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Integrative Environmental Research

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

Graphic: WOHLFAHRT

An integrated approach to environmental research

Some people feel that things are not really so bad and there is still plenty of time left. Others believe that mankind has not much influence anyway. Then there are others who are fully convinced that we do not have a moment to lose.
However, the fact is - our environment is changing in many ways, whether through natural processes or as a result of human interference. Biological diversity is decreasing - water, air and soil are being polluted - whilst an increasing number of natural areas are consumed, paved or contaminated. Our society and its prosperity frequently grow at the expense of the natural resources urgently needed for our future development. Not only are the causes and the extent of these sometime slow changes not yet adequately understood and, hence, difficult to assess. We also do not know how they will affect mankind and the environment in the long run. This is because most elements and processes in the environment somehow interact with one another. Consequently, this complexity prevents us from easily producing results in great detail as well as very general terms. In addition, the national boundary conditions differ significantly with respect to the political, societal and technical factors and add to the complexity of the problem.
The special task of environmental research is to generate within a limited time valuable knowledge on the complex elements and inter-relationships of our environment so as to be able to support decisions and contribute to solutions for specific problems. Apart from the practical needs, environmental research must also meet general scientific needs. This is a two-fold challenge with the requirement that today's environmental research dominated by natural sciences is increasingly interlinked with human and social sciences as well as environmental law. Environmental research must expand its viewpoint beyond the classical fields of biology, chemistry, geography or geology and become driven by the environmental problems themselves. We need to learn to deal with great complexities, uncertainties and application-oriented decision-making. This requires exchange of knowledge, comprehension, communication, the combination of disparate skills and complementary utilisation of specialist knowledge – in short, integration at the highest possible level.
In this edition of the UFZ magazine we wish to provide an insight into the 12 topics of research at the UFZ. On the basis of a summary and two project examples for each topic we portray how scientists from different natural and social science disciplines work together on "real world" environmental problems. We show how decision-makers and people directly affected are actively involved in our research, and how complicated it is to develop application-oriented solutions. The UFZ faces this challenge day in and day out and is committed to continuing along this long but exciting avenue.

PROF. GEORG TEUTSCH
SCIENTIFIC DIRECTOR, UFZ

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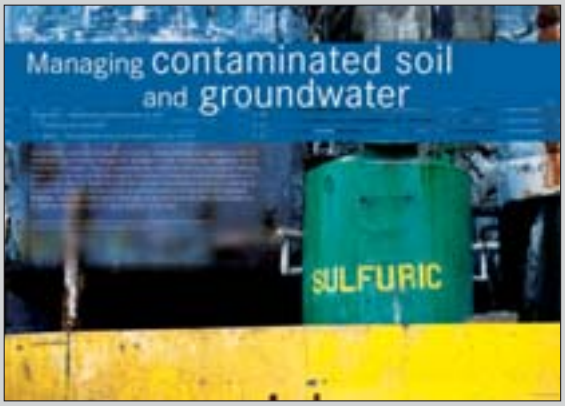

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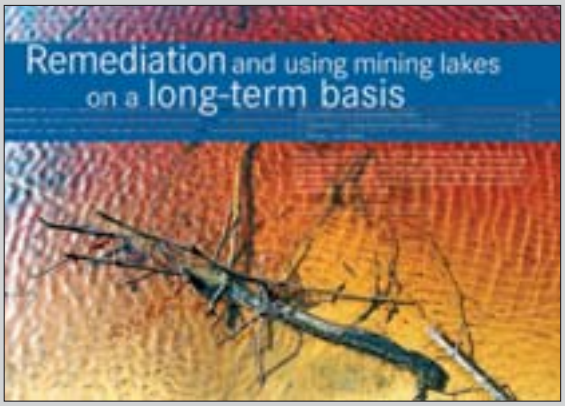

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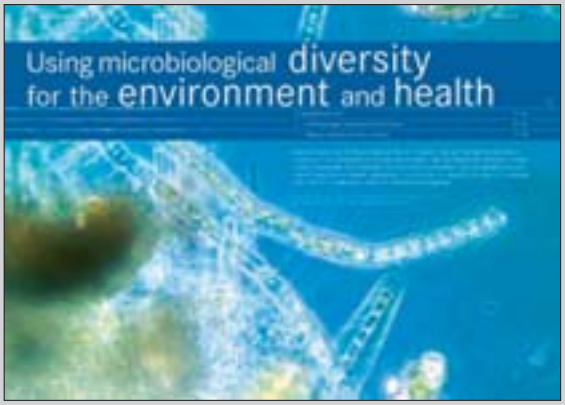

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Biologists and sociologists at the UFZ are studying the biological and human processes which regulate biodiversity and the stability of ecosystems. They are developing models which help assess biodiversity and computer-assisted prognostic tools which predict the dynamics of diverse biological systems. Researchers at the UFZ are working on integrated solutions for land use conflicts or investigating the dispersal processes of migrating plant and animal species as well as determining their ecological impact. Their goal is to provide political and economic decision-makers with a methodical system based on modules concerning issues such as land use, regional planning and maintaining biodiversity. 52

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Microbiologists, biotechnologists, chemists and engineers at the UFZ are researching potential microorganisms to use them in a targeted way for biosynthesis and biotransformation processes. They wish to find new ways to create valuable materials and active agents. For example, they are developing methods to modify yeasts genetically in such a way that that they can produce the modules for industrial chemical processes from renewable raw materials. Or they are studying the thermodynamics of biological systems so that they can better predict the behaviour of biocatalysts.
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Sustainable urban developm

Scientists at the UFZ are investigating urban processes such as transformation, demographic change, expansion and contraction of urban areas, the transport of pollutants and their effects on mankind and the environment. They draw up scenarios and models to help secure a sustainable urban development and quality of life. In doing so, they take into account social, planning, legal and economic components of both urban and natural environment processes, and work closely together with the movers and shakers of urban development – for example, town planners, town administrators, residential property companies and town dwellers.

SPEAKER FOR THE RESEARCH TOPIC "SUSTAINABLE URBAN DEVELOPMENT AND QUALITY OF LIFE":
DR. SIGRUN KABISCH, HEAD OF DEPARTMENT OF URBAN AND ENVIRONMENTAL SOCIOLOGY.

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Sigrun Kabisch, Kristin Schirmer and Marlis Heinz

Farewell to the town?

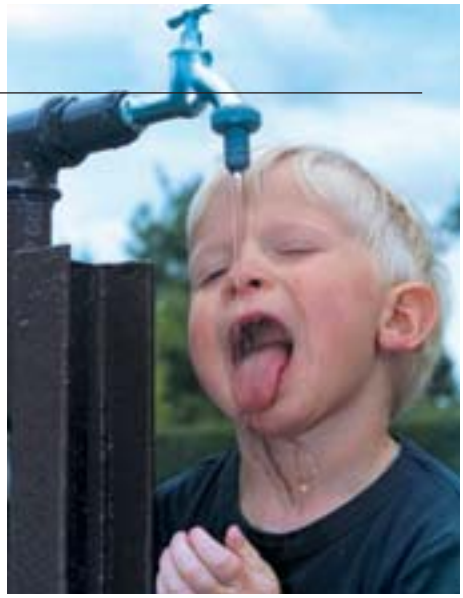
For many decades towns and cities were synonymous with growth, implying more people, houses, infrastructure and economic power. Towns and cities expanded, swallowing up nearby villages and, in particular, natural areas. While this trend continues in regions with strong economic growth, other areas are concerned about losing inhabitants. Since the 1990s, towns and communities of the former GDR have been slowly bleeding to death. What will be their fate in the 21st century? Social and natural scientists at the UFZ are investigating the causes and effects of urban processes on people and the environment. They are developing scenarios and models for a sustainable form of urban development to secure the quality of life.

Numerous cities are shrinking. Landlords and property owners are attempting to keep the number of empty buildings within limits by resorting to demolition or promptly renovating them to increase their value. However, what is life like in towns that are hollowing out?

It is as if a film of the 1970s was running backwards. The crane lifts up panel after panel from the 16 storeys of the building and lowers them to the ground; the high-rise apartments that had until recently towered over Leipzig-Schoenefeld now dwindle floor by floor. From time to time, one of the sociologists of the UFZ takes out a camera and records the progress of this deconstruction. They could hardly wish for a better illustration for their scientific work than the scenario being played out just in front of their office windows.

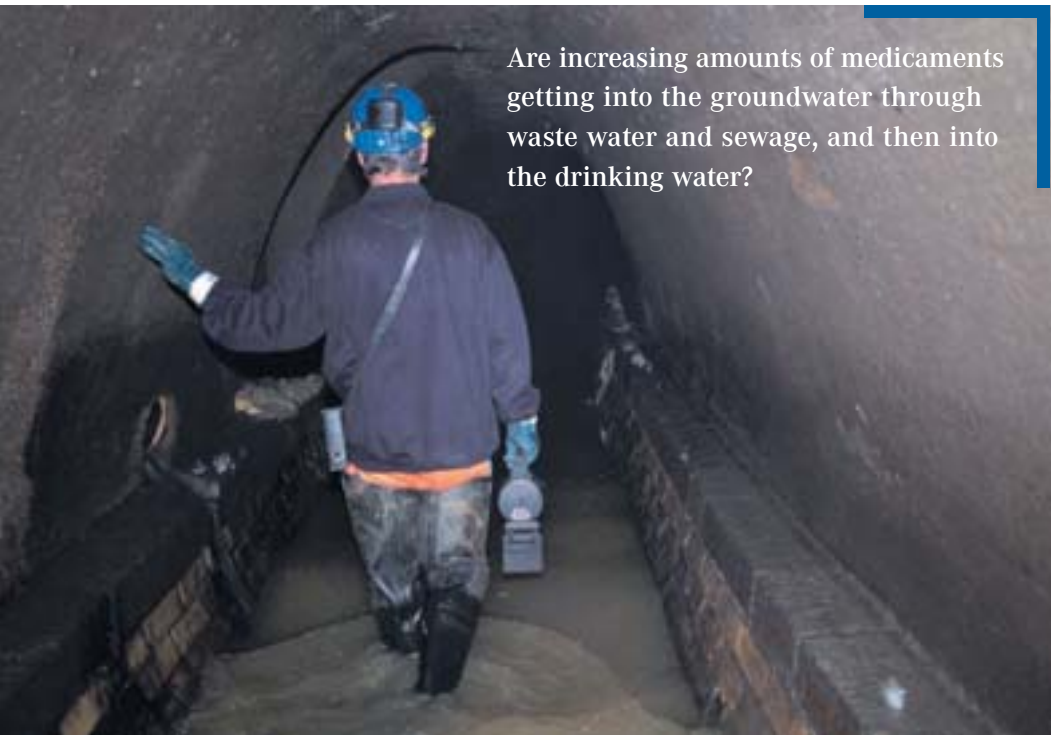
However, research on sustainable urban development covers a wide range - everything from an analysis of the individual microorganisms to a justification of the very latest urban development strategies. Research topics in an urban context are now of such complexity that a single discipline can no longer cover them. Yet you simply cannot toss together the statements from biologists or sociologists or geologists or legal experts to get in-depth statements. Experts from the various disciplines really need to work together and to constantly coordinate their ways of thinking.

The urban-related field of research at the UFZ covers several areas. For example, under the heading of “urban ecology and urban development” the scientists tackle questions related to ecology, management and environmental planning in towns and urban regions. For instance, they examine the biological diversity of urban vegetation so as to be able to make recommendations for the protection of nature. Also, aspects related to health policies play a role in urban development. Large sections of the population, and children in particular, increasingly have to struggle with respiratory problems and allergies. Here it is essential to track down the environmental pollution that causes these complaints and, if possible, to make predictions when decisions have to be made.



Medicaments in the tap water?
Sociologists initially look at the reconstruction of the town from their own perspective. Their starting point: the number of people in our cities is dropping, and it is mostly the young, active and the relatively affluent who are turning their backs on the city. Is this going to upset the functional balance of the big towns and cities? The existing infrastructure is being used – and financed - by an ever smaller number of people. This puts a question mark over schools and water treatment plants as well as residential areas, local transport systems, libraries and many other components that make up the fabric of a town. And this is not just a financial problem. Does a reduction in water flow through the drinking water supply system entail the possible risk of a more rapid development of bacteria in the pipes? On this point, biologists stand shoulder to shoulder beside the sociologists. If people in the city centres become increasingly older on average, it can then be assumed that the amount of medicaments consumed by each inhabitant will rise. At the same time, is it also to be feared that increasing amounts of these substances will get into the groundwater through the waste water and sewage and from there into the drinking water? In order to be able to answer this, micro-contamination of the water is one of the topics associated with the research field of sustainable urban development. The goal is to determine what risks there are to human health and the ecological system from micro-contamination. Is the person who swallows a glass of supposedly clean water unknowingly ingesting medicaments from previous water cycles? In order to be able to mechanistically understand and better quantify the behaviour of micro-contaminants, primarily at the interfaces of air, soil and water, the "WASSER Leipzig" concept (Water And Sewershed Study of Environmental Risk in Leipzig) is being developed. Here scientific research questions are brought together with sociological urban analyses.

> Can our society afford the luxury of maintaining all the existing settlements when the number of inhabitants continues to drop?



> Are increasing amounts of medicaments getting into the groundwater through waste water and sewage, and then into the drinking water?

Analysing "the prefabs" without emotion
The research results of the UFZ do not, of course, remain in the scientists' filing drawers but also attract considerable interest from the decision-makers. For example, Wolfgang Tiefensee visited the research centre while he was still mayor of Leipzig. He was given information on the long-term study that had been made of the Gruenau residential area since 1979 and was greatly surprised by some of the outcomes. Results from a number of regularly conducted questionnaires showed a recent increase in the proportion of people who like to live in the Gruenau residential area, built in the 1970s and 1980s. When asked if they would advise a good friend to move into this area, in 1979 around 78% answered "Yes" without any reservations, in 1987 it was 61%, but the absolute low point was reached

in 1995 with a figure of 33%. However, in 2004 the interviewers found that 60% of the people had nice things to say about Gruenau. This change of view came about as a result of renovation work and new infrastructure. The people who live in Gruenau today now want to remain. Analyses of this sort prevent overly emotional and highly partisan debates about "the prefabs", may put bold plans for demolition in another light and also help in making decisions as to which parts of the areas within Gruenau should be consolidated. If 60% of the inhabitants want to stay, then Gruenau has a future. At any rate we should now give the area a respite and allow the new structures to stabilise, according to the interim summary.

Anyone who is expecting a potpourri of simple recipes for sustainable urban development is on the wrong track. The task of the UFZ scientists is to explain the status quo and how it arose, and to make statements on further development. In doing so, they highlight the opportunities and limits of re-urbanisation and pass on this knowledge to partners involved with the practical side.

Furthermore, the researchers add a new twist to the problems posed and tackle topics previously tabooed, pushing hard for a fundamental rethinking on the future of the urban communities: can our society afford the luxury of maintaining all the settlements that currently exist when the number of inhabitants continues to drop? And, for example, what will happen over there in Schoenefeld when the 16 storeys disappear bit by bit? How do the inhabitants of the buildings that are still standing feel about the demolition? Are they relieved, or do they also move away? However, the sociologists have to hurry up with the photography, because in a few days the relatively short life of that apartment block, which only stood for three decades, will finally be over. ■

USEFUL INFORMATION

What risks are involved with a **megacity** as a place to live in is currently impossible to tell. For that reason, researchers from five (as of now) Helmholtz centres have combined forces for a new research initiative under the overall guidance of the UFZ. In Latin America they will work on strategies for sustainable development in megacities and conurbations on the basis of Santiago in Chile. Scientists will research land usage conflicts, risks posed by nature, social polarisation within the various areas, air pollution and hazards to health, deficiencies in the supply of energy and water and the disposal of waste. The Helmholtz initiative is linked with the programme initiated by the Federal Ministry of Education and Research [BMBF] "Sustainable development of the megacities of tomorrow" and the main programme "The informal dynamics of global change" of the German Research Foundation [DFG] as part of a "national research initiative on megacities".

SOCIOLOGIST DR. SIGRUN KABISCH IS HEAD OF DEPARTMENT OF URBAN AND ENVIRONMENTAL SOCIOLOGY. DR. KRISTIN SCHIRMER IS A BIOLOGIST AND HEADS THE CELL TOXICOLOGY DEPARTMENT.

Dagmar Haase and Marlis Heinz

A red fleck on the landscape

The small red fleck on the screen represents Leipzig in 1870, surrounded by farmland and woodland. Industrialisation gets into gear at the touch of a button, the red spreads out and gobbles up the open areas, it changes the course of rivers, swallows the woodland ... now they are all history. All urban development until the present day can be recorded and tracked with relatively little difficulty in a sort of time-lapse film. However, when we come to today, we are faced with the question as to what will happen with towns and cities in the future? How much further will the red spread out? Will it break up at the centre? And what will fill the empty spaces then? Or will the fleck shrink again one day?

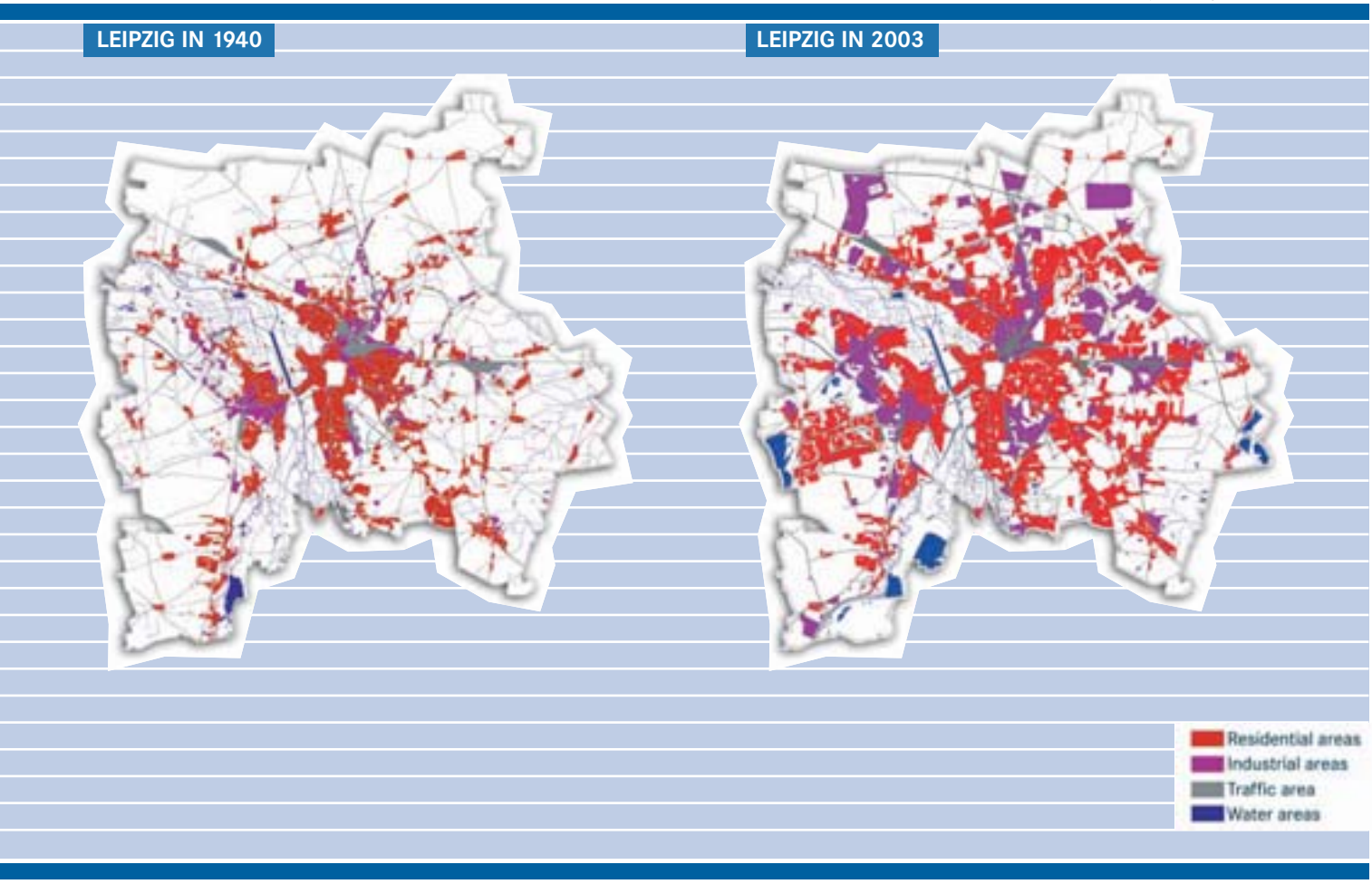
Perpetual growth?

