a safety issue because it is needed to put out fires. In addition, water is necessary for industrial uses, such as producing goods or operating machines and plants. Without functioning water and sewage systems, economic development can be jeopardized. It is estimated that cities are responsible for 80% of global economic growth, so urban water deficits come at a very high cost. For example, growing water problems are costing China around 2.3% of its annual gross domestic product, as a study published in 2007 by the World Bank revealed.

This is an immense challenge. "We are at risk of losing the fight for access to water and sanitation facilities in many cities," water expert Anders Berntell warned participants at the World Water Week in Stockholm, Sweden, in 2011. More than half of the Earth's population already lives in urban metropolitan areas; by the middle of the century, this figure will be 70%. Around 9.6 billion people are expected to live on this planet by then, according to estimates from the United Nations (U.N.). Strong growth will especially be seen in the cities of India, China, Nigeria, the United States and Indonesia, the U.N. says.

In many places, water consumption is already growing faster than the available resources can supply. Falling groundwater levels, empty riverbeds, dried-up reservoirs – water shortages are increasingly making the headlines, and it is no longer just a phenomenon seen in drought-prone countries. Even urbanites in industrialized countries are experiencing water shortages. Following two unusually dry years, strict water-saving measures were imposed in some areas of Great Britain in the spring of 2012. Watering the lawn or washing a car using a hose were punishable by a fine; in London, the fountains were turned off. And after a long dry period, in 2008, Barcelona even had to import tankers full of drinking water. This measure was expensive and not good for the city's image. According to critics, it was necessary because the city had failed to increase its water supply capacities quickly enough to keep up with the sharp growth in population.

Seawater: the source of the future

One year later, a seawater desalination plant was inaugurated in nearby El Prat de Llobregat. With a daily capacity of 200,000 cubic meters, it should be able to meet the drinking water needs of about one-quarter of the population of the Barcelona metropolitan region.

Desalination of seawater is a popular option for coastal cities around the world. One example can be found in the town of Nungua, about 12 kilometers from the Ghanaian capital of Accra. Once completed in 2014, a desalination plant under construction there should produce enough drinking water for around half a million people each day. The plant will also be using ultrafiltration technology from inge®, a Bavarian subsidiary of BASF (see box on page 25).

According to forecasts by the industry specialist Global Water Intelligence (GWI), 14% of the world's population will be meeting its water needs through seawater desalination in 2025. Today this figure is only 1%; 17,000 plants have been installed in 120 countries. The number of plants is expected to multiply by 2050, the GWI experts predict. The projects are already being constructed on a gigantic scale. For example, a plant that recently started operations in Melbourne, Australia, can supply around 440,000 cubic meters of desalinated water daily. But desalination has its price: Despite great strides in technology, desalinated seawater is still a comparatively expensive and energy-intensive option compared to conventionally abstracted drinking water.

These three cities are leading the way toward water systems of the future

Phnom Penh, Cambodia

Average rainfall: 1,300 millimeters per year; population: 1.5 million; daily water consumption per person: 108 liters

When Ek Sonn Chan was appointed general director of the Phnom Penh Water Supply Authority in 1993, he encountered a sobering situation: The utility company was only able to supply 65,000 cubic meters of water daily – not even half of its actual capacity. The pipeline system was dilapidated, corruption was rampant and more than 70% of the water was not generating any revenue. Because water was leaking from the system, people were tapping into the pipelines illegally and invoices were simply not being paid, the water authority had barely any income. With international support, Chan successfully updated the technical infrastructure and introduced modern management practices. Today every household has access to clean water. Water meters have been installed throughout the city and the pipes are inspected regularly. The water utility, which has now become a joint stock company, generates a profit every year. For these reforms, Ek Sonn Chan and his team won the 2010 Stockholm Industry Water Award from the Stockholm Water Foundation.

Lima, Peru

Average rainfall: less than 15 millimeters per year; population: 8.5 million; daily water consumption per person: 250 liters

More than one million residents of Lima, the capital city of Peru, have no access to clean drinking water. The Rímac, a river that flows from the Andes, has long been the main source of the city's water supply. Now the city wants to create new reservoirs. Since 2012, the Huascacocha reservoir, located around 100 kilometers from the megacity, has been delivering 273,000 cubic meters of water per day to Lima. It is part of a modernization program started in 2009 by the water utility Sedapal. The utility also plans to invest a total of \$1.5 billion (€1.1 billion) in projects such as desalination plants, additional reservoirs in the Andes and transferring water from neighboring catchment areas into the Rímac. Sedapal is also trying to limit water wastage. Currently, up to 45% of water in Lima is lost through leaky pipes. Water meters are being installed so administrative losses can be discovered and reduced. The meters will also give Lima residents a clear picture of the value of water because, with a consumption rate of 250 liters per capita each day, they are at the top end of the scale of global water consumption.

City-state Singapore

Average rainfall: 2,400 millimeters per year; population: 5.3 million; daily water consumption per person: 152 liters

Although Singapore is surrounded by water, drinking water here is scarce. The water issue was therefore declared a priority as early as the 1960s. Singapore's creative methods of handling this resource can be seen in the NEWater visitor center located at Marina Barrage. Completed in 2008, Marina Barrage was designed as a reservoir for rainwater and has now become an important source of drinking water. Singapore's national water agency PUB takes a four-pronged approach to water management: precipitation water, wastewater recycling, seawater desalination and water imports from Malaysia. The gem among these is the recycling program for urban wastewater, known as NEWater. It is treated in a three-stage process which results in water that is of even better quality than the normal drinking water, according to PUB. With a capacity of 273,000 cubic meters per day, NEWater now meets about 30% of the urban water demand. By 2060, this share should rise as high as 55%. Furthermore, conservation initiatives encourage residents to save water.



Desalination of seawater is a popular option for coastal cities around the world.



Right Desalinated seawater from plants like this one in Cyprus could be providing water for 14% of the world's population in 2025, according to industry experts.

* Brian D. Richter et al., *Tapped Out: How Can Cities Secure Their Water Future?*, Water Policy, 2013.

Wasteful water consumption

This is one more reason to use water carefully, but many cities are far from achieving that. Some water companies postpone repairs. Instead of fixing leaks, they only take action when pipes break. As a result, millions and millions of liters of drinking water trickle away without being used. A vivid illustration of the consequences of overly wasteful water consumption can be found in Mexico City, a metropolis of millions which is gaining around 300,000 new residents every year. After decades of overexploitation of its groundwater, the city is sinking – the historical city center is now approximately 9 meters lower than it was in 1900. Around 62,000 liters of drinking water are consumed in the Mexican capital every second. As much as 40% of this amount is lost through the antiquated water pipes. And this is water that has first been pumped from as far as 300 meters below the city's surface, or transported from 200 kilometers away and over 1,100 meters of altitude difference. On the other hand, entire city neighborhoods are flooded during

heavy rains. The city wants to solve this flooding problem with the major project "Túnel Emisor Oriente." Costing \$1.2 billion (€0.9 billion), this 62 kilometer-long wastewater tunnel with a diameter of 7 meters should be completed in 2016. Although a local environmental organization, Isla Urbana, has recommended using rainwater as well, city planners have not been receptive to this idea so far.

In cities in Southeast Asia in particular, "rainwater harvesting" is well established and this practice is also advocated by UN-HABITAT, the United Nations Human Settlements Programme. In addition to Singapore, one of the most popular examples of this can be found in the Sumida district of Tokyo. For more than two decades, municipal policy here has supported the collection and reuse of rainwater. Residents can get subsidies for constructing rainwater storage tanks. Some city buildings, such as the Tokyo Skytree – which opened in 2012 and, at 634 meters high, is the second-tallest building in the world – contain cisterns with filters in the lower basement levels. The water tank in the new broadcast

tower holds around 2,600 cubic meters of water. It is fed by rainwater, which is used to cool the solar panels on the roof and flush the toilets; it also helps provide emergency flood control during heavy rains.

Contaminated land and rivers

The "dirty truth" about the oftentimes all too careless and thoughtless management of water is especially apparent when it comes to the issue of wastewater. Worldwide, 80% of urban wastewater is released directly into rivers, lakes or the sea without being treated – even in London, where millions of liters of untreated wastewater flow into the Thames during rainy weeks because the capacities of the treatment plants are overwhelmed. The situation is particularly dramatic in the cities in emerging and developing countries. In Buenos Aires, for example, the rivers are very polluted; in Kolkata, India, the population is struggling with fecal contamination and an elevated concentration of arsenic in the groundwater. The situation in China is also alarming: 90% of the groundwater in cities is

contaminated, according to a recent study by the China Geological Survey. An analysis of 118 Chinese cities also found that 64% of the water sources were "heavily" polluted, while 33% were "mildly" polluted and only 3% fell under the category of "sanitary."

Closing the materials loop

According to international water expert Professor Asit Biswas, Ph.D., the real issue is not that there is not enough water, it is the poor quality of available resources. "The main problem is not physical scarcity of water, but its continued mismanagement! Unless water management can be improved significantly, the world's water problem cannot be solved," says the founder of the Third World Centre for Water Management in Mexico.

"Traditional water use models lead to water shortages," says Dr. Max Maurer, a professor for urban water systems at the Institute of Environmental Engineering at the Swiss Federal Institute of Technology Zurich (ETH). The traditional European model of collecting all wastewater, >>



including rainwater, in a sewage system and then processing it in a wastewater treatment plant is not a global solution, he believes. “We have to work on creating overall systems that are effective and flexible at the same time. Sewers are a perfect solution for the inner city, but it is also important to develop alternatives that work on the outskirts of cities, in the slums,” Maurer says.

A great example of this was the 2011 “Reinvent the Toilet Challenge” issued to universities by the Bill & Melinda Gates Foundation, he adds. Around 2.1 billion urban dwellers worldwide currently have no access to hygienic sanitary facilities, according to the foundation. The challenge in this competition was to design toilets that could capture and process human waste without piped water, sewer or electrical connections, and transform human waste into useful resources, while keeping costs below 5 U.S. cents per user per day. The Peepoo single-use toilet, for example, is a similar solution (see box on page 13). Maurer stresses it will be a huge advance if we are able to “break the link between the toilet and water consumption, and process the waste materials to create valuable goods.”

Water recycling gains popularity

Good water management conserves resources and is ecological. It seems this message is finally getting through – albeit slowly. Experts believe that tapping new water sources is important, but even more potential exists in water recycling. One of the pioneers in this area is Singapore. By 2060, the island state wants to meet up to 55% of its water demand with NEWater – wastewater that has been treated to bring it up to drinking water quality (see box on page 10).

The London-based utility Thames Water is also considering recycling wastewater into drinking water and is conducting a survey to test the public’s receptiveness to this idea. Widespread acceptance of such a program is necessary, as was demonstrated a few years ago in Brisbane, Australia. The city was set to add recycled wastewater to its drinking water supply, but had to backtrack because the population simply could not be convinced that the water was pure enough to drink.

The same sort of problems should not be an issue for the water recycling strategy in the emirate of Qatar, which is set to host the soccer World Cup in 2022 and

has one of the lowest rates of precipitation in the world. Recycled wastewater here is primarily used for irrigation in parks and green areas. Some 24,000 cubic meters of water are recycled using BASF’s ultrafiltration technology each day at the recently completed Doha North Sewage Treatment Works.

Interdisciplinary thinking

Clean drinking water, proper sanitation facilities and wastewater treatment plants will be essential to the future of cities. Solving urban water problems will require thinking outside the box – and this is where many fail. The lack of willingness to think and act in an interdisciplinary way is one of the main hurdles in water management, according to one of the conclusions of the Switch project, which was sponsored by the E.U. and involved 30 cities worldwide over a period of five years. A change of perspective is needed. Wastewater should be seen as a valuable resource rather than a problem and, as in Singapore, water reservoirs should be integrated into the urban fabric in a way that also allows them to serve as a recreational area for residents. This was also illustrated by Khoo Teng Chye, former CEO of

Singapore’s national water agency PUB: “In order to be a sustainable city, we always have to be forward-looking, visionary and bold thinkers. We need innovations, not only in technology, but also with regard to how we approach integrated water management.” ■

Water-saving tips

Teeth brushing

If you leave the water running while brushing your teeth, you could be wasting up to 17 liters of water per minute. By using a cup of water to brush your teeth instead, you can reduce your water consumption to just 0.2 liters.

Drips add up

A dripping faucet loses about 5,500 liters of water per year.

Toilet flushing

Around 12 liters of water are used to flush a toilet. A dual-flush toilet can reduce this figure to between 3 and 6 liters. If you do not want to convert your toilet, you can also place a plastic bottle filled with stones and water into the toilet tank – by lowering the amount of water in the tank, this reduces the water consumption per flush by as much as 2 liters.

Washing machine

Only turn on the machine when it is completely full. Avoid the pre-wash cycle, which is often unnecessary, and use the energy-saving mode to reduce water and energy consumption.



Shower instead of bath

Taking a bath uses about 80 liters of water, while a short shower only requires one-third as much.

Faucets, shower head

A faucet aerator in the bathroom and kitchen can reduce water flows. It mixes air into the water stream, changing the perceived strength of the water flow. This cuts water consumption to between 5 and 6 liters per minute.

Harvest rainwater

Collecting rainwater and using this to water your garden can be a huge water saver. An added benefit: The low lime content of the rainwater is good for the plants.

Car washing

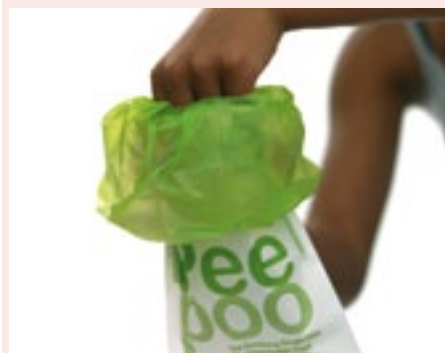
Washing a car with a hose uses around 150 liters of drinking water. Using a bucket and sponge saves water.

Sources: www.waterwise.org.uk; www.bmu.de/en

Above left Singapore's improvements to water infrastructure also create a high-quality public recreational space.

Right Peepoo is an inexpensive and germ-free single-use alternative to the flush toilet. Peepoo was developed by Professor Anders Wilhelmson, a Swedish architect.

Better hygiene thanks to Peepoo



As cities in developing countries grow, diseases can spread quickly because people in the sprawling slums have no access to toilets. But help can be found in the form of a small toilet. Professor Anders Wilhelmson, a Swedish architect and urban planner, has developed a simple alternative to the flush toilet: Peepoo, a single-use toilet in the shape of a bag.

When unfolded, Peepoo measures 14 by 38 centimeters and therefore fits atop all standard buckets. After being used, Peepoos are collected at a central location and then both the toilet and the content are composted. Peepoo is made mainly of the biodegradable plastic ecovio®, developed by BASF. Peepoo also contains urea, which turns into ammonia when it comes into contact with

urine and feces. Ammonia destroys the dangerous disease-causing bacteria within just a few days and accelerates decomposition. Peepoo disintegrates within a few months, leaving behind valuable nitrogen fertilizer – a rare commodity in Africa.

The single-use toilets have been distributed following natural disasters, such as the earthquake in Haiti in 2010, with the help of aid organizations. They are also being used in Kenya and Pakistan. The company Peepoople was established to produce and distribute this solution, which improves hygiene and protects the limited local drinking water resources from becoming contaminated. For users, the costs are barely more than the equivalent of 3 euro cents per toilet. In most cases, public toilets are more expensive and dirtier. It makes things especially easier for women who lack toilet facilities in their home and have to make a long and often dangerous journey at night away from their settlements. Those who return the used Peepoo to a collection point receive approximately one euro cent back. Thanks to donations, the single-use toilets have been distributed to more than 60 schools.

Wilhelmson wants to continue to expand this project. His goal is to have 150 million people using Peepoo every day and for Peepoople to become “what could be described as the ‘Google’ of sanitation.”

Water availability and water use worldwide

Every drop counts

Drinking water is vital to life. But drinkable freshwater reserves are not distributed evenly around the world. And they are becoming scarcer. This graphic shows where people are suffering from acute water shortages and where people consume the most water.

