UFZ Special

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ JUNE 2011

WATER: A SPECIAL ISSUE

Whether it is shortages, flooding, contamination, overuse or poor management – water poses a challenge for politicians, economists and scientists alike. The UFZ is able to contribute to the sustainable management of water resources by implementing its expertise in the field of interdisciplinary water research.

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CENTRE FOR
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WATER – A GLOBAL ISSUE

Since July 2010 the basic human right of access to clean water has existed – however the practical implementation of this is still lagging behind with almost one billion people in the world still having no access to clean drinking water and 2.6 billion people living without toilets or hygienic wastewater systems. Forecasts show that the worldwide population will increase to nine billion by 2050 and for global temperature changes an increase of two to six degrees Celsius by 2100 will also be expected. As a result, the water problems that already exist will be exacerbated and new ones will arise. Beyond that the rising demand for food and energy in developing countries and newly industrialising countries will lead to a considerably higher water consumption all over the world, which will reach or even exceed the limit of the total available resources in many regions. Depending upon initial situations, the climate and geographical situation and basic political conditions, impacts will be very different, as will the challenges for science, economics and politics.

In most European countries we have to deal primarily with water quality issues – decades of industrialization and the intensification of agriculture have left behind their chemical footprints and changed the morphology and biological status of numerous water bodies. The implementation of the European Water Framework Directive has started to successfully undo the damage and as a result 90 percent of the rivers and lakes in Germany have been able to achieve a good chemical status again. By contrast however, a good ecological status has only been achieved for 10 percent of water bodies. Furthermore, climate change will not spare Europe completely. World climate predictions forecast a decrease in precipitation of between 20 and 40 percent by the year 2070 for some regions in the Mediterranean that are already quite arid. In other places however, extreme precipitation will increase the number of flooding events considerably. It will therefore be necessary to adapt water and wastewater technologies to these changing environmental conditions. Here, one particular challenge for science will be the development of more complex and nevertheless reliable observatory and forecast systems for the scale of catchments with time perspectives of up to 100 years.

In the arid and semi-arid regions of Asia, Africa or Latin America we are particularly faced with a quantitative water issue, where

continually lower water quality exacerbates matters. Here the challenges are evident: a more efficient water use particularly in agricultural practices, innovative water-saving technologies, accurate water balances as well as sustainable water management. Furthermore, it is a question of making new water resources available. It will be imperative to shift water-intensive activities to those areas where water is abundant, as in some cases those countries that experience water scarcity export water-intensive agricultural products at the expense of their own resources.

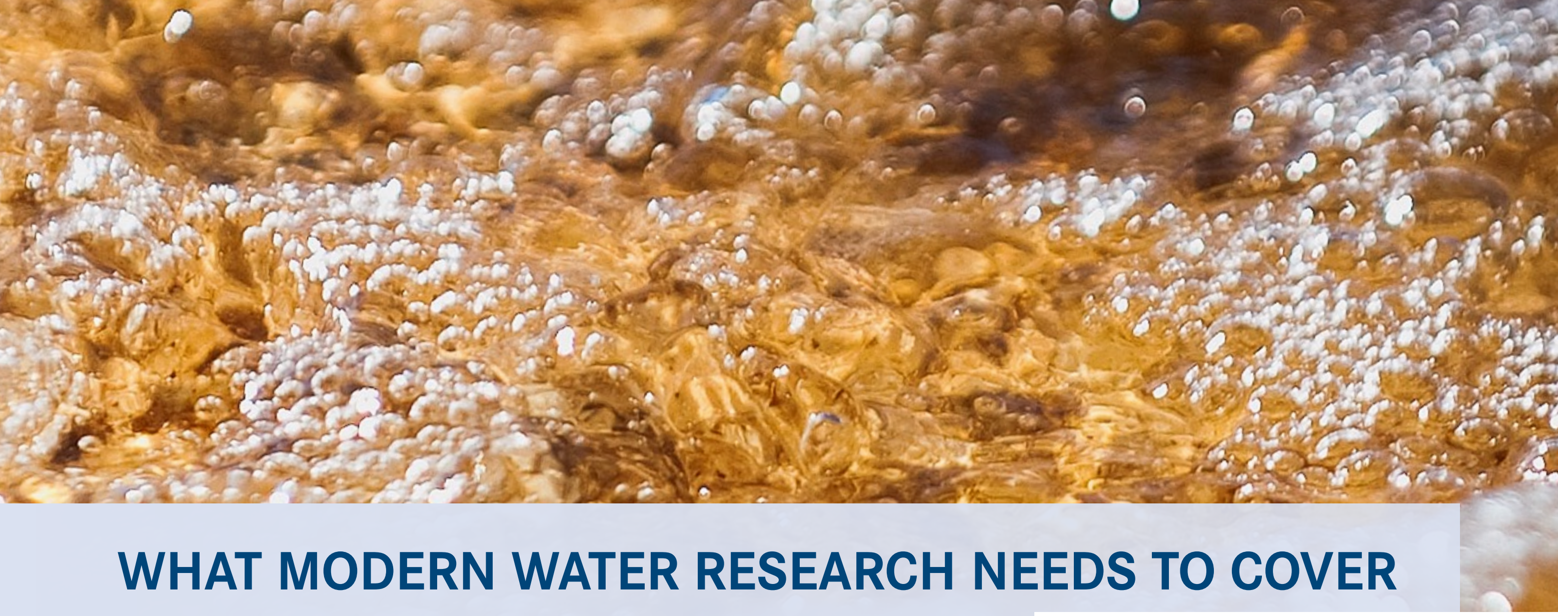
As different as these water problems around the world might be, scientists agree that there is a common solution, namely Integrated Water Resource Management (IWRM). This means that qualitative, quantitative, technical and social aspects of water management must be integrated and that land use changes, climate change, demographic change and water-dependent economic and industrial sectors are all to be included, if water resources are to be managed sustainably. In principle, the conditions for achieving this in German water research are very good: We develop sophisticated technologies, environmental monitoring and early warning systems, hydrological models and know-how in water analytics and water management. Annually between 200 and 250 million Euros of public funding and other funds from industry flow into German water research and it is distributed to more than 150 publicly funded institutions. What has been lacking so far however are long-term network structures to optimally pool the scattered knowledge that exists. Modern application-orientated water research requires the integration of many individual disciplines from the natural sciences, engineering, economics and the social sciences and cannot be covered holistically by a single institution.

In 2009 the UFZ received a mandate from the Helmholtz Association's Senate to develop a concept – the Water Science Alliance, which should help to overcome the deficits observed in co-operation or networking. With the Water Science Alliance a reliable framework is to be established in which selected, crucial issues in water research can be integrated, in which the prominent groups of researchers and institutions develop and implement common research goals and strategies in a suitable and complementary manner, including partners from industry and the authorities from the onset. Furthermore, the competencies of the next generation of "water scientists" are to be developed in a more integrated way. In cooperation with stakeholders from water research and water management as well as research funding bodies – the Federal Ministry of Research and the Federal Ministry of the Environment as well as the German Research Foundation – overarching research fields that were seen to be the first of greatest prominence for further research were defined in the first "White Paper" (http://www.watersciencealliance.ufz.de/index.php?de=19854).

The UFZ was explicitly given the role of "facilitator" for the implementation of the Water Science Alliance, because we have developed a substantial integrated water research over recent years whereby a very broad and internationally recognized competency has emerged with 17 of 34 departments that are now directly working in the field of water. The fields of expertise at the UFZ thereby range from river ecology, water chemistry, eco-toxicology to soil physics, geohydrology and catchment hydrology as well as model development and visualization on all levels. In addition to this there are measuring and exploration technologies and long-term expertise in socio-economic research, which is indispensable in water research.

This special edition of our UFZ Newsletter will provide you with an insight into some of our current research topics from the interdisciplinary field of water research at the UFZ. I hope you will enjoy reading it.

Prof. Dr. Dr. h.c. Georg Teutsch
Scientific Director of the Helmholtz Centre for Environmental Research – UFZ



WHAT MODERN WATER RESEARCH NEEDS TO COVER

Whether or not water security is provided in sufficient quantity and quality is a question of survival for both humans and natural ecosystems. Although water appears to be abundant on a global scale (more than 70 percent of the earth's surface is covered by water), only a very small percentage (approx 0.3 per cent) of the water on our planet in the form of lakes, rivers and groundwater can be directly used as drinking water. In addition to this, water is not evenly distributed around the world and water consumption whether as drinking water, for industrial use and energy production or for cultivating plants in agriculture is strongly influenced by the season or region. Moreover, water is often used for particularly water-intensive purposes, where it is already scarce. With the worldwide growth in the population, there has not only been an increase in the direct pressure on water resources, but also in the indirect pressure on these resources from increasing food production and consumer goods and increasing energy requirements. Impacting further on these pressures are the effects of climate change that are manifesting in the form of extreme floods and droughts.

Water management: think global – act local

In order to keep up with the future challenges to cover the demand for water, integrated approaches for a sustainable use and management of water resources must be developed and implemented. These should be adapted to different regional water resources, different demands and the changes that are foreseen in terms of availability and demand.

In this respect the well-known slogan "think globally, act locally" becomes particularly significant. Following this, water use must be brought into balance with the available quantity, quality and ecological functions of surface waters and the groundwater to ensure sustainability. Not only the water resources themselves but also the natural functions of aquatic systems have an essential value for humans. Our waters provide ecological services such as the provision of drinking water and the provision of energy, transportation and self-purification, food resources, aesthetic and cultural values among others. No other system or technology can replace these functions. This can be illustrated by the following example: twelve percent of all known plant and animal species in the world live in surface water bodies, although these do not even account for a ten thousandth of the water volume on earth and only cover a proportionally very small part of the earth's surface. Moreover, approx. 41 percent of fish species and 25 percent of all vertebrate species more or less directly depend on freshwater ecosystems.

A modern and sustainable management of water resources therefore cannot be isolated and can only be developed and implemented when related to the water management sector. The key issues here are adaptation strategies, flexible infrastructures and considerably higher resource efficiency in terms of all water uses.

Water research: more disciplinary or interdisciplinary research?

What should modern water research cover? Can it seriously face the challenges of the worldwide water crisis? In principle yes: It is very well set up in the individual disciplines ranging from the natural sciences, engineering, economics and social sciences. At the same time however there is the dilemma of the "classical" disciplines in water research. Water research has an outstanding analytical and modelling understanding of physical processes or biogeochemical reactions on the small scale for individual water bodies or under strict laboratory conditions. It develops the most fastidious measuring technologies, and produces data at a temporal or spatial resolution and in a quantity for which methods of analysis are still not available. In water analyses, substances of an almost arbitrary number and of inconceivably small quantities can be analysed. Such research progress is of tremendous importance for understanding fundamental processes. However continuative and interdisciplinary approaches are imperative if sustainable solutions to regional and global water problems are to be achieved. Regardless of whether we are concerned with the emergence and dynamics of floods, the more efficient use or storage of so-called "green water" found in plants and the soil, the mobility or residual release of nutrients and pollutants, the functioning of aquatic ecosystems or the management of water quantity and quality under global change scenarios: we are dealing with complex, structured and managed environmental systems, in which various processes, interactions and

feedback take place. Indeed, the water cycle as a whole equates to more than the sum of its individual parts (see pages 16/17).

Interdisciplinary research however is not an end in itself and does not necessarily mean that everything has to be connected before statements can be made. It is rather the case that the art of interdisciplinary water research is in setting up an integrative approach in such a way that those system structures and characteristics can be identified and quantified that are crucial for the functions of the overall system and for the hypothesis at hand. Thus one should be careful not to get lost in various detailed processes or to make unacceptable over-simplifications through rough abstraction. It is intelligent and credible syntheses that are called for, because it is only in this way that rational decision bases can be made available for water and environmental management. These are absolutely imperative, when looking for solutions for example to increase the efficiency of different water uses – whether for agriculture (as the principle water user), the drinking water supply, the extraction of raw materials, manufacturing or wastewater treatment.

Solutions for a modern water research

For water research that is taken to be interdisciplinary this means that our scientific methods must be able to project the future developments of global change processes and their impacts on different scales without contradictions and with greater accuracy and reliability than has been possible so far. In doing so it is necessary to observe and analyse the single dominant processes in a way that reliable projections can be made for the behaviour of the whole system e. g. as a reaction to land use or climate change. Here, models and simulation tools will play a crucial role. These are indispensable for the development and examination of scientific hypotheses, and must be applied to system and process studies in the future far more than in the past. The basis for identifying dominant processes and developing models is the observation of environmental variables on different temporal and spatial scales – for example with the help of long-term observation time series on respective instrumented observation sites (like for example in the context of the observation platform TERENO, see pages 6/7). It is not only the classical environmental compartments such as air, water and soil that are of special interest, but in particular the transition zones between the water from vegetation, soil and groundwater as well as surface waters. This is where different key processes are taking place on small scales, which for example contribute to the build up of a flood or the deterioration of water quality.

Nowadays, water researchers agree on the fact that scientific research must be linked to sociological aspects. Here the crucial issue of effective water management must be dealt with. Which stakeholders, institutions and administrations are involved in which decision-making processes and which roles do they play there? Which legal and economic instruments are available for managing individual water uses (e. g. a regulation of water prices)? How can they be better co-ordinated and generally applied more effectively? Which role does the more or less environmentally-aware consumer play? Which administrations and incentives are in place to implement cost recovery principles or polluter pays principles more consistently? How successful is co-operation in international river catchments and how can a reconciliation of interests be organised between upstream riparians and downstream riparians?

The very different water issues on a global and a regional scale require a high level of knowledge in various fields in order to be able to act effectively. However, there is one thing that should not be forgotten: at the end of the day the key to solving water problems in a sustainable way is held by humans and civil societies. For this reason, basic and advanced training as well as knowledge transfer from water research to the relevant social sectors is imperative. In this respect "water research" and "water knowledge" are inseparable.

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View of a section of the Rappbode reservoir – a focal point of the environmental observations within the TERENO project.

ENVIRONMENTAL OBSERVATIONS THROUGH TERENO

The TERENO project set up in 2008 is nothing short of a new terrestrial observation network. Several centers belonging to the Helmholtz Community have joined together in order to investigate the large-scale, long-term development of the natural environment using various methods in a comprehensive and interdisciplinary fashion. For this purpose, observations, investigations, measurements, experiments and models are all being pieced together to form the basis for projections of future development. TERENO is coordinated by the Research Center Juelich (FZJ) with project partners from the Helmholtz Center Munich (HZM), the Karlsruhe Institute of Technology (KIT), the Helmholtz Center Potsdam (GFZ), the German Aerospace Center (DLR) as well as the UFZ.

Four regions in focus

Four regions of Germany are in focus, where long-term exploration is to be carried out on how climate change and land use change will have regional impacts on water cycles, the climate and the weather, biodiversity, soil and air quality. For this, both mobile and stationary equipment will be used and the socioeconomic impacts of climate change and land use change will also be examined so that the necessary intervention and adaptation strategies can be found.
In the meantime the research infrastructure for the long-term complex network is almost in place and many observations, investigations and measurements are already being conducted. The observatories in the four observation areas in the northeast German lowlands, the Central German lowlands including the Harz mountains, the Eifel and the alpine uplands are equipped with weather stations, geophysical measuring technology, radar systems to record precipitation, soil sensors and groundwater measuring systems among others. At the same time experiments are being conducted and scientific models for different environmental processes are being developed and tested. An important component of TERENO is also the development of methodologies and concepts, in order to be able to close the gaps between different scales of measurements, models and management.