Scientists around the world have been attempting for decades to model such processes. This means they are attempting to generalise all data on the development of towns and cities to date in such a way that they can use past trends to derive a sort of equation for the future.

Also, scientists of the UFZ are working on the modelling of urban landscapes. They get the necessary facts either from the UFZ itself or from outside. These range from the state of the stock of buildings to the situation of the people living there as obtained from empirical questionnaires; from the proportion of green spaces to the density of traffic; from the presence of individual types of animals to climatic peculiarities. As the insatiable hunger for data by a model, such as that at the UFZ, can be satisfied from all directions, we can also talk of interdisciplinary modelling. In this way it is possible to combine social scientific findings and knowledge that is difficult to quantify with exact spatial information. Nebulous concepts such as “feeling good” are thus fed into this system along with exact measurements. Each grid point within the urban landscape, such as the line of a street, to take an example, is then assigned a certain development potential during the next step in the modelling. Then the changes start to show themselves.

Modelling the use of land in the area of present-day Leipzig in 1870, 1940 and 2003

Graphic source: Dagmar Haase, UFZ



Each cell does what it has been programmed to do. This resembles a biological process that can, like the growth and death of a tree, be calculated for the future.

Shrinking according to a model

Urban modellers at the UFZ are not alone in doing this work, combining inputs from multidisciplinary groups. However, their intention is to fill a gap in the international "model market" that is dominated by simulation of growth. They want to model shrinking cities. These models are intended to show how to maintain the quality of life in a sustainable way despite falling numbers of inhabitants. Shrinkage models of this type could illustrate the new social, economic and ecological qualities of a perforated town, whose face no longer corresponds to our centuries-old impression of European dense and compact towns.

A great deal of what the town modellers at the UFZ calculate is done on the basis of the city of Leipzig. For example, on a mosaic-like map of the recently built-up area of Gruenau they have calculated just how long the average route to the nearest school is. On another map they have shown the proportion of green areas in the immediate vicinity. This assigns various qualities to the residential area and can thus form the basis for planning decisions. Where should the high-rise apartments be pulled down? Where could single-family houses be put up? And where would it be fatuous to destroy existing structures?

Nevertheless, even if Leipzig often serves as the object of the research, the actual goal of the modellers is an ever-improving model with widespread applicability. After all, the designation of "shrinkage patient" that is applied to towns in eastern Germany will no longer be a special case in the not-too-distant future. ■

GEOGRAPHER AND LANDSCAPE ECOLOGIST DR. DAGMAR HAASE IS A SCIENTIFIC WORKER IN THE COMPUTATIONAL LANDSCAPE ECOLOGY DEPARTMENT.

Wolfgang Köck and Marlis Heinz

Legislation for more green

There is so much that man can do, almost as he thinks best; he can rebuild or restructure ever more areas, he can create extreme temperatures or achieve speeds greater than sound. However, other than in coastal areas, it is impossible to create virgin land. Only when it lies undamaged at our feet does the water cycle function, and flora and fauna flourish. Our food grows in the soil, the air that we breathe depends on it.

And yet mankind treats land as if it will keep on growing. Towns sprawl across adjacent areas and bury living nature under shopping centres, industrial plants, industrial and commercial areas, residential areas, roads and railways. Around 120 hectares of land in Germany are currently sacrificed every day for buildings and roads. And this against the background of a population that is stagnating, or even declining in some regions. In theory, this would mean a reduced need to pave the living earth – but that is merely in theory.

The current requirement for around 120 hectares of new land each day for housing and transport is to be reduced to 30 hectares a day by 2020 and to zero in the long term.

Who is going to apply the emergency brake?

Experts observe this trend with great concern because it has significant negative effects on the natural function of the soil. The strategic goal is the increase in the growth of areas taken for housing and traffic to be reduced to a maximum of 30 hectares a day by the year 2020. Per day – that means that the expansion will not come to an end, merely that its advance is to be slowed down. However, from a long-term point of view no further new land at all should be used for buildings and roads according to the recommendations of the expert advisory council for environmental matters, an advisory committee of the German Ministry of the Environment. The demand for land to use for building and the construction of roads should be secured by a form of recycling of used land areas, such as brownfield redevelopments.

However, how can a land recycling system of this kind be set up? Legal experts in environmental matters at the UFZ in Leipzig-Halle have set themselves the task of converting the general requirement of land use reduction from an

areas

ecological point of view into an instrument that can be applied from a political and a legal point of view. They cooperate with political scientists, geographers, planners, biologists and sociologists, which is a good precondition for searching for the right questions and finding the answers to them.

Tradeable land use permits?

There are numerous examples of questions that scientists are working on at the moment. Can it be expected that the problem of increasing land usage will resolve itself through demographic trends? What trends in the land usage can be predicted? What are the land use impacts of the existing governance structures for making local and regional land use planning decisions? What steering mechanisms does the state have at its disposal? Are its instruments effective? If not, then how can they be applied in a way that restricts the freedom of local decision-making as little as possible? What consequences would there be from a policy of enforced conservation of land, and what effects would it have on the distribution of land? Could synergies be created? Is conservation of land viable, not only from an ecological point of view, for example as a result of reducing transport pollution, but also socially – and as a result of a reduction in infrastructure costs - economically as well? What can we learn from other countries?

Thus legal experts are deliberating together with their scientific partners both within and outside the UFZ on, among other things, whether completely new economic instruments such as negotiable rights to develop land, for example, in much the same way as the trade in emission rights would be useful. A municipality would have available a legally specified number of land use permits for construction purposes. If it does not use this right, it could then be sold to another municipality. In theory this sounds highly attractive, but how would it actually work in practice? Based on various planning models set up with partners from towns and communities it shall now be determined how such an instrument would affect local decisions so as to be able to come up with realistic recommendations. ■

ENVIRONMENTAL LEGAL EXPERT PROF. WOLFGANG KÖCK IS HEAD OF DEPARTMENT OF ENVIRONMENTAL AND PLANNING LAW.

Managing contam and grou

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Geoscientists, chemists, biologists, economists, social scientists and engineers at the UFZ are developing innovative management strategies so that contaminated megasites can be evaluated and treated. They are developing new analytical and eco-toxicological methods, researching the natural microbiological remediation potential (natural attenuation) in groundwater, and are designing cost-effective and innovative processes for cleaning up. The SAFIRA research infrastructure at various locations in Germany (for example, Bitterfeld, Leuna and Zeitz) and in other regions around the world offers ideal conditions for testing these strategies in actual practice in the field.

SPEAKER FOR THE RESEARCH TOPIC "NEW STRATEGIES FOR THE MANAGEMENT OF CONTAMINATED SOIL AND GROUNDWATER"
DR. HOLGER WEISS, HEAD OF THE DEPARTMENT FOR GROUNDWATER REMEDIATION

inated soil
ndwater

Source: Photodisc by Getty Images

Holger Weiss and Doris Böhme

Megasites – abandoned polluted areas in XXL

In Germany and in all other industrialised countries round the world there is a large number of locations that have been contaminated and polluted over large areas as a result of industrial use. According to conservative estimates, there are thousands of such sites in Europe alone, and there are around two dozen of them in eastern Germany. Primarily areas used for mining and the petrochemical and chemical industries, but also for goods handling and transportation or military facilities, have been subjected since the beginning of industrialisation in the 19th century to pollution of the soil, groundwater and surface water to an extent that often affects entire sections of the landscape. They are therefore also called megasites. They involve areas in the centres of towns and cities, historical industrial areas at the edge of settled locations, but also areas that had formerly been used for military purposes in landscapes that remain close to the original natural ones. Growth and stagnation, the establishment of new branches of commerce and industry or industrial down-sizing, a growth in population or unemployment and the emigration of the people who once lived there – the fate of towns and regions depends on whether and how this troubled and weighty legacy that industry has left behind is handled.

An ecological and economic dilemma

Thousands of different chemicals were processed over many decades at locations used by the chemical industry, millions of tons of products were handled every year at the sites used by the petrochemical industry – but not without losses, leakages or war damage. At innumerable places large quantities of a wide variety of pollutants seeped into the ground over long periods. The areas that were affected are frequently anything from several hectares up to several square kilometres in size. Nonetheless, "only" around 5% of the bodies of groundwater in Germany do not meet the quality requirements of the European Water Framework Directive, due to the fact that pollutants occur in so-called point-type sources. This has led to an almost completed recording of the state of the groundwater bodies in Germany. However, this 5% is almost exclusively made up of megasites of this type.

Thus if the quality of such groundwater and the associated surface waters is to be improved, and this is indeed required by the Water Framework Directive, then innovative management concepts need to be found. However, it is not possible either to investigate the huge areas completely and to determine all the damage done, nor can all the pollutants from the ground under the surface be removed. The immediate proposed solutions for cleaning up and, in the last resort, to minimise the risk to people and the environment simply are not adequate to cope with problems of this scale. Nobody is in the position, from a technical point of view, to apply conventional clean-up procedures when the scale is of the order of several square kilometres. And nobody would be able to come up with the required investment of the order of a double-digit figure of millions (in euros).

Thus what is urgently being sought are alternative concepts for a meaningful and viable way of dealing with these areas. After all, who would like to take the responsibility of simply leaving potential hazards where they are, to abandon entire regions, or to reduce their utilisation to an extreme extent?

This is an ecological and economic dilemma, because the "consumption" of land as a resource that must be reduced without fail in the densely populated regions of central Europe from the point of view of a sustainable form of use of the land. The German government is pressing for this "consumption of land" to be reduced from the current figure of around 90 hectares of land per day to 30 hectares a day by the year 2020 (see also the article on page 16). Hence, instead of taking "new" areas for industrial, residential and infrastructure use, we must in future to an increasing extent resort to making use of the areas of land that are being used today and have often simply been abandoned. However, such pieces of land have been avoided because they are bedevilled by the problem of great uncertainly over how much their value has been reduced. Who would willingly take on an economic risk of this type that involves a totally unpredictable commitment to cleaning up the land in question? And this is quite apart from the fact that such locations frequently do not have the best of reputations anyway.

New concepts are required

What are the scientists doing to resolve this ecological and economic dilemma? They are developing innovative management concepts to minimise the risks entailed by these megasites, and thus to integrate the socio-economic aspects of an increase in value of the areas. The fact that geoscientists, chemists, biologists, engineers, economists, social

A “direct push” drilling unit in use. It allows the aquifers to be quickly, effectively and very precisely investigated, samples to be taken, and measurements to be done online. Thus it is possible to localise the sources of pollutants or to install groundwater measuring stations and monitoring systems. The special point about this device, as opposed to conventional drilling equipment in which a drill is driven into the ground, is that this system works with a hollow rod which is simply pushed into the ground (direct push).

scientists and environmental legal experts have to work together on this lies in the very nature of the matter. Determination and observation require concept-related work and coordination, elaborate and complicated infrastructure preconditions need to be set up at the model locations, and pilot tests need to be carried out. The researchers are combining scientific facts with a risk evaluation of the various options for cleaning up and action in general, taking into account the overall conditions imposed by national legislation or the EU Water Framework Directive and to analyse and compare the costs involved.

Each individual step is a challenge for the scientists. How dangerous are the complex mixtures of pollutants for ecosystems or for man? Which of the substances are the actual ones that are causing the risk? Often the toxic effect arises from compounds that had not been noticed before, because they only develop their hazardous potential as a result of the action of light or the air or only in combination with other substances. Thus targeted cleaning up only makes sense if the hazardous substances and their effect have been identified through combined chemical and biological test methods. And even if reference cases are available after numerous experiments and forecasts, many questions still remain open nonetheless. Are there exceptions to the rule? Is something that functions in the laboratory or a computer model actually usable in the case of real-world eco-systems that are far more complex than an experiment in a “test tube.”

For that reason groundwater researchers from the UFZ are identifying areas of investigation with model locations that are especially well suited to study, for example, the behaviour of organic pollutants, their transport and natural breakdown, accumulations and accretions in the constituent parts of the ground, or dilution effects. To do this, they are developing and using in conjunction with scientists from other research institutes innovative methods for measuring, detecting, monitoring and cleaning up.

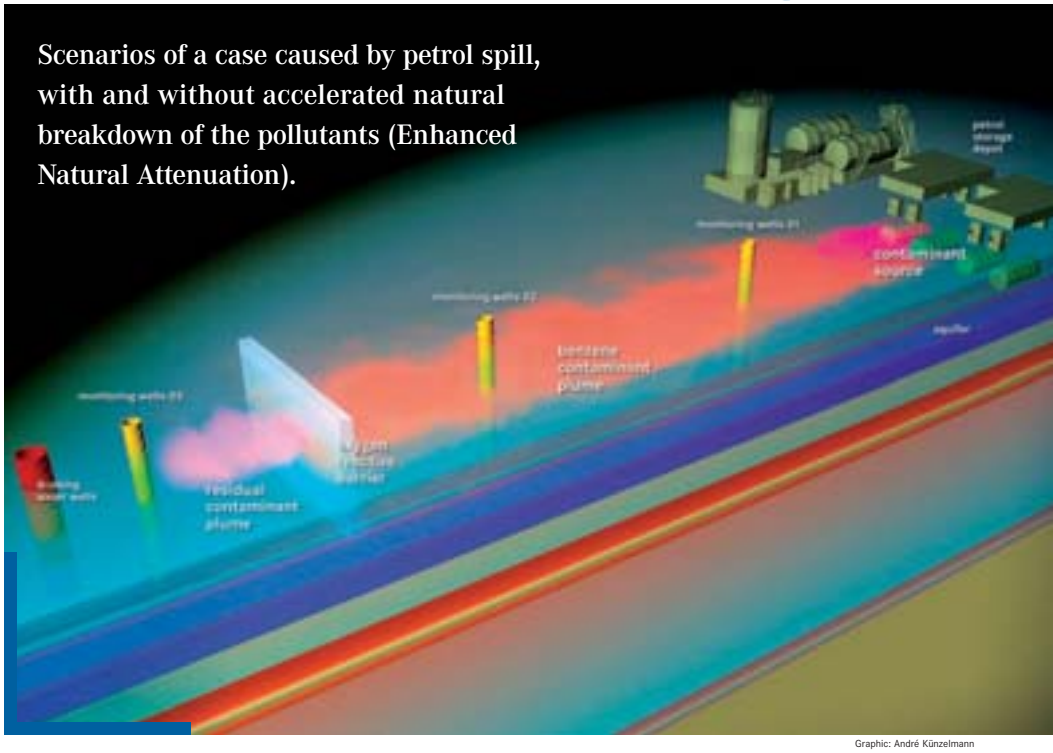
The aim is, in addition to the development of the methods, concepts and technologies, to also transfer this scientific knowledge to the political, public administration and public spheres. The handling of historically polluted areas on a regional scale is a task that by far exceeds the timeframe of the history of the pollution itself. Creating a sense of consciousness of this is a task that is just as urgent as the provision of tools to cope with the actual problems. ■

GEOLOGIST DR. HOLGER WEISS HEADS THE DEPARTMENT OF GROUNDWATER REMEDIATION.

Mario Schirmer and Doris Böhme

Cleaning up naturally?

When petrol seeps into the ground from leaks in tanks and gets into the groundwater, it can form huge pools floating on the water table. The pollutants from these sources then move in a similar way to smoke from a chimney in the air, with the slowly flowing groundwater downstream. The zone of contaminated groundwater is called contaminant plume. Scientists have proven that contaminant plumes of some chemicals do not spread out as much as others. Natural breakdown and retention processes (Natural Attenuation) can slow down or even completely stop this spread of the pollutants in aquifers. The pollutant molecules can adhere to soil particles, they can be deposited or even eaten up by microorganisms. To take an example, chlorinated hydrocarbons or the so-called BTEX aromatics – that is the collective term for benzene, toluene, ethyl benzene and xylenes – can form stationary plumes. In other words, the amount of pollution dissolving from the source into the flowing water is the same as the amount that is broken down by microorganisms in the groundwater.



Scenarios of a case caused by petrol spill, with and without accelerated natural breakdown of the pollutants (Enhanced Natural Attenuation).

Graphic: André Künzelmann

Investigating and monitoring

UFZ scientists want to understand when one can rely on this natural phenomenon as an alternative to conventional and often very costly groundwater cleaning approaches. Cleaning up polluted groundwater is difficult, annually swallowing up huge sums of money in Germany and worldwide. However, the prerequisite for trusting that natural attenuation will do the job is knowing that these time-consuming processes will always run in a stable manner and prevent contamination of valuable resources such as drinking water wells or rivers. For that reason it is not only necessary to obtain an approval from the relevant official authorities but also to carry out a comprehensive site investigation and monitoring programme. This kind of clean-up strategy is called “Monitored Natural Attenuation” (MNA).

Scientists from the UFZ and other research institutes are developing effective methods at the Zeitz site to investigate if such retention and degradation processes in the groundwater are actually running in a stable way. Among other things, this includes calculating how the contaminant mass moves and changes in space and over time, together with microbiological and isotope chemical methods.