13,400 m³
Average volume of water available per capita per year in the United States and Mexico

2,470 m³
Average volume of water available per capita per year in the Caribbean

7,200 m³
Average volume of water available per capita per year in Latin America

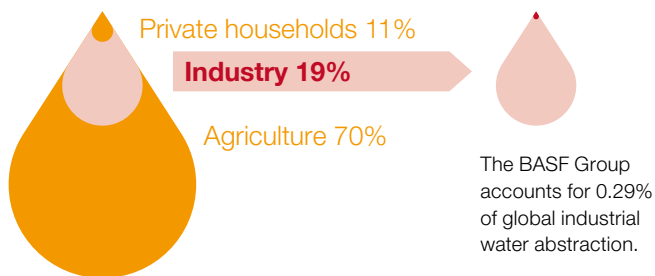
0.5%



Although 71% of the Earth's surface is covered with water, drinking water is a scarce resource because 97% of the water on this planet is saltwater from the seas. The remaining 3% that is freshwater is mostly frozen as a permanent layer of snow and ice in glaciers or encased deep under the Earth's surface. Therefore, only 0.5% of the total water volume is accessible drinking water.

● Total water use
■ Areas of high water stress

Worldwide water abstraction by sector



Total worldwide water abstraction
3,862,000 million cubic meters per year

Water use* by the BASF Group 2012

	Million cubic meters per year
88% Cooling	
– Closed-circuit cooling	4,044
– Flow cooling	1,706
12% Production	249
Total (rounded):	5,998

* As much water as possible is reused in closed circuits. This means less water has to be abstracted.

4,740 m³

Average volume of water available per capita per year in Europe

1,000 m³

Average volume of water available per capita per year in Sub-Saharan Africa

500 m³

Average volume of water available per capita per year in the Arab world

2,970 m³

Average volume of water available per capita per year in Asia Pacific

1,150 m³

Average volume of water available per capita per year in Australia

Total water use per country

Scale of the graphic

761,000 million m³/year

427,000 million m³/year

189,000 million m³/year

46,000 million m³/year

<1,000 million m³/year

What are water stress areas?

Water stress areas are regions where water is a scarce resource and where more than 60% of the available water is abstracted by humans. The most important factors leading to water scarcity are: low precipitation, high temperatures, low air humidity, unfavorable soil properties and high water abstraction rates.

BASF's 2020 water goals

Less drinking water in production processes (baseline year 2010)

-50%

Sustainable water management in water stress areas

100%

Lower emissions


We want to reduce our emissions to water of organic substances and nitrogen by 80% and of heavy metals by 60% (baseline year 2002).

Water scarcity and water stress in 2050

Number of people affected

	2010	2050
Water scarcity	397 million	2.1 billion
Water stress	1.6 billion	2.0 billion
Total	2.0 billion	4.1 billion

Sources: www.unwater.org; Areas With High Water Stress, changed according to: Pfister et al., 2009; Food and Agriculture Organization of the United Nations (FAO), *Water Use by Sector and Source*, Aquastat online database, 2010; UNESCO, *United Nations World Water Development Report – Water for People, Water for Life*, 2003; FAO, *Water Availability by Region*, Aquastat, 2013; Population Action International, *An Update – People in the Balance: Population and Natural Resources*, 2012

A close-up portrait of Professor John Briscoe, a middle-aged man with dark, wavy hair, wearing a grey suit jacket, a light blue dress shirt, and a patterned tie. He is looking directly at the camera with a neutral expression.

“
In water
the glass is
always half full.
It is true that we
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and droughts, but
we have some
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adaptive practices.”

Professor John Briscoe, Ph.D.,
Director of the Harvard Water Security Initiative

”

A world of water

As the global population increases and the impact of climate change is being felt, concerns are rising about how sustainable our future water supplies will be. Former water advisor to the World Bank, Professor John Briscoe, Ph.D., explains that by investing in innovation, smart infrastructure and good institutions, we can be prepared to deal with these changes.

John Briscoe

Professor John Briscoe, Ph.D., is a South African who is one of the world's leading experts on water management, having worked for 40 years in the field of water and economic development. He most recently served as the World Bank's senior water advisor and as country director for Brazil. During nearly 25 years at the World Bank he lived in India and Brazil. He has in the past worked as an engineer in the water agencies of South Africa and Mozambique and as an epidemiologist at the Cholera Research Center in Bangladesh.

He is currently the Gordon McKay Professor of the practice of environmental engineering at the Harvard School of Engineering and Applied Sciences. He is also director of the Harvard Water Security Initiative, a body that has formed collaborative partnerships with eminent universities in Australia, Brazil, Pakistan and the United States to help develop a secure and sustainable platform of water institutions and infrastructure.

Creating Chemistry: You have dedicated most of your career to water. What sparked your initial interest in this resource?

Professor John Briscoe, Ph.D.: Very simple, I am from South Africa and grew up in a country in which the rain falls on the coast and God put the diamonds and the gold a long way from the rain and in a big rain shadow. The country subsists on very large hydraulic programs to move water from where it is, to where the people and the economy are. I grew up with a sense of the value of water and the threat of water scarcity, so in that sense it is very visceral for me. I studied civil engineering in Cape Town and I discovered that water is such an amazing subject. You have to know engineering; you have to know finance, economics, public health, religion and politics. It is a great area for people who have a wide range of intellectual interests, which is my case. It has been my privilege to live in Bangladesh, Mozambique, India and Brazil and work in dozens of other countries on these issues over the last 40 years. I now feel like I know 10% of what I need to know!

You are now director of the Harvard Water Security Initiative, a cross-disciplinary research program that you set up within the Harvard School of Engineering and Applied Sciences. What are its aims?

There are two main bumper stickers for the program. The first is to create a new type of professional for modern water management. In dealing with water you need good engineers, good lawyers, good economists, good agronomists and good energy people. You need specialists who can communicate with other specialists. So the first bumper sticker is to train a new generation of 'specialized integrators,' strong in their basic

discipline but capable of dealing with other disciplines. The second issue is that in the water world there is a great disconnect between the 'high-thinkers' and the practical reality. So the second bumper sticker is to link students with 'thinking practitioners.' We also work primarily in places where I have decades of hands-on experience and so focus on just four geographies – Brazil, Australia, Pakistan and the Mississippi.

The planet's population is growing as we experience the impact of climate change with flooding in Pakistan, drought in Australia, shifts in Indian monsoon patterns and the potential filling of Cyprus's exhausted aquifers with saltwater. How serious a situation do you think we are in?

First of all, when dealing with water there is no 'we,' every water situation is local. The water situation in Massachusetts and the one in California are essentially independent problems. There is thus no world water crisis. There are a multitude of local issues, each one with quite distinct characteristics.

Secondly, we have always had droughts and floods; they are biblical and they did not start in 1997. Climate change certainly adds an element of uncertainty. The recent floods in Europe – is that a climate event? Probably in part so, but it is much more definitively a land use issue, which is a consequence of the occupation of floodplains.

Thirdly, in water the glass is always half full. It is true that we face a lot of floods and droughts, but we have some examples of good adaptive practices. To cite just two examples where we work, Australia is the best in the world at dealing with water shortage and the Mississippi River Commission has

done a brilliant job with managing floods. We have a lot of practical, field-tested knowledge of what works. As a practitioner, my view is that too much attention is given to producing colored graphs about how the world is going to be a catastrophe in 2080 and far too little attention is given to recognizing that hydrological variability is a long-established fact of life and that our first focus should be on creating resilience to known variability. Those who have dealt with known variability are much better equipped to manage a variety of unknowns, be it climate or other shocks.

Populations are increasingly concentrating in cities. What challenge does this pose to the delivery of sustainable urban water supplies?

I don't see urbanization as an insurmountable problem. Yes, of course, there are many problems, but they are no worse than they have ever been. London in the 1850s was not a lovely bucolic city in which to live. In most instances things are getting better. A critical issue, however, is the availability of resources. It is much easier to address the problem of flooding in, say, New York or Shanghai than it is in, say, Lagos or Kolkata. So while we do need to be more proactive and adaptive in all cities, in the developing world a primary focus must remain economic growth and the enhanced productivity of cities.

How do we deal with the 10% of the world's population who lack access to safe water?

It is important to recognize the extraordinary progress that has been made on this challenge. Over the past 20 years, every single day about 280,000 people have obtained access to an adequate supply >>



Water supply and sanitation are pieces of a bigger picture and you cannot solve them without addressing that.

**Professor John Briscoe, Ph.D.,
Director of the Harvard Water Security Initiative**



of drinking water for the first time. Almost all of this progress has been the result of economic growth. Poor people don't have many things, such as jobs, transport, healthcare, education or food. Water supply and sanitation are pieces of a bigger picture and you cannot solve them without addressing that. Where economies grow, there is broad improvement and the water supply issue is solved as part of this. That is how we in the developed world got safe water. These are crippling issues for poor people but they are not going to be solved without growth and sound financial policies.

Is there a role for business when it comes to providing adequate water management in the developing world?

In the developing world, a huge issue is that the basics, such as a good legal and regulatory framework and good management capacity in the public sector, are not in place. If you can get multinational companies to work with local companies and have them assist the government in strengthening these core capabilities then this can make a tremendous difference. Companies need to engage with political leaders and find ways in which they can support with money and knowledge the capacity of governments to manage water more effectively. This is much more important than the typical 'give a donation to an NGO' approach of most companies.

What sorts of innovations are needed to help achieve sustainable water management?

I see three main areas where technologies can help. First, remembering that 70% of water is used in agriculture, a critical issue is that we need to use science and innovation to produce the types of crops that can use less fertilizer, less

pesticide and water more efficiently. This is absolutely central. Among the tools for achieving this must be genetically modified organisms. The European position on GMOs is, in my view, very harmful to the environment and to development.

The second area is treatment technology. The most discussed is desalination, where, ironically, the technology has reached its thermodynamic limit and there is likely to be little change. But through the application of nanotechnology we are now able to design membranes to meet very specific treatment requirements. This means technology can be tailored to clean particular types of wastewater in an effective way and reuse them. This is hugely important and a chemical company like BASF has a tremendous role to play.

Third, we need to use information much more intensively and intelligently. The use of sensors, remote sensing, big data analysis and just-in-time delivery mechanisms already play a fundamental role in advanced water management systems like in Australia and are of great importance in most places. These innovations are central to us adapting, so they are very important.

What do you see as the role of hydroelectric power in meeting future energy needs?

Hydro is almost always a source of low-carbon energy. Rich countries have used 80% of their economically viable hydroelectric potential. Switzerland, Norway, Japan, the United States and Canada used hydro as a backbone of their economic development, and it remains so to this day. The equivalent number for Africa is 5%. Yet, well-meaning people from rich countries tell poor countries that they will not support hydro. This is deeply and, in my view, appropriately resented as

a form of colonialism at worst and moral hazard at best. Developing countries have a straightforward view of development. They want to follow the path that now-rich countries have followed. For sure they want to learn from mistakes that were made, but they are not willing to serve as guinea pigs for rich people's experiments on 'alternative paths.'

How do you respond to critics of dams who claim they displace populations, add to climate change and destroy down-river ecosystems?

All big innovations have big upsides and big downsides. So it is with dams. Most large dams have brought great benefits in terms of protection from floods and droughts, production of clean and cheap electricity and food production. But there are downsides too. One relates to the impacts on the environment, which we are learning to mitigate. In most of the developing world, however, the big issue is resettlement. Changing where people live involuntarily is always traumatic. A great deal has been learned and much progress made in recent decades. The philosophy here is that local people must be the first beneficiaries from these projects and there are cases of this working well.

Access to water has always been a source of possible conflict between communities. How big a threat do water wars pose today?

The word 'rivals' comes from the Latin *rivalis*, which refers to someone using the same river as another, so conflict over water has been going on for a while. But the simple fact is that few wars have actually been fought over water. The idea that the United States and Canada would go to war over water is absurd because water is one of hundreds of issues they deal with. If, on the other hand, you look at Pakistan and India, they have very few ties that bind and thus a highly sensitive and political issue like water becomes one of the few issues on which the countries have worked together. This is the case with the Indus Basin, which is a very dangerous potential flashpoint.

There have been great changes in approach since you started working in water management 40 years ago. What changes do you expect to see 40 years from now?

If we have economic growth then we will have a lot more ability to deal with difficult problems. This is particularly important for the still-poor parts of the world. I also hope we can act





Above The Kuroyon Dam in Kurobe, Japan, was built between 1956 and 1963 to address the country's power shortages after the Second World War.

Below left Worldwide, irrigation of agricultural land accounts for 70% of all freshwater consumption.

more intelligently. We know that we can deal with extremes – both floods and droughts – better. Let me give you two examples where our work at the Harvard Water Security Initiative illustrates this: In Australia, there has been a 70% reduction in water availability in the Murray Darling Basin over a period of eight years and virtually no impact on agricultural value. The basic reason this worked was because market mechanisms meant that water moved voluntarily from low-value uses such as rice to high-value uses such as fruits when water was scarce. On the flood side, the Mississippi is a fascinating case. Two years ago, they had the biggest floods since 1927, which, at the time, had been the biggest natural disaster in the history of the United States. In 2011 when they had the floods, no one in the United States knew it had happened; the area submerged was 30% of what it was in 1927. In 2011, not a drop of water went to a place that was not designated to receive this water. Lessons are learned and are then put into practice. Again, details will differ by place, but the philosophy of 'making room for the river,' building smart infrastructure and good institutions is a constant.

What are the water issues where you live today and how do you take care in the way you use water in your own daily life?

I live in a small New England town of 5,000 people in the United States. We live on a man-made pond and we have a little dam down at the end and I am the dam master. The residents love to have the pond full, but if there is a lot of rain and it gets too full we can lose our dam, so you have to watch the level. My wife is a keen observer and she says 'I think it is low enough now we can put the boards back.' We have a lot of fun managing our own dam! ■

280,000

Over the past 20 years, every single day about 280,000 people have obtained access to an adequate supply of drinking water for the first time.

70%

Murray Darling Basin in Australia has experienced a 70% reduction in water availability. But as a result of well-functioning market mechanisms to move water use from low-value to high-value uses, there was virtually no impact on agricultural value.

80%

Rich countries have used 80% of their economically viable hydroelectric potential. The equivalent number for Africa is 5%.



To find out more, visit:

<http://watersecurityinitiative.seas.harvard.edu>



Children are the agents of change

Water scarcity is a cause of concern in several states across India. Access to clean drinking water is an additional challenge, especially in rapidly developing cities like Mangalore. Unclean water is one of the main causes of disease. Lack of clean sanitation can also be one of the reasons why children do not finish their education. Girls, in particular, are put off attending schools that lack private and decent toilet facilities.

To address these problems, in May 2011 BASF Stiftung – a charitable foundation based in Ludwigshafen, Germany – together with UN-HABITAT, the United Nations Human Settlements Programme, launched a special water education project in Mangalore. The project was implemented by The Energy and Resources Institute (TERI) and supported by BASF India. The aim of the project was to provide sanitation facilities and, through water education, to raise awareness among the students and the community of effective water-quality monitoring and conservation techniques.

Some 25 schools were selected

to participate, involving a total of 5,000 students. The schools were given water testing kits and teachers and students were trained to use them for monitoring water quality at their sites. Eight of the project schools were equipped with water laboratories to carry out water quality monitoring. Water classrooms were established in two of the schools to educate the students on the water cycle and water conservation methods. The goal was to develop water quality maps so that any discrepancies could be reported to the authorities.

The project was comprehensive and integrated in its approach: from installing water supply infrastructure and providing education and training to students, teachers and the local community, to sharing information with the public and local authorities and building cooperation between communities. The result: Children have a better chance of finishing their education in good health and the progress that is made is sustainable over the long term. With this initial support, these communities can now help themselves.

Left These students from the Shri Venkataramana Higher Primary School, in the Indian city of Mangalore, were among the 5,000 school children who took part in the Water Education Project set up in 2011 by BASF Stiftung and UN-HABITAT. BASF Stiftung is a charitable foundation based in Ludwigshafen, Germany.

Right As part of the Water Education Project, students from Shri Venkataramana Higher Primary School, with their science teacher, test water quality in the reservoir near the BASF site in Mangalore. Using a water testing toolkit, they test the physical, chemical and biological parameters of the water sample. The reservoir, which holds over 25,000 cubic meters of water, was built by BASF on its premises to store water from the neighboring Netravati River for industrial use.







Left The science teacher explains the water testing process to the students. By educating pupils, the Water Education Project aims to provide sustainable, long-term improvements in water quality for the local communities.

“ By targeting school students and imparting education on water, sanitation and hygiene, we aim to influence the community members to bring about a behavioral change in water management. In this respect, the Water Education Project will have long-lasting impact on a large group of people in Mangalore.

Prasad Chandran,
Chairman, BASF companies in India & Head South Asia

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Left The school students use the water testing toolkit to test for impurities in well water drawn from the school premises. One of the project's aims is to raise the students' awareness of water and sanitation issues and to bring about behavioral change in the way they use water.



Left Water laboratories were installed in eight of the schools that were selected to participate in the Water Education Project. Equipped with glassware, reagents, apparatus and resource materials on water education, the labs enable the students to test drinking water quality and to analyze the physical and chemical properties of water, as well as track impurities and acquire skills for purifying water.