A close-knit investigation network

An important element of TERENO are the so-called hydrological observatories. A closer look makes it more apparent just how large-scale, all-encompassing and thoroughly TERENO has been set up: “In every river basin, which forms the basis of a hydrological observatory, sub-basin areas are defined within which particularly intensively-investigated sites or test areas are defined. In this way we want to optimise the data yielded over areas of different sizes both quantita-

The four TERENO observation areas in Germany

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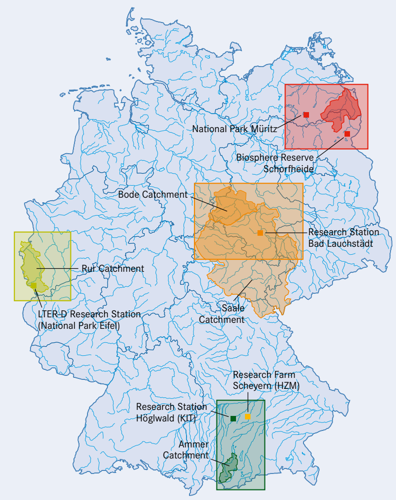

UFZ observation area
FZJ observation area
FZK / HZM observation area
GFZ observation area

tively and qualitatively", explains Dr. Steffen Zacharias from the UFZ, who is coordinator of the research work in the Central German lowlands and the Harz Mountains. The detailed data obtained in this way are linked up and entered into models and scenarios. The extent of the investigations becomes clear when we look at the UFZ's observation area: In three corridors – along the course of the river Bode into the Magdeburger Boerde, from Leipzig via Halle to the Harz mountains and the Elbe floodplains, almost 26,000 square kilometres are under investigation. In the river basin of the river Bode three sub-basin areas were selected that are exemplary for different conditions: In the Sauerbach basin the connection between fluxes of water and matter in an agriculturally-rich basin area is primarily being investigated; in the sub-basin of Schaefertal, hydrological processes and their connections are being investigated on different scales, in the Selke basin, the water regime and the modelling of a sub-basin, as well as groundwater processes are the focus of investigations. In the forested area 'Hohes Holz' a 50-meter high tower has been erected and equipped with measuring instruments, in order to be able to determine the connection between solar radiation, water transportation and CO_2-exchange. Another focus of observation is currently being set up at the Rappbode reservoir (see box). "From soil samples to remote sensing, from water discharge flumes to weather observations, from observations to experiments – with TERENO we are able to collate various forms of data and transform them for interdisciplinary purposes", says Zacharias.

MOBICOS – WATER RESEARCH FROM THE CONTAINER

At a focal observation point within the TERENO observatory at the UFZ, researchers want to examine a phenomenon in more detail that is of global concern for water management, namely the quantity of humic substances that is increasing in many water bodies. In Germany too, concentrations have been rising for approximately 15 years in many reservoirs. Humic substances are actually non-toxic products of decomposing plants, but for drinking water treatment they present a problem: they turn the water brown, decompose very slowly and when water is disinfected using chlorine, harmful by-products can be produced. In order to find out the causes of this development, scientists from the UFZ together with the reservoir authority of the state of Sachsen-Anhalt will install extensive measuring technology in and around the Rappbode reservoir over the next few months.

An important part of the research infrastructure at the reservoir and its inlets is MOBICOS (Mobile Aquatic Mesocosms): These are mobile containers placed in or at waters in which semi-natural investigations and experiments can be carried out. "The surface water is fed into the containers into various experimental basins where it can be subjected to various experiments like for example the addition of nutrients or a change in temperature. The containers can be implemented universally for the improvement of ecological processes in running or still waters. MOBICOS will provide a platform, which can also be used by external co-operation partners", reports Dr. Weitere. It is not only about observing procedures but also about understanding why these take place. The implementation of the mobile "experimentation boxes" in the Rappbode reservoir is therefore only one of many different possible uses.

Assembling lysimeters at the TERENO-site of Sauerbach in the Harz Mountains. With the use of lysimeters scientists are investigating the impact of climate change on the soil.

TERENO in the Mediterranean

Based on the concepts and experiences from TERENO in Germany, the plan is to set up TERENO MED in 2012. This will be in the form of an observatory network for the Mediterranean, whereby the initial research focus will be on water cycle investigations. Talks with Spain, Italy, Greece and Turkey are already underway, with other countries in the region, particularly those in North Africa joining soon. Eight to ten observatories are planned.

For several years the UFZ has been actively involved in various research projects in the Middle East. In Jordan there is the project SMART which is concerned with wastewater strategies (see page 20) and in Saudi Arabia UFZ scientists are working to establish a water balance with extremely high precision (see page 22). "In the Mediterranean the impacts of climate change can already be measured. Above all water security will be the greatest challenge" according to Zacharias. That is why it is urgent to finally collect the data required for an integrated water resources management in this region.

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Direct-Push technologies enable a more cost-effective, rapid sampling and data collection from unconsolidated soils and sediments.

SUBSURFACE CHARACTERIZATION BECOMES MORE EFFICIENT

In spite of its abundance, water cannot always be seen by the casual observer: it can often be found trickling through small pores and crevices, or accumulated in larger cavities below the earth's surface in groundwater reserves which, for most regions of the world, provide an indispensable source and supply of drinking water. However, what happens when toxicants contaminate the groundwater or when water is extracted from underground sources at a faster rate than it is recharged? To find answers to these questions, the processes that take place in the subsurface must be investigated and cause-and-effect interactions explored and understood.

For near-surface groundwater resources within unconsolidated sediments, modern Direct-Push technologies have opened up extraordinary new realms of research possibilities. These technologies are based on steel rods that are driven into the ground, thereby enabling rapid sampling and data collection. This technique holds several considerable advantages over conventional drilling and exploration processes, not least the ability to rapidly measure parameters directly from unconsolidated soils and sediments but also the high vertical resolution achieved in results. Within just 30 minutes, it is possible to obtain a resolution of five centimeters while taking a 15-meter depth electrical conductivity profile – an indicator for differentiating between different kinds of unconsolidated sediments. By comparison, a more conventional drilling process (using drill core analysis) would take several hours to provide the same level of vertical resolution information.

However, the potential of Direct-Push (DP) technologies has still not been fully exploited. A major challenge faced by researchers is to develop and implement robust and functional miniature technologies, which can then subsequently be incorporated into DP steel rods, often with a diameter of less than six centimeters. Therefore, UFZ scientists are not only developing DP sensors to measure chemical and biological parameters, but also DP sensors that will allow the characterization of distribution hydraulic permeability. Having an insight into this kind of distribution is important for a better understanding of transport processes in aquifers and to help therefore in analyzing risks. To accomplish this, scientists use the functional principles that conventional pumping tests are based on. Whereas with conventional pumping tests, permeability values would only be provided for the entire depth of a groundwater aquifer, the DP sensors enable a vertical resolution down to the last decimeter. Results from fieldwork show that hydraulic permeability on this scale can vary by several orders of magnitude. That means that the quantity of flowing groundwater can also fluctuate by several magnitudes to the power of ten, and that a detailed characterization of the variability of hydraulic permeability is essential for an impact assessment.

Considering the extension of a groundwater aquifer, DP investigations (like conventional drillings) are just the tip of the iceberg, in relation to the bigger picture. A major challenge is still finding out where to drill, which is why researchers are also dealing with the further development of geophysical technologies. By moving from the classical concept of using sensors that are planted into the ground to using towable equipment, it is now possible to characterize areas with a size of 25 hectares in three dimensions with several parameters from just one day of sampling. This is considerably quicker than any other sampling techniques used to date. The structure of information that is collected can then be used to find the best locations for the DP investigations in an adaptive process.

The towed geophysical devices are combined with Direct-Push-Technologies in the context of the UFZ research platform MOSAIC. The abbreviation stands for "**Mo**del Driven **S**ite **A**ssessment, **I**nformation and **C**ontrol", emphasizing the basic idea behind the model-driven and purpose-oriented application of various site characterization technologies. *Peter Dietrich and Susanne Hufe*

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POINT OF VIEW: ARE TOXIC CHEMICALS IN OUR WATER BODIES A THING OF THE PAST?

Dr. Werner Brack is head of the Department of Effect-Directed Analysis at the UFZ. His main research interests are identifying and assessing toxicants in water and sediments and deciphering cause-and-effect relations between contamination effects and the underlying toxicants. From 2005-2010 he coordinated the EU-funded integrated project MODELKEY with 26 partners from 14 countries. Currently he is head of a working group on effect-directed analysis for identifying new hazardous pollutants within the European network NORMAN (www.norman-network.net).

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Rivers with high concentrations of toxicants with acute toxic effects on fish and other river organisms have become rare in Europe. Modern production processes with low emissions, innovative waste water technology, numerous prohibitions in the manufacture and use of particularly hazardous substances, not to mention the closure or relocation of emission-intensive branches of industry have considerably reduced chemical loads in many water bodies. In Germany it is assumed that 88 percent of some 10,000 surface waters currently have a good chemical status (on WFD, see page 27). But how does this report of success fit in with the declaration that only 10 percent of these waters are in a good ecological status? One explanation for this is that not only those chemicals currently being monitored by the authorities influence the ecological status of waters, but that other unaccounted for chemical substances can also play a major role as well as factors such as river engineering, nutrient loads and the invasion of alien plant and animal species.

Concentrating on the chemical aspect: the chemical status of waters is momentarily monitored on the basis of 41 hazardous substances defined as priority substances, which are not allowed to exceed a fixed limit value. However, the impact on our environment from chemicals is much more complex. Typical environmental samples contain tens of thousands of different chemical compounds. About 30,000 synthetic substances are used for everyday products with a considerably higher number in industry and new substances are being added on a daily basis (the majority of these ending up in the environment sooner or later). If we take a closer look at the 41 monitored priority substances and compare them with those that are used today, a further problem arises: the list of substances is not up to date. This can be demonstrated using the example of pesticides. Only four of the 15 pesticides being monitored are still being used in Germany and only two of the 35 most quantitatively significant pesticides used in agriculture are on the priority list. It is therefore no wonder that the chemical status according to the WFD says very little about the true loads of harmful substances in our water bodies and that the results from chemical analyses do not often correlate with the measurable harmful impacts on water organisms.
An amendment to the list of hazardous substances, as is currently being discussed on the European level and the additional monitoring of so-called toxic substances in river basins are therefore implicitly required. For economical reasons alone however, not all chemical substances can be monitored and therefore two crucial questions have to be answered: Which changes need to be made to the list of 41 substances monitored in Europe and what needs to be changed beyond that?

Due to an increase in chemicals, on the level of aquatic communities, a decline in sensitive species and an impairment of important ecosystem functions can be observed, like for example the decomposition of dead plants and animals. At the same time, the biotests that were conducted within the framework of the EU-funded project MODELKEY coordinated by the UFZ showed that cells and organisms do not only react to chemicals that are present in large quantities but also to chemicals in very small concentrations that are even below environmental quality standards.
In fact, even when no direct effect can be found, this does not exclude the indirect effects of chemicals together with other stress factors. A well-known North American study on the worldwide decline in amphibian species supports this assumption. There it was demonstrated that pesticides impede the immune system of tadpoles, increasing their susceptibility to the larvae of a parasitic flatworm. The pesticide was the trigger for the fact that the relationship between the host and the parasite lost its balance.

Thus, there are clear indications that above all the loads of complex chemical mixtures typically found in many countries in Europe can (even in relatively low concentrations when combined with other stress factors) impair the ecological status of our aquatic ecosystems, their biodiversity and functions. This could provide an explanation for the current discrepancy that can be observed between the chemical and ecological status of German waters. In addition to updating the list of substances it is therefore imperative from my point of view to extend water monitoring to intelligent effect monitoring. Beyond that, a better understanding and the forecast of hazardous impacts in multiple stress situations are to this extent certainly one of the central challenges for research on toxicants in the near future.

To ascertain matter fluxes, a wealth of data on the concentration of various substances has to be continuously collected on a long-term basis.This is partially carried out at stationary measuring stations although sometimes the researchers themselves have to go into the river to take samples.

WATER AND MATTER FLUXES

Streams and rivers have been used since one can remember for the transportation of goods. However, substances are not only transported on the surface of the water, but also in the water and between the water, the soil and the atmosphere. Whether solids or solutes, inorganic or organic, desired or undesired, these substances range from nutrients and suspended matter to a whole range of contaminants from industry, agriculture and households.

When they are transported in water, complex biological, chemical and physical interactions take place that determine their fate, decomposition and impact on the environment. These processes have become the focus of research that preoccupies a group of hydrogeologists, biologists and chemists at the UFZ. Many of these substances present a true problem for water quality e. g. in the extraction of drinking water, which is becoming increasingly more complex and expensive, the more undesired substances there are to be removed. Furthermore, they also impair the natural functions of aquatic ecosystems such as food chains or filtering and purification processes.

The researchers not only strive for a better understanding of processes such as groundwater dynamics, the exchange between ground water and surface water or the spreading and decomposition of contaminants. They also want to be able to quantify and predict solute and matter fluxes. “Using data to describe this kind of complex hydrological and biogeochemical processes and then simulate these in computer models is a real challenge, but also the only way to make reliable predictions”, says hydrogeologist Dr. Jan Fleckenstein. Such predictions are needed to form a basis for management decisions, e. g. concerning the implementation of the Water Framework Directive (see page 27 on WFD) or in terms of adaptation strategies to climate change for entire river catchments.

The key processes that are actually relevant for large-scale matter fluxes often take place at much smaller scales, for example at the sediment-water interface, in the pores of soils or in the transitional zone between ground water and surface water. Individual chemical processes such as the reduction of nitrate by so-called denitrification are quite well known. However the complex interaction of several processes, involving a multitude of substances under very dynamic hydrological and biogeochemical boundary conditions (e. g. flow velocity, oxygen content), has only been partially understood and is rather difficult to track with current sensing techniques. This is a prerequisite, however, if a reliable basis for management decisions is to be established for entire catchments, e. g. where and how the restoration of rivers would make sense in order to create buffer zones for natural nitrate attenuation, or in defining wellhead protection zones for drinking water wells.