Helping out

However, if the pollution source and contaminant plume include substances that do not break down easily, such as methyl tertiary butyl ether (MTBE), for example, then Monitored Natural Attenuation is no longer an option as a possible strategy for cleaning up. This is due to the fact that the resources downstream from the source would be potentially placed at risk. In these cases it is necessary to attempt to support or accelerate "Natural Attenuation" in a targeted way. Experts call this approach "Enhanced Natural Attenuation" (ENA). Since MTBE can cause serious groundwater problems, scientists are using sites at the Leuna chemical plants to see how ENA can help promote the crucial processes in the breakdown of MTBE. They have constructed a so-called conditioning channel structure that makes it possible to mix substances and microorganisms with the groundwater in an open channel or in reaction chambers. For example, the aerobic breakdown of MTBE by local organisms is enhanced by injecting precise amounts of oxygen. Another option is the addition of nitrate to speed up the anaerobic decomposition in an oxygen-free environment. Scientists see other possibilities in the isolation and targeted multiplication of microorganisms that can break down MTBE, or in the addition of alkanes and isopropanol to remove MTBE by means of so-called co-metabolism. The scientists use laboratory experiments to optimise the complicated tests in reaction chambers to break down MTBE as efficiently as possible. The process that works best will then be put into practice to help clean up the Leuna site. Thus, there is no question that the geologists, hydrologists, chemists, microbiologists and engineers of the UFZ are working closely together with the authorities in the relevant specialised areas to help them carry out their obligations to clean up and to work on site with the consulting companies. ■

USEFUL INFORMATION

Methyl tertiary butyl ether (MTBE) has been added to petrol in North America since the 1970s to raise the octane number and to reduce air pollution. It is soluble in water up to about 50 g/L, it is transported in water, it does not decompose easily biologically, and it has a noticeable smell and taste, even at concentrations as low as 20 µg/L.

Although MTBE has been added to petrol in Germany for many years, primarily as an additive for Super grade petrol (up to 14% by weight), it is not routinely measured in the event of accidents involving petrol. Consequently, it is very difficult to estimate the extent of MTBE contamination in Germany.

GEOPHYSICIST PROF. MARIO SCHIRMER HEADS THE HYDROGEOLOGY DEPARTMENT.

Conditioning chambers for use of ENA for the breakdown of MTBE at the Leuna site.

Christian Siebert, Stefan Geyer and Doris Böhme

Water – the greatest source of conflicts in the world?

High population growth and expanding agriculture mean that today more than 1.2 billion people no longer have access to clean drinking water. And this tendency is increasing. Drier areas of the world in particular where there is little rain, such as the Middle East, are affected by this. So, too, is the Dead Sea Rift (Jordan Graben) that is occupied by Palestine, Jordan and Israel. Since the Six Days War in 1967 the territorial dispute between Israel and Palestine increasingly also revolves around the issue of the lack of water, because one of the most important resources of the region is the groundwater under the West Bank and the Sea of Galilee in northern Israel. Due to increased demand these resources have

Photo: UNEP

Dead Sea Rift

The Sea of Galilee is located in the northern part of the Dead Sea Rift (Jordan Graben), some 50 km south of Lebanon and is the lowest-lying freshwater lake in the world at 209 m below sea level. Depending on the level of the water, it is up to 21 km in length, and 12 km wide at its broadest point, the area of the water is 165 square km, and it has a depth of 46 m at its deepest point. It is the second lowest-lying body of water in the world after the Dead Sea (approx. 400 m below sea level).

been overused for years so that the quality of water has become worse due to wastewater produced by man and/or increasing salinity.
However, what do researchers at the UFZ have to do with that? They will not be able to resolve the political conflicts, although perhaps they might be able to indirectly make a contribution to a solution. For a number of years they have been working with other Helmholtz centres and universities in Germany, Israel, Palestine and Jordan – making up a total of more than 20 cooperation partners –

USEFUL INFORMATION

The name “rare earths” comes from the time of the discovery of these elements and is based on the fact that they were initially only found in rare minerals and were isolated from them in the form of oxides (formerly called “earths”). The metals of the rare earths group include the chemical elements of the 3rd group in the periodic table, the lanthanoids. Representatives of these include cerium, gadolinium, europium and neodymium. They occur in water in concentrations of billionths of a gram per litre. Due to these exceedingly low concentrations they show minimum changes and processes much more clearly than, for example, major elements such as calcium or sodium.

Photo: EROS Data-Center USGS Landsat TM

Taking samples of lake water and groundwater in the Dead Sea Rift.

Photos: Christian Siebert, UFZ

on concepts and strategies to set up an integrated water resources management system in this region.

Salt in the soup

The sole freshwater lake in Israel, the Sea of Galilee, has a volume of 4.2 billion cubic metres of water. Almost half of the drinking water for Israel and Palestine – more than 400 million cubic metres of water – is pumped out of it every year. However, the level of the lake varies greatly. If there is too little precipitation, then the level of the lake drops rapidly. In addition, brackish water flows into the lake bed from sources that had not been located until recently. Consequently, the salt content of the lake has long since reached the level of 250 mg per litre – the limit set by the WHO for drinking water. So far, it was not known what types of sources contribute the salt. Excessively high measuring errors only allowed estimates to be made of the amount of salt that is coming in. For that reason the UFZ researchers developed a new method to locate, characterise and quantify the sources. They were able to determine the addition of a minimum of 20,000 tons of salt a year for the first time by using a method based on rare earths. Combined investigations of groundwater close to the shores and lake water, based on the stable isotopes of oxygen and hydrogen and on elements such as calcium and bromine, led the scientists in addition to the cause of the brines. They are rising from deeper parts of the crust as remnants of a strongly dried-out prehistoric sea and from shallower parts of the crust due to leaching a huge body of salt. Now, based on these well-founded results, it may be possible to constitute strategies to keep saltwater away from endangered resources. The new cognitions in groundwater flow directions show where and from which groundwater aquifers fresh water or saline water have to be pumped out so as to delay the entry of salt-laden water into the lake and hence to prevent it penetrating into bodies of fresh water.

Where should it be taken from, if not stolen?

From the point of view of the UFZ, integrated water management also means finding new resources. Thus, with the aid of simple wastewater treatment systems, such as plant-based treatment units, the large amounts of wastewater which are produced are to be treated. Hence they can be reused for agricultural irrigation. Following treatment, pollutants that accumulate in the ground and endanger high-quality groundwater are removed. Israel possesses such technologies, and the first applications of them are being made in Jordan, but Palestine has practically none at all. Scientists are constructing together with German small business companies a demonstration plant in Jordan to transfer know-how to the region and to collect experiences. At the same time, they are trying to convince people of the efficiency of the technology. In addition, scientists are developing simple strategies and technologies to help cut down on the use of water by the biggest consumer, namely agriculture. For example, less thirsty plants should be grown instead of bananas which require extremely large amounts of water.
Apart from many scientists and engineers, there are now a number of socio-economists at the UFZ and Palestinian NGOs (Non-Government Organisations) also sitting in the same boat, because it is important to take into consideration the complicated political situation, religions and national traditions, customs and habits so as to build up confidence and acceptance. ■

USEFUL INFORMATION

Isotopes are atoms of an element. They have the same number of protons and electrons, but a different number of neutrons in the atomic core. For that reason the isotopes of an element have the same periodic number but different mass numbers, also known as isotopic numbers. Stable isotopes are present everywhere and do not emit radiation unlike radioactive isotopes. They are therefore used, among other things, to examine metabolism processes, to mark sources and flows of substances, or to act as markers in conversion processes and reactions.

HYDROGEOLOGISTS DR. CHRISTIAN SIEBERT AND DR. STEFAN GEYER ARE SCIENTIFIC STAFF MEMBERS IN THE DEPARTMENT OF HYDROGEOLOGY.

Remediation and on a long-ter

using mining lakes
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Mining lakes as an environmental problem P. 30
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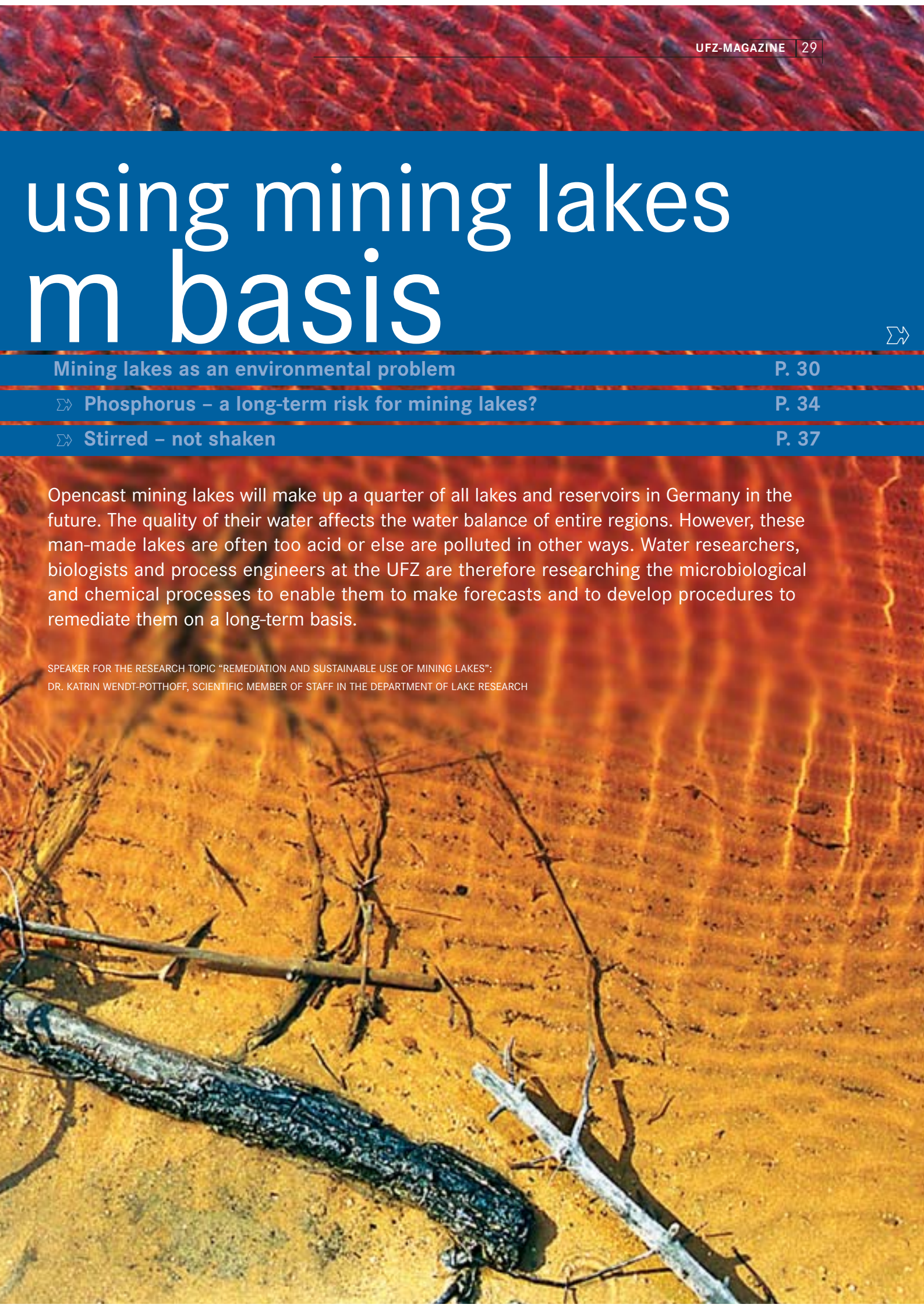
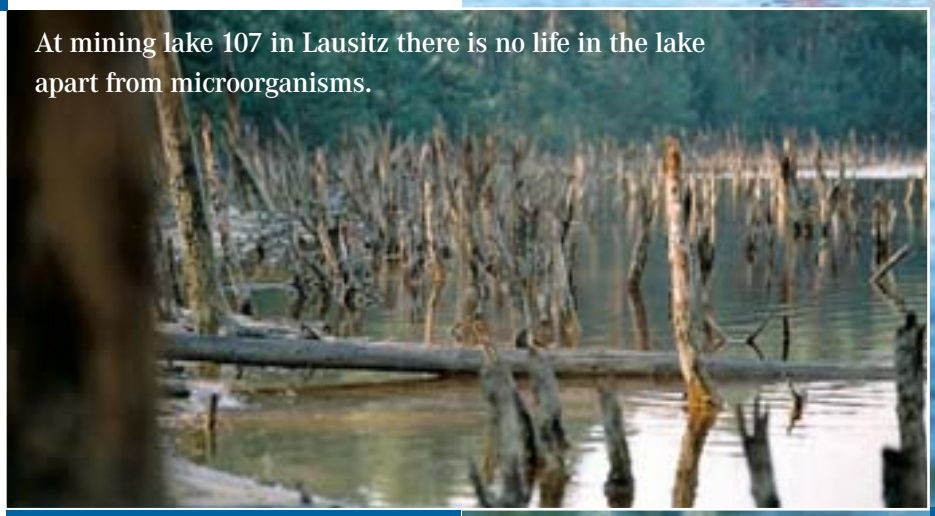
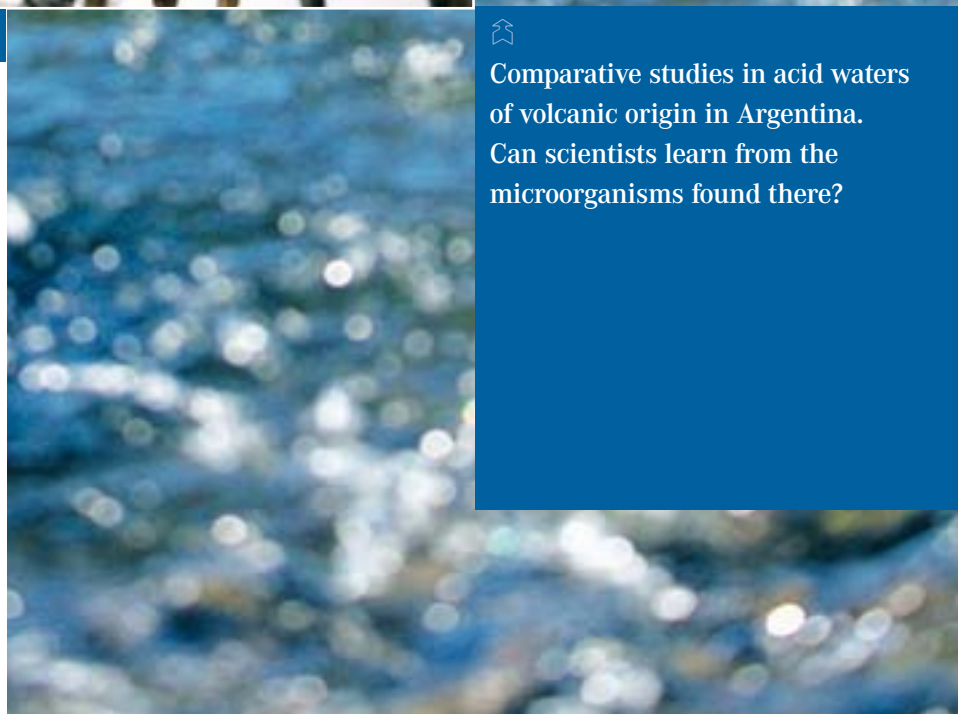
Opencast mining lakes will make up a quarter of all lakes and reservoirs in Germany in the future. The quality of their water affects the water balance of entire regions. However, these man-made lakes are often too acid or else are polluted in other ways. Water researchers, biologists and process engineers at the UFZ are therefore researching the microbiological and chemical processes to enable them to make forecasts and to develop procedures to remediate them on a long-term basis.

SPEAKER FOR THE RESEARCH TOPIC "REMEDIATION AND SUSTAINABLE USE OF MINING LAKES":
DR. KATRIN WENDT-POTTHOFF, SCIENTIFIC MEMBER OF STAFF IN THE DEPARTMENT OF LAKE RESEARCH





At mining lake 107 in Lausitz there is no life in the lake apart from microorganisms.



Comparative studies in acid waters of volcanic origin in Argentina. Can scientists learn from the microorganisms found there?

Katrin Wendt-Potthoff and Tilo Arnhold

Mining lakes as an environmental problem

There are already more than 350 lakes that have been produced as a result of mining in Germany. Another 120 lakes are currently being created in East Germany alone due to the closure of many open-cast mines for brown coal, producing a real lake district in the future in the vicinity of Cottbus, Leipzig or Cologne – as is already the case now in Mecklenburg, Brandenburg or Schleswig-Holstein. The water in many of these artificial lakes is extremely acid, with pH values of 2.5 to 3.5, and also rich in iron and sulphur due to the sulphur in the brown coal and the layers of soil surrounding it. In total, all this water that has been acidified with sulphur adds up to around three cubic kilometres, which is roughly the amount of water held in Lake Starnberg. Other water resources can be affected or placed at risk if the lakes are in exchange with the groundwater or the rivers and streams. They represent one of the most difficult long-term environmental problems facing Germany. Indeed, the number and the importance of lakes produced as a result of mining are also increasing worldwide, whether in the coal-mining areas of Poland, the Czech Republic or the People's Republic of China, or in the former open-cast mines for various metal ores in the USA, Canada, Russia, Spain or Australia.