“
The Water Education Project equipped students to monitor water quality in their neighborhoods and raised awareness in the local community about the careful use of this natural resource.

Dr. Hartmut Unger,
Managing Director, BASF Stiftung

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Above Many of the students at Shri Venkataramana Higher Primary School come from low and middle-income families living in the local community. The school offers them cultural, social, language and environmental education and also provides them with lunch every day.

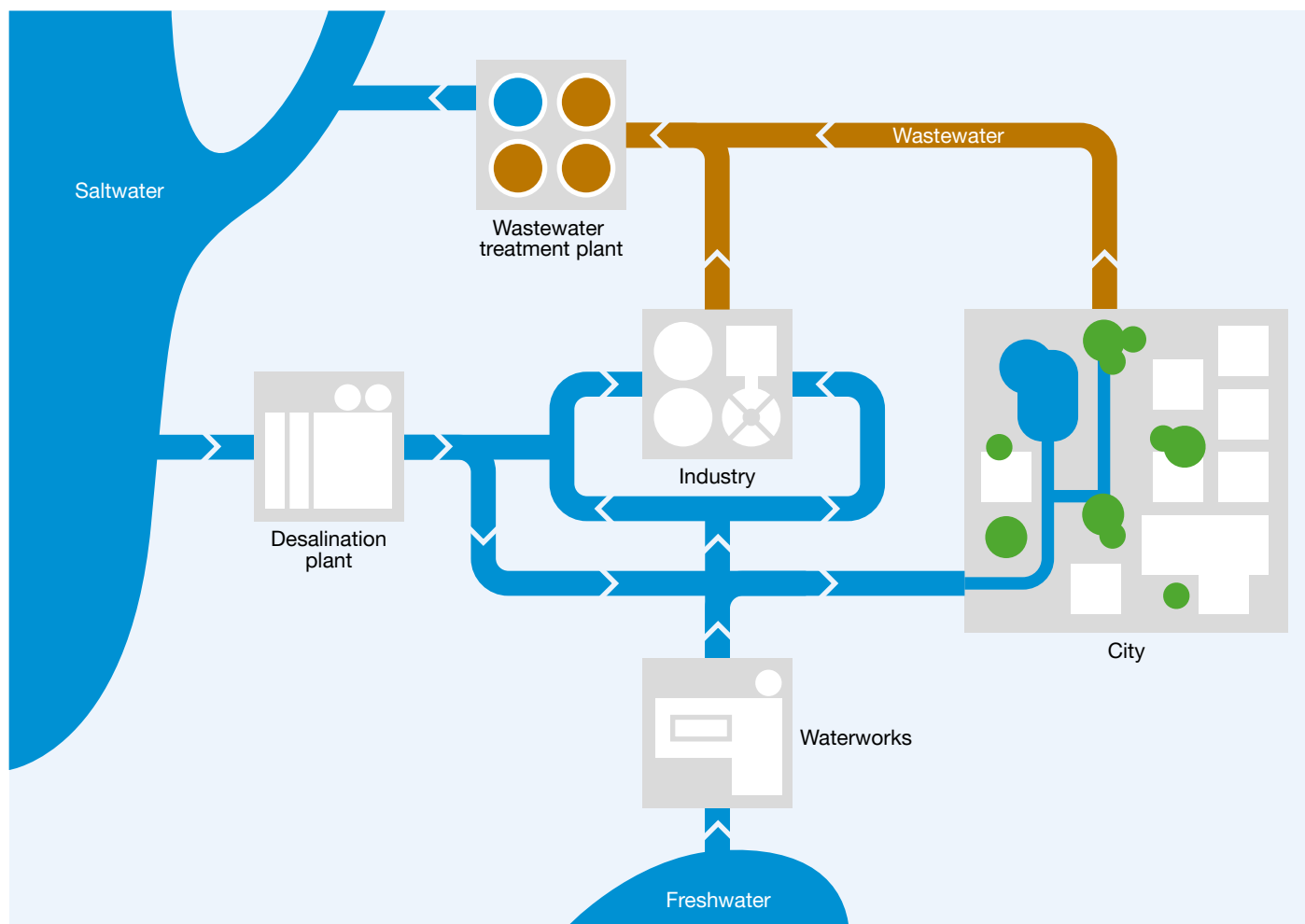
Right The students help spread the message of effective water management to the community living around the schools. Prominent display boards remind people to save water. By raising awareness and educating students and the neighboring community, the positive impact of the project is expanded.



The right treatment

Although 71% of the Earth's surface is covered with water, in many regions water is scarce. In theory, existing freshwater supplies should be sufficient to quench the thirst of the roughly 7 billion people living on this planet. But in reality, these water resources are distributed unevenly and are in high demand: More than two-thirds of global water supplies are used for agriculture and are therefore no longer available as drinking water. As well, industry needs water for its production processes. So it is vitally important that this precious resource is not wasted. BASF's products contribute to efficient water use and the company is developing solutions for the water supply of the future.

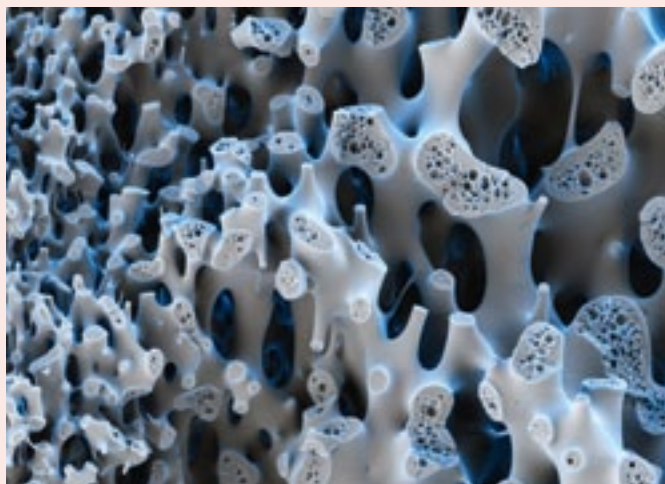
Below Drinking water, process water and wastewater: how an efficient closed-loop water system works.



Ultrafiltration membranes – all-rounders for water systems

Ultrafiltration membranes help us to utilize a diverse range of water sources. Used, for example, to pre-treat seawater before desalination, the extremely fine pores of the filter can separate out impurities, such as algae, from the water. Used in water treatment, they reliably filter out the tiniest microorganisms, such as viruses and bacteria; this even makes it possible to turn wastewater into drinking water. The membranes work in a similar way to conventional filters. While water molecules can squeeze through the pores that are only a few nanometers wide, suspended solids like sand, clay, algae and

even pathogens get caught in this barrier. The BASF subsidiary Inge® produces ultrafiltration membranes under the Multibore® brand name for a wide range of applications. BASF also uses these membrane modules. The core is made of BASF's high-performance Ultrason® plastic. This plastic is also contained in the LifeStraw® Family portable water purification system manufactured by Vestergaard Frandsen. Especially in areas with insufficient water supplies, LifeStraw® helps to turn large quantities of contaminated water – for example, from puddles or rivers – into drinking water.



Above The small pores of the Multibore® membranes filter out viruses, bacteria and other materials from water.

Drinking water – vital to life

A lot of our drinking water comes from groundwater or surface water sources. Before it flows to households, this water is treated by waterworks, which de-acidify it using activated carbon. However, this process also oxidizes iron, creating tiny molecules that cannot be filtered out of the water. Help comes in the form of flocculants such as Magnafloc® LT from BASF. They separate solid molecules from fluids and thus help to remove the finely distributed impurities from the water.

In dry regions, the sea is also becoming an increasingly important source of water. Although the volume of water available is almost unlimited, it has to undergo a complex desalination process. Many seawater desalination plants operate using thermal techniques. Similarly to a kettle, the seawater is heated using lots of energy to create steam from which drinking water is produced. This leaves behind a salty brine, which is then returned to the sea. However, the desalination process creates stubborn deposits. Crystals which form in the heating pipes and distillation chambers can lower efficiency so much that the plants need to be cleaned every two to three months. In order to considerably lengthen the time between cleanings, dispersing

agents such as the water-soluble polymer Sokalan® from BASF are used. They comprise long polymer chains with a negatively charged molecule strand. Due to the resulting electrical charge, they can dock onto the salt molecules, preventing crystals from growing or taking hold. The same principle is applied in reverse-osmosis desalination. In this method of seawater desalination, saltwater is put under high pressure using a strong pump; this forces the water through the reverse-osmosis membrane and leaves the salt behind.

Process water – the source of production

Industry uses water as a cooling agent, solvent and detergent, as well as to manufacture products. In doing so, industrial companies must overcome some of the same challenges we all face at home: Scale can build up in boilers, components can rust and solids can clog up pipes. Products from BASF help to keep plants running smoothly for as long as possible, without the need for frequent maintenance. For example, BASF has developed the Antiprex® product line. Biodegradable Antiprex® CM prevents mineral build-up and Antiprex® MSA is used as an environmentally friendly detergent. Neither one contains

phosphorus so they do not contribute to algae growth.

Accounting for around 20% of water use, industry and energy companies are the second-biggest consumers after agriculture. Accordingly, BASF has set itself ambitious goals for the responsible use of this valuable resource (see graphic on page 15). This is especially true for the approximately 60 BASF sites – around one-fifth of the total – that are located in water stress areas. One of these is the Tarragona site in Spain, where BASF was the first chemical company to achieve gold-level certification according to the European Water Stewardship (EWS) standard. With the help of the EWS standard, companies and agricultural operations can evaluate how sustainably they use water resources. For the certification of the Tarragona site, the third-party institute TÜV assessed and tested the entire water management performance. The test criteria demonstrated that water is abstracted in accordance with sustainable principles. This means, for example, that the Tarragona site only draws as much water as it needs. Furthermore, the certification shows that good water status is ensured, high conservation areas are protected and all activities are subject to an appropriate level of control. The assessment also requires a water

recycling strategy and a cohesive crisis management strategy to be in place.

Wastewater – part of the water cycle

Every year, private households, industry and businesses worldwide generate more than 160 billion cubic meters of wastewater, which is sent to treatment facilities. While more than 95% of the households in Germany are connected to the public sewage system, in India only 6% of the larger cities even have a sewage network.

To treat sewage, flocculating agents such as BASF's Zetag® are used. The long-chain molecules unroll in water like a ball of wool and attract even the smallest particles of dirt, creating larger flakes that accumulate and can be filtered out of the water. This ultimately produces thickened sludge and clear water. Once the sewage sludge is sufficiently dry, it can be incinerated for energy recovery or used as fertilizer in agriculture. ■



To find out more, visit:

www.watersolutions.basf.com

New discoveries

Inventiveness is in demand: Innovations make our everyday lives easier in a host of ways, and help improve sustainability. In this section, we present a selection of inspiring examples.

Magnetic cooling

The next generation of refrigerators and air conditioners will be even more environmentally friendly thanks to an innovative technology: magnetocaloric materials, which will one day replace conventional compressor technology. Compared to traditional appliances, this could reduce energy consumption by up to 50%, experts believe. Furthermore, the new appliances are quieter, do not vibrate and require no coolants that are harmful to the climate. They work using the principle of magnetic cooling. Magnetocaloric materials heat up in a magnetic field and cool down again when the magnetic field is removed. BASF is currently working with leading universities and partners around the world to develop the innovative materials and functional components for magnetic cooling. The technology should be ready to launch on the market in a few years.

www.basf-new-business.com/en/projects/magnetocalorics.html



Quenching thirst with saltwater

Eliodomestico, a solar-powered water distiller for coastal populations in the developing world, works like a coffee percolator turned upside down. Created by Italian designer Gabriele Diamanti, it is easy to use. The container on the top is filled with saltwater in the morning. By evening, the water has evaporated and condensed again into the container on the bottom, producing 5 liters of drinkable water. This novel water distiller made of inexpensive clay needs no electricity and should cost around \$50 (€38) – about half the price, but nearly 70% more effective than most existing models. Eliodomestico is an open-source project that allows anyone to build a copy of this saltwater treatment equipment.

www.gabrielediamanti.com/projects/eliodomestico



Slippery solution

Getting the last bit of sauce out of a bottle can be annoying. Even after leaving the bottle upside down for minutes, no amount of shaking or tapping can get the liquid out. This problem could soon be a thing of the past. Five students from the Massachusetts Institute of Technology (MIT) and their professor, Kripa Varanasi, Ph.D., have developed a gel-like surface coating called LiquiGlide. It could someday prevent everything – from ketchup in a bottle to ice on the wings of airplanes – from sticking to surfaces. The plant-based product consists of a microscopic slippery layer that can be applied to all kinds of material, including glass, ceramics, metal and plastics.

www.liquiglide.com



Robots eliminate desert dust

Ridha Azaiz was just 13 when he came up with an idea that he has not been able to get out of his head ever since. After reading that solar modules lose much of their efficiency when they get dirty, he tested and proved this theory on his balcony. He then set to work finding a solution to the problem: a cleaning robot. Now, at the age of 28, he has built his first functioning prototype, which moves over the slanted solar panels and cleans them with a brush, making them efficient again. Another output of his tinkering is Solarbrush, a company that Azaiz hopes will soon be selling its first robots to markets with sunny, but dusty desert climates.

solarbrush.de





Powered by play

Soccket is a ball – and a tiny power station. During a regular game of soccer, it generates and stores electricity. Just 15 minutes of playing are sufficient to power an LED lamp for 3 hours. Inside the ball, which is barely heavier than a standard leather soccer, there is a small pendulum that charges up a battery when it swings. Former U.S. President Bill Clinton was so impressed by this idea for regions without a regular electricity supply that he donated money for its development. According to the World Bank, 1.4 billion people have no access to an electricity grid and another 1.3 billion have no stable source of energy. Clinton was not the only one who supported the project: In March of this year, more than one thousand fans donated money online, raising more than \$92,000 (nearly €70,000). Now the start-up Uncharted Play plans to begin large-scale production of the ball.

us.soccket.org



Energy every step of the way

With the new Energy Boost running shoe, the impact energy of jogging is no longer wasted – it is sent back to the runner. As soon as the compression from the foot's impact is released, the foam of the shoe's midsole springs instantly back into shape. The energy expended in a footfall is thus largely returned to the athlete. This is made possible by a new technology developed by BASF and adidas, which enables athletes to move as if they were on cushioning foam capsules. It is based on Infinergy™, the world's first expanded thermoplastic polyurethane (E-TPU). To make it, BASF foams up TPU granules into highly elastic foam beads: 2,500 of these are then formed into a midsole, creating a novel cushioning and shock-absorbing system.





A tokay gecko can be up to 40 centimeters long – and yet it can cling easily to a smooth wall. This is possible because its feet are covered with adhesive pads measuring only a few nanometers which can nestle perfectly into any tiny niche of the surface.

Nanotechnology – a science under discussion

For many years, nanotechnology has been considered a science of unlimited possibilities. These tiny particles and structures enable materials with exceptional properties to be produced. They can, for example, help to make plastics both lighter and more stable, or to make high-gloss coatings scratch-proof. They can also be used to develop new medicines. But, at the same time, there is some doubt. Critics see a risk that nanoparticles will get into human cells or the environment – and warn that there has not yet been sufficient research into this technology.

There are big expectations for these new materials. The starting material, on the other hand, is extremely small. One nanometer is just one-millionth of a millimeter. In comparison: A human hair has a diameter of around 100,000 nanometers. Thus the origin of the word *nanos*, which is derived from the Greek word for dwarf.

Nanostructures are nothing new in nature. They give geckos and flies their ability to adhere to surfaces, provide the dazzling colors in a butterfly's wings and create the lotus flower's self-cleaning effect. People have also been utilizing the benefits of nanomaterials for a long time – even though they might not have known it. The glowing red color in church windows, for example, is created by gold nanoparticles.

Research on the synthetic production of nanoparticles has been conducted since the 20th century. The breakthrough was achieved in 1981 with the invention of the scanning tunneling microscope by physics Professor Dr. Gerd Binnig

and Dr. Heinrich Rohrer. This device enabled scientists to see individual nanostructures and understand nano-scale phenomena.

Proponents from the worlds of business and politics believe nanotechnology will be one of the strongest drivers of innovation that will help solve the challenges society faces in the future. Nanomaterials can filter water and make it potable again, they can reduce the exhaust emissions from cars and they can help fight cancer.

Yet there are concerns about some other applications. Experts do not consider products which contain nanostructures or bound nanoparticles, such as paints and coatings, to be problematic. However, sprays are a different story because they contain unbound nanoparticles. If these are inhaled, they could be harmful to health.