The river-groundwater interface

On the Selke, a tributary of the River Bode, one of the observatories within the TERENO initiative (see pages 6/7), UFZ researchers are investigating how morphological structures of the riverbed e. g. gravel bars and meander loops, influence the exchange of river water with sediments. This so-called hyporheic exchange brings river water to the porous subsurface, where due to slower flow velocities and mixing with inflowing groundwater, which has a different chemical composition and temperature, contaminants are degraded or eliminated through natural attenuation processes or transformed by redox processes. This natural self-purification potential of rivers can be disturbed by changes to riverbed morphology (e. g. river straightening) or interferences with groundwater dynamics (e. g. an intensified pumping of groundwater for agricultural irrigation). Using measuring instruments that have been installed permanently along a 300-meter long reach of the River Selke the scientists record pressure heads (hydraulic potentials) at the riverbed, in the sediment and in the adjacent aquifer as well as the relevant physico-chemical parameters such as oxygen content, electrical conductivity and temperature at high spatial and temporal resolutions. Gradients in the hydraulic potential indicate where and how quickly the water will flow belowground, while chemical parameters provide information about the chemical environment, in which the substances are transported. The data will be used to estimate the decomposition and transformation potential of the transition zone between the river and the groundwater. Eventually researchers will use numerical simulation models to quantify the effects of climate change e. g. changes to temperature and discharge on hyporheic exchange as well as possible changes to riverbed morphology and groundwater dynamics.

Tracing nitrates

UFZ researchers are taking a closer look at nitrate in the Sauerbach – a small stream affected by agriculture in the investigation area of the River Bode, one of the TERENO-observatories. Nitrate from agriculture still presents a threat to drinking water quality in many parts of Europe. The nitrate concentrations in spring water, which feeds into the Sauerbach, are already well over the thresholds from drinking water regulations. "Our regular sampling and analyses of various chemical substances and parameters have shown that nitrate concentrations are decreasing significantly along the course of the stream, but we want to know why this is the case. Is nitrate reduced in the hyporheic zone? Or does the concentration become lower when it is diluted with groundwater or water from agricultural drainage?" asks Jan Fleckenstein. The Sauerbach is also a good example of how hydrological dynamics can affect water and matter fluxes. Under very wet conditions and during intense rain events it can episodically come to the influx of nitrate-poor water into the stream from parts of the system that are not permanently involved in the discharge processes, clearly reducing nitrate concentrations in the stream. Unravelling such complex dynamics is important, in order to be able to sufficiently assess the effects of climate change on the flux of contaminants.

When humic substances become a problem

For some years now increasingly higher concentrations of dissolved organic carbon (DOC) have been recorded (as they have been all over the world) in the Rappbode reservoir in the Harz Mountains, which is the largest drinking water reservoir in Germany. "DOC is produced during the processing of humic substances, which are products of plant decomposition, and is transported by rivers and streams and surface discharge into the reservoir", explains aquatic ecologist Dr. Karsten Rinke. If humic substances are present in higher concentrations in the water, this can result in technical problems in the filtration process of raw water for the drinking water supply because the more humic substances that are present, the more difficult it gets and the more expensive the flocculation step becomes, which is then reflected in higher water prices in the long run. What is even more problematic is when humic acids that are actually not poisonous get into the purified water. "Our drinking water is disinfected with chlorine and chlorinated hydrocarbons can be formed as by-products during disinfection, which are in effect poisonous and therefore become a health risk", says Rinke. Currently, researchers want to find out in a long-term investigation, where exactly the sources of DOC are, why they are getting into the water at an increasingly higher rate and how long the trend will continue. Past research points to the fact that the flux of DOC into streams and rivers is controlled by processes in peat-forming riparian wetlands. Nine measuring stations have been set up all the way around the reservoir and starting from this year all influxes into and discharges from the reservoir will be observed as part of the TERENO-project.

A comprehensive understanding is imperative

Human interference with the natural cycling of matter, the climate and land use as well as new contaminants present in the environment all change the boundary conditions of the processes that control water and matter fluxes. "The quantification and prediction of matter fluxes in catchments is a complex, interdisciplinary challenge, for which we are well equipped with the numerous departments at the UFZ that are active in water research", says Fleckenstein. In addition to the development of tools and methods for assessing and predicting matter fluxes, the scientists are also working on methods for assessing the toxicological effects of contaminants on aquatic ecosystems as an indicator of water quality (see information box). "It is only together that we will achieve a comprehensive understanding of water and matter fluxes and their impacts on the environment", says Fleckenstein, "and this is what we are working to achieve."

Jörg Aberger and Doris Böhme

SPEAR – SPECIES AT RISK

When pesticides or other substances are dispersed in water, they have direct impacts on the organisms living there. Microbes and other small living organisms such as insects for example helped the biologist Dr. Matthias Liess and his colleagues to develop an instrument – SPEAR – which can be used to measure the impacts of pesticides on living organisms and the quality of the water.

First, the researchers determine which species and how many of each species are present in and along rivers. It is already known how the species react to contaminants – whether they migrate, whether their reproductive behaviour changes and how sensitive they are to different contaminants, therefore they are now being monitored on a regular basis. This task is carried out by the water authorities for the waterbodies within their jurisdiction and the species present there. The data obtained is then entered into the SPEAR-calculator, which monitors the water quality. If there are significant changes, measures can be taken immediately by the responsible authorities. At present the scientists are refining the instruments to be able to identify individual groups of substances, which are used in pesticides. The development is by no means final however: SPEAR can be adapted in such a way that industrial pollutants, salt-water intrusion or even heavy metals can be accounted for.

www.systemecology.eu/SPEAR/contact.php

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Prof. Dr. Peter Grathwohl studied geology at the University of Tübingen until 1985 where he received his Doctor's title in 1988 with a thesis on chlorinated hydrocarbons in the unsaturated soil zone. After a Post-Doctoral position from 1989 to 1990 at Stanfort University (in the USA) he returned to the University of Tübingen, where he has been working since as a scientist – since 1996 as a professor for hydrogeochemistry and since 2010 as Deputy Dean of the Mathematics/Science Faculty. Prof. Grathwohl is a member of the Federal Environment Agency Soil Protection Commission and leads the working group "water quality" in the project "Geo-resources Water", from acatech.

LEADING WATER RESEARCHERS COLLABORATE

What does "WESS" actually stand for?
WESS stands for **W**ater and **E**arth **S**ystem **S**cience. It is a strategic alliance on water research between the three Baden-Württemberg Universities of Tübingen, Stuttgart and Hohenheim together with the UFZ. Beyond that the alliance maintains close connections to international water centers, among others the Department of Earth Sciences at the University of Waterloo in Canada, and the Catalan Institute for Water Research (ICRA) from Gerona in Spain. The main focus of the work is on the effects of changing environmental conditions to the water cycle and on the flow and pollutant dispersion in the water, soil and atmosphere.

What are the strengths of the individual partners?
All four partners have leading water research groups throughout Europe. Their key competences are in different fields of research and these are connected based on a division of work within the alliance over several years. The Center for Applied Geosciences (ZAG) at the University of Tübingen contributes its expertise in the fields of hydrogeology, geochemistry and research on pollutants. The colleagues from Stuttgart concentrate more on environmental analysis and modelling. The scientists from Hohenheim contribute their know-how from the fields of soil science, weather and climate change research as well as interactions between the earth and atmosphere. Finally, the UFZ contributes with its strengths in the fields of exploration, monitoring, modelling and the visualization of processes in aquatic ecosystems as well as through its Integrated Water Resources Management (IWRM). We not only complement each other with respect to our fields of specialisation, but also in terms of our structures. As a Helmholtz Center, the UFZ for example has access to methods and infrastructure, which we cannot provide as universities and due to the fact that we are educators, we have access to excellent young scientists.

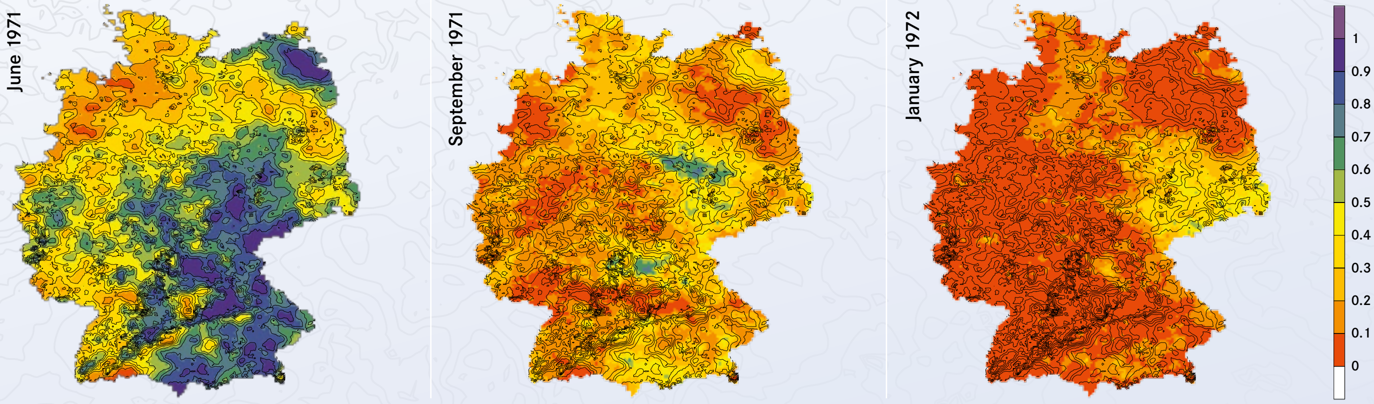
How is WESS financed?
The funding up to 2013 is 3.6 million Euros – half of which is government-funded through the UFZ and half of which is provided by the German Federal State of Baden Württemberg.

Which specific projects are funded?
We are currently looking at four very different river catchment areas in Germany, which differ in terms of their climate and land use. In Central Germany we are investigating water flows and physical parameters in the catchment area of the River Bode, at one of the large research observatories of the UFZ. In the South of Germany we are looking at the flow and pollutant dispersion in three tributaries of the River Neckar: the Goldersbach tributary that is almost entirely situated in a nature park, the Ammer tributary which flows through a very intensively-used agricultural area and the Koersch tributary, where wastewater is discharged from the treatment plants of the greater communities in the Filder lowlands in the vicinity of Stuttgart.

What exactly do you mean by "looking at"?
At various South German research sites we have so far installed 25 measuring stations where samples are taken once per month and analysed according to approx. 120 parameters. Apart from the standard parameters such as the pH-value, conductivity or temperature, a wide range of anthropogenic pollutants are also analysed. These include chemicals from agriculture (among others nitrates and pesticides), waste substances from households (among other things anti-corrosive and pharmaceutical substances), and finally pollutants from industry. This current data that is recorded complements the data that we already have extending well into the past. For this we require the cooperation of the local water utility companies, but generally speaking this is not a problem because they are also very interested in our results. The issue of increasing nitrate or pesticide content in the groundwater is for example of particular interest to them, as it is a problem in many regions and poses a challenge for the drinking water supply. At the end of the day nearly 75 percent of drinking water in Germany is from groundwater supplies. How will the nitrate content change in the future? What effect would a change in agricultural practices have? How quickly would the system react? Similar questions arise for the overall chemical footprint left behind by humans. How can this be traced in the groundwater and thus in drinking water? How long will our descendants have to combat these problems? I can assure you that there will still be traces of many of the substances deposited in the environment by humans for many generations!

So all the data collected can be fed into your models ...
Precisely. Data with a high resolution collected over a longer period of time are a prerequisite for the models, enabling us to develop scenarios for water quality. In an iterative process we are developing models for the first time that incorporate the entire water catchment area. At present we are still working with different model hierarchies and are concentrating on individual hypotheses, because the models that are available are simply not yet able to calculate the reactions of all substances on large scales. However, computer technology is developing all the time and so are our possibilities.

The interview was held by Susanne Hufe



These three pictures show a snapshot of the drought development in Germany at the beginning of the 1970s. Increasingly more regions have suffered from extreme aridity since the Soil Moisture Index (SMI) was under the 0.2 threshold.

INVESTIGATING DROUGHTS

Many meteorologists can still remember that April 2007 was a record month because it was the warmest and driest April with the most hours of sunshine recorded since the start of meteorological data recording in Germany. What pleased many holidaymakers turned out to be an economic disaster for many farmers whose crops and seedlings died off, because their fields became too arid. So far only a handful of scientists in Germany have conducted research on these droughts in great detail and one of them is Dr. Luis Samaniego, a hydrologist at the UFZ. He has been investigating how many drought events there have been in Germany since 1950 and how severe, extended, and lasting these extreme events were. He has found that approximately 2180 drought events have occurred in Germany from 1950 to 2009, each one characterized by an average spatial extension, duration and severity. The longest drought event lasted almost three years, from August 1971 to July 1974 affecting almost half of German territory. The drought event between March 1959 and September 1960, on the other hand, was the largest with respect to areal extension since almost two thirds of the country was affected by extreme arid conditions.

Soil moisture plays a major role in defining agricultural droughts, as it constitutes the water that is stored in the root zone of the soil profile due to hygroscopic and capillary forces that act against the force of gravity. Depending upon the type of soil and morphology, this zone varies between 40 centimetres and two meters below ground. “Soil moisture works like a switch that is responsible for controlling the water and energy fluxes of the soil-vegetation-atmosphere system”, reports Samaniego. On the one hand, soil moisture content controls the amount of precipitation that might leach, run off, or evaporate. On the other hand it provides a kind of memory to the system as it stores precipitation for days or weeks, which is essential for the growth of vegetation. In general, larger proportions of clay minerals in the ground induce larger soil moisture retention periods. By contrast, sandy soils tend to leach water quickly and thus become drier easily. The degree of soil moisture content, however, depends primarily on precipitation and temperature. “The weather conditions are responsible for droughts” argues Samaniego.

Regionally speaking, drought events in Germany are of a very different nature. Over the past 60 years, particularly long events occurred in Saxony and Saxony-Anhalt based on the soil moisture index developed by Samaniego and his co-workers at the UFZ. Why these two German Federal States, in particular, were affected is still not completely understood from a scientific perspective. One possible reason for this according to Samaniego could among other things be the morphological characteristics such as the soil texture and the low precipitation owing to an unfavourable geographical location on the sheltered side of the Harz Mountains. In contrast to this, the German state of Baden-Württemberg appeared to be the least susceptible among all German federal states. According to Samaniego’s opinion this is most likely due to the above average rainfall in the south of Germany which is partly related to the presence of the Alps and the Black Forest.

Looking at the past is only one part of the research project that the 45-year old UFZ researcher has been dedicating his work to since 2006. Using his mesoscale hydrologic model (mHM) he wants to be able to make accurate predictions about which regions in Germany will be faced with extreme droughts in the future under certain conditions. “It seems very likely that we will experience not only more frequent but also longer and more intensive droughts due to climate change” says Samaniego. To find this out, he wants to run some simulations with a climate model that researchers of the Karlsruhe Institute of Technology are currently working on.

Those who will greatly benefit from Samaniego’s research are the farmers. They will be able to get a better idea of whether or not their agricultural land is located in areas with high drought risk and whether in the future it would be better to switch to artificial irrigation systems to avoid poor harvests and crop failure. The UFZ hydrologist sees his research as still being in the early stages. There are still so many questions to answer, he says: What are the causes of droughts? Is the occurrence of droughts linked to the distribution of high and low pressure areas? These are just two of the many questions that Samaniego would like to answer as soon as possible. *Benjamin Haerdle*

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A 3D VIEW BELOW THE GROUND

From a bird's eye view the Arabian Peninsula largely resembles a reddish-brown desert landscape – quite different to what is seen on the six by three meter screen in the UFZ's Visualization Centre (Vislab) in Leipzig. When the working group of Prof. Dr. Olaf Kolditz switches on the computer, the Saudi Arabian desert lights up in different colours. The geological layers are displayed in many different colours, 2000 different coloured towers are stacked as boreholes in the desert and red lines portray groundwater flows. In different simulations Prof. Kolditz can take all the wells on the peninsula out of operation, causing the groundwater level to rise and making the colour change from bright red to green as a sign of rising groundwater.