As acid as vinegar

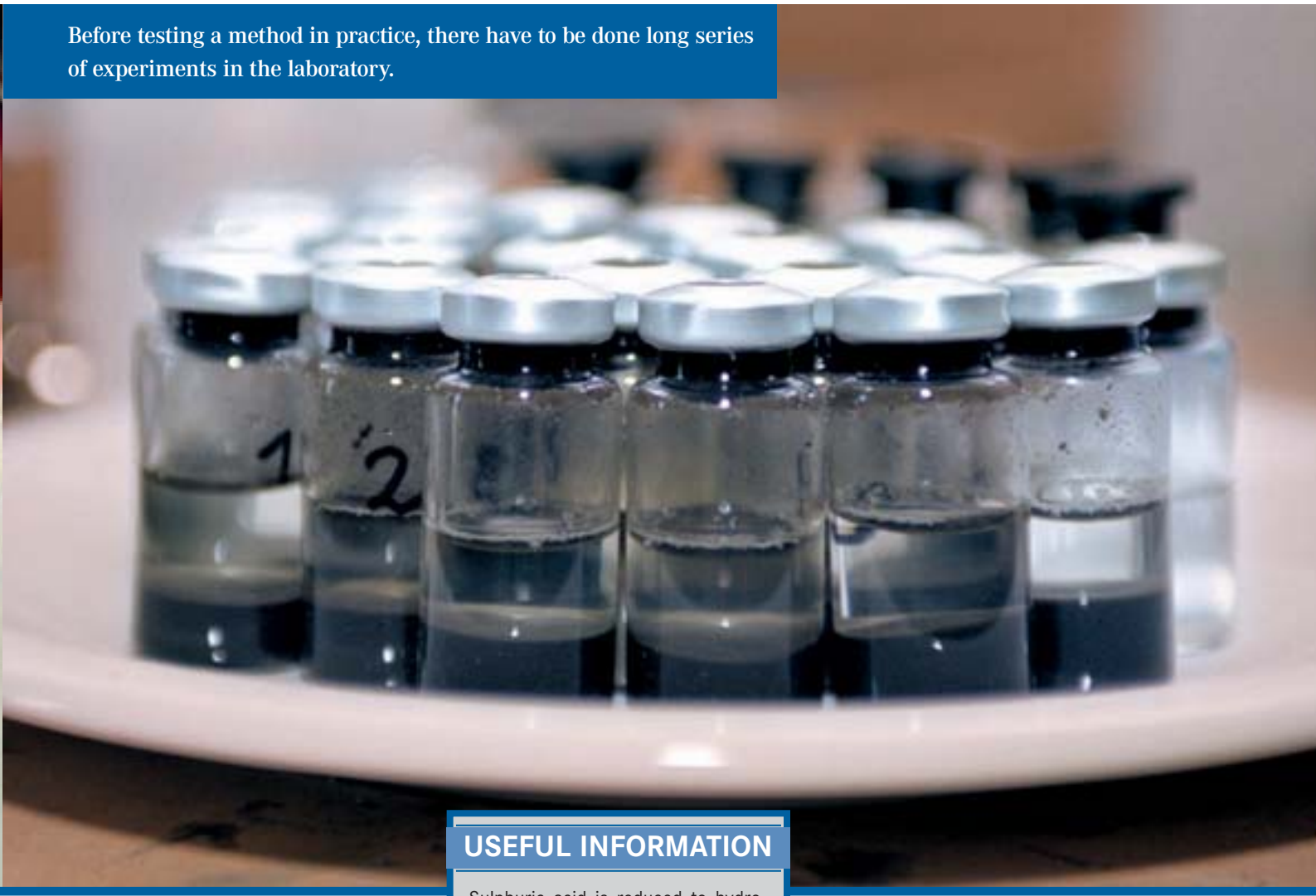
Many of the lakes have already been acid for many years and thus do not provide a place to live for fish or other higher organisms. They are just as little use to the people in the region to use as a source of water, for water sports or for bathing and angling. Nevertheless, it is precisely the sort of landscape that is left in the wake of mining that offers unique design possibilities that also provide some hope of economic development of the regions concerned through tourism after the extraction of brown coal has finished. The restructuring of the post-mining landscape is done in the medium term as an area left for nature and within society as a whole. The associated research must therefore have an interdisciplinary structure with a very long timeframe. The Helmholtz Centre for Environmental Research (UFZ), working in collaboration with other research institutes in a long-term research project, has set itself the goal of bringing about a neutralisation of the lakes produced as a result of mining with the simplest possible and most cost-effective procedures. As part of this, natural development potential for the open bodies of water are to be investigated and utilised in order to clean up these lakes on a long-term basis. If it is ever to be possible to control the development of lakes in such a way as that, it is necessary to understand the functional relationships of the microbial community living in them as well as the chemistry of waters that have been acidified with sulphuric acid. This research will enable biologists at the UFZ to make fundamental findings of the ecological relationships and interactions in the food webs that cannot be investigated directly in "normal" lakes with a wide variety of species and feeding levels.

USEFUL INFORMATION

The term **pH value** is derived from the Latin words for the amount of hydrogen, and by chemical definition it is the negative decimal logarithm of hydrogen ion activity. It states how acid or alkaline a solution is. Values below 6 indicate acidic conditions, while values above 8 indicate alkaline ones. Pure water is neutral and has a pH value of 7.

Many disciplines – one goal

The interaction of the lakes with groundwater in the area of the sediments is also important for the properties of and developments in the water in the post-mining landscape. Up to now, very little has been known about this. Natural and artificially added tracers provide the first starting points here. It is also necessary to develop new research methods to find out exactly what happens when the groundwater penetrates the bed of the lake and, conversely, what happens when water flows out of the lake. These methods must be tested on site before they can be passed on to consulting companies. An important goal is also to understand and predict the developments and changes in the individual lakes. This makes it possible to give recommendations for action to the mining companies and official policy-makers. This brings the knowledge and findings of chemists, biologists, physicists and engineers together in the construction of models that take into account the hydrodynamics as well as the biology and chemistry of the water column and the sediments in the lake. Models of this type can help to reduce the scale and cost of the acquisition of data. At the same time, it increases the chances of being able to transfer the findings from the Central German and Lusatia brown coal-mining areas to other climatic regions. This is an important goal, since opencast and strip mining represents an environmental problem worldwide. Above all, models should be able to serve as a forecasting instrument for planning to enable the areas that had been used for opencast mining to be recultivated and used optimally. In order to meet this demanding requirement, scientists from various disciplines are undertaking joint research campaigns and sharing data from their measurements with their colleagues. While microbiologists investigate the number, types and activities of the relevant microorganisms with classical and molecular biology methods and microsensors, chemists and geologists evaluate the development of the geochemical environment and nutrients in the water and sediment. Physicists studying water bodies analyse the stratification and thus the associated flows of substances and energy in the lake in the course of the seasons. Outside of the UFZ, the University of Potsdam, the Brandenburg Technical University Cottbus and the University of Western



Before testing a method in practice, there have to be done long series of experiments in the laboratory.

Australia in Perth (Australia) are the main participants in this long-term research project.

East German lakes as an example?

The testing of new remediation procedures on a large scale experimentally cannot be done solely by the environmental researchers alone. Thus for the technical implementation, such as the construction of large enclosures and bioreactors, for example, they work closely together with engineering consultants and special companies. A central role for the restructuring of the post-mining landscape in Lusatia and Central Germany is played by the mine administration company, Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft (LMBV), which is responsible for remediating the aftermath of mines and with which a close and constructive cooperation has existed for a number of years now.

USEFUL INFORMATION

Sulphuric acid is reduced to hydrogen sulphide in the course of **sulphate reduction**. This takes place in the absence of oxygen through special microorganisms that breathe with sulphate and thus neutralise the water. Bacterial sulphate reduction is an important part of the sulphur cycle of the upper layers of the earth.

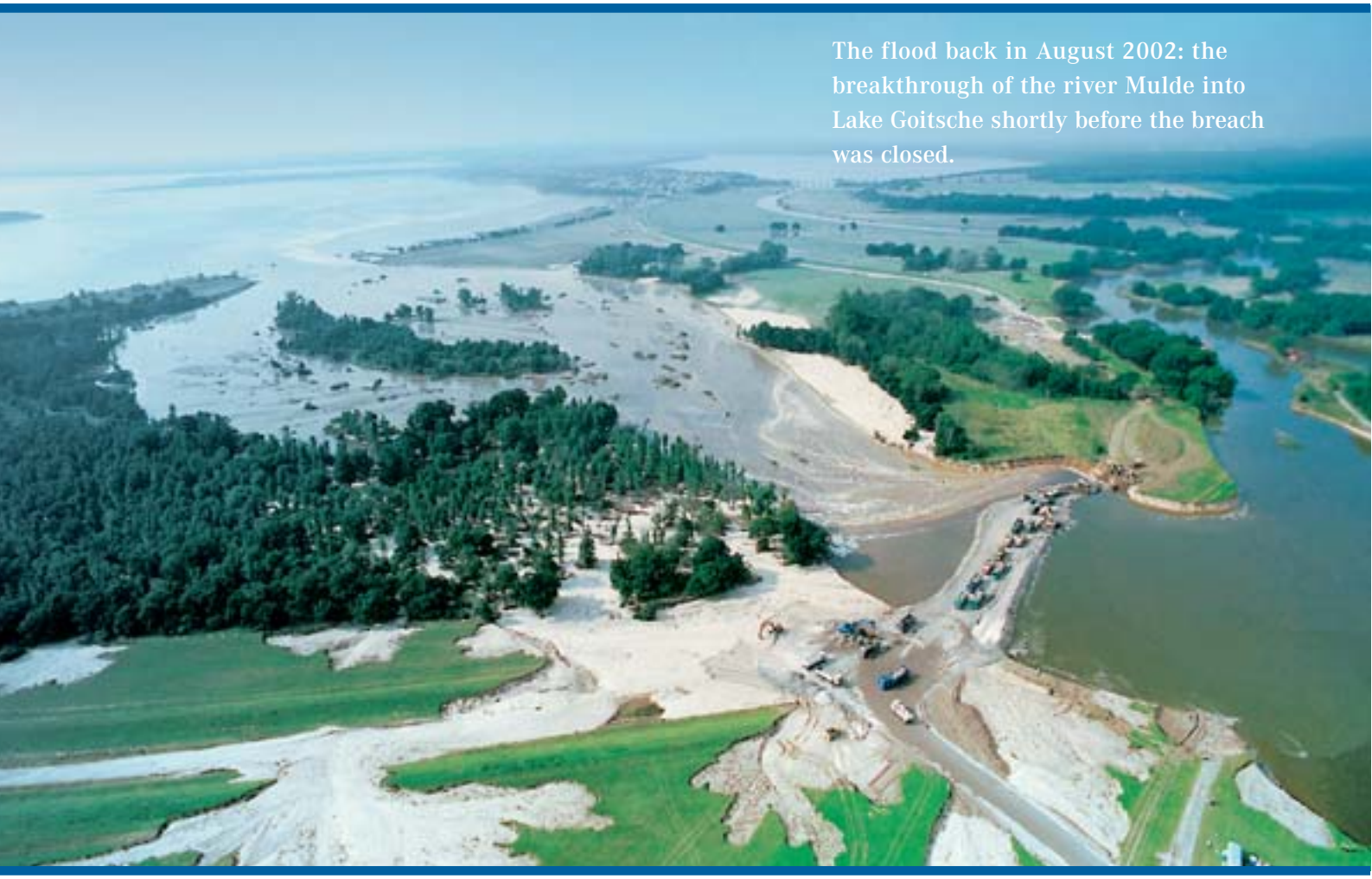
The LMBV is very much interested in gaining and using the results of the research at first hand and must of course also pay close attention to the risks within the measures proposed, financial feasibility, and finally acceptance by the persons concerned in its capacity as the responsible official body. For that reason the LMBV brings concrete requests and proposals for the course of the research work. It also finances other research and development projects in the mining sector and appoints staff from the UFZ to the corresponding project steering committees. For the researchers, the LMBV is the central interface with the official authorities.

In future we can expect an increasing tendency to shift mining work to parts of the world where environmental and social standards are far lower than those that apply in Europe and where there is corresponding less funding available for the associated research. For that reason the UFZ researchers and their partners also wish to assist in recultivating other areas that have been affected by mining with their knowledge gained over time and entirely within the context of a sustainable way of making use of natural resources. ■

KATRIN WENDT-POTTHOFF IS A BIOLOGIST AND SCIENTIFIC MEMBER OF STAFF IN THE DEPARTMENT OF LAKE RESEARCH.

Martin Schultze and Tilo Arnhold

Phosphorus – a long-term risk in mining lakes?



The flood back in August 2002: the breakthrough of the river Mulde into Lake Goitsche shortly before the breach was closed.

The quality of the water in natural lakes in past decades has been adversely affected by eutrophication, i.e. the import of too many nutrients into the lakes. The construction of wastewater and sewage channels and sewage treatment facilities brought about an improvement in many places. However, eutrophication still continues to be the biggest problem regarding the quality of the water in lakes, because phosphorus stored in the lake sediment in the past gets back into the water of the lake. This delays an improvement in the quality of the water, or even prevents it completely. Most of the new lakes that have arisen in eastern Germany in areas that had been subjected to opencast mining have been filled with river water. The disadvantage here is that even if the quality of water is improved drastically, the waters of our rivers are still a long way from the ideal quality required for bathing. This also applies to pollution from phosphorus. A further risk of eutrophication is the use of mining lakes for bathing or fishing. The "phosphorus" risk follows immediately after the main problem of acidification in the list of water quality problems relating to lakes produced as a result of mining.

The limits of what water can take

In order to be able to reliably estimate the risk of eutrophication in lakes that had resulted from former mining operations, investigations were made at the UFZ in recent years concerning their long-term behaviour under the special conditions prevailing in such lakes. Taking the example of the filling of Lake Goitsche near Bitterfeld with water from the river Mulde that was tracked in detail, scientists were able to establish that the risk of eutrophication was much less than had been expected for the first few years after the filling. The lake was even able to withstand the enormous rise in the amount of phosphorus due to the breaking through during the floods in August 2002. The ability of the lake sediment to absorb substances and the strength of the chemical bond are so good there that it was back almost to its original condition within around just half a year. And it would appear that this trend is stable there. A comparison with other mining lakes filled with river water in recent years shows that evidently the extent of the acidification plays a truly decisive role, having an effect on the phosphorus behaviour that goes far beyond neutralisation. The lower the tendency to acidification in the lake, the greater the risk of eutrophication. Fortunately, a sustained trend towards eutrophication was not detected in any of the cases. However, evidence showed that water can only take so much and we cannot just blindly transfer the very good results from Lake Goitsche and expect reliability. This also means, of course, that the utilisation of these lakes with very good water quality must be done with circumspection so that their valuable potential is not simply lost carelessly – as had been the case with the natural lakes up until the 1970s – and they will require costly restoration in the future.

The art of control

However, there are also mining lakes where eutrophication can be regarded as the lesser of two evils or even considered to be a very helpful process. If there is a constant supply of acidified groundwater from the waste dumps of former coal-mining operations, then the process of eutrophication can help in maintaining neutral conditions. And in the case of lakes produced as a result of the opencast mining of metal ores carefully controlled eutrophication has already been successfully used to remove toxic heavy metals from the lake water. The trick here is to control all the processes in such a way that the desired effects are achieved but there is no long-term eutrophication with all its disastrous consequences, such as fish kills, for example. In such cases it is necessary to be able to really understand all the processes involved and all their complex interactions. Many questions still need to be answered here, which are also of very great interest internationally. ■

Invasion of *Elodea nuttallii*, Lake Goitsche, summer 2004.

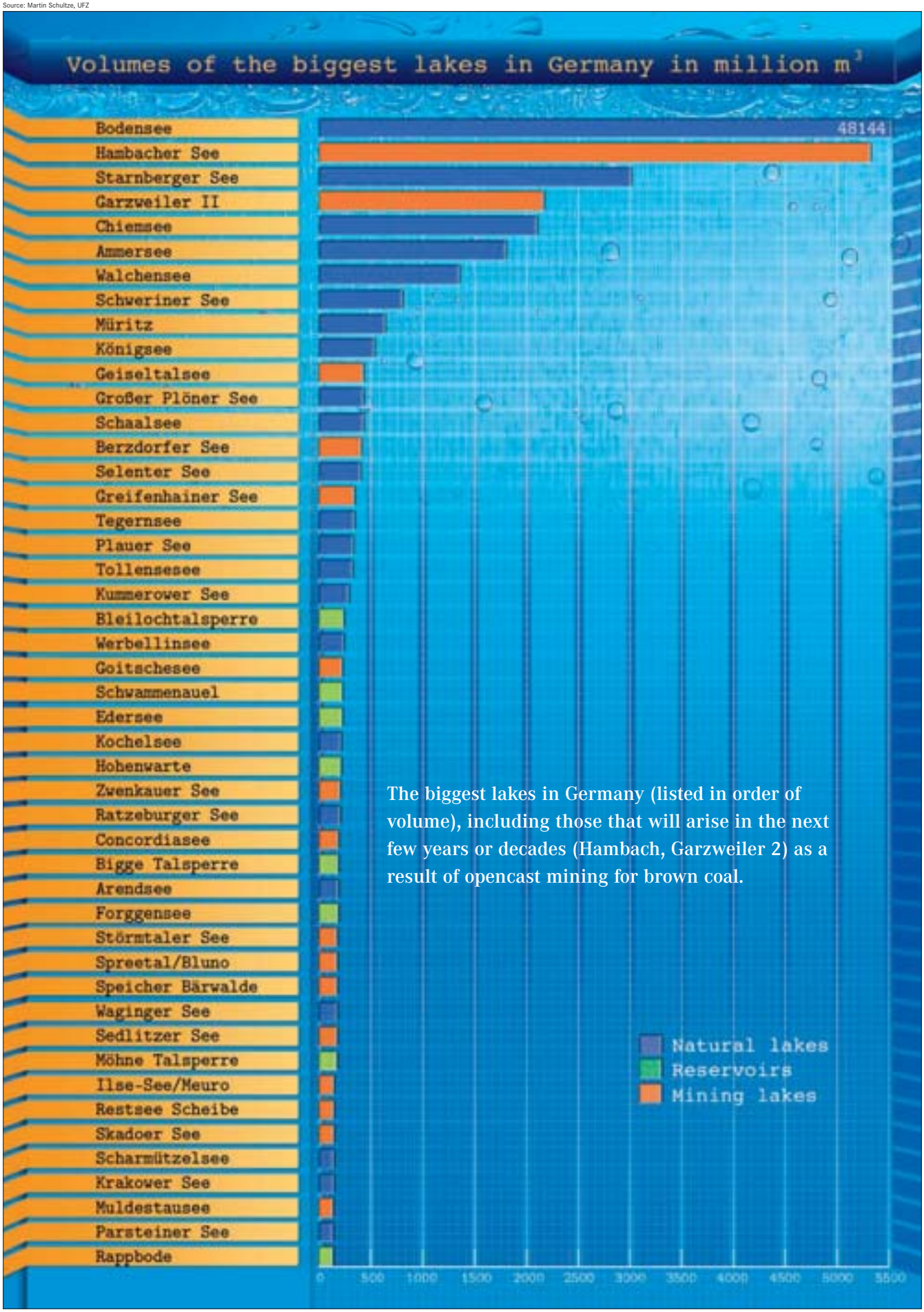
Photo: Michael Beyer, UFZ

USEFUL INFORMATION

Lake Goitsche arose through filling of an open-cast mine with river water. Brown coal was mined from this location at the edge of Bitterfeld from 1908 until 1991. Over a billion cubic metres of overburden were dug out and removed, four villages were resettled, and a river was diverted. After the fall of the GDR and reunification of Germany the mined area was recultivated by the LMBV, creating a recreational and nature reserve area of 60 square kilometres. During the floods in 2002 water forced its way in from the adjacent river Mulde and accelerated the growth of the lake that is currently the biggest in Saxony-Anhalt.

MARTIN SCHULTZE IS A CHEMIST AND SCIENTIFIC MEMBER OF STAFF IN THE DEPARTMENT OF LAKE RESEARCH.

Source: Martin Schultze, UFZ



The biggest lakes in Germany (listed in order of volume), including those that will arise in the next few years or decades (Hambach, Garzweiler 2) as a result of opencast mining for brown coal.

Bertram Boehrer and Tilo Arnhold

Stirred – not shaken

Swimmers do not feel a difference, while divers may notice some peculiarities. For fish and other organisms that require oxygen from the water, however, meromixis can be a decisive feature, as only the circulated part of the lake suits them as a place to live. A lake takes up oxygen from the atmosphere at its surface. Enriched with oxygen, this water can descend into the deeper layers and contribute to the oxygen budget there (so-called holomictic lakes). During the summer, this process is suppressed due to the lower density of the warmer surface water. Organisms in deep waters have to live on a limited oxygen budget until the next winter. However, not all lakes have sufficient surface cooling and wind action in the winter to circulate the lake down to its deepest point. In a number of lakes, a body of water remains stratified at the deepest points (so-called meromictic lakes) during the winter circulation phase. Hence the transport of substances through the water column is restricted and the exchange of gases with the atmosphere is suppressed – with all the consequences involved for living organisms.