Professor Dr. Wolfgang M. Heckl, head of acatech, the topic network on nanotechnology of the German National Academy of Science and Engineering and Jurek Vengels, nano expert at BUND (Friends of the Earth Germany), discuss the pros and cons of nanotechnology.





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In almost every field, nanotechnology can make important contributions to solving society's problems.

Dr. Wolfgang M. Heckl, Professor of Science Communication at the Technical University of Munich and head of acatech, the topic network on nanotechnology of the German National Academy of Science and Engineering

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Dr. Wolfgang M. Heckl

is Professor of Science Communication at the Technical University of Munich (TUM). After obtaining his doctorate, the biophysicist worked in the IBM research group led by Nobel Prize winner Professor Dr. Gerd Binnig. One of the founding fathers of nanoscience, Binnig was a co-inventor of the scanning tunneling microscope, which – for the first time – allowed atoms to be seen, manipulated and researched. Since 2004, Heckl has also been Director General of the Deutsches Museum (German Museum) in Munich, where he established a permanent exhibit on nano- and biotechnology with an open research laboratory. He also made it into the Guinness Book of World Records for drilling the “world’s smallest hole” by writing an atomic bit. Heckl is head of acatech, the topic network on nanotechnology of the German National Academy of Science and Engineering and an advisor to the European Commission and German government on the field of nanotechnology.

Creating Chemistry: Professor Heckl, as Director General of the Deutsches Museum (German Museum) in Munich, you established a nano department there. But this technology is still very new – did it not have to prove its importance to society before being given such an honor?

Professor Dr. Wolfgang M. Heckl: In almost every field, nanotechnology can make important contributions to solving society’s problems – everything from global nutrition to recycling scarce raw materials like the rare earth metals. And nanotechnology is already found in many products. You can be quite sure that all of the components of a smartphone are ultimately based on an understanding of material at a nano-scale; in other words, matter with a size of between 1 and 100 nanometers. Or consider affordable sunscreen with a sun protection factor of 50+. This breakthrough was made possible by nano-scale titanium dioxide.

What is your motivation for trying to help people gain a better understanding of nanotechnology?

A new technology that is so complex and challenging always needs someone to act as an intermediary with society. In particular, we have to get young people excited about it so that the scientific and technological illiteracy in our country does not continue to grow! This is why we have set up open research laboratories in our Center for New Technologies in Munich. They are a place where young people can watch my students at work and ask them: ‘Hey, what are you doing there? What are the opportunities? What are the risks?’ The idea behind this is they don’t just get to know the science, they also get to know the scientists.

Supporters of nanotechnology often like to describe it as some sort of magic formula for the future. Is it really?

I would be very cautious using such terms. Throughout history, people have always tried to present new technologies as something magical. But nature is complicated and every little advance requires great

effort. There is no road map that shows where discoveries will lead some day. But if we don’t take part in innovations, we will miss out on an enormous opportunity.

You have described nanotechnology as a cross-sectional technology. What does that mean?

Understanding the composition of matter is the foundation of every type of materials science. And nanomaterials science, in turn, is the foundation for a number of research areas – from nanoelectronics to nanomedicine.

Which nanotechnology applications do you believe have the greatest potential?

Real innovations are always targeted at where the demand is greatest. What does mankind want? Health! This is a huge issue in an aging society. However, we still do not understand the causes of 70% of all known illnesses and therefore we are unable to treat them. There is an incredible need to catch up, to understand the molecular processes that lead to illnesses such as Alzheimer’s disease or cancer. And nanomaterials are already being developed that can transport cancer medication directly to where it needs to take effect.

After the initial excitement about nanotechnology, it seems some disillusionment is now setting in. The materials have turned out to be expensive and the development of applications is taking longer than expected.

How do you respond to this?

Nanotechnology is a technology of the future; in some areas it will create breakthroughs, in other areas it will prove to be a dead end. And the excitement is definitely still there. One hundred years ago, nano was just a theoretical physics concept. Today, we are finally able to find practical applications for this concept. Being able to see and actually work with molecules and atoms has created incredible impetus.

How important is nanotechnology for the economy?

It is critical to survival. And if we want to stay on the ball, we will have to

tough it out through phases where not everything succeeds quickly. I can’t imagine, for example, that we will be able to abandon nuclear energy without the scientists who are active in both fundamental research as well as in the industrial applications of nanotechnology.

Nanotechnology can be controversial and there is a lot of talk about the risks. How do you address this?

In many cases, there is simply a lot of talk based on unquestioned fear. As far as I know, there has been no serious incident causing harm to human health which can be attributed to nanotechnology products. Just by sitting around a campfire, you are already breathing in a lot of harmful nanoparticles. We always need to weigh the risks and opportunities. From a philosophical-ethical perspective, someone might say we have to evaluate everything first and make sure it is watertight. But someone closer to the issue – a person who has a relative with a brain tumor, for example – will be happy if there are people working on nanoparticle cancer therapy. This person might be willing to accept greater risk.

Could nanotechnology become a conflict-laden issue, as genetic technology did?

I believe we have done things much better here than with genetic technology. For example, we got humanities scholars involved at a very early stage. And we established a dialog on opportunities and risks through the NanoCare initiative supported by the German Federal Ministry of Education and Research, which enables people to talk to researchers and developers. We will be on the right path if, instead of taking a top-down approach to helping people and deciding for them, we invite them to take part as much as possible in the decision-making process. ■



To find out more, visit:

www.deutsches-museum.de/en
www.nano-science.de

Creating Chemistry:

Mr. Vengels, nanotechnology is considered a promising technology of the future. It is already providing benefits, for example, in membranes for water treatment and in cancer therapy. Yet you warn that caution is necessary. Why?

Jurek Vengels: At BUND, we do see many opportunities in nanotechnology – but also risks. Many questions simply haven't been answered yet: What effect do nanoparticles have in the environment? And what might they do to the human body? That is why we advocate first investigating these risks and then determining which materials we can use safely and what we might have to avoid using.

Not all nano products are the same. Are there any applications that you are particularly concerned about?

In my view, it is especially problematic when unbound nanomaterials are used because these can then get into the environment, or people can come into direct contact with them. In food, textiles and cosmetics, for example, nanomaterial could be absorbed by the body and we simply don't know enough about this. We are also worried about particular nanomaterials, such as certain kinds of carbon nanotubes. When these are inhaled, they can have the same effect as asbestos in the lungs: They can cause inflammatory reactions and eventually lead to the development of tumors.

Why is BUND, an environmental organization, interested in nanotechnology?

We believe that this is an important technology with a lot of potential. And we also hope that 'nano' will bring advances in environmental technologies. There are definitely some interesting applications in wind and solar energy which can create improvements – although much of what is advertised has not yet been realized. It is certainly a technology that we will be coming into contact with more frequently – both humans and the environment in general. As such, it is an important issue that the environmental movement should address. We are, of course, very

interested in the issue of releasing it into the environment – what consequences will that have? For example, one of our particular worries is that nanosilver in sewage sludge will be spread on fields, returning it to the food chain and eventually into human bodies.

But in Germany, waste and wastewater are properly treated and disposed of, aren't they?

With nanosilver, there is the fear – especially with regard to wastewater treatment facilities – that this substance, similarly to traditional silver, could harm the microorganisms that keep the water in the plant clean. This could possibly prevent the wastewater treatment plant from functioning properly and thus disable the environmental protection mechanisms. Studies show that nanosilver is generally harmful to aquatic organisms. So we say: 'Wait a minute!' We need to proceed cautiously. Especially because the use of nanosilver is very widespread. It is added, for example, to detergents or clothing to prevent odors and can be released into the environment when the clothes are washed.

How much do we really know – apart from some specific examples – about the negative effects of nanotechnology on humans and the environment?

The terrifying thing is that we know so little. Recently published preliminary findings from a research project by a high German federal authority found that much work is being done on the fundamentals of analysis and that there are barely any concrete results. Unfortunately, when it comes to nanotechnology, we have been hearing for years that there will soon be good methods to evaluate the particles, but there never really seems to be any progress.

Why, in your opinion, does safety research lag so far behind the technological development?

The majority of public funding for nanotechnology flows into development, while only about 5% is directed to risk research. So there is always a gap between what the industry is bringing onto the market and the knowledge about what these

materials are doing to us and the environment. We are therefore calling for the share of funding spent on risk research to be increased to between 10% and 15%.

What do you expect from the companies that use nanotechnology to develop their products?

They should test their products very well for potential risks if they are using nanomaterial. There are companies that are already carrying out very extensive testing, while others perhaps do not make quite as much of an effort. The companies that test insufficiently or not at all could cause a crisis if they use a material that turns out to be problematic – this would then also discredit the entire industry. It should therefore really be in companies' best interest to have better regulations on nanomaterial.

What form could regulations take that would reconcile safety for humans and the environment with technological progress?

We are calling for a general labeling requirement for nanomaterials in consumer applications and a registry that lists these applications. It should also contain more in-depth information, such as: What purpose does the nanomaterial serve in the product? What effect can it have? Where are there possible gaps in the research? This would allow me as a consumer to find out more and make an informed choice. From mid-2013, there is an E.U.-wide labeling requirement for nanoparticles in cosmetics and this will apply for food as well from the end of 2014. But we consider this too slow, so we have decided to take action ourselves. BUND has created an online database for nanoproducts. Our goal is to create basic transparency so consumers can know what they are buying. ■

Jurek Vengels

studied political science and international relations in Berlin and Freiburg, Germany, and in Bucharest, Romania. Since 2007, he has been a research associate in the chemicals policy and nanotechnology project at BUND (Friends of the Earth Germany). As an author and co-author, he has been involved with many BUND publications, including *From the Lab to the Dinner Plate: The Use of Nanotechnology in the Food Sector* ("Aus dem Labor auf den Teller – Die Nutzung der Nanotechnologie im Lebensmittelsektor") and *Nanosilver: More and More Everyday Applications Despite Unknown Risks* ("Nanosilber – immer mehr Alltagsanwendungen trotz ungeklärter Risiken").



To find out more, visit:
www.bund.net

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In my view, it is especially problematic when unbound nanomaterials are used because these can then get into the environment, or people can come into direct contact with them.

Jurek Vengels, a research associate in the chemicals policy and nanotechnology project at BUND (Friends of the Earth Germany)

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A powerful driver of innovation

Nanotechnology is not a magic formula, it is simply a tool that offers us enormous opportunities. We use it to develop materials that have structures, particles, fibers or platelets whose size is measured in nanometers.

At the same time, nanotechnology is a powerful driver of innovation in research and development because it helps us work on finding solutions in areas such as climate protection, mobility, medicine and energy. We need it to answer the questions that will be even more relevant in the future: How can we provide clean water to a growing population? How will we meet the constantly increasing demand for energy? How can we achieve the best environmentally friendly design for rising transportation volumes and individual mobility? It will take more than gradual product improvements or yesterday's approaches to find answers to these questions. We need new technologies that open up new perspectives.

One example: These days, we use about 20% of electrical energy worldwide to power various light sources. By using organic light-emitting diodes (OLEDs), this energy consumption could be reduced by more than 30% in the future. These OLEDs comprise a thin layer made up of several organic semiconductors which is about 100 nanometers thick,

embedded between a transparent anode and a cathode. When an electric current is applied, the nanofilm glows. Our research goal is to develop material for lighting that consumes 50% less energy than today's energy-saving light bulbs.

Nanotechnology also has great advantages when it comes to water treatment. Plastic membranes made of Ultrason® have small pores, just 20 nanometers across, which filter out germs, bacteria and even viruses from water. This ultrafiltration technology is used to purify drinking water and process water as well as to manufacture products from surface water, groundwater and spring water.

Acceptance will be absolutely key if we want to be able to use nanotechnology in the future as well. In order to achieve acceptance, we have to be open and provide understandable information, engage in discussion, address concerns and find scientifically sound solutions on which there is consensus. In this regard, BASF relies on dialog. We are the first – and so far only – company in Germany to have started a regularly occurring forum. At the Nano Dialog Forum,



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In order to achieve acceptance, we have to be open and provide understandable information, engage in discussion, address concerns and find scientifically sound solutions on which there is consensus.

Dr. Andreas Kreimeyer, member of the Board of Executive Directors of BASF SE and Research Executive Director

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Dr. Andreas Kreimeyer

has been a member of the Board of Executive Directors of BASF SE since 2003. He is Research Executive Director and responsible for the divisions Crop Protection and Coatings, the region South America, Biological and Effect Systems Research, BASF Plant Science and BASF New Business. Kreimeyer holds a doctorate in biology and began working at BASF in 1986. Prior to joining the Board of Executive Directors, his positions at the company included heading up the fertilizer, dispersions and functional polymers divisions. From 1995 until 1998, he worked for BASF in Singapore.

established in 2008, we meet with representatives from environmental and consumer organizations, unions, academic institutes and churches in order to discuss current political and social developments and issues. This dialog has been a very good experience for us so far. It helps us to better understand concerns and reservations about nanotechnology, which ultimately allows us to respond better to them.

Germany is at the forefront of nanotechnology worldwide and is the leader in Europe. To ensure this remains the case, we need a political and social environment that welcomes innovation. Industry will have to continue to do its part, but politicians must also play a role. Our political leaders now have to set the course and regulate the use of nanomaterials in a way that allows us to take advantage of the enormous opportunities offered by this technology. After all, a technology is intrinsically neutral, neither good nor bad. The important thing is that the application of this technology and the resulting products be managed responsibly.

We take on this responsibility. This is true for products that contain nanomaterials, just as it is for all other BASF products. That is why we have already been conducting extensive safety research on nanotechnology for many years and we are participating in external studies, as well. One such example is a project in which Germany's Federal Environment Ministry, the Federal Institute for Occupational Safety and Health and BASF are jointly researching the long-term effects of nanoparticles. Thanks to this safety research, we are able to recognize potential risks and develop safe products and applications, thus preventing risks from turning into hazards.

As a large industrial company, we have considerable responsibilities: for the safety of our products, to our employees and to society. I also see it as our responsibility to take advantage of the opportunities that arise for society from new technologies. Only if this is possible will we be able to maintain our future success. ■

Above Crystalline nanostructures, known as metal organic frameworks (MOFs), should significantly extend the range of natural gas-powered vehicles.



To find out more, visit:

www.nanotechnology.basf.com



Making a career through life-long learning

Businesses today operate in a rapidly changing political, technological and economic environment. In addition to globalization and the digital revolution, changing demographics are also creating challenges for companies everywhere: With an aging workforce in the West and a burgeoning new generation bringing to bear its own attitudes and expectations around the world, employee training and development are increasingly gaining in strategic importance for companies.

“When the outside world changes, organizations must change or die.” This is the stark warning from Dr. Dave Ulrich, Professor at the Ross School of Business at the University of Michigan and a partner at the RBL Group. “When social, political, economic and demographic trends change, so too do the expectations of customers, investors, suppliers and regulators.” And so too do the expectations of the people who work for those businesses. For companies, managing these changes is vital to survival.

In the industrialized West, businesses are having to face up to the challenge of an aging population. Lower birth rates have produced a younger generation that is significantly smaller than its predecessors. Added to this, the legal retirement age in many Western countries is increasing and older people are remaining fitter for longer. The impact on the world of work is clear. In the future there will be a higher proportion of older employees at work. By 2017, around 60% of the workforce will be over the age of 50 and working into your late 60s and 70s will become the norm.

Businesses and individuals alike need to prepare for this change now because technological and other societal changes mean that no job will stay the same for long. In many countries, today’s 40-year-old has almost 30 years left until reaching

the legal retirement age. Companies have to ensure that the skills of all their employees keep up with these changes.

“As the half-life of knowledge gets shorter, individual ability and the capability of organizations have to adapt more quickly,” explains Ulrich. “In the past, organizations succeeded as a result of role clarity and predictability. Now, organizations succeed with adaptability and innovation.” His recommendation? Employee learning – because learning creates individual ability and capability of organizations and enables both to adapt to changing conditions.

Life-long learning

How do 40, 50 and 60-year-olds learn best? This has become a focus of much attention in the West. The common perception is that the older we get, the less readily we learn new skills. Yet research shows that this does not have to be the case. People who continue the learning habit throughout their lives remain just as capable of learning in old age as they were when they were younger. It is therefore in everyone’s interest to keep learning. The longer we keep learning, the longer we will have the mental agility to learn new skills.

The idea of “life-long learning,” which has been around for decades, is now becoming widely recognized as a commercial necessity for companies managing an aging workforce. The traditional view that training is only for new recruits and

young management hopefuls is disappearing. “Companies are only just starting to understand that it’s one thing to retain an employee and it’s another thing to develop that person. Not only in the typical vertical way: You also have to develop people along a lateral career path, to find new activities over and over again,” says Professor Dr. Ursula M. Staudinger, an expert on lifespan development and aging, and founding director of a new Aging Center at Columbia University in New York. Training is no longer just about climbing the corporate ladder, it is about ensuring the whole workforce is in shape to master future challenges (see interview on page 39).