The goal of Vislab that is operated by 13 computers and 13 beamers is to provide complex modelling in 3D that is close-to-reality. It therefore makes the work of many researchers much easier. "It is an important tool for us because the 3D-view constantly provides us with new insights into complex environmental systems", says environmental informatics expert Prof. Kolditz. Apart from this, Vislab also promotes interdisciplinary co-operation. When groups of researchers from different disciplines get together, it is a tremendous advantage to be able to discuss research results that can be displayed well visually and to test their consistency. Another positive outcome from Vislab is that it facilitates communication with the public. With the help of Vislab, UFZ researchers can make complex research topics more comprehensive to politicians, journalists or students.

In this way Vislab is unique for environmental research in Germany. It is used at the UFZ for research on city developments, to visualize landscapes for example in planning wind parks or to find answers to geo-spatial questions such as optimising carbon sequestration in the soil. The main research focus is on water however. This can not only be seen from the example of groundwater modelling in Saudi Arabia, but also from the contract with the Peking water utility company, for which Prof. Kolditz's team is to develop a forecast model on how nitrate content in the groundwater is reduced as a result of less intensive agricultural practices. "In these virtual worlds we are able to visualise the most diverse scenarios because of numerous model calculations", says Prof. Kolditz.

Vislab that was set up in 2007 has even more to offer however than its 3D-cinema for researchers. It is a tremendous database, where information is linked up to every last visual element and with integrated modelling, innumerable outcomes and future developments for real systems can be run and perfectly visualised.

The programming for integrated modelling is no longer as painstaking as it was for UFZ environmental informatics experts. Researchers are rather faced with greater hurdles from the mass of data that can be collected with modern investigation methods. Whether or not the data are both suitable and reliable for the desired model study are now two of the most important questions that the scientists working with Prof. Kolditz have to keep asking themselves.

Various modeling programs are linked up so that the virtual worlds can be analyzed consistently, efficiently, and in a manner that enables adaptation to new insights. For this the scientists have created a complex numerical modelling platform (OpenGeoSys), which enables numerous processes to be viewed in different ways for the most diverse ranges of application. In order to improve the features of computer programs such as OpenGeoSys, UFZ researchers are looking for methods that test the usefulness of the model approaches and the accuracy of the simulations. Prof. Kolditz and his colleagues have therefore cooperated with various research institutions and compiled more than 100 test examples in the form of a benchmark book. With this they want to create a quality standard in order to test the precision of complex computation methods. The more complex the individual computer programs are, the more susceptible they are to inexpedient model assumptions. There is no 100 percent depiction of reality according to Prof. Kolditz: "Models are always simplified depictions of reality, but they are the only way of looking into the future."

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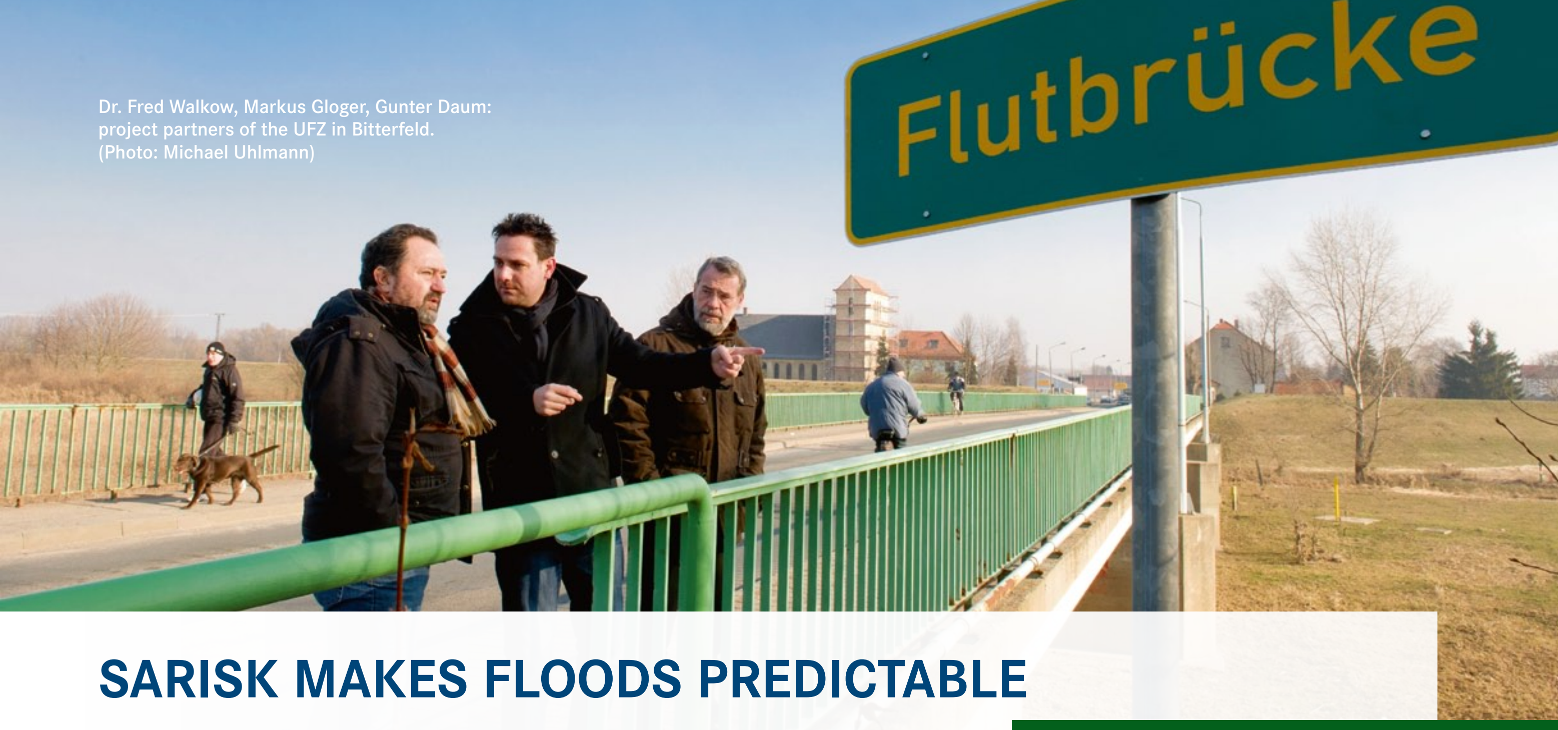

Dr. Fred Walkow, Markus Gloger, Gunter Daum: project partners of the UFZ in Bitterfeld. (Photo: Michael Uhlmann)

SARISK MAKES FLOODS PREDICTABLE

After the extreme flood of 2002 a group of UFZ researchers were contracted by the BMBF to investigate pollutants in the flooded areas of the Mulde and the Elbe catchments. "We were faced with extensive areas and took soil samples from these to the best of our knowledge, but we were uncertain as to whether we had taken them from the right places", reports Dr. Wolf von Tümpling (one of the researchers involved in the work at the time). As a result, he and his colleagues looked into methods that would enable a more focussed sampling to describe the impact of pollutants after a flood. Although they were able to establish computer models for specific individual questions such as pollutant dynamics or hydraulics, a meaningful link between the models and the data was still missing. Hence, the idea was born to bridge this gap. In 2005 the scientists were funded by the BMBF to start work on the Model-based Decision Support System SARISK, which not only improves information about the impacts of pollutants after a flood, but also enables better forecasts on how high the water level could be in the event of flooding. The District of Bitterfeld was the perfect case study for the scientists not only because 100 years of mining and industry had left their mark there, but also because the researchers had access to a wealth of data from the past on this district. The scientific research (including for example the development of a Digital Elevation Model and the modelling of the dispersion of pollutants) was conducted by v. Tümpling and his colleagues in a team with researchers from the University of Halle and Osnabrueck, whereas the user interface of the program was designed at Dresden's Leibniz Institute of Ecological and Regional Development. After three and a half years of work, at the beginning of 2009 the forecast model was finally ready. Markus Gloger from the environmental authorities in Bitterfeld knows the program inside out and works with it on a regular basis. "It was all theory to start with", he says. "But then it was put to the test by the flood in January 2011. At the moment where it looked as though the flood would affect the district, we arranged to meet the district water weir officials. We entered the current water level into the system and SARISK informed us that we had approx. one or two hours until the flood peak would hit us informing us how high the water would be. As a result, we had enough time to inform those who would be affected and asked them to drive their cars away." The model was able to predict the water levels with an accuracy of 10-15 cm, helping to place personnel and equipment where it was most needed. Bitterfeld now knows exactly which areas will or will not be flooded. "As a result of this, we are now able to avoid unnecessary evacuations", Fred Walkow (Head of the District Building and Environment Authority) is pleased to announce.

"This is where all the stops are pulled out. There will always be some people with objections. At the end of the day we are dealing with residential homes for senior citizens and hospitals. The more certain I can be about my decision, the better." But the precautionary opportunities that SARISK can provide are even greater, for example with respect to investment decisions concerning areas that are threatened by flooding.

Gunter Daum, Head of Bitterfeld's Environment Office uses a different calculation: "With the flood in 2002 the largest single damage amounted to 30 million Euros, which was our newly-built hospital that was affected by the flood. At the same time, approximately the same amount of compensation was handed out to homeowners. Ironically, the costs of developing the model are only a fraction of this." The administrative district of Anhalt-Bitterfeld wants to extend the system (that can zoom into the household level) to areas at risk of flooding along the River Saale. "Those regions without dams could benefit tremendously from such an investment." The exact costs depend on the raw data however. The more accurate and the more extensive these are, the less expensive the modelling will be. Of course, SARISK will also serve the purpose for which it was originally designed: "After the event of a flood we have got a much better idea of where contamination will occur", says scientist v. Tümpling reassuringly.

(Source: Annette Schneider Solis/Sachsen-Anhalt-Magazin 1/11)

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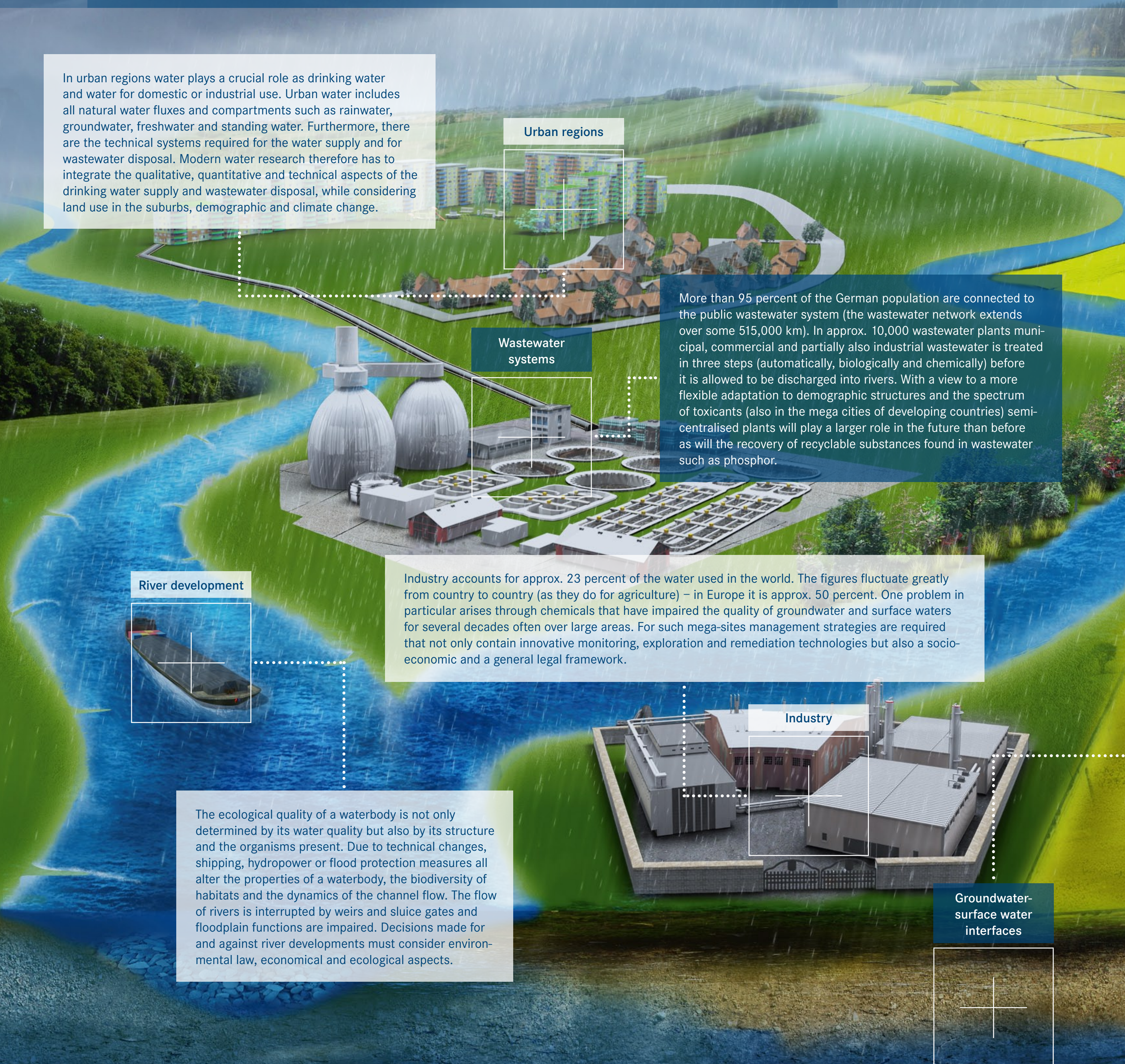
Water can be found everywhere in our environment: in the atmosphere, in the oceans, in rivers and lakes, in groundwater, in the soil, plants and organisms. In a natural cycle water moves between different compartments of the environment, transporting matter and energy fluxes.



In urban regions water plays a crucial role as drinking water and water for domestic or industrial use. Urban water includes all natural water fluxes and compartments such as rainwater, groundwater, freshwater and standing water. Furthermore, there are the technical systems required for the water supply and for wastewater disposal. Modern water research therefore has to integrate the qualitative, quantitative and technical aspects of the drinking water supply and wastewater disposal, while considering land use in the suburbs, demographic and climate change.

More than 95 percent of the German population are connected to the public wastewater system (the wastewater network extends over some 515,000 km). In approx. 10,000 wastewater plants municipal, commercial and partially also industrial wastewater is treated in three steps (automatically, biologically and chemically) before it is allowed to be discharged into rivers. With a view to a more flexible adaptation to demographic structures and the spectrum of toxicants (also in the mega cities of developing countries) semi-centralised plants will play a larger role in the future than before as will the recovery of recyclable substances found in wastewater such as phosphor.