Crater lake Toya on the Japanese north island of Hokkaido.

Photo: Bertram Boehrer, UFZ

Small difference – big effect

Even small differences in the concentration of salt can be sufficient for a layer of water that is not affected by the winter circulation process to form at the bottom. In particular, lakes in opencast mine pits or stone quarries are prone to such a situation. One example of this is the salt-water bath at Stassfurt near Magdeburg. Due to incoming saline groundwater, the deepest water layer remains permanently stratified and does not contain any dissolved oxygen. In addition to groundwater, a small number of geochemical processes can cause permanent stratification.

Measuring probe for the investigation of lake stratification. It has a special design for lakes with an extremely low or high salt content. It measures temperature, electrical conductivity, oxygen concentration, pH value, speed of sound, depth and light transmissivity.

Photos: Bertram Boehrer, UFZ

Dr. Wataru Makino, a Japanese scientist recovering a measuring probe from Crater lake Towada [Towadako] in the north of the Japanese island of Honshu.

In many lakes in opencast mine pits or stone quarries the water that is rich in oxygen does not reach the bottom – with obvious consequences for the organisms there.

Back in school, we learnt that water has its greatest density at 4°C. That is almost correct, but the world is not really quite as simple as that. Indeed, the deep water in Lake Baikal – the deepest lake on Earth - is only 3.3°C cold. The reason for this is the temperature-dependent compressibility of water that shifts the temperature of maximum density to lower values in very deep lakes. This effect can also be seen in the crater lakes in Japan. A difference of 0.7°C may seem little, but it represents a significant magnitude in terms of measuring precision in oceanography or limnophysics. Even small temperature differences ensure that oxygen-rich water sinks from the surface to great depth. In exchange, water that is low in oxygen but is rich in nutrients rises from the bottom to the top. This cycle is crucial for the survival of many organisms and thus the whole ecosystem of the lake. Measurements with a special probe have shown that the water in the salt-water bath at Stassfurt remains below 4°C all year round at depths of 10 to 15 metres, although the surface water reaches bathing temperatures of around 20°C and more in mid summer. This is a consequence of the high salt content of 20 ppm, or 20 grams

Crater lake Kuttara [Kuttarako] on the Japanese island of Hokkaido.

of salt in 1 kilogram of lake water. For comparison, ocean water contains 35 ppm. In parallel to pressure, dissolved salt lowers the temperature of maximum density. Hence deep ocean waters have a temperature of around only 0°C.

USEFUL INFORMATION

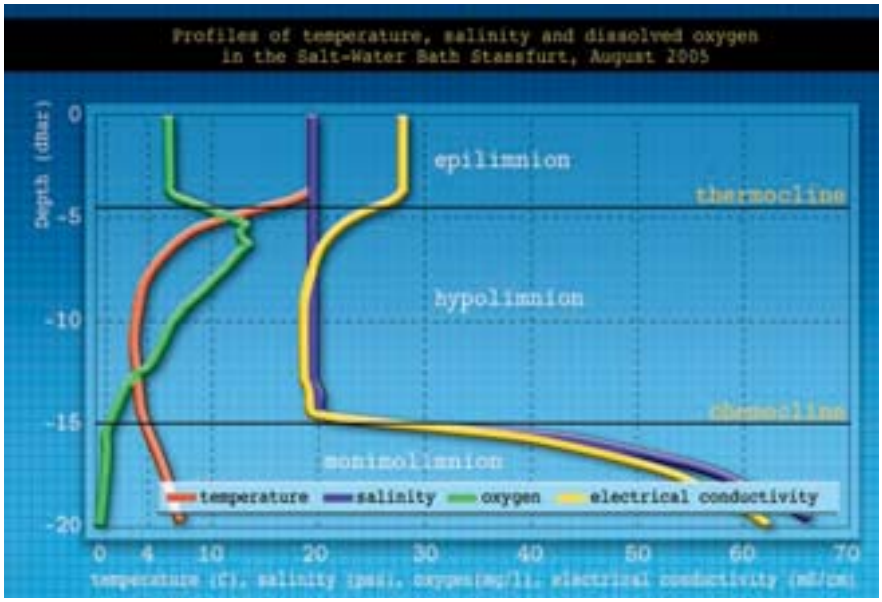
The **epilimnion** is the upper layer of water in a standing body of water. It is warmed up by solar radiation and currents can be directly driven by wind action.

The **hypolimnion** is the deep water layer that is only moved by internal waves and exhibits a relatively constant, low temperature.

The **monimolimnion** is the layer of water that remains permanently at the deepest points of the lake and is not involved in the exchange of gases with the atmosphere.

The **thermocline** – named after the rising temperature – separates the layers of the epilimnion and the hypolimnion.

The **chemocline** – named after the chemical changes – separates the layers of the hypolimnion and the monimolimnion.

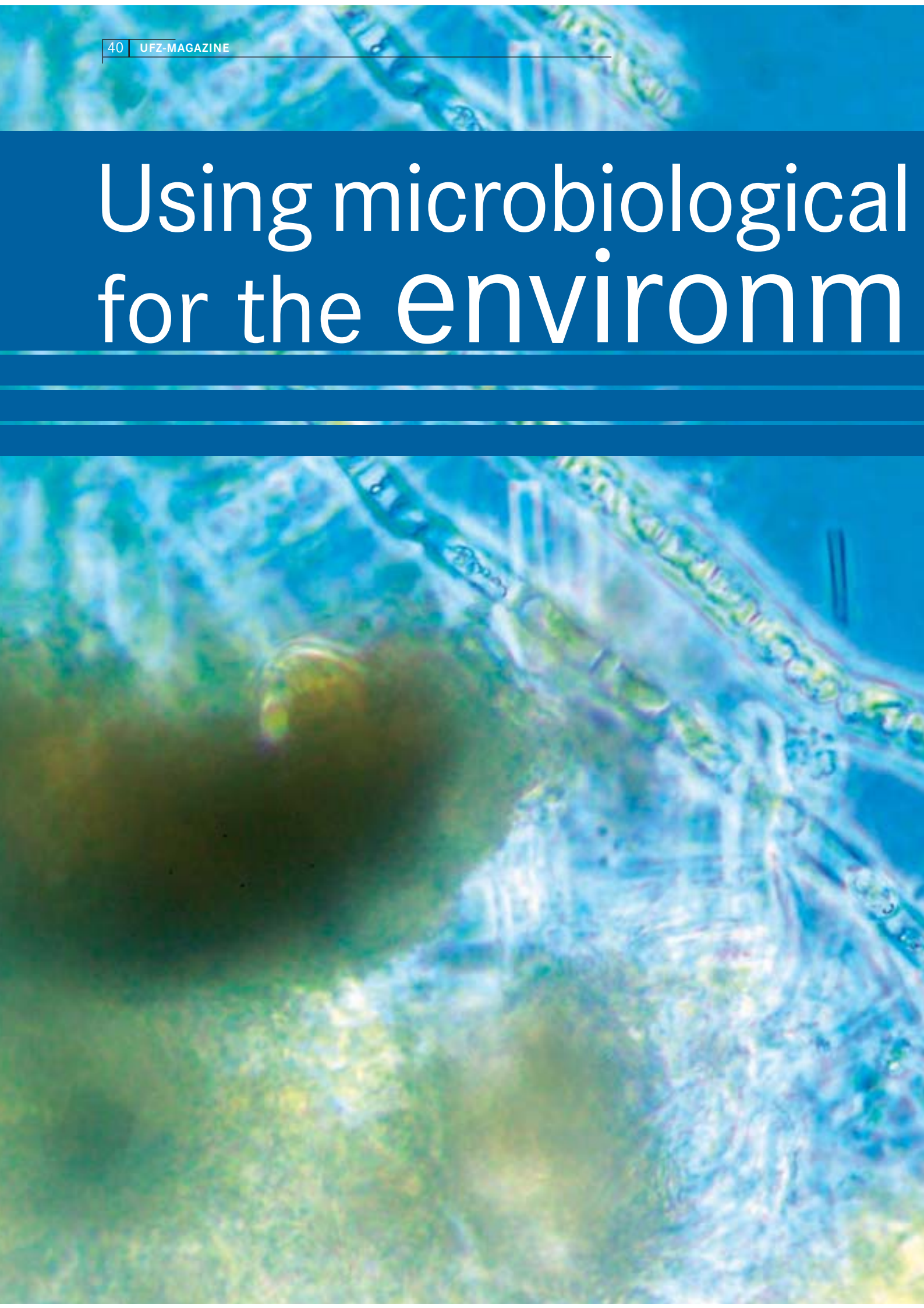


Forecasts required

Under favourable conditions acidity is abated by microbes in the anoxic zone. Due to a lack of dissolved oxygen, microbes use oxygen from sulphuric acid for the decomposition of organic material. The key to de-acidifying former mining lakes may be found at the lake beds. As the lake stratification can have dramatic consequences for the water quality, prognostication tools are required. Scientists at the UFZ are working on quantifying the stability of these boundary layers. They are investigating the chemical processes involved and including them in models. Such questions arise when flooding former opencast mines, but it is also necessary to understand the changed circulation patterns with regard to global change. A greater understanding of these processes would also help to better understand climatic history from deposited lake sediments (see chapter “Comparing climatic trends across space and trough time” on page 118).

DR. BERTRAM BOEHRER IS A PHYSICIST AND SCIENTIFIC MEMBER OF STAFF IN THE DEPARTMENT OF LAKE RESEARCH. HE HEADS THE LIMNOPHYSICS WORKING GROUP.

Using microbiological for the environm



diversity ent and health

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Microbiologists and biotechnologists at the UFZ intend to use and manage the enormous potential of microorganisms in the best way possible. They are developing methods to cultivate and characterise microorganisms and microbial communities. They are studying microbiological breakdown processes, attempting to control them for specific purposes or to optimise them and so to make them usable for biotechnical procedures.

SPEAKER ON THE RESEARCH TOPIC "MICROBIOLOGICAL DIVERSITY IN THE ENVIRONMENT AND HEALTH":
PROF. HAUKE HARMS, HEAD OF DEPARTMENT FOR ENVIRONMENTAL MICROBIOLOGY

Hauke Harms and Marlis Heinz

A handful of soil

The diversity of microorganisms exceeds that of plants and animals by a vast extent. Estimates of the number of types in a gram of soil from farmland range from a few thousand up to a million. The bulk of tiny organisms that mainly inhabit the soil and groundwater could be compared with all the creatures living above ground as if a tropical rainforest was flourishing under our feet. However, how is life “above” linked to the life “below”? It is already clear enough that microorganisms are the monopolists for vital environmental processes through their biological diversity. Without them, the world would choke to death on itself. Therefore the question is, how should we handle them?

The health of a landscape is based on the functions of its smallest inhabitants. Sometimes appearances can be deceptive; the rich green of golf courses that are ecologically valueless is just one example. The aim is to evaluate the microbiological integrity of landscapes and to use them like a blood test for the patient, Mother Nature. An environmental diagnosis that can make a statement of any value must therefore take into account these microbiological communities, hence the life in a handful of soil. And if this handful of soil came from the Bitterfeld area, it would have to put up with much more than just chemicals. And the bacteria, algae, fungi, yeasts and protozoa living in it would have to do likewise.

The battle that is raging underneath our feet

If you consider the soil and the waters underneath our feet, it is shocking to see what dramas are played out there when the natural cycles have been seriously disturbed as a result of man-made events or by repellent environmental conditions. The careless or unscrupulous handling of chemicals, the cutting down of a forest, the flooding or paving of open areas and mining activities that turn the surface of the landscape upside down result in life being slowed down there. In the last resort, this means that parts of the countryside can no longer carry out their essential but often less well-known tasks of environmental hygiene.

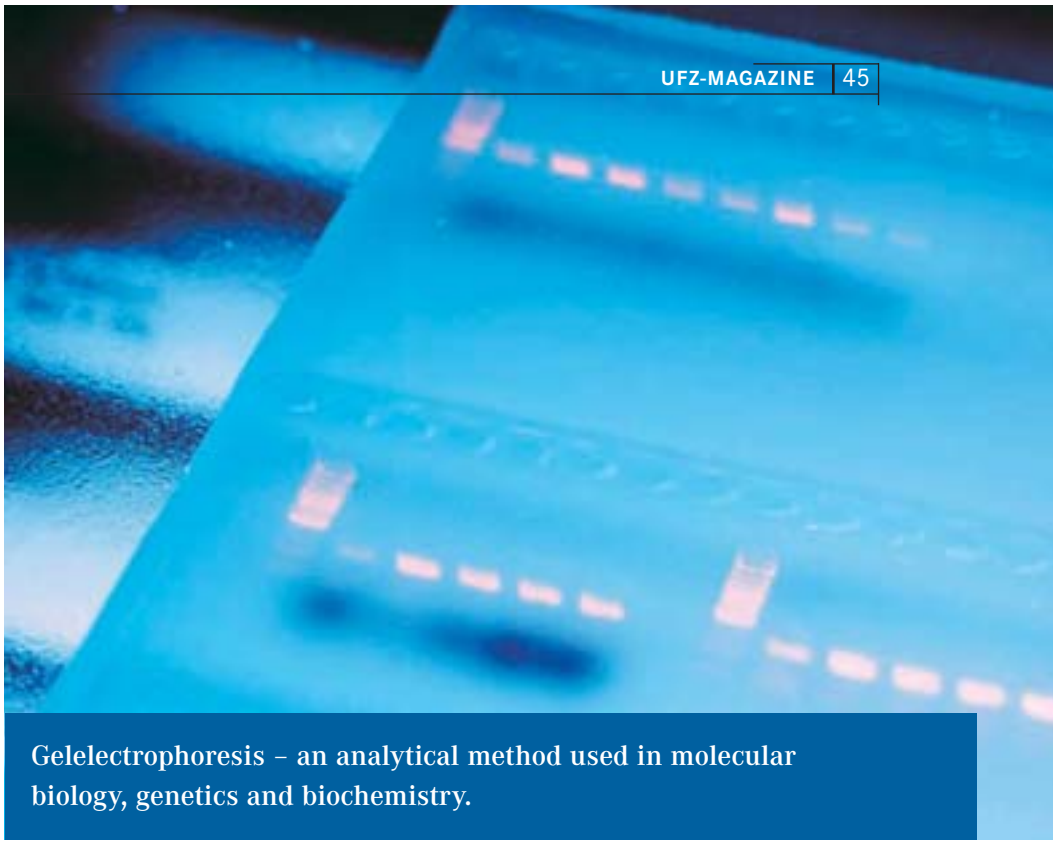
And for that reason this handful of soil must answer innumerable questions in the laboratories of the Helmholtz Centre for Environmental Research (UFZ). Which microorganisms within this complex community take care of which disposal tasks? How stable and adaptable is this community? What is its flexibility based on, and what it will come to grief over, sooner or later? And how can we place this form of life under the protection of nature? The questions are asked and gradually being answered by environmental microbiologists, genetic engineers, ecologists, geologists, chemists, physicists and modellers from the UFZ. In addition to the unusual mix of disciplines within its own premises, the partnership arrangements with other scientific institutes such as the Helmholtz Centre for Infection Research [HZI] in Brunswick and the universities in Bayreuth, Copenhagen and Lausanne help in tackling this complex topic from all angles.

Only around 30 grams of soil is enough to keep a dozen scientists busy for five years to answer the questions about the life that is underneath our feet. And even then the experts only know about a small portion of the microorganisms that populate this handful of soil.

The molecular nameplate

So what exactly happens with this handful of soil in the laboratory? Since the assumed wealth of varieties greatly exceeds the number of known microbial services performed in all cases, the basis of microbiological work is the identification of the key figures for the breakdown of pollutants or the recycling of plant nutrients. In other words, who ate what and to what extent in the "feeding frenzy"?

In order to find that out, the microorganisms living in the sample of soil, or to be more precise, their DNA, must be isolated. This is done to identify them, since the genetic material is so to speak the molecular nameplate of a microorganism. The DNA spectrum provides information on which microorganisms are present in the soil that is being investigated. It is then possible to deduce indirectly from this just which inhabitants broke down a particular pollutant. For example, if all the bacteria that are found in soil that had been polluted with octane are identified, these should have been the ones that had been most involved in the metabolism of the octane.

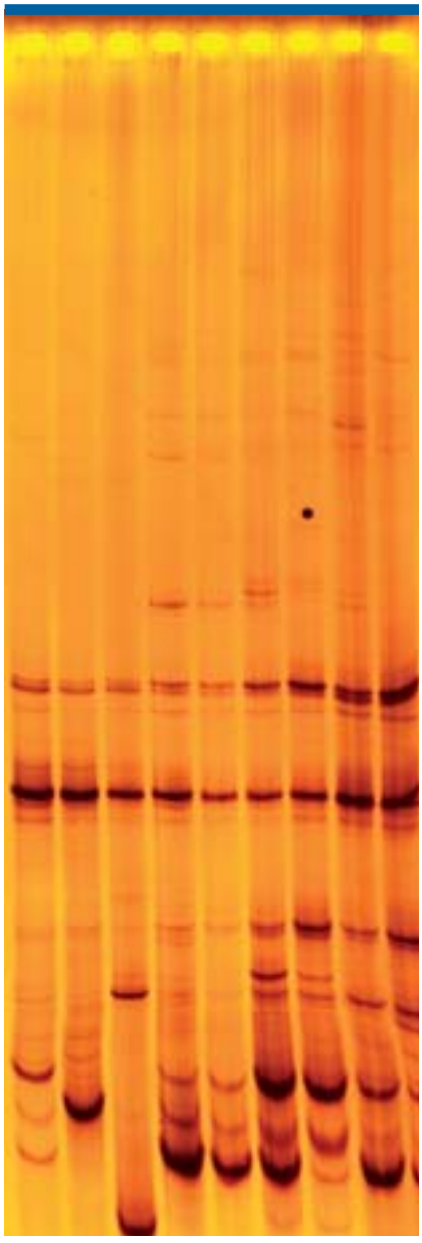


Gelelectrophoresis – an analytical method used in molecular biology, genetics and biochemistry.

Further tests can then be carried out on the gene sequences that have been obtained. The complementary – i.e. mirrored – gene sequence of a particular type of bacteria is given fluorescent markers and put into a sample of the original soil. If the bacteria in question live in this soil, then the fluorescent markers dock onto their related genetic material and colour the sample. If the bacteria are not at home there, then no reaction is seen. Thus if our chosen type of bacteria is especially dominant, then this indicates that its "favourite food" – e.g. a particular pollutant – is or was there and that it played a crucial role in breaking it down.