An individual approach

But traditional training programs aimed at new recruits simply do not fulfill today’s requirements. A different approach is necessary. Training needs to be designed to be of value and relevance to each individual, taking into account their particular circumstances. So training has to become more individual, but it also has to become a shared responsibility. It is no longer good enough to sit back and wait for your superior to send you to a course. We all have to wake up to the need to continue learning and keeping our skills relevant if we do not want to be left by the wayside.

This can have other benefits as well. Look at what happened when the Hong Kong-based airline Cathay Pacific changed its approach >>

Will the supply of educated workers meet demand in 2021?

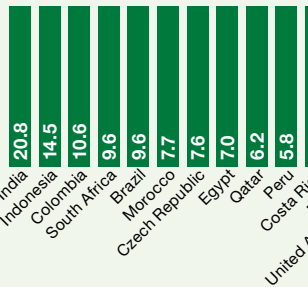
Over the next decade, as access to higher education improves in fast developing economies, the pool of educated people available for work will increase dramatically. In developed economies, by contrast, lower birth rates mean growth will be slower or even grind to a halt.

Will there be enough job opportunities in countries with a large number of qualified young people? Which countries will experience shortages and where will supply and demand be in balance?

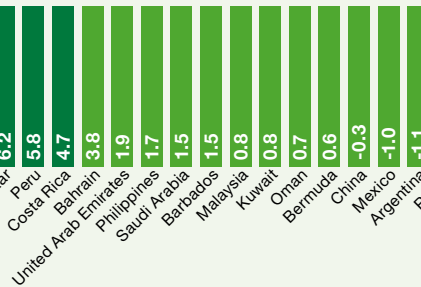
The chart shows how the gap between supply and demand is expected to evolve in different

countries over the next decade. A surplus is shown in dark green and a deficit in light green. The middle of the graphic shows the countries with a broad balance. The numbers report the average annual percentage change of the deficit or surplus.

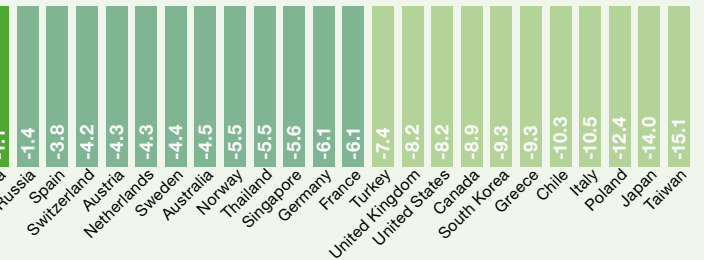
Strongest trend talent surplus



Demand and supply for talent in balance



Strongest trend talent deficit



Source: Oxford Economics, *Global Talent 2021, 2012*.

to training. The airline's business success is based on customer retention and its motto is "Service straight from the heart." But it found that its old approach to training and development was promoting a culture of compliance, rather than one of commitment. Cathay Pacific decided to encourage its employees to take responsibility for their own performance and plan their own development. In discussion with their managers, employees began to assess how they were doing, consider what they could do better and set their own goals. Together, they developed their own personal plan for achieving those goals. The company found that when people take responsibility for their own success, they not only get more satisfaction from their work, it also increases their commitment toward their company.

Learning from experience

Of course it is not just age that differentiates people – they have different learning styles and requirements. In order to meet the individual training needs of each employee, we can no longer think of training as just attending seminars.

Standardized offerings have to be supplemented by a whole array of training tools. Companies are providing a wider range of options from job rotation and job shadowing to coaching and e-learning.

Increasingly, companies are realizing that development means benefiting from one's own and others' experience and applying the knowledge daily in a practical and profitable manner. HR professionals talk about the 70:20:10 learning formula. This describes the split between different types of learning, whereby 70% of what you learn is from your own experience at work because this is the best way to learn, 20% is learned from those around you, and only 10% is from formal training.

At the BASF Leadership Experience Center established this year in Ludwigshafen, Germany, the company offers managers the opportunity to work together as teams to improve collaboration and develop a common management understanding. An essential aspect is that the team members bring their own questions or challenges with them from their business units. The one-day workshop is not so

Training around the world*

Cultural and traditional differences mean that approaches to employee training and development differ from country to country.

China

The country's authoritarian and hierarchical tradition meant, in the past, that employee empowerment and participation were not so readily accepted. Employee loyalty was also rather low. But as market reforms and global competition take hold, the need for training has increased. The strong reciprocal culture means that companies that offer training and development receive increased commitment from their employees.

India

India is fast picking up best practices from the foreign companies outsourcing there. Companies now invest substantial time and money to train new recruits. Employees participate in a wide range of education programs, including not only technical training but also soft skills and management skills. Career advancement and salary increases are usually tied to the completion of such training.

Mexico

Increased levels of training are often driven by international investors requiring consistency across their operations. A major focus has been skill development for lower-level employees. As young people often lack the resources to fund their own further education and typically start contributing to their family's income relatively early, company training and development is seen as an important stepping stone to a better future.

Germany

Vocational training has long been highly valued by employers and employees alike. Job-specific technical training has a strong tradition in many industries in Germany, with trainees following a dual system of formal and on-the-job training. Although further training opportunities tended in the past to be restricted to conventional courses for potential managers, this attitude is now changing.

much about knowledge transfer as about learning from experience and from others.

Job-sharing and mentoring schemes are also growing in popularity. New employees learn quickly and effectively in this kind of exchange with their colleagues. At Mars, the food company behind brands such as Mars® chocolate bars and Whiskas® pet food, employees are offered a range of opportunities for growth and advancement.

"Mentoring is an important part of our culture," explains André Martin, Chief Learning Officer at Mars. As a highly decentralized company, building good relationships is essential.

New "associates" receive mentoring as a way of introducing them to the corporate culture. It is also part of the training for high-potential associates. Mars puts great emphasis on ensuring that senior leaders who volunteer to be mentors are given the right tools and knowledge to be good mentors. "Mentoring is not the same as coaching. Mentoring is about sharing stories. It is a relationship fundamentally driven by the mentee," says Martin.

Among the diverse business units at Mars, mentoring is used in different ways. One of the U.S. business units, for example, introduced peer-to-peer mentoring among women, as part of its focus on diversity, to help build networks among like-minded people at a similar place in their careers. "There is no vanity around learning at Mars," says Martin. "It is part of our culture of mutuality." At another U.S. business unit, the management team was mentored by the younger generation and introduced to the use of social media. "It is all part of understanding what the world looks like through the eyes of the next generation so we can begin creating organizations that will be attractive to them," says Martin.

Let's focus now on these younger employees – the people in their 20s and 30s. The generation born

between 1981 and 2000, labeled by demographers as "Generation Y", is the first truly digital generation – a generation of young people who have grown up with computers, the internet and social media. They are well educated, tech-savvy, and they know a lot about the world around them. They want a workplace that offers inspiration and responsibility and high on their list of priorities is career development and training. But what is important about this generation is not only the different attitudes and expectations, but also the fact that their numbers vary from country to country.

A generation in demand

In the aging West, they form a smaller cohort than the preceding generations. In Germany, the problem is very clear: Whereas today there are 9.7 million Germans between the ages of 20 and 30, by 2030 there will only be 7.5 million. In rapidly developing regions like Asia, the demographic picture is very different and the number of educated young people is growing rapidly. According to Oxford Economics, already more than half of the world's college graduates (54%) come from the top emerging markets – China, India, Indonesia, Brazil, Mexico, Russia and Turkey (the "E7"). Over the next decade, this percentage is predicted to rise to 60% – that's around 217 million college graduates, as opposed to 143 million in the developed world. It is, of course, not just the higher birthrates in these countries that are helping them overtake the West; equally essential is the combination of accelerating economic growth and technology-enabled training.

The question is whether the supply of these young, educated people meets demand. The situation is not the same everywhere. In parts of the West, there are fewer of these young people than there are job opportunities. And they know >>

Three questions for Professor Dr. Ursula M. Staudinger



Professor Dr. Ursula M. Staudinger is an academic leader in the field of lifespan development and aging research. This year she joined the Mailman School of Public Health as the founding director of a new Aging Center at Columbia University in New York. Previously she was Vice President of Jacobs University in Bremen, Germany, and Founding Dean of the Jacobs Center on Lifelong Learning.

Creating Chemistry: How does our potential to develop and learn change throughout our lives?

Professor Dr. Ursula M.

Staudinger: When we are very little, we know nothing and we are absolutely motivated to take in everything that is around us. By early adulthood, we have mastered the basic cultural skills that we need to survive – and that influences our motivation. Cognition and learning are based on cognitive resources but they are also carried along by the fuel that comes from motivation. Cognitive resources decline with age but the rate of decline differs tremendously depending on lifestyle and contextual factors. So the older we get, the more important it is that we realize why we have to learn. We have to construct society so that people find rewards that make them expend effort on learning across the lifespan.

What can companies do to create a working environment that encourages employees' learning and development?

Companies need to show new recruits, at all levels of qualification, that there is a long-term career pathway they can take and that training and development opportunities will be provided along the way. It is pivotal that employees do not work too long in one position. Timely activity changes are the key

“Companies that provide continued development for their employees will be the winners in the competition for the best brains.”

to maintaining productivity and job satisfaction. Companies have to invest in developing such varied work biographies together with their employees. But this investment will pay off as, according to the latest United Nations predictions, the world population will level off by 2050 and decline thereafter. Companies that provide continued development for their employees will be the winners in the competition for the best brains and hands. This is a fundamental paradigm shift. It's a revolution.

What kind of advantages do you see in mixed teams consisting of people with different experiences, backgrounds and ages?

There was a study some years ago in Denmark of a representative sample of companies relating their profit in a given year to the age composition of the employees of that company. The study found that the most profitable companies were those that had an equal number of employees in every age range. This tells you something about the advantage of age diversity at a macro-level. But diversity is a tricky business – there are no easy answers. At the micro-level, we need to look at the task to be managed by a given team, then we can decide whether age diversity will be helpful or not. If speed is an important part of the task, age mix is not a good idea. Whereas if sustainable creativity is what is required, bringing older and younger engineers together has been demonstrated to be very profitable. On a meso-level, companies need to talk about and make visible the strengths of all age groups. At the same time, work has to be organized in such a way that the weaknesses of different age groups are compensated. If you want to maintain productivity in a workforce encompassing a range of ages, you have to make sure that every age counts.

* Sources:

Ellen A. Drost et al., *Benchmarking Training and Development Practices: A Multi-Country Comparative Analysis*, 2002.

Vivek Wadhwa, *India's Workforce Revolution*, The Wall Street Journal, July 23, 2008.

Vinod Mishra / Russell Smyth, *High Performance Work Practices and Workplace Training in China: Evidence from Matched Employee-Employer Data*, 2012.

German Federal Institute for Vocational Education and Training (BIBB), *Continuing Education and Training in Germany* ("Berufliche Weiterbildung in Deutschland"), August 1, 2007.

they have a competitive advantage. In strong economies, companies wishing to attract them face fierce competition and therefore have no choice but to take seriously their values and attitudes.

The emerging economies, meanwhile, are booming as businesses increasingly choose to base themselves in these countries. Demand for young graduates is therefore also growing. As a result, surveys predict that future demand for young talent is likely to grow fastest in Asia, by more than 20% over the next ten years. But the rate of growth of demand and supply is not the same everywhere (see graphic on page 38).

In China, increasing numbers of graduates are met by increasing numbers of job opportunities. This young generation is faced with a world of choice unlike anything their predecessors knew. Many businesses are facing the problem of job-hopping, with younger employees simply moving on to a new job as soon as something does not suit them. For a well-educated graduate it is easy to do – the opportunities are there. To stem the problem, companies have to work hard to prove they can offer their young workforce an exciting career path with real learning and development possibilities.

In India, by contrast, although companies are increasingly looking to the subcontinent to set up business there, the fast expanding pool of skilled and educated young people still outweighs the opportunities. As a result, competition among young Indians for jobs at multinational

companies is intense. This can lead to problems of its own and highlights the need for a regionalized approach to employee development and learning, as Philipp von Sahr, President of the BMW Group in India found out.

The work-life balance

BMW has around 650 employees across India. When von Sahr first took over at the BMW office in Delhi he was impressed by the level of dedication and stamina shown by his employees. Many of them stayed working in the office late into the night. "With the average age at 30, we have a lot of young managers in the company who are highly motivated and want to excel at their work. They are self-driven and put in additional effort and work hours over and above what is expected," he explains.

But von Sahr came to realize that the long hours were having a detrimental effect on their creativity and decision-making. His ambitious and hard-working staff were putting BMW before everything else – even before their own health. The company therefore introduced a range of initiatives to encourage employees to put their health and families first, followed by BMW, so that they could be fit to meet the daily challenges of a globally competitive business on a sustainable basis. "The leadership team at BMW India places high importance on maintaining a work-life balance. We believe that if employees are healthy, they will perform better – this is true for every organization," says von Sahr. "We make a

conscious effort so employees can leave work on time and are able to have a life outside of office hours."

The idea of work-life balance – like the idea of life-long learning – has been around for many years. What is interesting about this example is that it shows that today's competitive pressures mean there is no choice but to address this issue and to take it seriously.

That's why BASF is establishing its Center for Work-Life Management in Ludwigshafen. The center provides all BASF employees a range of offerings relating to family and career, fitness and health, as well as social and care counseling. It aims to meet employees' needs in all their different phases of life, allowing them to bring the demands from the private and professional sides of their life into balance.

Staying fit for life

With older people staying in the workforce longer, staying healthy is good not just for the individual, but also for the company. People who are physically healthy will be able to continue learning and developing through every stage of life and into ripe old age.

Training is no longer just about skills acquisition for younger employees – it is now a life-long pursuit that empowers the individual. It also creates a workforce that, whatever their age, has the agility and creativity to keep the business ahead in today's highly competitive global economy. For all of us around the world, in whatever profession, the message is: never stop learning. ■

“We believe that if employees are healthy, they will perform better – this is true for every organization.”

Philipp von Sahr,
President of the BMW Group in India

Employee development is key to success

"It is only as we develop others that we permanently succeed." This was recognized by Harvey Samuel Firestone, who founded the U.S. tire company Firestone in 1900, and is still true today. Demographic change, increasing global competition and technological progress mean that employees and companies have to be forward-looking and adaptable. In order to meet these ongoing challenges, BASF has gradually been introducing a standardized global concept for

employee development over the past two years. The extraordinary thing about this concept is that it includes more than 110,000 BASF employees. By 2017, all employees will have agreed on development measures with their supervisors. Employee development is thus a major priority for managers. Supervisors advise and support employees, who evaluate their own skills and interests and actively contribute ideas about their own development. The aim of employee development at BASF

is a flexible, highly qualified and motivated team that will increase the competitiveness of the company in the long term. "Our concept enables us to take an individualized approach to development that considers the various stages of life," explains Anke Schmidt, head of the project Employee Development BASF Group. "At the same time, our business units in all regions are able to effectively incorporate their demand for specific skills early on."



Left Employees of BASF.

Right Dr. Wolfgang Hapke, President of Human Resources at BASF.



Dr. Wolfgang Hapke has been head of the Human Resources Competence Center of the BASF Group since March 2013 and is responsible for BASF's personnel work worldwide. During his career, he has worked in the United States and Hong Kong, where he was responsible for BASF's division Market and Business Development, Asia Pacific.

“Employees want a total package”

Dr. Wolfgang Hapke is President of Human Resources at BASF. Here he talks about trends in human resources. His view: Life-long learning makes us – both companies and employees – more successful.

Creating Chemistry: Before becoming head of Human Resources, you were responsible for BASF's engineering plastics business. Where do you see the biggest challenges in your new position?

Dr. Wolfgang Hapke: For me, it is the responsibility of reconciling the ambitions and expectations of more than 110,000 employees with social influences and the needs of our business units. From my own experience, I know how important it is for human resources and operating divisions to work closely together. I see my task as ensuring that new demands from the operations side of our business are implemented quickly in our personnel activities. This enables us to support our employees in their day-to-day work. And by the same token, we try to recognize human resources trends at an early stage and integrate these in our work. This allows us to offer good service to the business units in the long term. The two most important trends, in my opinion, are employee development and life-long learning.

You have spent several years working in the United States and in Hong Kong. Have you noticed any differences in professional development and learning?