Industry accounts for approx. 23 percent of the water used in the world. The figures fluctuate greatly from country to country (as they do for agriculture) – in Europe it is approx. 50 percent. One problem in particular arises through chemicals that have impaired the quality of groundwater and surface waters for several decades often over large areas. For such mega-sites management strategies are required that not only contain innovative monitoring, exploration and remediation technologies but also a socio-economic and a general legal framework.

The ecological quality of a waterbody is not only determined by its water quality but also by its structure and the organisms present. Due to technical changes, shipping, hydropower or flood protection measures all alter the properties of a waterbody, the biodiversity of habitats and the dynamics of the channel flow. The flow of rivers is interrupted by weirs and sluice gates and floodplain functions are impaired. Decisions made for and against river developments must consider environmental law, economical and ecological aspects.

Worldwide approx. 60 percent of freshwater is used for agriculture (in Europe it is approx. 44 percent; in water-poor regions such as the Middle East it is around 80 percent). Agricultural impacts on water arise from diffuse residues from pesticides, nutrients from fertilizers and sediments from soil erosion, chemical compositions as well as the quantity of groundwater and surface water.

With the increasing global demand for energy, the demand for bioenergy and therefore biomass will also increase in the near future. Here, new areas of conflict are expected to arise e. g. in the protection of species or in water management, as an increase in the demand for biomass requires more land, more pesticides, more fertilizers and more water.

Reservoirs can act as barricades, reservoirs, water extraction systems, or floodwater overflow systems. However they are also related to considerable changes to the landscape and the impairment of natural ecosystems that alter the natural flow of water regimes. Their function as a drinking water reservoir has been impaired over recent years from an increase in the content of dissolved organic carbon in the water. Whether the flux of matter is of geological nature or caused by land use and climate change now forms a substantial part of scientific research.

In water protection zones, surface waters and groundwater are to be protected in the form of bans and rules. Groundwater is enriched and the run-off of precipitation as well as the washing away or discharge of soil components and fertilizers into the groundwater are prevented. Depending upon the protection zone category (I, II or III) restrictions to use are applied e. g. with respect to building, agricultural use, road construction, the application of liquid manure or sewage sludge, the disposal of waste substances or industrial livestock farming.

The drinking water from several larger urban agglomerations is extracted to a large extent from riverbank filtration. Apart from which, the EU Water Framework Directive (WFD) explicitly stipulates an integral view of groundwater and surface water resources. For this reason there has been a considerable increase in the scientific interest to investigate the hydraulic and biogeochemical conditions of water interfaces and the interactions between groundwater and surface water in an integrated manner. Furthermore, new methods will be developed to quantify and simulate exchange processes.

(Illustration: CAST Dresden)

Monitoring of the SAFIRA pilot facility in Zeitz. On the grounds of the former hydrogenation plant UFZ scientists examine the microbiological decomposition of benzene in the groundwater.

INNOVATIVE SOLUTIONS FOR CONTAMINATED GROUNDWATER

According to estimates of the Federal Office for the Environment, there are approximately 300,000 sites in Germany alone that are thought to be brownfield sites, among them some that stretch over several hectares to square kilometres that are therefore referred to as "megasites". On the European scale there are supposed to be thousands of them. The spectrum of brownfield sites extends from garbage dumps, industrial waste depots and chemical treatments to disused tin mines, militarily land and former sites from the pharmaceuticals industry and crude oil processing. Due to leakages and accidents large quantities of the most diverse pollutants seeped into the soil substrate over longer periods. If these sites are seen to be a hazard to ecosystems or human health, then the sites must be remediated. "Remediation" in the majority of these cases refers less to the re-establishment of a semi-natural state but more so to a removal of the main pollutant as much as possible. Using the example of a typical pollutant from industry we can clearly see just how expensive this kind of remediation can be. It costs one Euro to produce one kilogram of the volatile chlorinated hydrocarbon perchloroethylene for example, but removing one kilogram of the potentially carcinogenic substance from the groundwater can easily cost more than one thousand Euros. This might still be technically feasible in cases with low damage. However where vast areas or megasites are concerned with their complex spectrum and various sources of pollutants, it is usually impossible to carry out a thorough investigation of the sites and to record all of the pollutants, let alone to remove them completely from the soils and groundwater. If they are left uncontrolled however, the pollutants can spread further underground getting into floodplains, the surface water or even into cellars.

Scientists from the Helmholtz Centre for Environmental Research are developing economic and innovative remediation concepts and management strategies to avoid these dangers to humans and the environment and to support a meaningful future use of brownfield sites that incorporates the sustainable use of land. In the context of the research project SAFIRA II an infrastructure has been set up at suitable model sites in Germany comprising of exploration, monitoring and remediation technology, in order to study the transportation, the natural decomposition and the accumulation of pollutants in parts of the soil and dilution effects.

Microorganisms for remediation

It has showed up time and again that there is a great potential from a controlled implementation of microorganisms to eliminate pollutants in a cost-effective and successful manner. Microorganisms can provide a genuine alternative to conventional procedures like for example so-called "Pump and Treat" measures, upon which a major part of groundwater remediation technology in Germany is still based. "Pump and treat" means that the contaminated groundwater is pumped upwards and treated either chemically or biologically in technical facilities. However, with the enormous amounts of groundwater and complex chemical compositions that are involved, this costs a great deal of time and money.

By comparison, the decomposition of pollutants through naturally occurring microorganisms in the soil would be a remediation technique that not only saves energy but is also semi-natural if it can be proven that these decomposition processes run smoothly and that no subjects of protection such as drinking water wells or rivers are at stake. Scientists from the UFZ are testing this research approach in two pilot facilities on the grounds of the former hydrogenation works in Zeitz. A facility for benzene was operated there in the immediate vicinity until 1991. "We have thoroughly investigated the benzene in the groundwater aquifer and the self-purification processes to every last detail. From this we have been able to establish that the benzene plume could become stationary and that remediation action is therefore not necessarily required. In this case, one could simply leave the natural decomposition processes to run their course", explains groundwater expert Prof. Holger Weiss, adding that: "Such processes take place very slowly however. If we want to ensure that the sites can be used more quickly by potential investors, then the natural decomposition processes must be accelerated." In the pilot facility the researchers are therefore testing whether the addition of nutrients will accelerate the decomposition of pollutants in the groundwater and which ones are most suitable.

At the site in Leuna the scientists believe that microorganisms can cope with this 'potent cocktail'. Until 1996 Leuna was one of the largest oil refineries of the former GDR. Due to damages during the war and handling losses, petroleum-derived hydrocarbons or so-called BTEX aromatic compounds (benzene, toluene, ethylbenzene and xylene) as well as gasoline additives managed to seep into the groundwater for decades.
In the pilot facility of the project "Compartment Transfer" (CoTra) groundwater researchers, chemists and biologists from the UFZ have been testing five semi-natural remediation techniques. What is common to all of these techniques is that the contaminated, anoxic groundwater is transferred into systems close to the surface with high oxygen content such as surface waters, the root zones of plants or ventilated soil zones. Here, oxygen, plant roots and soil particles provide the most optimal living conditions for microorganisms to decompose the pollutants. The pollutant transfer works best in an "open ditch" system and the so-called vertical filter process. Owing to filtration through a ditch facility, the groundwater does not have to be removed, but remains in the man-made ditch, through which it slowly flows. The ditch is filled with straw and supplied with oxygen, which accelerates the microbe decomposers considerably.
With the vertical filter process contaminated water is fed through planted wetlands, where microbial decomposition occurs at the bounding surfaces of plant roots and soil particles, which not only provide the most optimal conditions for microorganisms but is also where they can form very stable and effective biofilms. This process is currently being transferred to a true-scale in co-operation with a remediation company.

A bypass to groundwater treatment
The complex and harmful mix of pollutants found in Bitterfeld's groundwater can not be resolved by microorganisms alone. "The main pollutants that we have to deal with in Bitterfeld are chlorinated hydrocarbons", explains Holger Weiss. He is holding a small bottle in his hand that is emitting a potent smell – a groundwater sample from the city of Bitterfeld that once stood for environmental pollution and a dilapidated economy. The sample was taken from the one hundred million cubic meter groundwater body situated in the large-scale ecological project Bitterfeld-Wolfen. Even if the region has become attractive again thanks to an attractive lake landscape and a modern pharmaceuticals industry, a large amount of contamination is still lurking down below. Without controlled water-pumping measures in particularly endangered areas, the contaminated groundwater would get into the cellars of houses and become a health hazard to inhabitants.

The company BilfingerBerger GmbH for environmental remediation is therefore operating a high-technology plant for groundwater treatment on the megasite. The groundwater is collected via well galleries, cleaned by stripping (blowing out with air) and by binding the pollutants to activated carbon and is finally fed into the river Saale through a sewage works on site. 200 cubic meters of water can be treated per hour. Some parts of the plant do not work optimally however because in addition to the chlorinated hydrocarbons volatile sulphur compounds are also air-stripped. Above all it is the rare sulphur compound 'carbon disulfide' that creates havoc. With the catalytic burning of the pollutants in the airflow, sulphuric acid is formed, which leads to a rapid corrosion of reactors and heat exchangers.

The UFZ has been contracted by Bilfinger-Berger to solve this problem. In a kind of bypass process, part of the groundwater flow is redirected from the large treatment facility into different reactor systems of the Treatment-Train facility of the UFZ. Different processes are installed there that have previously been tested at the laboratory level and are constantly being optimised. Together with colleagues from the Technical University of Darmstadt, the UFZ researchers have now come up with an innovative and economical procedure, which is based on the hydrolysis of carbon disulfide with alkaline aluminium oxide. Thus all sulphur compounds can be completely and selectively removed under moderate conditions without having to convert the chlorinated hydrocarbons that would result in the production of hydrochloric acid. The procedure was applied for patents and has meanwhile been successfully in operation in various pilot periods. In the next step a so-called power test run will follow. "That is to say, we must demonstrate to the client that the procedure works in our pilot facilities and complies with the very fastidious treatment requirements. If that is the case, then the operator can decide whether or not the UFZ procedure will be implemented in the large-scale facility", explains chemist Prof. Frank-Dieter Kopinke from the UFZ. "Naturally we hope that the process is so attractive that our industrial partner will say: The process is an absolute necessity, both at the Bitterfeld site and elsewhere." Since the Treatment-Train plant facility comprises of flexible containers and reactors it can also be used on other contaminated sites once the project has been completed.

Bettina Hennebach and Doris Böhme

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In the pilot plant of the project "Compartment Transfer" (CoTra) various semi-natural remediation techniques are being tested to eliminate BTEX aromatic compounds in the groundwater.

In the pilot and demonstration facility in Fuheis (Jordan) decentralized technologies for wastewater treatment are tested using different systems.

SMART SOLUTIONS FOR WASTEWATER USE

New concepts for a decentralized water management for the Middle East are being developed in the international research project SMART (**S**ustainable **M**anagement of **A**vailable Water **R**esources with Innovative **T**echnologies). How decentralized wastewater treatment and reuse can work properly is soon to be tested by the inhabitants of a Jordanian village together with scientists.

The Middle East is one of the worst water shortage regions in the world. Together with colleagues from Jordan, Palestine and Israel, researchers from the Helmholtz Center are exploring ways to stabilize the water supply in this region. The main goal is to use scarce resources in the best possible way, therefore enabling the reuse of wastewater, while at the same time taking into account religious provisions. "This is the real challenge, which can only be realized with the help of local stakeholders and the acceptance of the population", as Roland Mueller, the project manager of SMART knows. Part of this project that was started in 2007 is a decentralized wastewater treatment strategy for Jordan, which was developed by researchers at the UFZ together with local stakeholders and passed by the Jordanian government in 2009. The project's first outcome was the opening of the SMART Research Demonstration and Training Facility in March 2010 with several pilot project facilities for decentralized wastewater treatment in Fuheis near Amman in Jordan. The site, which was handed over to the Technical University Al-Balqua was designed and developed by the UFZ in co-operation with the BDZ e. V. (Training and Demonstration Centre for Decentralized Sewage Treatment) in Leipzig. Financial support is provided by the German Federal Ministry of Education and Research (BMBF) as well as some of the companies that are involved.

In the next step the insights from the demonstration facilities in Fuheis are being transferred to real locations in other villages: "Nine to twelve facilities are to be developed at selected sites in Jordan", explains Mueller. The size of the decentralized wastewater treatment facilities should be extremely variable – ranging from a solution for an individual house to systems for a small village with a maximum of 300 inhabitants. The aim is to generate experiences and concrete figures to gain insights into jurisdictions, costs and necessary maintenance work in order to pave the way for a wider distribution of decentralized technologies. Different treatment technologies are used and adapted to the site conditions such as eco-technologies (soil filtering systems), Membrane Bioreactors (MBR) and Sequencing Batch Reactors (SBR). Mueller's coworker Manfred van Afferden praises the constructive co-operation: "We are making good progress, because participants are all pulling together, even those that are competitors. Our recently defined term for this is "coopetition" – a term derived from "cooperation" and "competition".

The third phase of the SMART-project consists of including larger catchment areas and realizing concrete projects: "On the basis of our research results so far we have made a priority list from which suitable regions have been selected together with the Jordanian Ministry of Water and Irrigation. Our research results must be reflected in such a way that make investments available in cluster solutions – irrespective of the applied technology", stresses Mueller. In co-operation with the BDZ, system solutions are to be found and made available. The UFZ researchers' idea for Jordan is a "decentralized infrastructure cluster, which is however financed, operated and maintained centrally." At present the two researchers from Leipzig are holding talks with other project stakeholders with all involved Jordanian Ministries, local and regional decision-makers. "A wide acceptance and trust from the Jordanians has created a good base for the next steps", stress the UFZ researchers. An enormous task lies before them – once political decisions have been made, it will be a question of informing and sensitising the population, eliminating any doubts and facilitating know-how. It is not only a question of the sustainable use of available resources, but above all about involving the population in an improved water management. "As soon as people have understood that reused wastewater can irrigate their fields or green their city, then they will be more open for new technologies", Mueller and van Afferden both agree. *Gundula Lasch*

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Drinking water is only available in canisters in the yurt districts on the outskirts of the town of Darkhan. The majority of the inhabitants neither have access to drinking water nor are they connected to a wastewater treatment system. With just under 80,000 inhabitants, Darkhan is the third largest city in Mongolia and is situated in the basin of the river Kharaa, which flows into Lake Baikal in southern Siberia. (Photo: Lena Horlemann/UFZ)

FAREWELL NOMAD LIFE

On the outskirts of the town of Darkhan, there is a clash between traditional and modern lifestyles, for it is here that many Mongolian families have settled that used to be pastoral nomads. Their housing has remained the same for centuries: Living in yurts they settle in peri-urban areas, and perhaps later on become the owners of a certain plot of land upon which they build simple houses made of wood, stone or bricks. Although this way of life worked for centuries in such a sparsely populated country, it is now becoming a hygiene and environmental problem due to a high population density in such a confined area, as there are neither drains nor wastewater treatment plants in these so-called Ger districts. In fact, drinking water has to be collected from water kiosks. For the first time this problem is now being closely investigated from a sociological perspective by water researchers in the context of the International Water Alliance of Sachsen (IWAS). UFZ scientist Dr. Katja Sigel who is coordinating a participative case study for water infrastructure planning in Ger districts conducted a survey in 139 households on the water, sanitation and health conditions: "People consume only 12 litres of water per person per day on average which raises the question as to whether they can meet their basic needs with this. Many of them have private wells on their plot of land to extract additional water free of charge. But this water runs the risk of being contaminated by unsealed pit latrines from nearby", reports Sigel.