Another possibility of testing the "tastes" of the microbes is to mark with heavy isotopes the substrate, hence, for example, the octane in the soil sample. As soon as the microorganisms break down the octane, they automatically incorporate the isotope markers into their own biomass. After separating out the DNA in a centrifuge, it is possible to pick out through their heavy DNA those that had eaten with an especially hearty appetite at the meal of the pollutant. This then allows conclusions to be drawn regarding the natural function of individual types of microbes.

However, even then a number of important statements are missing, namely, the circumstances under which a particular type of microorganism tackled the pollutant. The fact that both exist simultaneously in a sample of soil still does not mean that microbes always come promptly into contact with the relevant substances. Perhaps that only happens in the presence or in the absence of oxygen. Perhaps there are other limiting factors. It is also important to find out under what circumstances a successful meeting of the pollutants and the microorganisms that break it down can be achieved, such as is done in the case of the cleaning of wastewater and sewage or active cleaning of the soil, for example. More certain verdicts on the self-cleaning abilities of the soil and the groundwater can be given through such research. A pollutant is not always automatically broken down and rendered harmless if it occurs in lower concentrations. Unwanted dilution processes can merely provide an illusory solution to the problem.



If you were to take a bacterium...?

Although it would be very practical if all you had to do was to take a particular bacterium off the shelf to break down pollutants, in practice it does not work like that. The assignment of environmental functions to individual types corresponds to our innate love of simple relationships between cause and effect, but it only rarely works like that in the case of environmental processes. Almost always entire consortia are required, microscopically small communities of microorganisms. Detecting these consortia is an especially difficult task for which innumerable methods have been applied. However, even that is not enough.

The microorganisms do not live in their own world, but are in a situation in which they exchange with higher creatures, be it as food for creatures living in the soil, as a supplier for plant fertiliser or by causing illnesses and infections. The incorporation of such organisms and entire eco-systems is made possible by the collaboration with plant and animal ecologists, with researchers working on the protection of nature and with modellers. And suddenly this handful of soil is important in many greater contexts. ■

PROF. HAUKE HARMS IS A MICROBIOLOGIST AND HEAD OF DEPARTMENT FOR ENVIRONMENTAL MICROBIOLOGY.

Hauke Harms and Marlis Heinz

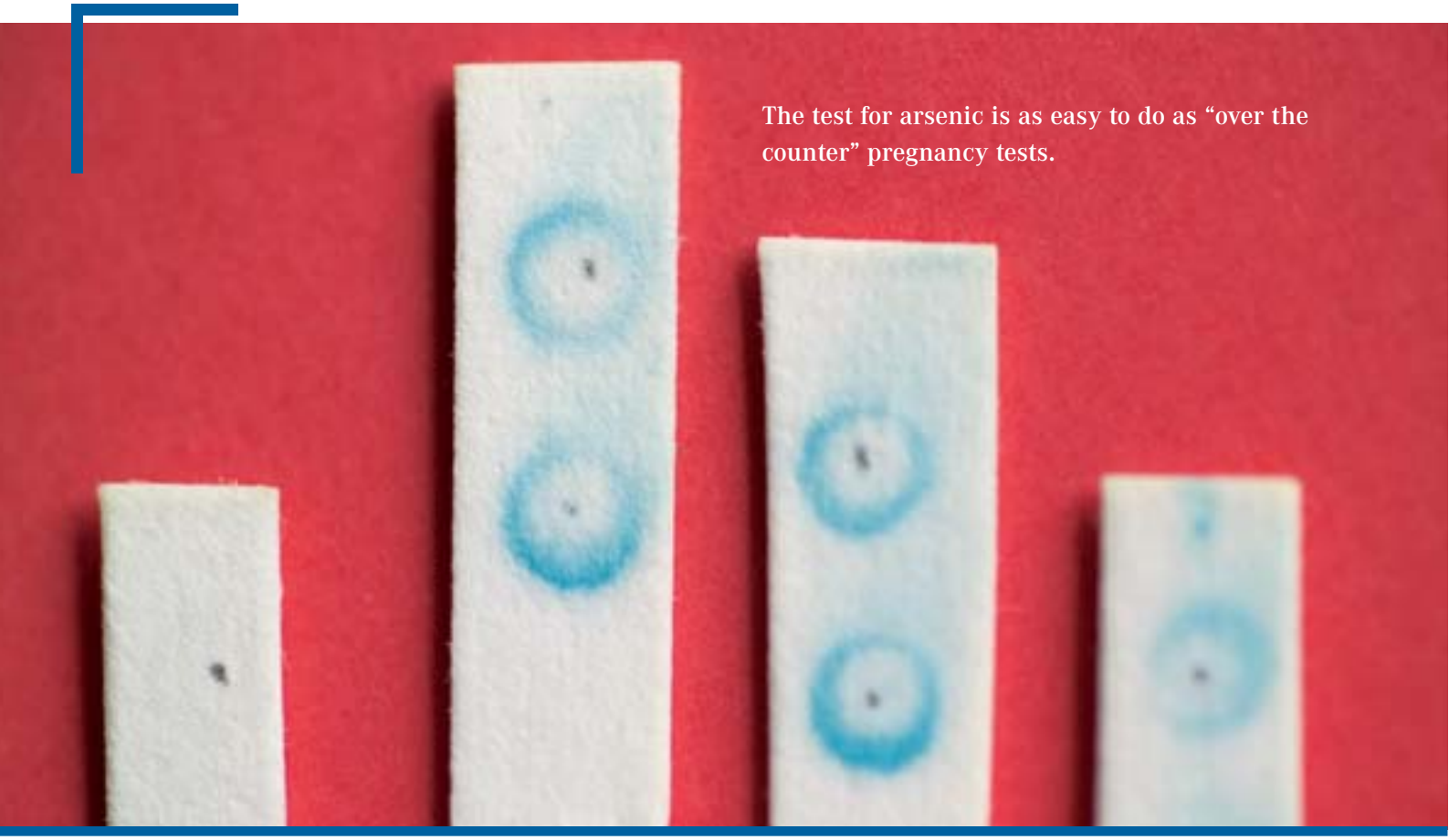
Cutting-edge research into arsenic

In the 1970s international aid organisations supported the drilling of groundwater wells in places such as Bangladesh to combat diarrhoea and similar dangerous illnesses. Around five million hand pumps were installed so that families in this Asian country had clean drinking water available directly in their houses or in the yard, and another five to six million such pumps were provided for agriculture. The project was successful; the infant mortality rate dropped sharply after the pumps were installed.

The devil and Beelzebub

However, the evident usefulness was accompanied by a negative development. In the middle of the Nineties someone noticed in the same region an increase in excessive skin pigmentation, problems with liver and kidney function, and various types of cancers. All this pointed to arsenic poisoning. Indeed, analyses showed that over a million of these drinking water wells that had been such a boon – 30 million people make use of them - were contaminated with this element. The limit value set by the World Health Organisation (WHO) was exceeded by up to a hundred times. Similar problems to those in Bangladesh also cropped up in Vietnam. Nevertheless, it is not necessary to travel so far to find groundwater that contains arsenic. Contamination due to mining for metal ores occurs in southern Saxony as well.

From a global point of view, arsenic is the pollutant that causes the most problems with drinking water today. Options available to provide analysis facilities to test



The test for arsenic is as easy to do as “over the counter” pregnancy tests.

Photos Vietnam: Hauke Harms, UFZ

A well for drinking water in a suburb of Hanoi (top left). From a global point of view, arsenic is the pollutant that causes the most problems with drinking water today. So, too, in Vietnam.

millions of sources of water are simply not available, especially in the poorer countries. However, inhabitants of a village would only be able to find out which neighbouring well they ought to switch to from time to time or whether the water needs to be filtered by making use of this type of test. For that reason a search is currently underway as a matter of urgency for simple, cost-effective and yet reliable alternatives to elaborately equipped professional laboratories.

Bacteria as tasters for the poison cocktail

Environmental microbiologists at the Helmholtz Centre for Environmental Research [UFZ] are also involved in this search. Their starting point is the fact that plants, animals and bacteria have already been battling for millions of years against arsenic, a cell poison. Bacteria have developed microscopically small pumps that eject poisons which have forced their way into the cells before they can take effect. However, these bacteria are too small to keep the appropriate pumps for the relevant poisons in constant readiness for the worst possible situation. They only react by means of genetic switching mechanisms once they make actual contact with the poison. These switches play the central role in the development of an analysis method to detect arsenic, and it is highly complex in biological terms, but it promises to be very simple to use.

The basic principle of the test was developed in Switzerland. It is based on the possibility of modifying bacteria genetically in such a way that they show colour reactions or reflect light when they come into contact with arsenic. Microbiologists from various research institutes are now working parallel on easy-to-use tests. The UFZ is placing its hopes on the advantages of a strip that resembles a normal "over the counter" pregnancy test and could be used by anybody without any problems, whether they are in a tropical village or at a campsite in Vogtland. This is done by applying the bacteria to the paper in dried form. Their blue colouration after they come into contact with water containing arsenic can be interpreted with the naked eye.

The development of this patented test took place at the UFZ together with the University of Leipzig. Field tests, information events and user training in the regions concerned were carried out at the same time as developing a marketable product.

How duty-conscious are the bacteria?

Even if the prototype of the test strip already functions properly, there are still a number of questions that have not been answered: how can you keep the bacteria on the strip inactive until they are used, but still alive, and how do you wake them up at just the right moment from their dry sleep? Or how comparable and clearly indicative are the colourings if not all the microbes on the strip do their "duty"? And, last but not least, there is much debate over whether the use of genetically modified bacteria is acceptable. ■

PROF. HAUKE HARMS IS A MICROBIOLOGIST AND HEAD OF DEPARTMENT FOR ENVIRONMENTAL MICROBIOLOGY.

Thomas Neu and Marlis Heinz

Hidden depths on sur

Photo: Margarete Mages, UFZ

A green film on rocks in rivers or lakes is nothing other than a biofilm.

We all know biofilms, and mostly we have a fight against them; for example when cleaning our teeth or when fungi show up in the corners of the shower, when a green layer forms on the water in the flower vase or when falling off from a slippery rock into a stream or river. These microbial communities can cause problems in technical and industrial systems, such as heat exchangers, all kinds of piping, or on ship hulls. In the medical field, there is a threat of dangerous infections if biofilms develop on invasive devices and implants that are inserted into the human body.

Biofilms – protection and threat

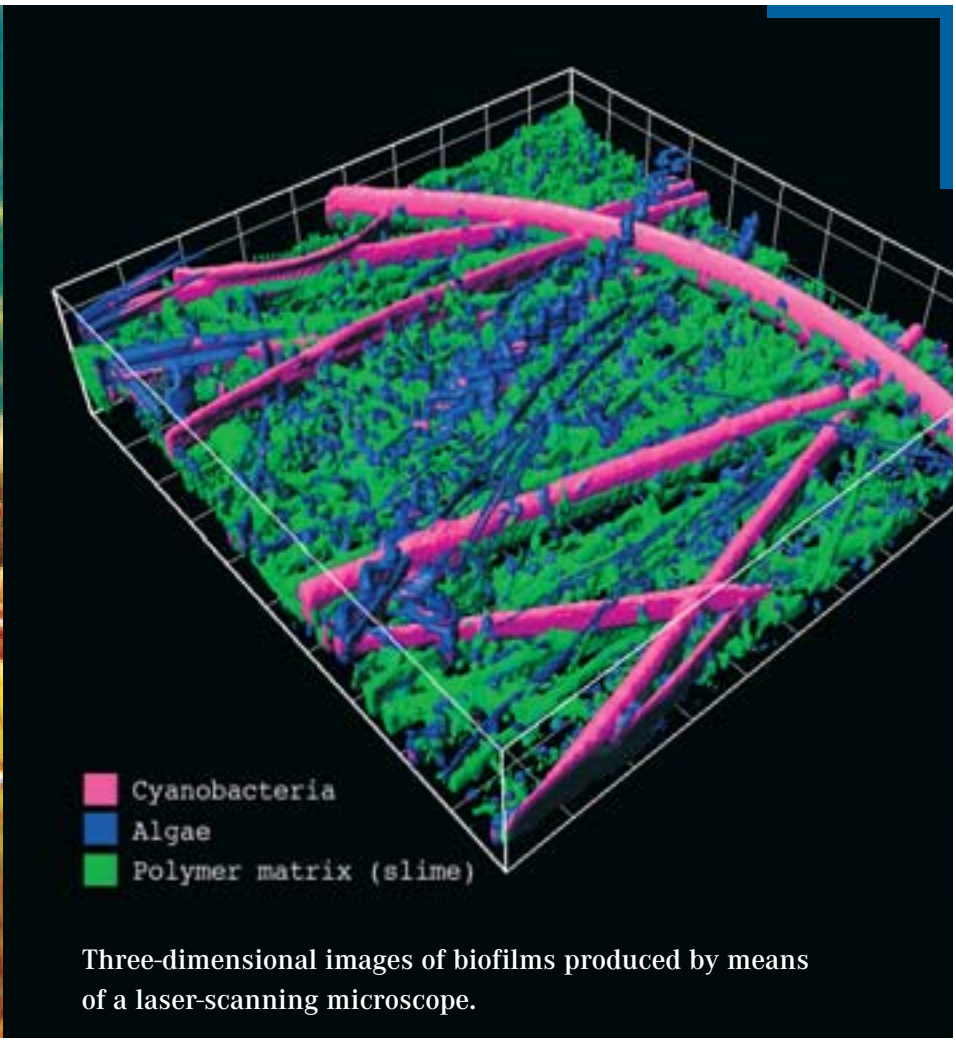
This does not necessarily mean that everything about biofilms is bad; on the contrary, in nature biofilms play an important role in cycling of elements. Bacteria are used to extract metal in so-called ore leaching by making it possible to cost-effectively use ores with a lower metal content. A variety of microorganisms live on the human skin to defend it against colonisation by harmful bacteria. Biofilm processes are also used in specific ways to produce, for example, vinegar. Biofilm systems are most intensively employed to clean exhaust air and in wastewater treatment.

In order to make use of microbes, they first need a large area to grow on. These may be sand grains, basalt particles, pumice or all kind of plastic materials some of which resemble hair curlers. These surfaces, having a large area, are usually packed into bioreactors through which the water or the air to be cleaned flows. The microorganisms are thereby supplied with plenty of nutrients – or they can feed upon the pollutants.

This means, on the one hand, we can take advantage of biofilms or even use what is called “biofilm engineering” resulting in tailor-made applications. On the other hand, we wish to control them in places where they would be a nuisance or even dangerous. For that reason biofilms are being very intensively investigated in the environment, in technical systems and in medicine. Biofilm systems are the focus of a research group at the UFZ Department of River Ecology in Magdeburg.

However, how can you look inside biofilms? In the laboratory biofilms are grown in microcosms – so-called biofilm reactors – in various dimensions. There the bacteria grow in form of white or yellowish films on 15 cm long plastic surfaces which may be attached to rotating cylinders. Small pieces of these surfaces can be directly stained and investigated 3-dimensionally under a laser-scanning microscope. Researchers mostly produce their biofilms from river water or from activated sludge of a sewage treatment plant. As light has a crucial influence

faces



Three-dimensional images of biofilms produced by means of a laser-scanning microscope.

Source of three-dimensional images: Thomas Neu, UFZ

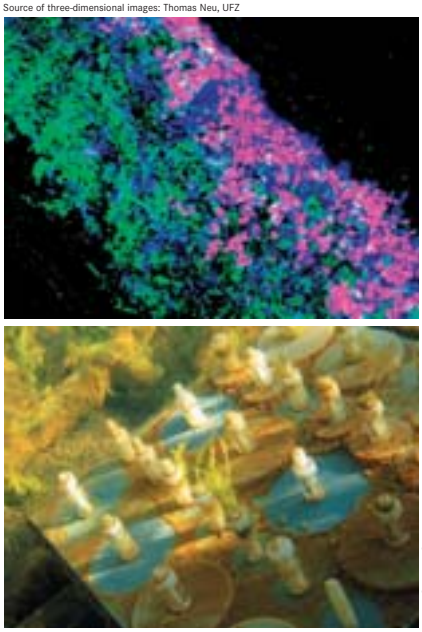


Photo: Margarete Magers, UFZ

Substratum for biofilm growths that were exposed in a river.

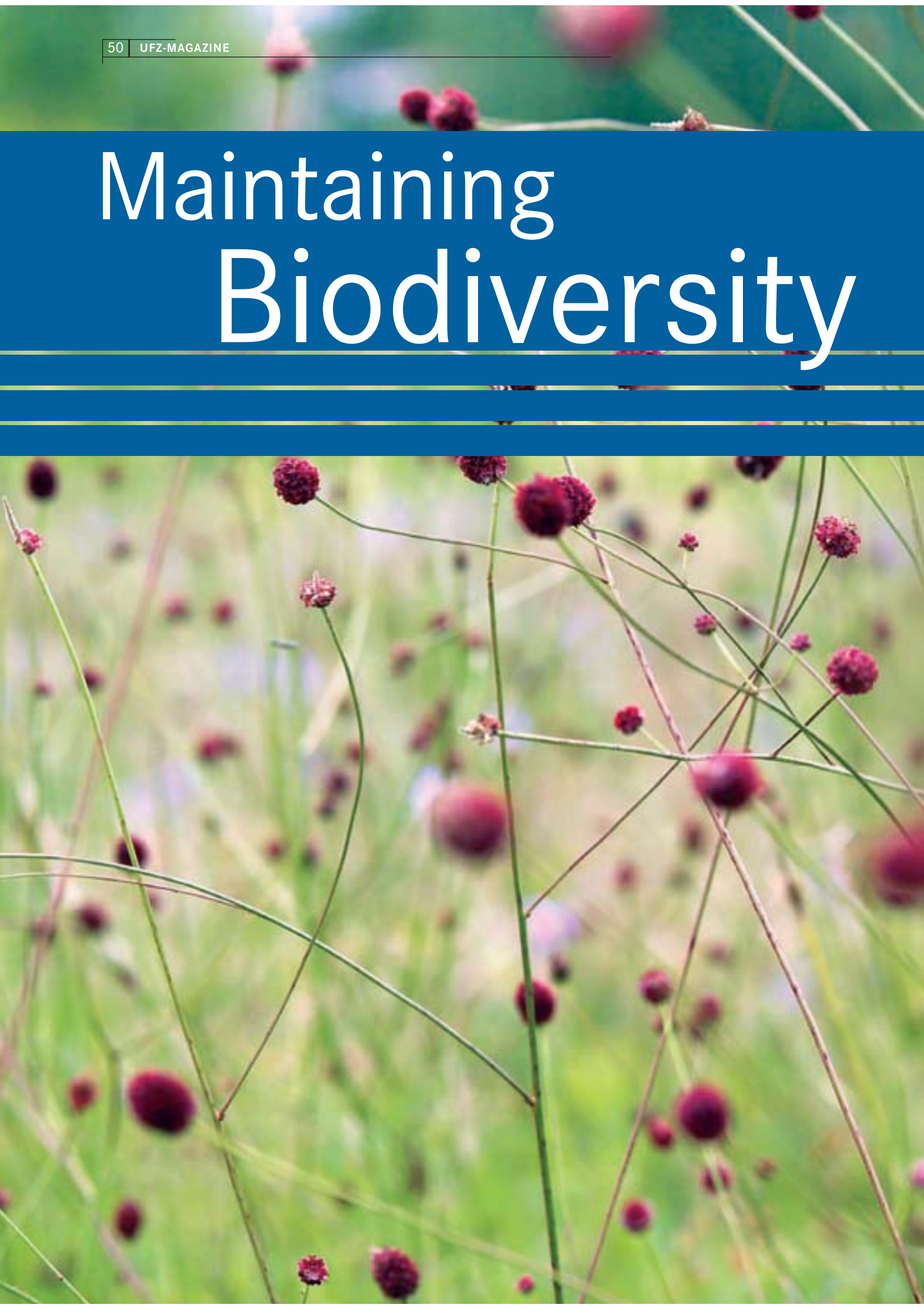
on microorganisms in the environment as well as in rivers and lakes, they also use special flow channels in which green phototrophic biofilms grow which are exposed to light. Scientists also collect their biofilms directly from the environment, they collect rocks or they grow biofilms on exposed surfaces in rivers or in groundwater. In general, the research is not done with pure cultures, but with complex natural biofilms of mixed microbial communities.