People are different in different regions – and yet they have much in common. The need to constantly

develop and improve our skills is something we all share. However, there are significant differences between us in terms of how we learn, how quickly we learn and what we learn. For example, take a look at Asia's emerging markets: People there have a very strong desire to catch up to the West as quickly as possible, so they are incredibly keen and willing to learn. People in China are mainly interested in the technology of the future. Almost nobody there is familiar with the old-style tube televisions, for example, but they do know all about the latest technologies. In relation to human resources work, this means that we need to find the right way to integrate important global topics and implement them in the environment specific to each culture and country.

Could you give us an example? How does an international company combine regional and global aspects in its personnel strategy?

BASF has a global strategy. Based on this, we have developed our Best Team Strategy. It sets out the most important human resources topics for the coming years: excellent people, an excellent place to work and excellent leaders. This will improve our leadership culture. That is our global framework. There are some topics at BASF where we want a uniform approach across the

Group. Leadership, for example, is one of them: In a global competency model, we describe the behaviors that we expect from our employees and managers. For other topics, the local companies can fill in the details of the framework. In other words: We want to provide attractive offerings for our employees worldwide, including compensation, benefits and a working environment that is oriented towards the employees' stages of life and focuses on their personal development. Every company then tailors these offerings to the locally prevailing conditions.

Why, in your opinion, does life-long learning play such a key role?

People who continue learning throughout their lives are simply more successful. The same is true for companies. For us, it is important to be prepared for constant change and keep our employees fit. This is why we offer learning opportunities to employees – throughout their entire career. We are also introducing a new global concept for employee development. The key to this concept is that employees and managers share responsibility for the individual development steps and measures. Employees who help shape their own personal development are more motivated and better performers. Our Learning Campus demonstrates how we implement our life-long learning

offerings at BASF. It is a learning platform that combines global opportunities for further training with regional offers, enabling employees to create their very own personalized learning program. In this way, we support their personal and career development. At the same time, we are doing something beneficial for our business because we have integrated the goals of our corporate strategy into the learning programs. This helps us prepare our employees for the challenges they will face in ten or 20 years' time.

What does a company have to offer its employees these days?

Money alone is certainly not sufficient. Employees today want a compelling total package: interesting responsibilities, personal development and a work environment that is both flexible and stable. Furthermore, we are finding it is becoming more important to achieve better work-life management. At our largest site in Ludwigshafen, Germany, we are currently building a new Center for Work-Life Management – including a day care center, social counseling and a fitness studio, all under one roof. But there is more to work-life management as well, for example, flexible working hours and a management culture that allows that. As you can see, life-long learning is also essential in human resources work. ■

A glimpse around the globe: colors

They can create moods, symbolize tradition or stand for new technologies – colors really grab our attention. Our glimpse around the globe features colorful phenomena from around the world and explains what is behind them.

True blue

Blue is the color of many gods – and the color of jeans. In 2013, the pants made of blue denim are celebrating their 140th birthday. Blue jeans were patented by textile merchant Levi Strauss and tailor Jacob Davis on May 20, 1873. Their characteristic blue color comes from indigo dye, which was first synthesized by BASF in 1897.

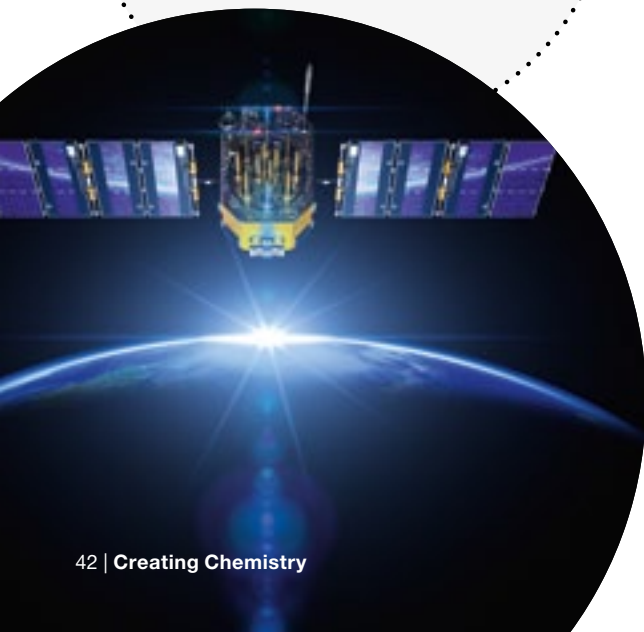


Pink prisons

Color therapy is going behind bars. The first prisons in Germany, Switzerland and the United States have started painting the cells of especially aggressive inmates pink. Why? According to the theory that colors can have a psychological effect on people, pink is believed to be calming.

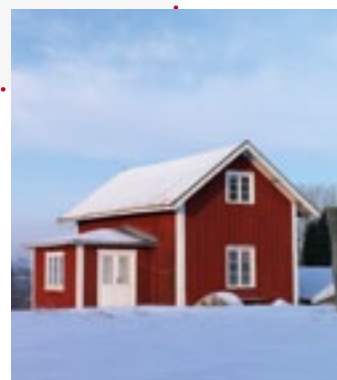
Super black blocker

It does not get much blacker than this: The U.S. space agency NASA has developed a 'super black' which can be used, for example, to block stray light in satellite instruments. This coating made of nanomaterial can absorb up to 99% of infrared, ultraviolet and visible light. Miniscule gaps between the carbon nanotubes capture stray light and prevent it from reflecting off surfaces.



Paint the town red

It is a very popular color for houses in the Nordic countries: This copper-based red, once a waste product from a copper mine in the Swedish town of Falun, was found to be a good and inexpensive coating for wood. Today, most wooden houses in Sweden and its northern neighbors are painted in *faluröd*, or Falu red. Not only is the color symbolic of a Scandinavian idyll, it also serves to preserve the wood.





A glimpse of brown

What is the most common eye color in the world? Brown! Originally, all humans had brown eyes. Today, around 90% of the world's population still does. But not in the area around the Baltic Sea: In Estonia, for example, the vast majority of people have blue eyes.



Green means go!

Bright, leafy green and elegant, dark green will be the car colors of the future, according to BASF's global design team. These shades reflect a spirit of optimism and society's changing values, the designers believe. Green provides a colorful counterweight to the increasingly technological and virtual world we live in today.

Red, yellow and green unite

The pan-African colors are red, yellow and green. They are used in 16 national flags in Africa and express the political unity among these nations. The meaning of the colors varies from country to country. In Guinea, for example, red symbolizes the sacrifice for liberation, yellow stands for the sun as well as the riches of the earth and green for the country's vegetation.



White facade

Pierrot, France's sad clown, wears a white costume and his face is painted like a mask. The color white emphasizes his facial expressions, strengthens the effect of his pantomime and underscores his melancholy.




Orange enlightenment

In Buddhist countries, orange is often associated with the robes of the Shaolin monks. Their robes, known as kasaya, were originally sewn together from patches of material dyed with saffron and turmeric, which gave them their color. To this day, the color stands for wisdom, maturity and the highest level of human understanding.







Young goat herders in South Sudan drink dam water through a filtration pipe that protects them from Guinea worm. The pipe was provided by The Carter Center as part of its efforts to eradicate Guinea worm disease.

Shining a light on hidden diseases

There is a group of diseases that have plagued humanity for centuries and which today blight the lives of a billion people in 149 countries worldwide. The impact on individuals and communities is immense and yet, until recently, they attracted little attention – and little was done to combat them. That has changed over the past few decades. Efforts are now beginning to show results. But the battle is not yet won.

The Guinea worm is a parasite that has tormented human beings since ancient times. One has even been found, calcified, in an Egyptian mummy. Today, people continue to catch the disease by drinking straight from ponds or other water sources that are infested with minuscule fleas. These fleas have eaten Guinea worm larvae which can penetrate the human intestinal wall. A female larva, having mated with the male, grows in the human body into a meter-long worm that mines through the subcutaneous tissue. Usually heading down to the person's feet, the worm exudes acid to form a blister and breaks through the skin. Its emergence is excruciatingly slow.

Winding the worm round a stick, daily, is all that can be done to hasten recovery. A patient can be incapacitated for weeks. Children miss school. Adults cannot farm their crops. Worse, to soothe the burning pain, sufferers are drawn to bathe in the local water source, whereupon the worm immediately releases thousands of larvae, perpetuating the cycle.

Largely hidden

Guinea worm disease is one of a group of diverse diseases known as neglected tropical diseases (NTDs). NTDs flourish mainly in impoverished environments, particularly in tropical areas. Although they do not cause the same numbers of deaths as tuberculosis or malaria, for example, they not only devastate individual lives, but also damage whole communities and, indeed, national economies by locking so many citizens in the poverty trap.

Previously more widespread, NTDs have gradually disappeared from places where living conditions and hygiene have improved. Today the populations most blighted are the desperately poor, in rural areas and urban slums in Africa, Asia and the Americas, where whole communities still lack adequate access to clean water, good nutrition, sanitation or quality-assured healthcare.

Those who suffer from NTDs are largely disenfranchised. They were described by World Health Organization (WHO) Director-General Dr. Margaret Chan, in the first ever WHO report on NTDs in 2010, as “largely hidden” and “largely silent.”

Controlling diseases

WHO itself helped raise the profile of these diseases a decade ago when the organization's then Director-General, Dr. Lee Jong-wook, instigated a key “branding exercise” to bring them to the world's attention. A WHO department nebulously dealing with “Other Communicable Diseases” was scrapped and the “Neglected Tropical Diseases” banner was adopted as a more focused target. There are now 17 diseases classified by WHO as NTDs.

But this was not the first attempt to tackle these diseases. In some cases, efforts had been going on for decades. The global Guinea Worm Eradication Program got rolling in the 1980s at the United States' federal Centers for Disease Control and Prevention (CDC) in Atlanta, Georgia. In 1982, the former U.S. President Jimmy Carter and his wife Rosalynn founded The Carter Center as a not-for-profit NGO dedicated to human rights and the alleviation of suffering. It has spearheaded the Guinea Worm Eradication Program since 1986, with Dr. Donald R. Hopkins from CDC becoming The Carter Center's Vice President for Health Programs. Hopkins brought with him the experience of overseeing the smallpox eradication program in Sierra Leone.

The Carter Center helped to develop cost-effective strategies to tackle Guinea worm disease such as providing at-risk communities with fine-mesh cloths to enable them to sieve out the fleas, and pipes with filters that can be used like drinking straws. Health education for the local communities is a vital accompaniment, for example, using a magnifying glass to show people the fleas in the water and explaining the transmission process. The aim is to spark behavior changes. If sufferers stop entering the water source, the cycle can be broken. >>

“Many developed countries haven’t addressed the issue of day-biting vectors at all. This is a time bomb if we don’t do something.”

Dr. Lorenzo Savioli,
Director of WHO’s Department of Control
of Neglected Tropical Diseases

”

Below Students distribute pamphlets in Lahore, Pakistan, during an awareness campaign on Dengue fever.



Engaging at the local level

“It’s not about just telling people what to do. Immediately challenging traditional beliefs is a non-starter,” Hopkins stresses. Some African villagers, for instance, regard their water source as sacred. “But,” says Hopkins, “if you genuinely discuss, engage and convince them that it’s in their interests, they’ll take the necessary action.”

Working in partnership with the ministries of health, teams of village volunteers are trained to check that their neighbors understand the transmission cycle, take in hand anyone who becomes infected, administer basic health care, call in more expert assistance to stem any burgeoning problem and report all new cases so that progress – and any aberrations – are closely monitored and analyzed.

Another important factor is that standing water sources can be sprayed with a larvicide, such as BASF’s Abate®, to interrupt the cycle. The active ingredient in Abate®, *Temephos*, is recommended by WHO for use in drinking-water sources at concentrations not exceeding one milligram per liter. BASF has made a long-term commitment to The Carter Center, and Abate® has been supplied, free of charge, for the Guinea Worm Eradication Program for more than 20 years.

Personal commitment

Meanwhile, President Carter has used his status around the world to galvanize political leaders. In 1995, he even brokered a truce in the midst of the Sudanese civil war, so that health workers could reach remote areas. This became known as the “Guinea worm cease-fire.”

Even now, in his late 80s, President Carter continues to visit remote African communities with his wife. As he explains: “There were over 26,000 villages with Guinea worm disease when we started out, and only about 3% of the men could write their name, and very few of the women. So we’ve taught them to change their behavior without written language, primarily using cartoons and pictures.”

The program’s tactics have proved highly effective. In 1986, Guinea worm disease afflicted approximately 3.5 million people a year in 21 nations. In 2012, there were just 542 cases reported – a reduction of over 99% – and they occurred only in isolated areas of Chad, Ethiopia, Mali and South Sudan. It looks as if Guinea worm disease will be eradicated soon, which will be no small feat. The only other human

illness ever to be wiped out was smallpox, back in the 1970s, following a major global effort. Unlike smallpox, Guinea worm disease is being wiped out without a vaccine or medicine.

Dr. Lorenzo Savioli, Director of WHO’s Department of Control of Neglected Tropical Diseases, is grateful. “We’d never be where we are today if it weren’t for President Carter. If we had, for each of the 17 NTDs, an ambassador of that level, life would be much easier.”

Savioli believes that we have come a long way. In January 2012, WHO published its NTD Roadmap, a document that expressed mounting confidence and called for scaled-up interventions against Guinea worm and other NTDs, setting ambitious goals to be achieved by 2015 and 2020. Inspired by the Roadmap, government officials, NGOs and pharmaceutical companies swiftly launched the London Declaration, a vow to cooperate even more actively to help eradicate Guinea worm, and to control or regionally eliminate at least nine other NTDs by 2020.

Ending preventable blindness

Another NTD where progress is beginning to be made is river blindness, or *onchocerciasis*. It is one of the world’s largest causes of preventable blindness and is among the diseases flagged in the Roadmap and Declaration. The Carter Center is also targeting it.

Another parasitic worm infection, river blindness can cause terrible itching and disfiguring “leopard” skin, together with eye lesions that can lead to blindness. This worm breeds inside people who have been bitten many times by infected black flies.

Insecticide can be of assistance again, hampering this cycle of contamination. BASF has expanded its long-standing collaboration with The Carter Center to contribute an extra 4,670 liters of Abate® to the Center’s river blindness program in Uganda by 2020.

Medicines also enter the equation with this NTD. Although there is no available vaccine, the 1990s saw mass drug administration schemes treating the infected. With its Onchocerciasis Elimination Program for the Americas, and working in cooperation with the African Program for Onchocerciasis Control, The Carter Center has been active in combating this disease in ten countries to date. “We’re very close to finishing with river blindness in the Americas,” says Hopkins. Only two small endemic zones remain, in Brazil and Venezuela’s cross-border jungle. The assumption has always

Dengue fever – facts and figures

How is it spread?

It is spread primarily by *Aedes aegypti* mosquitoes, which – unlike most mosquitoes – are active during the daytime. Infected humans serve as a carrier, transmitting the virus to mosquitoes that bite them and thus perpetuating the cycle.

Where is it found?

It is typically found in tropical and sub-tropical regions, especially in Africa, Asia and Latin America, but recently also in parts of Europe (Croatia, France, Madeira).

What are the symptoms?

Symptoms are fever, headaches and bone, muscle and joint pain.

How do you treat it?

There is no specific medication, but symptoms can be managed by taking acetaminophen, drinking plenty of fluids and resting.

How serious is it?

It usually clears up within two weeks. There are four different strains of the infection and recovery provides life-long immunity against that particular strain. But subsequent infections from other strains increase the risk of developing severe dengue, which can be very dangerous.

Can it be prevented?

There is no vaccine. To prevent catching it, in high risk areas wear protective clothing and use mosquito repellent day and night.

Dengue ranks as the fastest spreading vector*-borne viral disease in the world.



There has been a 30-fold increase in incidence over the past 50 years.

x30/50 years

Numbers of countries reporting cases of dengue:

1955: 3

1969: 9

2012: 125

It is estimated that more than 2.5 billion people – over 40% of the world's population – are now at risk from dengue.



* A vector is an organism that carries pathogens which are transferable to humans.

Source: World Health Organization (WHO)

been that river blindness in Africa is too pervasive to eliminate. Yet with concentrated efforts, Sudan recently stopped transmission in the Abu Hamad region north of the capital Khartoum. "And the government of Uganda," Hopkins points out, "is determined to end transmission by 2020, nationwide."

Hygiene and education

Progress in combating some other NTDs has been more difficult. Chagas disease is potentially life-threatening. It is caused by a protozoan parasite spread by insects known as "assassin bugs" or "kissing bugs." Up to 8 million people are infected, most in Latin America, where the kissing bugs infest the cracks of poorly-constructed homes and can contaminate food and drink. The bugs feed on blood and their feces infect the bite wound. Furthermore, there is also a risk that mothers will transmit this illness to their babies during pregnancy or childbirth, or that it can be spread by blood transfusions.