"We have selected the north of Mongolia as a pilot region for Integrated Water Resources Management (IWRM), because the rivers in Central Asia will be particularly affected by not only climate change and land use change but also by the exploitation of mineral resources from extensive mining over the coming decades – with dramatic consequences. "From inventories it was concluded that the number of brooks, rivers and lakes have drastically declined while many springs have also run dry", says project manager Prof. Dr. Dietrich Borchardt from the UFZ. The first phase of the project was therefore concerned with analysing the initial situation and verifying the data. In doing so hydrological balances, sediment and materials deposited as well as the ecological status were recorded and transferred into models. In the second phase the scientists want to look for solutions to apply these models to pilot projects and to make their knowledge available to local inhabitants. "Capacity Building" therefore not only includes training for students, but also further training opportunities for employees in ministries, local authorities, the water agency and operators of infrastructures.

"The problems in many regions of Central Asia are similar to one another: an extreme continental climate, strong population growth, lacking or dilapidated wastewater systems, increasing water consumption and decreasing water resources that are threatened by overgrazing, soil erosion and the overexploitation of natural resources. Furthermore, the average annual temperature has risen extraordinarily above average by +0.7 degrees Celsius over the last 50 years."

Great interest has been shown by the Mongolian authorities in an IWRM following the German model. "Concepts have already been drawn up on paper, but it is still not certain as to how these could be realised in practice. Unfortunately there isn't a universal blueprint for the very different problems around the globe in the water sector. Reforms are therefore always related to trial and error, conclude Lena Horlemann and Dr. Ines Dombrowsky, who are both investigating the institutional basic conditions, which have changed fundamentally since the political era. Centralised structures were dissolved, new ones developed and to some extent a power vacuum was created. In spite of these problems Mongolia has made considerable steps forward: A new water law has been implemented with the objective of developing an effective IWRM, and a national water agency has been set up." There are still problems however in establishing river basin organizations, which are supposed to mediate between the interests of various local water users, but still have too little rights or the financial means to implement this. Besides, the responsibilities are often ambiguous. Mongolian policy is still very much shaped by the centralised system from Soviet times. This often makes it difficult for local administrations to generate resources or to involve the public." The inheritors of Genghis Khan therefore still have a long path of reforms before them, which will only be successful if the balance is put straight between the increase in the demand for water and the decrease in availability. *Tilo Arnhold*

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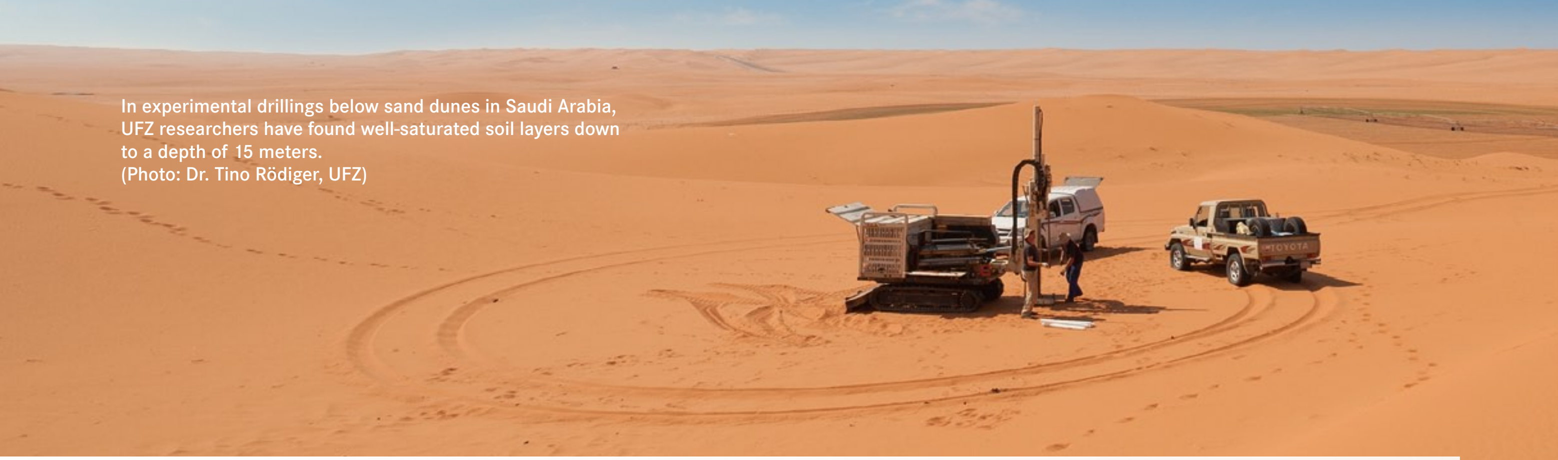

In experimental drillings below sand dunes in Saudi Arabia, UFZ researchers have found well-saturated soil layers down to a depth of 15 meters. (Photo: Dr. Tino Rödiger, UFZ)

ACCURATELY ESTIMATING GROUNDWATER RECHARGE

Water is a very valuable good – a fact that particularly applies to the very arid regions of the world such as Saudi Arabia, where it is urgently required for both drinking water and irrigation in agriculture. Because it hardly ever rains, the country strongly depends on the water that is extracted from wells. As a result: "for arid regions it is crucial to know exactly how much groundwater is available and how much groundwater is recharged every year", says Dr. Christian Siebert. The hydro-geologist from the UFZ has been conducting research on groundwater recharge for nine years – not only in Saudi Arabia, but also in other regions of the Middle East such as Jordan and Israel. The project in Saudi Arabia led by Siebert belongs to the International Water Research Alliance Saxony (IWAS, see pages 30/31). It is a joint research project, which is funded by the Federal Ministry of Research and looks for solutions on how to sustainably manage water reserves in five hydrologically-sensitive regions of the world.

Some areas on the Arabian Peninsula have less than 100 millimetres of annual rainfall per square meter. By comparison: even in the most arid areas of Germany such as the Thuringian basin it rains six times more frequently. It is therefore astounding that groundwater is available at all in such arid regions, particularly since most precipitation should theoretically evaporate immediately due to the high daytime temperatures of up to 60 degrees Celsius. Consequently, only a few millimetres actually seep through into the soil. "That sounds like very little" says Siebert, "but related to a surface of more than two million square kilometres, an amazing quantity builds up". Moreover, because every millimetre of precipitation per square meter counts, groundwater recharge must be estimated precisely. "What really counts are the figures after the decimal point", says Siebert.

It has been known to researchers for a long time that on the Arabian Peninsula there are groundwater resources available belowground in a mega-aquifer. This aquifer extends almost over the entire peninsula reaching depths as great as 2000 meters in some places. It is also common knowledge that the groundwater resources are rapidly declining, because the wells have to supply so much water for agriculture. However, what is not known is whether or not there is any groundwater recharge at shallower depths. In collaboration with scientists from the TU Darmstadt, UFZ scientists want to get to the bottom of this. This is proving to be a complex venture, as researchers in Saudi Arabia had not yet tried this approach at such a fine resolution.

UFZ researcher Dr. Siebert and his team are therefore looking for the "point of no return". That is to say: the depth in the soil at which the humidity that seeps into the sandy soil after a rainstorm does not evaporate any longer, but continues to move further belowground until it eventually reaches the groundwater table. The high temperatures not only ensure that most water evaporates quickly at the surface, but also that humidity is extracted from the soil. However, it is still not known until which depth this occurs.

The "point of no return", the very existence of which is openly disputed among scientists, is being determined by the team in a field investigation. On a 200 square meter experimental site on the Arabian Peninsula, artificial precipitation is being carried out. In this way, the team wants to find out how soil humidity changes with increasing depth, from which the critical point can then be derived. If this is successful, depending upon the condition of the soil and climate conditions the scientists hope to be able to say how much groundwater is recharged after a certain amount of precipitation. The preliminary results appear to confirm groundwater recharge: in experimental drillings below sand dunes, UFZ researchers have found well-saturated soil layers down to a depth of 15 meters.

In two years the hydro-geologists intend to submit their results. Although these results will not be representative for the whole of Saudi Arabia, because the morphology of the country is so diverse, they will however be typical for ergs (sand seas) and will therefore be substantially more precise than the empirical formulas that have been used so far. With these results they will be able to model the hydrological cycle in Saudi Arabia in a computer program, which will be of assistance to local decision-makers. "It can be simulated, for example what happens to groundwater resources, if the wells have to supply higher quantities of water for agriculture or if low precipitation becomes even lower" says Siebert. Water could be used and must be used in a smarter and more sustainable manner. *Benjamin Haerdle*

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Estuary of the rivers Saale and Elbe near Barby in the Middle Elbe Biosphere Reserve. Along the middle reaches of the Elbe 15 dykes are to be rerouted with a total planned area of 2600 hectares.

THE FLOODPLAIN DOESN'T FORGIVE AND FORGET

An environment with river and humans is an environment laden with conflicts, with both parties laying claims on the riverbanks. The river needs somewhere to expand when large volumes of water flow into it, while humans need a place for their cattle to graze, to build bridges and houses or to moor their boats. For centuries humans seemed to have had the upper hand – they have built dykes through valleys and lowlands and have taken the riverbanks from the river strip by strip. Over time the Elbe has been forced to cede approximately 80 percent of its original floodplain area from its middle reaches, while behind the dykes biodiversity has started to diminish and floodplain dynamics have slowed right down.

The Elbe flood of 2002 proved the fact that the river cannot take such restrictions without showing any reaction. For scientists at the UFZ this disaster was not the first eye-opener. At the end of the nineties they were already involved in the RIVA-project. Zoologists, botanists, hydrologists, soil scientists and statisticians were all involved in developing an indicator system that could be used to determine the ecological state of a floodplain. In essence, they actually did find that the presence of certain animal and plant species could be used as indicators to make statements about the extent to which the flood dynamics of a section of floodplain are in fact still or have returned to being semi-natural. It is important to know this because "intact floodplains are a bit like having a good insurance" according to Mathias Scholz (scientist at the UFZ). "They are not only home to threatened species, but also buffer floods and ensure that the impacts on humans are reduced. The criteria therefore have to be good enough to be able to make predictions about the ecological impacts on the floodplain ecosystem."

In October 2009 the Federal Agency for Nature Conservation produced the first report on the status of floodplains. According to this report: two thirds of former floodplain areas have already receded from the flood dynamics of rivers and only ten percent of floodplains are still in a semi-natural state in Germany. In another research project, UFZ scientists as well as other research institutions are now investigating the significance of floodplains in Germany in terms of habitats for plants and animals, flood management, nutrient retention, water conservation and climate change. "Our results will flow into policy recommendations", explains Mathias Scholz, who is coordinator of floodplain research at the UFZ. River landscapes provide very important functions and services, which have been underestimated over recent decades. "Floodplains not only offer protection from extreme flooding but also bind greenhouse gases, purify groundwater and are among those habitats with the highest biodiversity in Central Europe", says Scholz.

In addition to data collection, targeted changes and their observation were also part of the program. At the point of the Elbe that flows through Rosslau (part of Dessau-Rosslau in the Federal State of Sachsen-Anhalt), a so far unique experiment was set up for this river: In 2006 a new dyke was built inland in the Rosslauer Oberluch and the old one was cut off. Approximately 140 hectares of ancient floodplain was flooded and given the chance to become a dynamic floodplain again. But can one simply pull the lever in the other direction? Scientists from the UFZ under the direction of Dr. Klaus Henle wanted to find an answer to this question and waited in suspense for the first flood. In the meantime they covered the future floodplain area with a measuring net and recorded the status quo. On-site botanists, zoologists, soil scientists and hydrologists undertook investigations on plots separately reserved for each of them, while still in close proximity. The results were compared with two control sites in a floodplain protected by a dyke and a natural floodplain.

In spring 2009 the time had come: the first flood due to high water occurred in the area where the dyke had been cut off. Intensive counting and measuring began immediately. Has the number and activity of the snails, ground beetles and grasshoppers already changed? Has the sediment structure altered? How has the groundwater reacted? In order to make statements about the changes, data series are required over several years and appropriate analyses are necessary. Preliminary results indicate that the new flood regime is close to the natural state and that the groundwater table will rise again to the level natural for floodplains. Thus, within a short time, typical floodplain conditions will return and flora and fauna adapted to them will have better chances to survive. It looks as though we will just have to hold our breath to see what happens with the floodplain recovery.

Incidentally, the people of Rosslau have got used to their new dyke. Although the Elbe is now closer to their homes than ever before, this kind of flood protection is safer.

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Deputy Director General Dr. Fritz Holzwarth is head of the Directorate for Water Management in the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). He focuses mainly on technical and legal issues in national and international water management and marine conservation.

THERE IS NO TIME FOR ENDLESS DISCUSSIONS

Since 2010 water has been recognized as a basic human right, but it is a right that cannot be enforced. What can be done to change the fact that 1.1 billion humans still have no access to clean drinking water?
Irrespective of whether or not this human right is binding under international law, the recognition of this right by the United Nations has sent a clear signal: we still need far greater awareness of water and its related issues. The Millenium Development Goals set at the Johannesburg Summit in 2002 include significantly improving access to safe drinking water and providing people with adequate sanitation. We will not be able to achieve this by 2015. To realise this goal, further efforts will certainly be needed from all stakeholders in politics, industry and science.

For a long time economists and policy-makers have been reluctant to acknow-ledge water as a human right, and yet water is not a commodity like electricity, gas or oil.
We should not inflate the discussion of water as a human right into an ideological issue – neither in society as a whole nor in terms of the economy, as this will not contribute to solving the problems at hand. There is broad international consensus that water reserves must not be made private property, no matter where in the world. However it must be possible to place the management of water and wastewater disposal in private hands. A very good example of this is in Phnom Penh, the capital of Cambodia, where the entire water supply system was successfully modernised, with the introduction of cost-efficient accounting and payment systems and first-class water management, in order to supply all inhabitants of the city with water. The water authorities in Phnom Penh were awarded the "Stockholm Industry Water Award for 2010". This shows what can be achieved if the political will is there and if people feel that the change is for the better.