Markers reveal structures and processes

Up to this point, a great deal can be observed with the naked eye. However, microbial ecologists wish to know what are the cellular and polymeric biofilm constituents. What microorganisms can be found there? What are the relationships between different bacterial strains and over what period of time? How stable are they? Which pollutants are absorbed and, in particular, which ones are degraded? Researchers therefore require a closer view into the depths of the film in order to characterise the microbial community. Their most important instrument for this purpose is the laser-scanning microscope. The microscopic examination is done by using various fluorescent probes that are specific to biofilm constituents (cells, polymers, microhabitats). If they are exposed to light they emit a signal at a specific wavelength. When the biofilm is put under the microscope, even a thin film that is only 50 micrometres thick shows up as a mountain of microorganisms that are embedded in a slimy matrix. The sample is now optically cut into slices with the laser-scanning microscope. Later, this series of images is put together in the computer to make up a three-dimensional projection. These projections can be rotated on the screen like a cube in space and thereby reveal all the filigree features that are interlocked and interwoven with one another. Using the data obtained in this way, researchers are now beginning to model systems so as to be able to make statements on how a particular biofilm would behave under certain circumstances. ■

DR. THOMAS NEU IS A MICROBIOLOGIST AND IN CHARGE OF THE STUDY GROUP "MICROBIOLOGY OF INTERFACES" IN THE DEPARTMENT OF RIVER ECOLOGY.

Maintaining Biodiversity



Life means diversity P. 52
The great trek P. 56
Focus on biodiversity P. 58

Biologists and sociologists at the UFZ are studying the biological and human processes which regulate biodiversity and the stability of ecosystems. They are developing models which help assess biodiversity and computer-assisted prognostic tools which predict the dynamics of diverse biological systems. Researchers at the UFZ are working on integrated solutions for land use conflicts or investigating the dispersal processes of migrating plant and animal species as well as determining their ecological impact. Their goal is to provide political and economic decision-makers with a methodical system based on modules concerning issues such as land use, regional planning and maintaining biodiversity.

SPEAKER FOR THE RESEARCH PROJECT "BIODIVERSITY, ECOSYSTEM FUNCTION AND ECOSYSTEM STABILITY": DR. KLAUS HENLE, HEAD OF DEPARTMENT FOR CONSERVATION BIOLOGY

Klaus Henle and Susanne Hufe

Life means diversity

Life on Earth means diversity – diversity of species, ecosystems and genetic resources. Evolved over millions of years, biodiversity created and underpins the food supply. Biodiversity is the foundation for evolutionary adjustments to an ever-changing environment and enables a flexible response to environmental threats. It is an extremely clever but vulnerable system of creation and death. Since humans have walked the face of the Earth, hunting, gathering food and felling trees, they have interfered with the natural systems that sustain biodiversity. For many centuries, nature was able to cushion the impact of humans, as nature usually copes well with changes and threats. Now, however, natural systems are increasingly unable to resist the effects of human intervention because of disproportionate population growth and the resulting land use, exploitation of resources and overwhelming pollution of the environment. Within the last 50 years biodiversity has declined like never before.

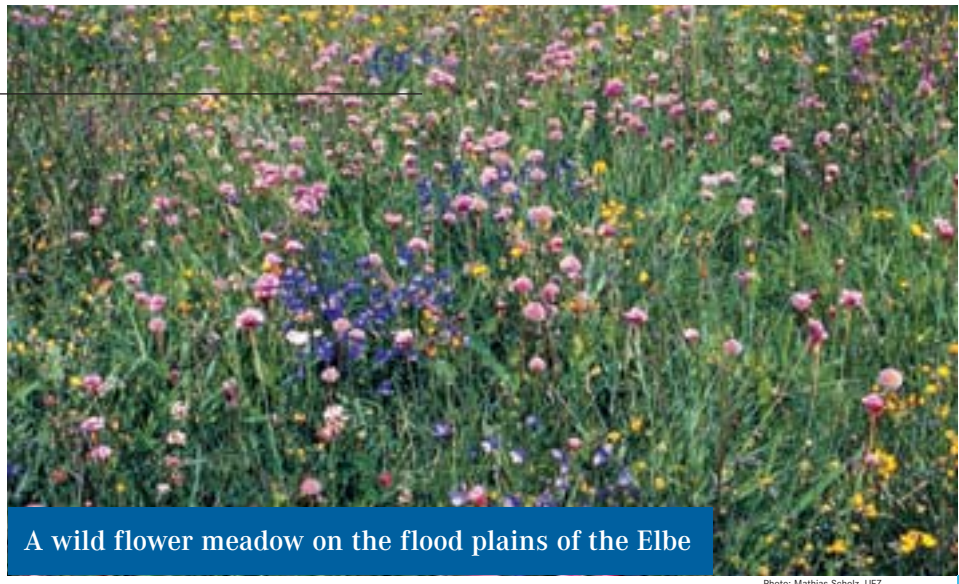
Photo: Klaus Henle, UFZ

Rainforests are the most biologically diverse ecosystems on Earth. More than half of them are irretrievably lost.

Symptoms of the loss

Scientists believe that the current rate of attrition of species is a thousand times higher than the natural rate. Globally, 10-30 percent of all species of mammals, birds and amphibians are affected. This decline of biodiversity automatically reduces the gene pool which is of critical importance for the evolution and health of ecosystems. As a result of the loss of individual species and their genetic resources entire ecosystems are endangered. Arguably the most striking example is tropical rainforests. It is estimated that 50 percent of these extremely bio diverse ecosystems have been lost as a result of deforestation either by slash and burn or timber logging or clearing the forest to create grazing land with far reaching consequences for climate change. The oceans, too, have been massively damaged as a result of warming, pollution and overfishing. And the arid regions are also in a sad state –almost 70 percent of arid regions have sustained losses in food productivity. People in developing countries bear the brunt of these changes, facing increasing famine, disease, poverty and political instability.

Foto: Photodisc Environmental Concerns



A wild flower meadow on the flood plains of the Elbe

Photo: Mathias Scholz, UFZ

No survival without diversity

In the 21st Century, the century of genetic engineering and data highways, life on Earth is hanging by a thread; dependent on functioning ecosystems and biodiversity. More than 70 percent of the world's population still uses natural medicines; more than half of the world population earns its living with agriculture; and more than 3.5 billion people are dependent on the oceans as their prime food source with the marine fishing industry annually producing food products worth 80 billion dollars. Biodiversity is the foundation of almost all bio-technological processes, including the production of food, cosmetics, and medication. In addition, with the recycling of waste, intact ecosystems provide a "free service" without which we would be inundated by our own waste. Biodiversity also ensures attractive landscapes with numerous animal and plant species giving people pleasant places to work and play. The loss of biodiversity, therefore, is not just an environmental problem but has far reaching social, cultural, legal and economic consequences.

A changing tide?

There have recently been positive efforts to protect biodiversity, including a whole range of significant international agreements. Arguably the most important agreement for biodiversity is the "Convention on Biological Diversity" which was signed in 1992 in Rio de Janeiro. More than 180

The mink (*Mustela vison*) is a North American carnivorous animal of the Mustelidae family, a close relative of the marten. In 1930, thousands of animals were imported by Argentinean fur farms because of their highly prized fur. Some escaped into the wild where their successors have procreated prolifically in the southern-most part of the inhabitable world, the Chilean island of Navarino, where they create serious problems.

signatories made a commitment to retain biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits from the use of genetic resources. The Rio Convention is being further defined and implemented by a number of global, national and regional agreements which include the Washington Convention on International Trade in Endangered Species of Wild Fauna and Flora as well as the Convention on the Conservation of Migratory Species. These and other initiatives, including private activities, are the reason why the number of conservation areas has grown in recent years and why some endangered species have made a comeback under strict protection and successful management programmes. Activities such as the Biological Diversity Day (on 22 May) contribute to this success as they raise public awareness of the importance of biodiversity. Public and private funding policies are changing. There is a discernable trend that financial assistance for land use explicitly supports the inclusion of environmental aims. Research into conservation biology is receiving a significant proportion of the overall science budget. For instance, the European Union's 6th Environment Action Programme allocated approximately 90 million euros for biodiversity.
However, despite all these positive steps the tide has not yet turned. The economies of too many countries are still unsustainable, and too many countries do not respect international agreements. Our knowledge about ecological change is still incomplete. We are still confronted with the urgent challenge to take effective steps to protect the biological foundations of our life. Science will play a crucial role in this, as it provides the basis for a proper understanding of our present reality.

Photo: Klaus Henle, UFZ

Vegetation change caused by over-grazing in the Australian outback.

Research into biological diversity

There are many scientific institutes and universities around the world researching into biological diversity. Several centres of the Helmholtz Association, including that of the UFZ, are integral parts in this international network represented by their "Biodiversity, Ecosystem Function and Ecosystem Stability" programme. On the one hand, scientists are analysing the role of critical factors on the loss of biodiversity. This includes research areas such as the destruction and isolation of habitats, the invasion of foreign species and changing disturbance patterns in habitats. On the other, they also throw light on the beneficial effects of biodiversity for humans, such as the microbial breakdown of pollutants, or the effects of biological diverse ecosystems on the pollination of food plants. Their research provided the rationale for changes in legislation, for example, the amendment of the Federal Nature Conservation Act. They aim to support political and administrative decision-makers by pointing out options and providing them with strategies for better conflict resolution. One of their projects attempts to reduce the conflict between over-fishing and the protection of maritime species. Other projects develop the best grazing strategies for arid regions and strategies for the management of alien plant species. Most scientists agree that science and social research must be reconciled in order to formulate successful theories and models and to develop integrated solutions - an analogy to the situation of individuals who make decisions about land use within the complex framework of their ecological, economic and cultural environment. ■

An ant (*Myrmica rubra*) "milking" an aphid – food symbiosis at work.

USEFUL INFORMATION

Since 2004, the UFZ has been coordinating the most extensive research project on biodiversity in Europe. Its centrepiece is the **ALARM** project which investigates potential risks for biodiversity, especially climate change, loss of pollinators, pollutants in the environment, and biological invasions. 67 partner institutions in 35 countries are taking part in analysing and assessing both the geographical and chronological dimensions of these issues.

THE BIOLOGIST, DR. KLAUS HENLE, IS HEAD OF DEPARTMENT FOR CONSERVATION BIOLOGY.

Ingolf Kühn and Susanne Hufe

The great

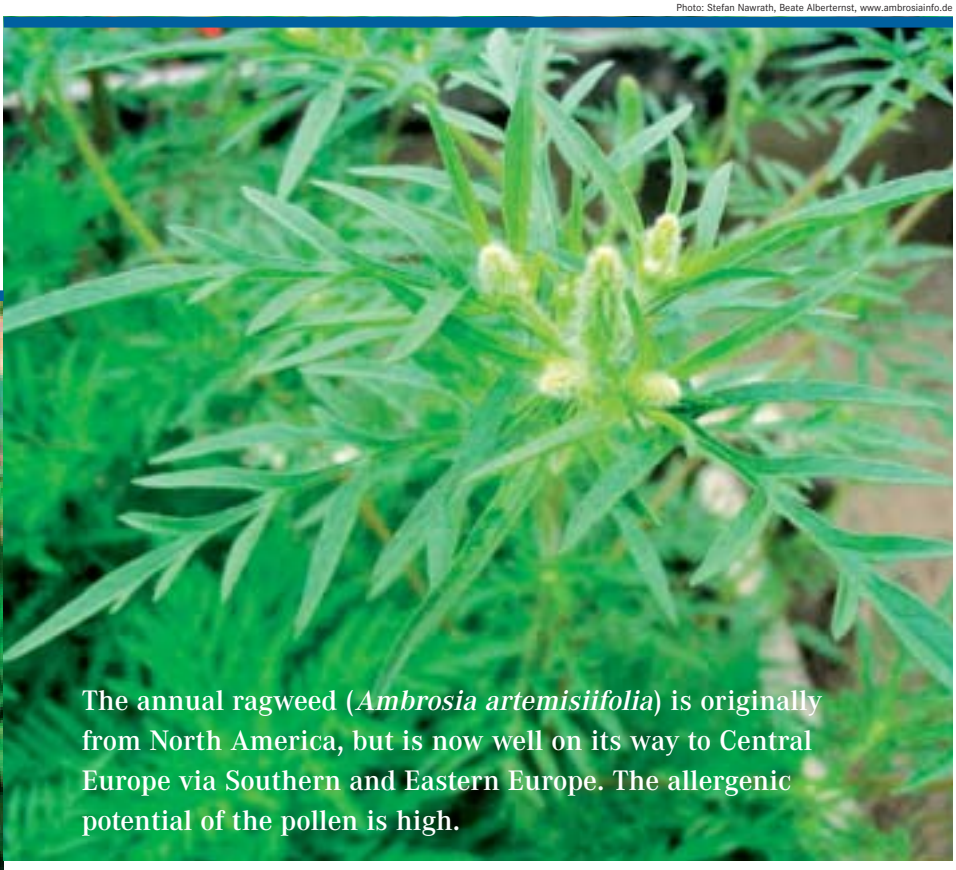
Photo: Norma Neuheiser, UFZ

The Oregon-grape (*Mahonia aquifolium*) originates from North America. It was introduced to Central Europe as an ornamental plant and is now rapidly spreading in the field.

The best life assurance for all animals and plants living on this Earth is to propagate as successfully as possible and to colonise new habitats. Nature has refined mechanisms to let seeds float over long distances or to carry larvae to distant destinations. Natural barriers, such as oceans, mountains, deserts or climate zones have restricted their travels for millions of years. However, since aeroplanes and ships transport hundreds of thousands of people and tonnage of goods from continent to continent on a daily basis, the natural barriers have ceased to be insurmountable. Now many organisms undertake long journeys, hitching rides in gaps, boxes, ballast water and on the hulls of ships. Others are transported intentionally as ornamental or food plants or as pets and livestock. But what are the consequences of all this? Whether they are introduced intentionally or unintentionally into their new habitats, many of the exotic species create problems. They alter ecosystems which have evolved over thousands of years; they replace or displace native species, and they create enormous damage in the agricultural and forest industries as well as in fisheries and transportation which can amount to millions of dollars.

trek

Photo: Stefan Nawrath, Beate Alberternst, www.ambrosiainfo.de



The annual ragweed (*Ambrosia artemisiifolia*) is originally from North America, but is now well on its way to Central Europe via Southern and Eastern Europe. The allergenic potential of the pollen is high.

Researching into biology alone is not enough...

Apart from researching into invasion biology it is just as important to assess the damage caused by invading species and to determine what legal means there are to counteract the intruders. For that reason, an inter-disciplinary team has been formed at the UFZ which, in cooperation with external scientists, aims at creating an integrated pre-emptive programme against plant invasion. The researchers focus exclusively on invasive plants which have been able to spread in Germany. Biologists reconstructed if these almost 700 species were intentionally or unintentionally introduced: whether they escaped cultivation or whether they were released into the countryside in order to better assess problem cases, UFZ scientists are pursuing two strategies. First, they analyse the more or less invariant biological features which characterise problematic species. These include the duration of flowering season, the ability to reproduce generatively and the longevity of plants. Second, scientists determine to what extent plants are able to genetically adapt to their new habitat, because this is also an important factor for their reproductive success. One of the plants analysed is the Mahonia, an ornamental plant introduced from North America. Do cultivated varieties of Mahonia differ in invasion success? Is there any evidence that Mahonia has made evolutionary adaptations to different habitats in Central Europe?

A study of 60 tree and shrub species in Germany shows that alien plants have an adverse effect on plant-feeding insects. Whether or not the insects have made any evolutionary adaptations to their new host plants is currently under investigation.