"The problem is that, in relation to treatment, we have seen no improvement for decades," says Professor Simon Croft, Ph.D., of the London School of Hygiene & Tropical

Medicine. He has also worked for the Drugs for Neglected Diseases Initiative and has carried out research on the drug *miltefosine* as a potential treatment for another NTD. His tests suggest that it might combat the Chagas disease parasite as well. At present, though, no vaccine exists and diagnosing Chagas is tricky. The drugs currently used for treatment work best during the disease's early phase. However, it is a long time before most people realize they are infected. Patients suffer enlargement of the esophagus or colon, which causes malnutrition, and they can also suffer heart failure.

"The most impressive effects so far have been with vector* control," says Croft. That means employing mosquito nets and insecticidal wall sprays such as BASF's Fendona® for indoor use.

But a large part of the solution comes down to improved hygiene. This involves educating people about the disease and helping them to prevent infection. A project run by BASF in Argentina aims to do just that. "Vamos por nuestro país" (Let's go for our country) is a community-development program, working with villagers in Chaco province to tackle Chagas (see box on page 49).

"Chagas is much more than a simple infectious disease," says Dr. Héctor Freilij, medical advisor to the National Chagas Program in Argentina. "It is linked to the economic, social and educational conditions of the population."

The fastest spreading NTD

Because of global travel, cases of Chagas disease have been increasingly cropping up in North America and Europe. A greater cause of rapidly escalating alarm worldwide, though, is dengue fever, which is demanding urgent attention (see box above). Thought to be as widespread as malaria, the mosquito-borne virus' incidence has soared 30-fold in 50 years. Each year, 50 million infections occur in more than 100 countries. A frequent cause of hospitalization and death among children, it produces flu-like symptoms which can intensify into severe dengue, with hemorrhagic complications.

Insecticides can be used, but no medical cure has been found and the primary vector, the yellow fever mosquito, is a daytime bloodsucker so bed nets will not help. A secondary vector, the tiger mosquito, has spread the disease to North America

and Europe. International cargos of bamboo and tires provide a breeding habitat, and tiger mosquitoes can survive even freezing conditions.

In 2012, dengue was declared the fastest spreading, vector-borne, viral disease with epidemic potential. Local transmission had been reported in France and Croatia in 2010. Then in 2012, the Portuguese Madeira islands startlingly saw 1,800 infected, with imported instances detected in further European countries. By January 2013, WHO's second NTD Report did not mince its words. "The world needs to change its reactive approach," it stated. Savioli underlines: "Many developed countries haven't addressed the issue of day-biting vectors at all. This is a time bomb if we don't do something." ■



To learn more about the NTDs prioritized by WHO, see: www.who.int/neglected_diseases/diseases/en/



Above Former U.S. President Jimmy Carter tries to comfort a 6-year-old girl at a hospital in Ghana as a Carter Center volunteer dresses her extremely painful Guinea worm wound.

Decades of dedication to fighting disease

Founded by former U.S. President Jimmy Carter and his wife, Rosalynn, The Carter Center has led the Guinea Worm Eradication Program since the 1980s. With Guinea worm disease poised to be the second-ever human disease to be eradicated, Jimmy Carter and Dr. Donald R. Hopkins – the Center’s Vice President for Health Programs – talk about the fight against neglected tropical diseases.

Creating Chemistry: What have been the biggest challenges in combating Guinea worm disease?

President Jimmy Carter: The lack of attention from the rich world. The first thing is for the rich world to be generous. The second challenge is that the people who have these diseases, living in the most isolated communities, have very little communication with their central governments, or access to the media.

Dr. Donald R. Hopkins: Early on – internationally and in the endemic countries – we had to contend with a lack of knowledge about Guinea worm disease and with apathy. Now, I’d say, the biggest challenges are the insecurity situations. We’ve got insecurity in four of the endemic countries, meaning helpers cannot safely travel to these areas: in Mali and some parts of Ethiopia, Chad and South Sudan.

Are there any moments that have been marker points for you?

Hopkins: Absolutely. One of the most striking, looking back, was in February 2007 when I went with President Carter to Ghana, to the northern

town of Savelugu where they had an explosion of cases of Guinea worm disease. So we went up to this epicenter and there were at least 200 kids there crying, including infants, having their worms extracted – rolled up out of their bodies. It was just terrible to see. That was the worst moment that I recall in the Guinea worm fight. Some of the good moments have just been going into villages and seeing how people, in all of their material poverty, are so spiritually rich and so caring. I draw energy from that.

Carter: We’ve had very difficult problems in some countries. For instance in Ghana, we had Guinea worm down to just a few hundred cases. Then the government changed from Jerry Rawlings’ administration, which had addressed the disease as a top priority. The new government didn’t want to address it, which prevented their making progress for five or six years. But eventually they did, then we very quickly did away with the disease there. We have been happy every time we have done away with the disease in one village or in one entire country. We’ve also been very fortunate, not only in getting help from companies like BASF and

charitable organizations like the Bill & Melinda Gates Foundation. Some countries – Great Britain and the United Arab Emirates among them – have been very generous to The Carter Center. And President Barack Obama recently made a speech promising to give more to neglected tropical diseases.

How important are contributions by the private sector?

Hopkins: Beside cash donations, the early contributions of the filter material and insecticides weren’t only important for their epidemiological impact. It also gave a kind of legitimacy, the fact that the private sector was willing to come forward. It gave encouragement to the endemic countries that these companies cared. And it made international agencies, ministries of health and others sit up and take notice. That was the political impact.

What more needs to be done to control neglected tropical diseases?

Hopkins: A lot of these diseases could be better controlled, particularly now that we have drugs – even donated drugs – to combat river blindness, various intestinal parasites and other neglected

tropical diseases. So we have those drugs and we need to apply the lessons we've learned about the importance of health education and the value of village volunteers doing regular surveillance.

Are there lessons you have learned from the Guinea Worm Eradication Program?

Carter: What I've learned is that as soon as these people in the villages are given the necessary help, the opportunity and the knowledge, they will do the work that's required themselves. They are remarkably hardworking and enthusiastic.

Hopkins: I would also underscore the value of marshalling data in a way that motivates people. Let them see the impact of what they've done so far and – if you can – compare that to adjacent countries or districts to really get the competitive juices flowing.

You have achieved a great deal over the past years – what have been the main driving factors?

Hopkins: We owe a lot to President Carter – he is driven, very detail-oriented and focused, and just inspiring. He has taken this cause on and he's very, very tenacious. In the beginning, people weren't paying attention to Guinea worm disease, either in the international community or the endemic countries themselves. President Carter got very important publicity about what we were doing. He was also very active in helping to raise money and in-kind donations, with the insecticide Abate® being the first big contribution in 1989. And he has been able to mobilize people, not just leaders at the international agencies and donor agencies. He visits countries, meets heads of state and ministers of health, as well as calling or writing them, and he goes out to villages. Mrs. Carter has also been very active, visiting the villages. Since President Carter is 17 years older than me, I have no basis for complaining of being tired or anything like that! He's constantly saying, 'Why don't you call on me more?'

What are your key goals for the coming years?

Hopkins: First, finish up with Guinea worm globally. Second, finish up with river blindness in the Americas and help promote the idea of eradicating it in Africa – which is now appearing more and more possible. So, there's plenty to do.

How long do you think it will be before Guinea worm disease is eradicated and how will you rank that among your life's achievements?

Carter: We think within two years we will be through with Guinea worm. Its eradication would be one of the most gratifying things in my life, because it has affected so many people. It's been one of the most challenging and long-lasting efforts I've ever made. I'd say it would even be equal to the Egypt-Israel Peace Treaty of 1979. ■



To find out more, visit:

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www.publichealth.basf.com

Rooting out the kissing bug

How BASF is helping to control the insect that spreads Chagas disease

The "kissing bug" sounds harmless enough, but it is an insect whose bite can be dangerous, if not deadly. That is because it carries with it the parasite that causes Chagas, a disease that starts with swelling of the eyelids, fever and fatigue, but can lead to malnutrition, cardiac disorders and even heart failure. It is considered primarily to be a disease of poverty, but there have also been significant numbers of cases in Europe and the United States, caused by travel and blood transfusion.

Triatoma infestans – to give the insect its scientific name – is endemic in many areas in Latin America, where it is also known as *Vinchuca*. WHO estimates that 8 million people are affected by it here. One example is Chaco, a province in the remote north east of Argentina. Here, the small town of Concepción del Bermejo is home to around 10,000 people, many of whom live in extreme poverty with inadequate access to clean water, healthcare, education and decent housing. The incidence of Chagas has been high among adults and children, with many of the roughly 170 rural dwellings and a large number of the 1,900 urban homes infested by the blood-sucking insects.

Since 2010, BASF Argentina has been committed to the community-based project "Vamos por nuestro país" (Let's go for our country) in this area. In cooperation with the National Chagas Disease Program of the Argentinian Ministry of Health, the project utilizes BASF's existing knowledge and state-of-the-art technology to help control, monitor and treat the disease. "'Vamos por nuestro país' is different from other programs because it is sensitive to the needs of the people affected by Chagas. No one else meets those needs," explains Marcelo Hoyos, technical marketing manager for BASF's Pest Control Solutions business and one of the 50 BASF volunteers from different business units

in Argentina who, together with their families, have committed to this project. As part of the three-year program, which has now been extended to run a further year until July 2014, BASF Argentina is not only supplying Fendona® – an insecticide which can safely be sprayed inside homes – it is also providing its expertise to the local authorities and local people.

A vital part of the program is to increase people's understanding of Chagas, to encourage the proper use of medicines and the insecticide, and to foster active community engagement. A network of strategic partners has been created, including the regional government, institutions in the town such as the hospital and school, and Solidagro – an NGO specializing in local development. Training courses are run for local people explaining how to stop the bugs from breeding inside their homes and contaminating food and kitchen utensils.

An innovative online management system has been developed for monitoring progress and the knowledge gained is being exchanged with other municipalities, provincial authorities and NGOs to produce a joint study of best practices. The results so far have been encouraging. The proportion of infested houses in the rural area has been reduced from 17.9% in 2010 to 2.9% outdoor and 0% indoor infestation in 2013.

"Vamos por nuestro país" is a self-sustaining project that will permit continuity and outreach to other communities after BASF's participation and can serve as a template for other programs tackling insect-borne diseases.

The experience of being involved in this award-winning project has had a huge impact, says BASF employee Hoyos. "We have seen that we can help people to help themselves and it has taught me to re-evaluate the importance of the family and education as the basis for improving the quality of life. But the battle has only just begun!"



Left Carter Center Vice President for Health Programs Dr. Donald R. Hopkins shows children in a village in South Sudan, where Guinea worm is endemic, how a pipe filter should be used in order to prevent infection.

CO₂ – from exhaust gas to raw material

Airplane travelers know that fuel combustion creates CO₂ emissions as exhaust. But in the future, carbon dioxide could play a different role in aviation. Researchers are working on how to use CO₂ as a feedstock for the chemical industry. One potential application could be formic acid, which can be used to de-ice airport runways, among other things.





The chemical industry produces 600,000 metric tons of formic acid worldwide each year. The acid is used, for example, in aviation to de-ice runways.

30 billion

Global CO₂ emissions have now reached more than 30 billion metric tons annually.

20 million

Around 20 million metric tons of these global emissions are already being used as industrial gases.

110 million

Of the global CO₂ emissions, another approximately 110 million metric tons are currently being used as chemical feedstock.

Source: Society for Chemical Engineering and Biotechnology (DECHEMA)

What if carbon dioxide was not just an exhaust gas but could, instead, be used as a feedstock for the chemical industry? It is, after all, inexpensive and available in large quantities. CO₂ is produced by any combustion of carbon-containing fuels, mainly for transportation and heating. Such fuels, especially crude oil, are the basis for the production of numerous products in the chemical industry, ranging from crop protection products to plastics and medication. Since the carbon required for this synthesis is also contained in CO₂, carbon dioxide could one day be a feedstock that replaces some of the crude oil, a raw material that is expensive and becoming scarcer.

Elsje Alessandra Quadrelli, Ph.D., is a chemist at CPE Lyon (Ecole Supérieure de Chimie Physique Electronique de Lyon) in France and carries out research on behalf of the European Union on ideas for utilizing CO₂. According to her calculations, between 250 million and 350 million metric tons of CO₂ could be saved in the future – provided that all technologies for CO₂ utilization are fully implemented, the necessary energy loops are fed with renewable energy (see box on page 53) and that fossil fuels are partially replaced by carbon dioxide. She believes the advantages are obvious: conserving fossil energy sources, lowering the chemical industry's dependence on fossil raw materials and promoting the expansion of renewable energy, among others.

In the Raw Material Change technology field, BASF experts are therefore conducting research >>

Right In the future, companies such as the Icelandic firm Carbon Recycling International want to utilize the geothermal energy from Iceland's hot springs as a natural source of energy to produce methanol from CO₂. Geothermal energy is already being used today: Iceland's Blue Lagoon is a geothermal spa that offers a fun bathing experience for tourists and locals and is fed by water from the nearby Svartsengi geothermal power plant.



on methods for using alternative raw materials and evaluating these processes with a view to balancing technological, environmental and economic considerations. After all, such investments will only be economically viable in the long term if these promising technologies can be implemented at a reasonable price. "To some extent, CO₂ can supplement the chemical industry's raw materials portfolio for certain applications," says Dr. Peter Schuhmacher, head of BASF's Process Research and Chemical Engineering technology platform. The gas can be obtained in places where it is released in large quantities, such as power plants or chemical factories.

However, using CO₂ as a feedstock will not eliminate the climate impact of emissions. More than 30 billion metric tons of carbon dioxide are currently released worldwide per year, but only a small share of this amount could be used as a raw material – right now it is only 0.4% of the global emissions. "This will not save the climate," said Germany's Federal Minister for Education and Research, Professor Dr. Johanna Wanka – whose ministry supports around 30 projects on material utilization of CO₂ in Germany – speaking at a conference

in Berlin in 2013 attended by partners from science and industry working in this area. Nevertheless, the use of CO₂ could make a contribution to resource conservation, she added.

Products made of carbon dioxide

Many potential applications are still a long way off, but there are already some products made using CO₂ as a feedstock. One of these is salicylic acid, a precursor to aspirin. CO₂ is also what makes carbonated beverages bubbly. Huge volumes of the gas are also used to produce urea, which is mainly required to make fertilizer. CO₂ is used as a cooling and refrigerating agent in the food industry and helps keep packaged meat and sausages fresh for longer. Dry cleaners also use it to remove dirt from clothes.

In the future, the goal will be to capture industrial gas emissions and re-use them. Researcher Quadrelli describes this as a "carbon dioxide economy" – an economy that no longer simply emits this gas, but also finds new uses for it.

Formic acid from CO₂

BASF is also working on CO₂ utilization. At the company's largest Verbund site in Ludwigshafen, Germany, waste products and

steam that arise from the production processes in one plant are used in other plants as raw materials and energy. This system is known as the Production Verbund. Some of the CO₂ arising in the production complex could someday be integrated into this concept – for example, to make formic acid.

This acid is a well established chemical product. Each year, 600,000 metric tons of it are produced worldwide. Animal feed producers, for example, use formic acid as a preservative. It is also useful as a de-icing agent for runways and streets as well as for high-quality leather processing. In addition, formic acid is a highly effective limescale remover in household and industrial cleaning. However, the conventional method of synthetically producing this acid from carbon monoxide and water is fairly resource-intensive. "It requires a whole lot of energy to ultimately produce a pure product," says BASF researcher Dr. Rocco Paciello. He and his colleagues have therefore been working on a new, more efficient process for the past few years. The experts are pinning their hopes on carbon dioxide. "Chemically, formic acid is the most similar to CO₂," says Paciello. The acid is therefore one of the products



that could be produced from CO₂ with the smallest-possible energy input.

Challenges remain

There are, however, still a number of challenges the BASF team has to overcome. These are mainly related to the thermodynamic characteristics of CO₂: “In theory, there are quite a number of possibilities with CO₂, but it is an extremely low-energy, inert gas. Most reactions therefore require enormous amounts of energy. If the energy expenditure is too high, the process is not cost-effective,” says chemist Paciello, summarizing the problem.

The key to solving this problem is finding the right catalysts – substances that help kick-start the reaction. They reduce the amount of activation energy required, making the reaction more efficient. It comes as no surprise then that more than 80% of all production processes in the chemical industry are based on catalysis, a cross-sectional technology.