Why is there still a lack of awareness among the general public regarding global water scarcity?
There is no global water scarcity. What we do have are regional water crises in the Arab world, in large parts of Africa, Asia, South America and, increasingly, in the South of Europe. In this sense the water debate is very different from the climate debate, in which an international regime can help launch national measures to reduce climate-damaging emissions. Moreover, in the case of the climate we are developing scenarios for 2040, 2050 or 2100. For water, on the other hand, in many parts of the world we simply do not have the time to discuss what is to be done – it is already the eleventh hour. The water crisis is actually a governance crisis. The Integrated Water Resources Management (IWRM) must be implemented everywhere and across sectors in order to finally achieve sustainable management of water resources. Here a paradigm shift is also needed. Until now supply has always followed the demand for water. Water management must now organise the demand-side so as to ensure that potential for conserving and distributing water is fully exploited before the supply is increased. Climate change is not the primary cause of the pressure, which is really the result of population growth, energy demand, agriculture and industry. Frequently the problems simply stem from poor water management.

Where do you see the greatest challenges for research?
1. In many regions with a water crisis, the crisis is really about water governance. Good water management needs good administration and legislation, but sustainable water management also requires innovative technologies. Therefore the real challenge for research is to bridge the gap between water governance, engineering, and the natural and social sciences. **2.** Up to now, traditional water research has been concerned with the direct issues facing the water sector. What we need is water research that incorporates water-dependent and water-relevant sectors of industry and analyses correlations and solutions. **3.** Germany and Europe have an established water research which explains cause-and-effect relationships in the hydrological cycle. We are also developing some complex technological solutions. However, we still have large gaps in our ability to adapt and implement our highly competent know-how in developing countries in ways that are practicable and acceptable for the people in those countries.

What role do you see here for the Water Science Alliance (WSA, see also page 28)?
The Water Science Alliance will play a vital role in making cooperation between different disciplines in water management a matter of course. Management regimes in the field of water are more than social processes. They only function if they have a scientific basis to guide the management process. Moreover, the WSA will help to unify and raise the profile of the considerable water research expertise in Germany, which at present is highly fragmented by the German research and funding structure.

The interview was held by Doris Böhme.

POINT OF VIEW: KEEP AND DEVELOP WATER USE CHARGES!

Prof. Dr. Erik Gawel is Deputy Head of the Department of Economics at the UFZ and Head of the Institute for Infrastructure and Resources Management at the University of Leipzig. His areas of expertise and research are public finance as well as environmental economics and institutional economics, particularly in the field of water protection policy. He is head of the research project UBA on the future of water use charges.

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Water is needed for so many different purposes: in food production, in industry, in the production of energy and in households. In this way, man's water consumption intervenes with the natural water balance and excludes it from alternative uses, hence water is used at a "cost" to us and from an economics perspective there is a "water scarcity". This scarcity should not be confused with the term "water shortage". As with bread or mobile phones for example there is certainly no "shortage" of such goods here in Germany, although from an economics perspective these goods can also be said to be "scarce", which is why they are rightfully given a price: This price indicates the value of the resources that were used to produce these goods had these resources been used otherwise. Prices provide an efficient solution to the conflicts that surround scarcity. This means that those uses prevail that have the highest surplus of economic advantage above the social costs.

Water pricing that incorporates cost recovery provides this kind of "efficient" assignment, by showing the user the total depreciation that its use means for society. Article 9 of the Water Framework Directive adopts this way of thinking: according to this Article, the water pricing policies of the EU member states should consider the principle of total cost recovery for water services such as wastewater discharge or water extraction. Apart from the actual costs of providing the services, the environmental and resource costs are specifically incorporated into cost recovery and therefore also the ecological impacts of water use that water utility or wastewater discharge companies would not typically include in the economic price.
All over the world, water problems are made worse not taking into account the cost recovery rule: Hence, scare water resources are wasted due to low, often subsidised water prices, particularly in agricultural irrigation that uses approximately 70 percent of all the water extracted worldwide. Water prices do not only have the role of making users make efficient consumption decisions, but are at the same time a source of funding that makes the provision of water services at all possible. On the other hand they reduce the purchasing power of users, which can lead to problems of affordability among socially-weak water users and set tight limits on a world-wide application of a water pricing strategy that incorporates cost recovery.

In Germany, the mandate in Article 9 of the WFD for a water pricing strategy incorporating cost recovery primarily addresses municipal wastewater charges and drinking water charges, where (economic) cost recovery has been standard practise (at least officially) for a long time. Instruments based on the "polluter pays principle" for additional environmental costs are therefore of particular interest. Long before the WFD, Germany had already implemented such pricing instruments in the form of federal wastewater charges and water extraction charges that are currently levied in eleven federal states of Germany. The wastewater charges law of 1976 came long before the eco-tax and emissions trading as a pioneer for the implementation of environmental-incentive instruments. For equally as long, these instruments have been accompanied by critics from science and policy: calls for a reform of incentive-based instruments thought to be too lax face at the same time repeated calls for their abolition. The fact that the organized interests of those obligated to pay (i.e. local enterprises, dischargers of industrial waste and individual promoters) are the first to criticise such charges, is hardly surprising. Water use charges fulfil an important function however in charging for environmental costs, which makes them irreplaceable: Water utility or wastewater discharge companies must indeed observe costly command-and-control requirements, which have already correctly assigned some of the externalities to the polluters in the interest of water protection. In principle however the remaining water uses are still free of charge. This is where water use charges come in.

For the German debate surrounding the future of water use charges it is clear: A commitment to a market-oriented environmental policy and to a more efficient fulfilment of water protection policy aims must at the same time represent a commitment to a noticeable payment charge on the "remaining use" of water resources. Only in this way can the cost recovery principle be comprehensively implemented and this incentive can only be provided through water use charges and not however through regulatory requirements, fees or (water extraction) revenues. Water use charges therefore offer a unique added value in the context of a market-based water protection policy. They should therefore by no means be abolished, as wished by many for obvious reasons but should in the future rather become what they were supposed to be from the onset, namely a market-oriented factor price, which treats the scarce and vital good "water" exactly the same as all other goods that naturally put a price on their scarcity and which therefore keeps producers and consumers making decisions about resource efficiency in the interest of common welfare.

One solution to avoid high nutrient contamination in water bodies is to carry out extensive agricultural practices on floodplains. With the EU policy on the climate however conflicting goals arise because the development of renewables for bioenergy rather entails an intensification of agricultural practises: areas for cultivation are expanded and the consumption of water and fertilizers increase.

(Source: www.fotolia.com)

COOPERATING FOR "GOOD WATERS"

All European water bodies (both groundwater and surface waters) have achieved a "good status", not only indicating good chemical conditions but also providing an attractive habitat for many plants and animals. The water bodies are managed according to river catchment areas, from the source to the delta including all tributaries and coastal waters. In this way they can provide a multitude of services to mankind: drinking water, agriculture, shipping, tourism and conservation. Further, groundwater is available in sufficient quantities without containing any pollutants that could be of danger to the ecosystem.

This vision of achieving ambitious environmental goals was intended to become reality by 2015. At least so it was set out on the agenda of the EU's Water Framework Directive in the year 2000, which set up a new regulatory framework within the EU for a common water policy, marking a fundamental change.

But the real question is whether European water management is on the right track for achieving these goals in the given time frame. Which problems might arise on the way and how can these problems be overcome? And are the administrative structures prepared for such new tasks? Since the beginning of 2010 scientists working in the fields of economics, law and philosophy have been looking into these and other questions on the sustainable management of water resources and the new responsibility structures created by the WFD. In a project funded by the BMBF for example, they are analysing how incentives provided by European and national legislation influence the decision-making behaviour of stakeholders in river catchments and are discussing suitable models for solving sustainability issues. Furthermore, on the basis of their own recommendations they want to contribute to an improved perception of water management goals.

"The governance dimension is central to the project and a general problem when trying to make steps forward towards sustainable development", says project manager Dr. Bernd Klauer. "Our central questions are: which level of responsibility and which tasks will be assigned to the state and to private stakeholders? On the grounds of their authority and legal competences are these stakeholders actually able to take on the responsibility to achieve the targets that have been set? This problem is exacerbated by the fact that rivers and their pollutants typically cross administrative borders." In the management of the River Elbe for example ten German federal states have to work together and cooperate with the neighbouring countries of Poland, Austria and the Czech Republic. In addition to the problems of spatial co-ordination there are also technical problems: "The state of the water bodies is not only determined by water management. If some groundbreaking steps in policies on agriculture and inland shipping are not undertaken shortly, then the ten billion Euros, which Germany intends to invest by 2015 to implement the goals of the WFD will fall far short of having the effect that was hoped for. The planning instruments that are currently available are not sufficient to appropriately master these coordination problems", explains Bernd Klauer.

On the whole there are significant difficulties in terms of reaching the environmental goals within the term set on the agenda. In view of the fact that for 82 percent of surface waters and 36 percent of groundwater bodies extensions of the timeframe have been demanded by the German federal states, it remains unclear whether the federal states sufficiently promote the reduction of water contamination and ecosystem degradation. In particular the goal of a good ecological status presents problems for Germany – this is mainly due to nutrient loads and morphological degradation of watercourses. In order to give rivers the space they need more land is required, but most of this is already used for agriculture. Nitrate loads, phosphor and pesticides that are discharged into water bodies still present one of the greatest problems. The scientists from Leipzig point out that a reconciliation of interests from agricultural policy and water policy is imperative if one is not to lose sight of the goals of the WFD. "The EU's common agricultural policy must be aware of its responsibility for water bodies. If this is not the case, then this issue can hardly be corrected at the river catchment level", argues Prof. Wolfgang Köck. According to the environmental law expert, the parameters that need to be adjusted on the European or national level are not only funding instruments, but also interventional control instruments like for instance charges for pesticides and fertilizers. *Bettina Hennebach*

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POINT OF VIEW: TEN YEARS IMPLEMENTATION OF THE WFD – A CRITICAL REVIEW

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Where do we stand on water protection in Germany and Central Europe ten years after the introduction of the European Water Framework Directive (WFD)? – a European environmental directive, which for many stakeholders was not just seen as another bureaucratic monster from Brussels, but as an innovative instrument and a bearer of hope for better water protection. It should be first noted that the formal conversion to national law, the initial river basin district characterisation as well as the implementation of the first river basin management plan period in Germany have essentially been adhered to. Unfortunately this cannot be said for all member states of the European Union. The figures on the status of waterbodies on the other hand are disillusioning for Germany: After the efforts that have been undertaken over several decades one is still a long way off the main target of achieving a "good ecological", a "good quantitative" or a "good chemical" status of surface waters and groundwater by 2015. In Germany "exemptions" have been applied to grant an extension of time for achieving objectives for approximately 82 percent of all surface water cases (including "heavily modified" and "artificial" waterbodies) and for groundwater bodies in circa 36 percent of cases. Similar figures have also been reported by other member states of the European Union. The good news however is that a "good chemical status" has been achieved in approximately 88 percent of waterbodies. This is an incontestable success in water protection, particularly in the reduction of wastewater loads from industry and settlements, which is not owing to the implementation of the WFD however, but to the consistent application of the 'polluter pays principle' in the wastewater sector over recent decades.

At this point in time the fact that extensions of time for achieving objectives are granted is both inevitable and correct due to the points already mentioned above. But does this not ultimately lead to "less stringent environmental objectives" and "exemptions" that are already common today becoming standard practise on a long-term basis? And wouldn‘t this do disservice to water protection with its extensive reporting and evaluation procedures? To put it plainly: "yes" this could be the case if we don't make substantial progress in the following points:

1. The 'polluter pays principle' that has been pursued very consistently and successfully in the industrial and local wastewater sector should also be applied to those users, who share major responsibility for the ecological deficits and the loss of ecological functions today. This includes the hydro-morphological status of waters, impoundments or regulation including uses for hydroelectric power and navigation and above all agriculture.

2. A central problem is the lack of available land for nature and water protection. River corridors that are sufficiently wide for example would create more favourable hydrological conditions, improve habitats and thereby increase biodiversity, reduce nutrient loads and eventually mitigate the residual effects of pesticide loads.

3. In the future a more effective water protection must be embodied in agro-environmental measures far more consistently than before. It must be decided, where non-binding measures are insufficient and therefore where restrictions of use should apply – with or without compensation. We will therefore need applicable instruments for an effective reconciliation of interests.

4. At present climate change is still given little relevance in management plans. However, the impacts of climate change that are already noticeable today such as extended dry periods or an increase in flooding events and the necessary adaptation strategies should be taken into consideration. In addition actual or assumed influences of climate change should not be used in the future as the reason for not having implemented the necessary water protection strategies.

The focus for future water protection strategies should therefore be in agriculture, energy production and transport policy and thus outside of the traditional fields of water management. The reconciliation of different users' interests from completely different fields of policy will therefore play a major role in achieving ecological objectives and this cannot be achieved using conventional instruments. The WFD thereby still provides an opportunity but no guarantee for achieving the required amount of water protection through an ecologically feasible design of uses and consequently to link a sustainable water management to other environmental or economic objectives. If this fails, then a unique opportunity would be lost. If it succeeds however, then Germany and Europe with their respective signal effect would be leaders in the future global task of finding a sustainable balance between the use and the protection of key resources.

INFORMATION PAGES

WATER SCIENCE ALLIANCE

The Water Science Alliance is an instrument that aims to pool together and reinforce German water research. To overcome the challenges in the field of water research, an integrated research approach is necessary that incorporates different natural sciences, engineering disciplines and socio-economics along with their strategies extending beyond the water sector.

The six priority research fields of the Water Science Alliance (White Paper) are:

1. **New challenges for water resources emerging from global and climate change (developing scenarios)**
2. **Innovations for a sustainable Water Resources Management**
3. **Quantifying water cycles and matter fluxes at the regional scale: Safeguarding our health and the environment**
4. **Integrated exploration, observation and data assimilation**
5. **Model development and data integration**
6. **Complex water management in the Circum-Mediterranean region**

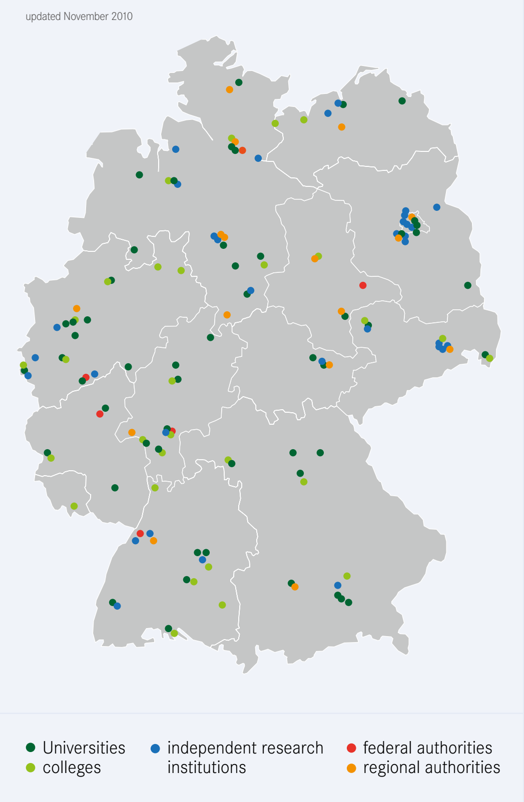
The Water Science Alliance is funded by the Federal Ministry for Education and Research (BMBF), the Federal Ministry for the Environment, Nuclear Safety and Nature Conservation (BMU) and the German Research Foundation (DFG). In 2009 the UFZ started to develop the idea and the concept of the Water Science Alliance under the mandate of the senate of the Helmholtz Association.