The successful production of formic acid from CO₂ also depends on the right catalyst. The chemistry behind this process has been known since the 1970s, but for a long time nobody had been able to put this theory into practice in a >>

“In theory, there are quite a number of possibilities with CO₂, but it is an extremely low-energy, inert gas.”

**Dr. Rocco Paciello,
BASF Homogeneous Catalysis
Research**



Below CO₂ could help excess electricity from solar panels and wind turbines be used more efficiently.



A good alliance? CO₂ and renewable energy

Carbon recycling is really only helpful for the environment when it binds more carbon dioxide than is released into the atmosphere. It takes a lot of energy to prompt the inert CO₂ molecules to react. So it makes little sense if this energy comes from coal-fired power plants, thus producing new CO₂ emissions. Instead, experts say expanding wind and solar energy is essential.

Carbon dioxide might even help excess green energy to be used more efficiently. These days, renewable sources sometimes produce more electricity than can be fed into the grid. With the power-to-gas process, this energy could be transformed into natural gas (methane) in a two-step process using CO₂ as a reactant. In a first step, the excess green electricity is used as an energy input to turn water (H₂O) into hydrogen (H₂) and oxygen (O₂). The hydrogen then reacts with CO₂ to form methane gas (CH₄). Methane is an energy store that can be easily fed into the existing natural gas network and can be used when needed.

The Icelandic company Carbon Recycling International (CRI) produces methanol from CO₂ using the geothermal energy from Iceland's hot springs as a natural source of energy. CRI opened the first commercial plant producing methanol using this carbon-neutral method in 2011. The company plans one day to produce as much as 50 million liters of this alcohol annually from carbon dioxide. It can be used, for example, to create energy in fuel cells or it can be blended into gasoline.

The companies BASF, Linde and ThyssenKrupp have recently started a project to produce syngas from carbon dioxide and hydrogen in an innovative two-step process. The concept: In the first step, a new high-temperature technology will process natural gas to obtain hydrogen and carbon. Compared to other processes, this technology produces very little CO₂. The hydrogen is then reacted with large volumes of CO₂, also from other industrial processes, to create syngas. This gas is a key raw material for the chemical industry and is also suitable for producing fuels.

cost-effective way. “We used appropriate catalysts and changed the process to optimize energy use,” says Paciello. A pilot plant has already been built at BASF in Ludwigshafen.

First breakthroughs

Researchers around the world are making their first breakthroughs in projects to turn CO₂ into a chemical feedstock. Fundamental research, as practiced mainly at universities, is a big contributor to this success, as is technology transfer from the laboratory to industrial applications. That is why the University of Heidelberg in Germany and BASF's Process Research and Chemical Engineering competence center teamed up in 2006 to found the jointly operated Catalysis Research Laboratory (CaRLa) in Heidelberg, where the partners work on developing new catalysts (see feature on page 55). “One of the research focus areas at CaRLa is finding suitable catalysts for using carbon dioxide as a feedstock to produce certain plastics that are currently

manufactured from crude oil, including raw materials for coatings,” says Heidelberg's Professor Dr. Peter Hofmann, who initiated the establishment of CaRLa.

Support from policymakers

Governments are also providing financial support to help launch new projects related to CO₂ utilization. The U.S. Department of Energy, for example, has invested approximately \$100 million in projects of this type in recent years. By 2016, Germany wants to invest the equivalent of \$132 million (€100 million) in innovative CO₂ ideas, while another roughly \$66 million (€50 million) will be coming from industry. The Chinese government also believes in the potential of feedstock based on carbon dioxide: Together with partners, it is spending the equivalent of nearly \$200 million (€150 million) on national projects for CO₂ recycling, according to the Society for Chemical Engineering and Biotechnology (DECHEMA). Japan, as well, wants to reduce its dependence on crude oil. In light of the rising prices, there

is demand for chemicals that are not based on oil, according to the country's Ministry of Economy, Trade and Industry. It therefore supports projects such as a pilot plant for artificial photosynthesis which opened at the end of 2012. With the help of light and catalysts, this facility will utilize carbon dioxide from a neighboring power plant to produce hydrocarbons – raw materials for the chemical industry.

All these initiatives encourage the development of new processes based on CO₂ that help conserve resources. However, the possibilities of recycling carbon dioxide should not lead to wasteful consumption of fossil fuels, stresses BASF researcher Paciello: “It is important to prevent emissions in the first place and everyone can do their part to help with this.” ■



Left A clever solution: The bacterium *Basfia succiniciproducens* should one day produce succinic acid and bind CO₂ as well.

Promising bacteria from the stomach of cows

Basfia succiniciproducens – BASF researchers have high expectations for this bacterium. It plays an important role in BASF's technology field White Biotechnology, which aims to use microorganisms to manufacture chemical and biochemical products. Through natural fermentation, bacteria from the *Basfia succiniciproducens* strain will soon be able to produce succinic acid while binding carbon dioxide. At the end of this year, BASF and its partner Purac plan to open a jointly operated production plant for succinic acid in Spain with an annual capacity of 10,000 metric tons. If the project is successful, another larger plant will be built. Succinic acid is used today in applications such as bioplastics, chemical intermediates, solvents and plasticizers. BASF researchers were the first to isolate the bacterium from the rumen of a cow in 2005, which is why the company name is contained in the word *Basfia*. The word *succiniciproducens* means “producing succinic acid.”

Catalysts help transform CO₂

How can CO₂ – an inert, low-energy gas – be turned into a raw material? Researchers from the University of Heidelberg and BASF have set out to answer this question. In the catalysis laboratory CaRLa, their projects include finding appropriate catalysts for CO₂ reactions. Patience and perseverance are needed when it comes to finding a ‘matchmaker’ like this that can make a reaction more efficient, as a visit at CaRLa reveals.



Right A scientist connects CO₂ to the pressure tank for the reaction. The gas will react with ethylene and a base to form sodium acrylate.

Left Dr. Michael Limbach and Professor Dr. Peter Hofmann examine the results of the reaction. The desired product is dissolved in the light-colored layer at the bottom of the container.



Opening a red metal cupboard, Dr. Michael Limbach points to some cartridges. “These are run-of-the-mill gas canisters filled with carbon dioxide, just like the ones used for beer dispensers at a beer tent,” the chemist explains. But Limbach and his colleagues at the Catalysis Research Laboratory (CaRLa) at the University of Heidelberg have unconventional plans. Together with their cooperation partners from the University of Stuttgart, the Technical University of Munich (TUM) and BASF subsidiary hte AG, they want to use this gas to make sodium acrylate, which is part of an important value chain at BASF.

There are only limited feedstock resources for the traditional method of production based on crude oil. “We have therefore been looking for a new process to manufacture sodium acrylate,” Limbach explains. He represents BASF’s research division in the management team of CaRLa, a new and innovative model of cooperation with scientists from the University of Heidelberg specialized in fundamental chemistry research. The idea sounds simple: combining carbon dioxide – a waste product of industry – and ethylene to produce the salt.

Although researchers discovered 30 years ago that this reaction is theoretically possible, nobody had been able to make it work until the CaRLa team achieved its breakthrough in 2012. The key to their success was a catalyst that brings together the starting materials. Limbach’s colleague from the University of Heidelberg, Professor Dr. Peter Hofmann, explains the principle: “A catalyst molecule suspended in a solution takes a molecule from one substance and one from another substance, combines them in several steps and releases the new substance back into the liquid.

Then the whole process starts again. Optimal catalysts do this millions of times per hour.”

The heart of the new catalyst is a nickel atom. The metal acts as the ‘matchmaker’ and is surrounded by ‘helper’ atoms which ensure that only a specific type and volume of the molecules from each of the raw materials make it into the heart of the catalyst to be combined. “Catalysts can be built together like Lego blocks,” Hofmann says. The trick is constructing them in such a way that only the desired reaction takes place without any unwanted by-products.

CaRLa was founded in 2006 as a pilot project of the Industry on Campus strategic initiative at the University of Heidelberg, which is recognized as a “University of Excellence” in Germany. Since then, Hofmann, Limbach and twelve other scientists from around the world have been working hard on catalyst research. According to Hofmann, catalysts play a vital role in the chemical industry: “They are needed to produce around 80% of all chemical products.” The development of catalysts for demanding and complex reactions such as the reaction to sodium acrylate requires a deep, fundamental understanding at the molecular level; sometimes this can be an undertaking lasting several years with an unknown outcome. “At CaRLa, our direct link to the university gives us opportunities for extensive fundamental research,” says the professor.

It took the scientists two years to build the right ‘matchmaker,’ as catalysts are sometimes called because of the way they pair up two substances. “We took a very systematic and rational approach to the problem,” Limbach says. Instead of conducting many experiments with various types of catalysts, the team concentrated exclusively on

a few promising ones. It first modeled these step-by-step on a computer before testing them. “It was a very clean study of the elementary steps. We wanted to understand why others who tried before us had failed,” explains Limbach.

While the new catalyst can get the job done, the experts know it needs to be much more productive. Right now, ten molecules of sodium acrylate are produced for each catalyst molecule. “We would be happy if we could get this number up to one hundred,” says Hofmann. But in order to implement the process on an industrial scale, this figure would have to be at least 1,000 times higher. However, the fundamental researchers will not have to continue working on the reaction until then – they are letting their research partners from BASF take over the next step. “What we are building here is like the motor for a small car, which the industry will later use to create the Lamborghini model,” says Limbach, describing how the work is divided. By next year at the latest, the Heidelberg scientists want to hand over the project to BASF for fine tuning.

In Heidelberg, everything is still being done on a small scale. The reactions are carried out in metal containers the size of a water glass and the final product still fits into small glass bottles. Limbach expects it will still be a few years until this innovative sodium acrylate will be launched on the market – by which time the conventional gas canisters will be far too small. ■



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Pioneering thinker – then

Carl Bosch

His arrival in Ludwigshafen heralded the beginning of a truly remarkable career: Having just completed his doctorate in chemistry at the Frederick William University in Berlin (now Humboldt University), Carl Bosch joined BASF in 1899, where the 25-year-old was given a research task that would shape the rest of his life. His challenge was to find out how to synthetically combine nitrogen and hydrogen to create ammonia.

The big breakthrough came in 1913. Carl Bosch was able to take the ammonia synthesis process developed by Fritz Haber and move it from the laboratory to industrial-scale production. He thus made it possible to independently produce mineral fertilizers, of which ammonia is a basic ingredient. His achievement helped to feed millions of people worldwide. For this process, Bosch developed a new high-pressure technology using reliable plants with special reactors and new kinds of steel. Since then, the Haber-Bosch process has enabled large quantities of ammonia to be produced from atmospheric nitrogen and hydrogen – which today is mostly derived from natural gas – using an iron catalyst.

One hundred years ago, BASF built the world's first industrial production plant for ammonia in Oppau, now part of Ludwigshafen, Germany. At the same time, Bosch was named an authorized signatory of the company – and became Chairman of the Board of Executive Directors just six years later. In 1925, he assumed the role of Chairman of the newly founded company I.G. Farben, a merger between BASF, Höchst, Bayer and other chemical companies. When Adolf Hitler seized power in Germany, Bosch was faced with a moral conflict. On the one hand, the business profited from the Nazis. On the other hand, Bosch – who had liberal leanings and vehemently rejected National Socialism – tried to persuade Hitler to save Jewish scientists from persecution, but was unsuccessful.

Bosch subsequently retreated more and more into his private life, without quite turning his back on the industry. He found refuge in the world of science. As a child, he had collected insects which he dissected or kept in heated terrariums he constructed himself. Over his lifetime, this collection grew to include millions of beetles, butterflies and minerals. Bosch even bought an additional house to store everything. To study the stars, he had two observatories built in his garden.

The Nobel Prize he was awarded in 1931 was surely the greatest recognition of his life's work. But this passionate observer of nature would have certainly also appreciated another honor: In 1990, 50 years after his death, an asteroid – 7414 Bosch – was named after him. ■



A high-pressure reactor being built into the ammonia plant in 1921.

Ammonia synthesis

The reactive partners in the Haber-Bosch process are hydrogen and nitrogen, both diatomic gases. In order to turn these into ammonia, the strong triple bond in the nitrogen molecule and the single bond in the hydrogen molecule both have to be broken. This requires a lot of energy – or a catalyst like iron, which lowers the amount of activation energy. But what happens on the surface of the iron? Professor Dr. Gerhard Ertl (see page 57) discovered that the splitting of the nitrogen is the decisive step. The nitrogen molecule (N_2) interacts so strongly with the electrons on the metallic surface of the catalyst that the bond between the two atoms in the nitrogen molecule is weakened and eventually breaks. This leaves both nitrogen atoms with three free electrons, enabling each atom to bond to three hydrogen atoms. At the end of the reaction chain, this combination forms ammonia as the final product. Chemical reactions on catalytic surfaces such as this one play an important role in many industrial applications, from mineral fertilizers to exhaust gas scrubbing.



Pioneering thinker – now

Gerhard Ertl

“ I use the methods of physics to answer questions related to chemistry.

Professor Dr. Gerhard Ertl, former director of the Fritz Haber Institute of the Max Planck Society and Nobel Prize winner in chemistry in 2007

”

As a 12-year-old, Gerhard Ertl discovered his passion for chemistry thanks to a book called *Successful chemical experiments* (“Chemische Experimente, die gelingen”). But his mother eventually put a stop to his experimentation because of the “strange noises and smells” coming from his bedroom, so Ertl turned his attention to physics and started building innocuous radios instead. His passion for these two branches of science would shape the rest of his life, eventually even winning him the Nobel Prize. The physics professor was informed on his 71st birthday that he had been awarded the 2007 Nobel Prize in Chemistry for his groundbreaking findings in the field of heterogeneous catalysis.

“I use the methods of physics to answer questions related to chemistry,” says Ertl, describing his way of working. He also followed this approach in his research on the mechanisms

behind the famous process of ammonia synthesis. Although, thanks to Carl Bosch, it had been possible to manufacture ammonia on an industrial scale since 1913, one question remained: What exactly was happening in the reaction on the surface of the iron catalyst? Ertl was the first to discover the secret of the molecular reaction (see box on page 56) – a milestone in the field of modern surface chemistry, for which he was later awarded the Nobel Prize. “Bosch was the engineer who enabled the large-scale application and I followed up later with the fundamental research,” says Ertl. Semiconductor physics first helped him get started with the detailed study of surface processes.

As a student of physical chemistry, Ertl wrote his doctoral thesis on the solid-gas interface, already working towards what would become his main subject matter. He received a post-doc qualification (habilitation) at the age of 31 with his investigation of the structural problems of

chemical reactions on a crystalline solid surface. His research made him one of the most important chemists of our time. Ertl's choice of a topic was clever – and daring – because at the time almost nothing was known about these phase boundaries. “This proved to be a very fruitful subject for my entire life,” reflects the 77-year-old.

But life outside the laboratory has also always been a priority for the interdisciplinary researcher. Ertl's family and music are important to him. As a student, the passionate pianist was able to support himself by playing music in a dance band. Today, the professor emeritus and former director of the Fritz Haber Institute of the Max Planck Society in Berlin spends one evening a week as a répétiteur for the Berlin Oratorio Choir. But chemistry also gives Ertl an opportunity for art appreciation: “To this day, I still find aesthetic pleasure in a nice formula or a beautiful microscopic pattern.” ■



How does toothpaste clean your teeth?

To protect your teeth from cavity-causing bacteria, it is advisable to brush them after every meal. But what exactly happens in your mouth when you do that?

The cleaning effect comes from abrasives, which are small particles in the toothpaste, such as silicate compounds, calcium carbonate or calcium sulfate. These abrasive materials have microscopically small edges that help scrub away the plaque – a tough layer of bacteria that cause tooth decay – from your teeth when you brush. This process is facilitated by surfactants, surface-active substances that create foam – just as they do in shower gel and shampoo – and ensure that the toothpaste is evenly distributed so that the hard-to-reach spots also get clean.

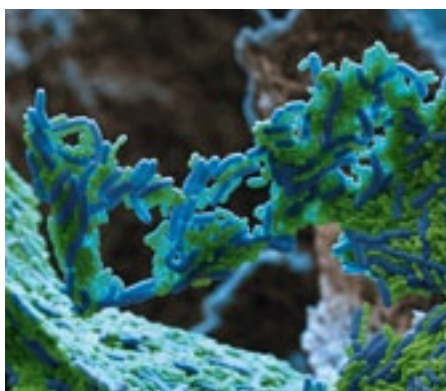
But toothpaste should not just clean your teeth, it should also protect them. It therefore includes other ingredients, such as sodium fluoride or stannous fluoride. Because tooth enamel is largely made up of calcium, it can form bonds with the fluoride, making the enamel harder and protecting it from acids and cavity-causing bacteria. This protection has to be regularly renewed – ideally after every meal. ■



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