DFG

Bundesministerium für Bildung und Forschung

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

WATER RESEARCH IN GERMANY



Water Research Horizon Conference

An important part of the Water Science Alliance is the annual Water Research Horizon Conference. With the second Water Research Horizon Conference on 8th /9th June 2011 in Berlin on “New Concepts in Model Development and Data Integration for Understanding Water, Matter and Energy Fluxes at Management Scale”, discussions on two of the six research fields of the White Paper are to be substantiated and the first projects and project proposals are to be initiated. The Federal Ministry for Education and Research (BMBF) will introduce its new field for priority funding “Sustainable Water Management”.

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IWAS AND WESS

Two important components of the Water Science Alliance are the International Water Research Alliance of Saxony (IWAS) and the Water and Earth System Science (WESS).

In **IWAS** researchers at the UFZ and the Technical University of Dresden as well as partners in industry like for example the wastewater works for the City of Dresden GmbH/Gelsenwasser AG develop applied system solutions for the respective water issues in different hydrological sensitive regions of the world (Eastern Europe/the Ukraine, Central Asia/Mongolia, the Middle East/Saudi Arabia and Oman, South-east Asia/Vietnam as well as Latin America/Brazil). IWAS is funded by the BMBF through the program “Research and Innovation Initiative for the New German Länder”.

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In **WESS**, the effects of changing environmental conditions to the water cycle and on the flow and pollutant dispersion in the water, soil and atmosphere are being investigated through a strategic alliance with the three Universities of Tübingen, Stuttgart and Hohenheim.

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INFRASTRUCTURES

TASK

The Terra- Aqua- and Site Remediation Centre of Competence Leipzig (TASK) endeavors to increase and improve the visibility, acceptance and marketability of new innovative technologies and concepts in the fields of soil and groundwater, contaminated site revitalization and remediation. TASK is responsible for the specific application of research results with a high innovation potential. This could be technical processes and methods, models, management concepts, guidelines and standards. By the development and realization of product specific support measures, like technology demonstrations, field demonstrations, product consultancy or trade fair presence TASK, supports and strengthens the positioning of products on markets in the national and international field. Since 2007 TASK has been funded by the BMBF and the UFZ and is supported by a continual network of experienced scientists and representatives of consultancies and administration, industry and politics.
www.task-leipzig.info

Megasite Management Toolsuite (MMT)

Numerous stakeholders are involved in the future use of brownfields (see pages 18/19): land owners, authorities, investors, consultants and town planners all have to come to an agreement and clearly communicate their intentions to the public. In doing so it is important to be able to run through various scenarios in order to estimate costs and optimize planning. With the Megasite Management Toolsuite (MMT), scientists from the UFZ and the University of Tübingen have developed a software tool enabling stakeholders to turn their visions of future uses for brownfields into economically attractive options. Modules linked to each other and to a Geographical Information System provide the user with reliable data and figures about how the potential of a location can be optimally used. If the contaminated areas are known, the Toolsuite can help to estimate, which methods can be used in brownfield remediation and the extent to which this is possible or what would happen if the land use was changed instead of site revitalization. The MMT thus assists decision-making in the complex process of site revitalization and is being continually developed in cooperation with remediation partners. **www.safira-mmt.de**

UFZ Research Vessel ALBIS

The ALBIS is a research vessel that is available to UFZ scientists, enabling them to take water and sediment samples from any point on the river – whether this be in extremely low water, in shallow rivers, surface zones or groyne fields – and to analyze these on board immediately. The vessel with a length of 15 meters and a width of four meters has a draft of only 50 centimeters. Since it first set sail in 1998 it has already embarked on numerous research expeditions covering some 1000 kilometers every year on rivers such as the Elbe, Saale, Weser, Werra and Fulda. The focus of investigations from recent years was the transport and exchange of solutes and particulate trace substances in water. At present the focus of water research is turning to research on entire ecosystems – on the control of macrobenthos in streams and rivers, on the impact of invasive species on aquatic communities and ecosystem functions or on the dynamics of hyporheic food chains (at the interface between rivers and adjoining groundwater tables).

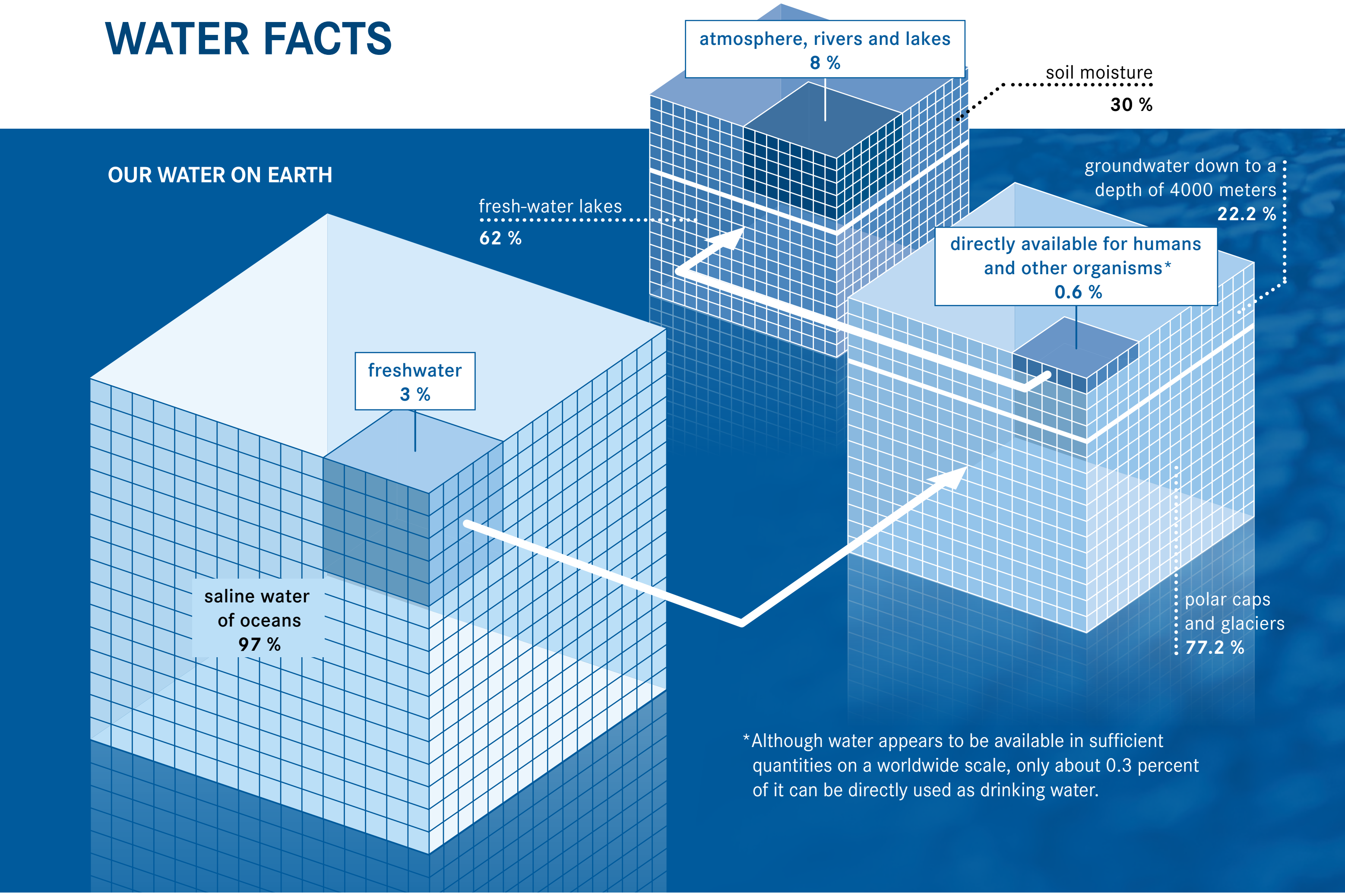
Photo: Sven Schulz / Elbe River Community

THE GERMAN WATER PARTNERSHIP (GWP)

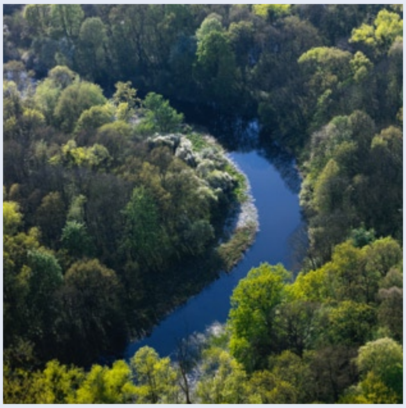
German Water Partnership

The German Water Partnership is a network, through which private and public companies of the German water sector, economic, scientific and research institutes can collaborate with one another. This unique initiative is supported by the Federal Ministries for the Environment, Research, Development, Economy and Foreign Affairs. The German Water Partnership pools the activities, information and innovations of the German water sector, to strengthen the economic advantage of the economy and research on international markets. The network improves the basic conditions for business development abroad, supports innovation and helps to solve worldwide water problems through adapted, integrated and sustainable approaches.
www.germanwaterpartnership.de

WATER FACTS



THE EUROPEAN WATER FRAMEWORK DIRECTIVE (WFD)



The WFD was set up in December 2000 by the European Union and stipulates a good chemical and ecological status of all European water bodies by 2015. By no means should the water quality get worse. The Directive refers to surface waters (rivers and lakes, partially also wetlands), groundwater, coastal areas and transitional waters (between the river and the sea). The modern form of management required for rivers and river catchment areas means that the influx of harmful substances must be gradually reduced and finally stopped, the self purification processes of water, natural runoff processes and natural floodplains are maintained or remediated and that water resources are used sustainably.

The administration and management of rivers should no longer be restricted to the border of countries but according to river catchment areas. Here international commissions will adopt the implementation of the WFD (IKSO / International Commission for the protection of the River Oder; IKSE / River Elbe; IKSR / River Rhein; IKSD / River Danube). For both national and international river catchment areas, separate management plans should be established.

In order to implement the WFD the EU has established the following agenda:

- **2003**
  Implementation in national law
- **2004**
  First inventory of water state in river catchments
- **2006**
  Monitoring networks are set up
- **2009**
  Management plans and programs of measures are finalised
- **2012**
  Implementation of measures
- **2015**
  Environmental goals are achieved

WATER FOR LIFE

Approx. 1 billion people have less than 20 litres of water per day at their disposal. Approx. 1 billion people lack access to safe drinking water.

Approx. 2.6 billion people live without adequate wastewater sanitation facilities.

The global water consumption increased four-fold between 1940 and 1990, while the global population doubled over the same period of time.

Drinking water that is not safe is the most frequent cause of illnesses in the world (diarrhoea, cholera, typhoid, tape worms, eye disorders).

One person requires between 2 and 5 litres of water per day to survive depending upon the climate zone.

A water-poor country according to the data of the World Watch Institute is considered to be a country in which less than 2.74 litres of water are available per person per day.

The human body is made up of 60 to 70 percent water; our bodily functions and our senses will not work without water.

WATER CONSUMPTION

Agriculture uses two thirds of freshwater. To produce one kilo of crops, 1,300 litres of water is required for irrigation, in a kilogram of beef there are around 15,000 litres.

Approx. 23 percent of the water used in the world isused for industry.

The average US American citizen consumes approx. 250 litres of water per day in the household, compared to the average European with 160 litres, the average German with 120 litres, the average Indian with 25 litres, and the average African with 20 litres.

VIRTUAL WATER

Virtual water (hidden water) is considered to be the water that is used to produce something. In a passenger car for example there is up to 300,000 litres of water; in a kilogram of bananas there are 1000 litres. Calculated in this way the average German uses approx. 4,000 litres of water per day. The British geographer John Anthony Allan introduced the concept of virtual water in 1995, for which he received the "Stockholm Water Prize" in 2008 from the Stockholm International Water Institute.

"BLUE" AND "GREEN" WATER

The water in rivers and lakes, the groundwater and the water stored in glaciers is referred to as **blue water**, and only accounts for a fraction of the freshwater on our planet, whereas the larger proportion of water that is found in plants and in the soil is referred to as **green water**. The opportunities and challenges of future water management is therefore to make the great potential of green water more readily available and to improve options for storing rainwater as green water in the soil and in plants or as blue water. One approach to this kind of "water harvesting" is to prevent a direct evaporation from the soil and to increase the storage capacity of soil and vegetation.

Imprint

Publisher:
Helmholtz Centre for Environmental Research GmbH – UFZ,
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Photos, picture editing: André Künzelmann
English translation: Sarah Gwillym-Margianto (info@der-fachuebersetzer.com)

Layout: noonox media GmbH, Leipzig
Printing: Fritsch Druck GmbH, Leipzig

Printed on 100% recycled paper
October 2011

HELMHOLTZ
CENTRE FOR
ENVIRONMENTAL
RESEARCH – UFZ

RESEARCH FOR THE ENVIRONMENT

ISSN 1868-7512

At the **Helmholtz Centre for Environmental Research – UFZ** scientists are investigating the causes and consequences of far-reaching changes to the environment. Their work is to contribute to solving concrete environmental problems. They provide knowledge of complex systems and interactions in the environment for politics, economics and society and recommend instruments and concepts for mitigation. This is not an easy task because the expectations and possibilities of various stakeholders are often very different.

The Helmholtz researchers work on the management of water resources and the impacts of land use change on biodiversity and ecosystem services. They develop remediation strategies and monitoring- and exploration techniques for contaminated ground and surface waters, soils and sediments. They investigate the behaviour and effect of chemicals in the environment and on our health and immune system and work on models that predict environmental changes, taking into account aspects of social science and economics. The environmental research at the UFZ that is shaped by the natural sciences is therefore also closely linked to the human and social sciences and law.

The UFZ was established in 1991 and has about 1,000 employees in Leipzig, Halle/S. and Magdeburg and a total budget of about 90 million Euros. A major field of research at the UFZ since it was founded has been the management of water resources. While the focus in the nineties was mainly on the sustainable remediation of contaminated ground and surface waters, nowadays the research of some 150 scientists working in this field at the UFZ has a much wider application. With its expertise in exploration and monitoring, the modelling and visualisation of processes and the flow of substances in aquatic ecosystems as well as Integrated Water Resources Management the UFZ aims to contribute to making the basic human right to water (recognised in 2010) become a reality.

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HELMHOLTZ-ASSOCIATION OF GERMAN RESEARCH CENTRES

The Helmholtz Association contributes to finding solutions for large and pressing issues in society, science and the economy through excellence in the following 6 areas of research: energy, earth and the environment, health, key technologies, structure of matter, transport and aerospace. With over 31,000 employees in 17 research centres and with an annual budget of approx. 3.3 billion Euros the Helmholtz Association is the largest scientific organisation in Germany. Work is conducted in the tradition of the renowned biologist Hermann von Helmholtz (1821-1894). **www.helmholtz.de**

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