...Economics and law are part of the equation

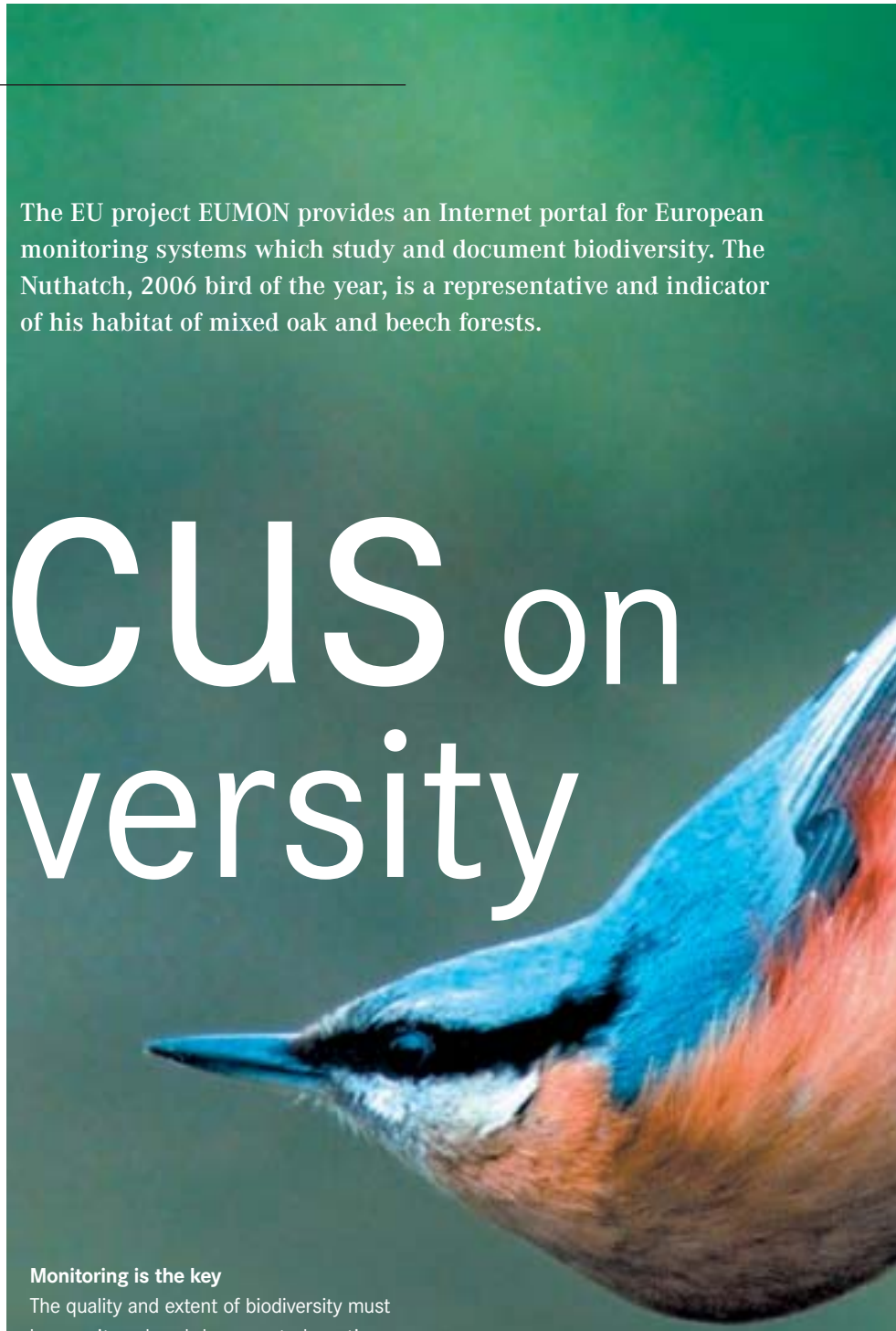
How can the consequences of biological invasion for ecosystems be assessed? For economists it is insufficient to simply quantify the damage. They therefore pay more and more attention to include prevention and control mechanisms as well as the indirect benefits to humans from diverse and intact ecosystems. Annual ragweed is a good case study as it is an extremely allergenic plant which is currently spreading in Central European habitats. What financial implications does the spread of the ragweed have for the health sector? And more generally: what are the ecological, economic and institutional circumstances which make control efforts feasible? Finally, the legal experts in the UFZ team are analysing the legal provisions of international, European, German as well as federal state law to determine whether existing laws can be invoked in the struggle against invasive pests. For instance, what conditions must prevail before the known import of foreign species may legally be stopped? What bio-security measures are permissible under what conditions? In the light of biological and economic studies, we can identify legal gaps and suggest the amendment of laws as well as changes to administrative practices.

DR. INGOLF KÜHN IS A BIOLOGIST AND SCIENTIFIC STAFF MEMBER IN THE DEPARTMENT OF COMMUNITY ECOLOGY

The EU project EUMON provides an Internet portal for European monitoring systems which study and document biodiversity. The Nuthatch, 2006 bird of the year, is a representative and indicator of his habitat of mixed oak and beech forests.

Bernd Gruber, Frank Dziock and Susanne Hufe

Focus on Biodiversity



In many respects Europe is an international role model with regards to attempts to stem the loss of biodiversity. In 2001 at the Göteborg Summit, the European Union member states agreed on the ambitious aim of stopping the loss of biodiversity by 2010. Following up on the United Nations Meeting in Rio de Janeiro in 1992, which has come to be known as the "Conference on Biodiversity", the European Union has created a number of additional activities. With the Habitat Directive and the legally binding obligation to implement them as part of the NATURA2000 network, each member state has a concrete agenda on how to extend conservation areas for diverse ecosystems and species. This includes the obligation to regularly report on the progress of improved biodiversity. However, how can the success of national conservation plans be measured, and can the European Union reach its goal by 2010?

Monitoring is the key

The quality and extent of biodiversity must be monitored and documented continuously over a long period. Monitoring systems are common, and there are approximately 100 000 European animal and 14 000 plant species to be monitored on a regular basis. As there are such a huge number of monitoring systems, no one really knows how many there are and which species are being monitored. However, a problem exists with compatibility, quality and consistency of data in the exchange of information across national borders. Data differs significantly because different methods and systems are used. In order to successfully reach the 2010 target, this patchwork must be evaluated for the feasibility of turning it into a unified network, which provides reliable information about the situation of Europe animal and plant life.

Best of...

Supported by the European Union, a UFZ-lead team of approximately 50 scientists from 11 European countries has been involved in registering and evaluating existing national and regional monitoring systems for specific species and habitats since 2004. They are focussing on 788 animal and plant species as well as 218 types of habitats as defined by the Habitat Directive, which will be representative for all other species and habitats. Important criteria for evaluating monitoring systems include the accuracy with which changes in propagation and population can be measured, the manpower which is needed to

Photo: NABU/M. Delpho

Photo: Steffen Caspari, Saarlouis

operate the monitoring systems, their cost efficiency and their transferability with regards to other species and regions. In addition, a sociological study is being carried out which aims to compare the integration of volunteers in four European nations. Not only is the data of the 500 Kachelmann meteorological stations recorded by volunteers; most species monitoring systems also depend on the regular input of volunteers who e.g. count butterflies, watch birds or appraise plant samples. The efficiency of the volunteer networks differs – apparently in relation to the geographical locations. In some regions it is difficult or even impossible to establish effective networks. Studies try to ascertain what qualities make a monitoring system successful or prevent it from being successful.

In the spring of 2005, the monitoring of butterflies started in Germany. Coordinated by UFZ, more than 500 volunteers collect data about butterflies on weekly transects on fixed circuits. The collected data documents the development of butterflies on a local, regional and national level. It can be used for comparison with data from other European countries (www.tagfalter-monitoring.de)

What shall we do with the data?

The results of the comparative study will not only be used by many people interested in monitoring activities, but they can also refine and complete the results themselves. In addition to conducting workshops, our scientists are in the process of setting up an interactive database which collects and makes accessible all relevant information about the monitoring systems (http://eumon.ckff.si) Users can contribute data and critiques based on their own experience and obtain answers to their questions. It is expected that once the project is over in 2008 the database will include all important monitoring systems in Europe. It will then also be possible to assess which methods and practices are best to establish new systems and, based on prudent allocation of resources, which species and habitats justify permanent monitoring. ■

USEFUL INFORMATION

The **Habitat Directive** [HD] is a European directive for the protection of natural habitats and wild animals and plants. In order to implement the Directive, a European-wide network of conservation areas (NATURA 2000) is being created with the aim of protecting habitats and species in the individual member states most seriously under threat. In addition, the Directive requires specific legal and practical protection for particular species of plants and animals. In Germany the Directive is named [Flora-, Fauna-, Habitat-Richtlinie (FFH)] and its legal protection is enshrined in the Federal Nature Conservation Act [Bundesnaturschutzgesetz]. To ensure the success of the conservation measures, member states have to monitor the quality of the protection areas and the conditions of the respective animal and plant species.

DR. BERND GRUBER IS A BIOLOGIST AND SCIENTIFIC STAFF MEMBER IN THE DEPARTMENT OF CONSERVATION BIOLOGY.
DR. FRANK DZIOCK (FORMERLY UFZ) IS DIRECTOR OF THE PROGRAMME FOR BIODIVERSITY DYNAMICS AT THE TECHNICAL UNIVERSITY IN BERLIN.

Managing water in river

Hydrologists, biologists, chemists and modellers at the UFZ are developing innovative analytical methods to be able to better characterise the ecological state of streams and rivers. They are studying key processes and reaction patterns that are initiated by chemical reactions or other so-called stressors. They are analysing together with economists and legal experts the dynamics of land use as the most important control variable for the balance of water and substances within river basins, and support business and politics alike in implementing the Water Framework Directive of the EU.

SPEAKER ON THE RESEARCH TOPIC "INTEGRATED MANAGEMENT OF WATER RESOURCES IN RIVER AREAS":
DR. MICHAEL RODE, HEAD OF THE HYDROLOGICAL MODELLING DEPARTMENT

resources areas

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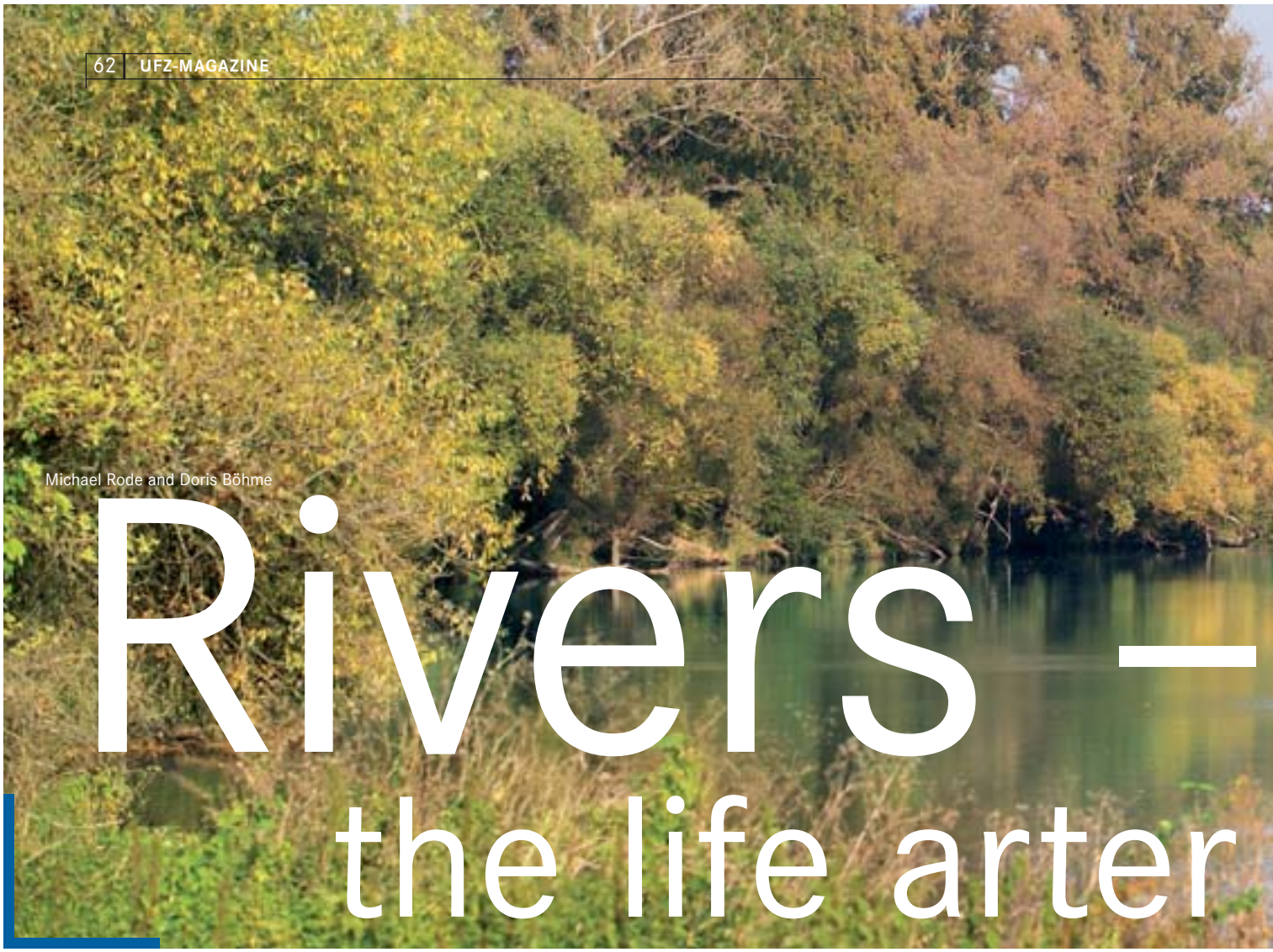
Chemicals – What can our rivers stand? P. 68



Michael Rode and Doris Böhme

Rivers – the life arter

A person can do without a portion of the lung or the stomach, if need be. A kidney too. If the liver ceases to break down harmful substances, then things are very bad for the patient. A blocked artery can have catastrophic results. There are limits, at the end of which the circulation fails – in people just as much as in cycles of nature. We often like to call rivers the arteries of life or the ecological backbone, they breathe life into the landscape around them – but they can also take it from them. Rivers and their catchments offer a place to live for a large part of the diversity of animal and plant life worldwide. They are a resource for drinking water, a source of energy, they constitute transport routes, and they provide food. They are places for leisure and relaxation, for hunting and fishing. They are also drainage channels to take away wastewater and sewage, a means of disposal. Pollution and nutrient export from agriculture, water extraction, weirs and dams, built-up channels, dykes and levees are putting pressure on these arteries of life. Land use and pollutants disturb the functionality of the adjacent water meadows and flood plains. The results are shown by an increasing risk of floods, by a loss of biological diversity, by higher costs for the extraction of drinking water. For example, around 80% of natural flooding areas have been lost on the Elbe as a result of the construction of dykes; on a global scale, around 20% of all species of freshwater fish are regarded as being at risk or have already died out.

The river Mulde at Jessnitz. Intact flood plains are not just aesthetically pleasing, they are also important for protection against flooding, for biological diversity, and for leisure purposes.

ies of the landscape

The European Union has given a clear signal by promulgating the Water Framework Directive in the year 2000. The policies regarding water must be more strongly focussed towards a sustainable and environmentally tolerable use of water. This has been done by setting quality goals and proposing methods as to how these goals are to be reached and so to maintain a good quality of water. If we add to that the Habitat Directive (HD) (see page 59), then Germany has a great many tasks to tackle in the future management of surface waters and their catchments. Thus the Water Framework Directive stipulates that not only the chemical but also the biological properties and the structure and morphology of water bodies need to be considered, and that by the year 2010 the supply of water must be done in such a way that its costs are covered. Wastewater and sewage is no longer to be cleaned "according to the state of the art" but instead "by the best available technologies." The goal of the Habitat Directive is to secure and protect wildlife, the areas that it lives in, and to set up a European networking of these areas.

Utilisation and protection – a balancing act

Rivers and their catchments are to be managed in such a way that economic growth is possible and, at the same time, aquatic forms of life are protected, agricultural runoff and pollutants are reduced, and less water is consumed – all of this represents a task that can only be handled by long-term collaboration between a number of different technical disciplines. How does the complex hydrological water cycle function? How are substances transported? Which pollutants are degraded, which ones are not? What effect do they have on creatures near and within the water? How do environmental stressors affect the water bodies? How do changes in the use of land affect the availability and quality of water? Perhaps we are lacking the knowledge to be able to correctly understand all these connections and interactions. The complexity and sheer size of the functions and rivers and their flood plains thus sets as a

The Elbe in flood in August 2002.

precondition that soil researchers, eco-toxicologists, economists, sociologists and legal experts have to be brought into the research in addition to the traditional water researchers of the UFZ.

More knowledge and many new questions

To take an example: UFZ scientists have only recently been able to prove that certain pharmaceuticals have a previously unknown and comparatively strong eco-toxicological effect on aquatic organisms. This is a finding that raises a large number of new questions: does this mean that the limit values were exceeded? Are there limit values at all for such substances? Or do they already have a toxic effect even in very small traces? Do they become more concentrated or are they decomposed, probably by oxygen and UV radiation? Are there interactions with other pollutants? How do pharmaceuticals get into the water at all? Is the wastewater and sewage not cleaned in a water treatment plant? Very well, so these substances are easily soluble in water and thus leave the water treatment plant unchanged? And if the functions of the eco-system have already been disturbed, is the effect then all the more devastating?

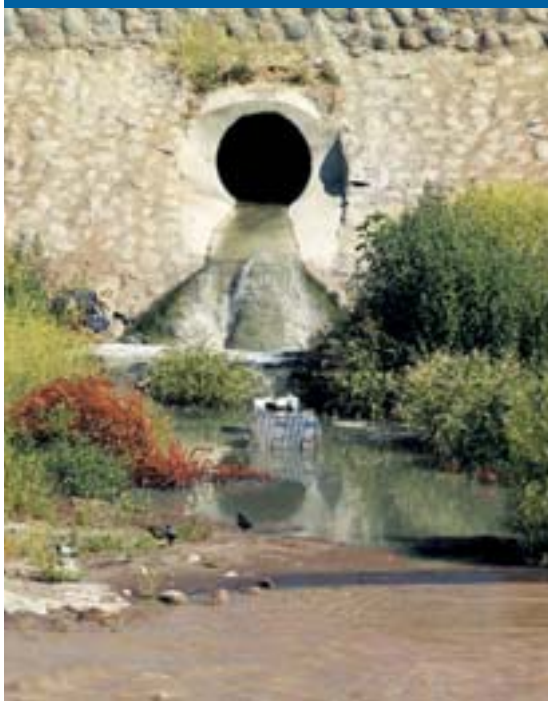
USEFUL INFORMATION

Analysing and evaluating chemical pollutants in water bodies; this is the aim of the Europe-wide MODELKEY full-scale project that was started in 2005. Under the leadership of the UFZ, scientists in 13 countries are to develop methods by the year 2010 with which so-called key chemicals can be identified and their effect on water systems determined. Why? So as to restrict contamination and to protect water resources in the long term on the basis of common standards for the protection of groundwater and surface water.

These are questions that can only be answered by an interdisciplinary team of scientists. Here they have to rely on models. Model substances, model communities of wildlife, model water bodies, computer models and simulations. It is simply impossible to research all chemicals and organisms, rivers and streams. Each organism, each river and each stream has its own unmistakable character, its individual personality.
To taken another example: pollutants get into the rivers both from point sources – these are primarily industrial facilities and water treatment plants – and also from diffuse sources, primarily as runoff from land being used for agricultural purposes. While it is relatively easy to determine with point sources what quantities land up in the river system, this is only possible with great difficulty in the case of diffuse sources. But it is essential to quantify the interactions between agricultural land use and the polluting of the water with various substances so as to reduce the amount of pesticides and biocides that get into the rivers. In order to identify areas where

Rivers have long been transport routes. But the further expansion of rivers for shipping is and remains a controversial topic.

Wastewater from industry and agriculture pollute the life arteries of the landscape.



especially large amounts of pollution come from, UFZ scientists are developing new models that describe the transport of pollutants and nitrogen and phosphorous compounds in agrarian ecosystems and their catchments.

Who benefits from all this research?
If future decisions are to be made for or against concrete regional changes in land use in river catchments on a foundation of scientifically-based knowledge and tools, then these must also involve the user or the decision-maker. For that reason, on the one hand computer-based decision support systems and user manuals for official authorities and environmental administrators have been developed that allow the various properties of riverine landscapes, such as the diversity of species, buffer functions to cope with flooding and pollutants, or their value for leisure activities to be evaluated or predicted both qualitatively and quantitatively. On the other hand, partners involved in practical work in research projects have been brought in. Scientists from the UFZ have developed, for example, robust indicators for riparian areas and river floodplains that show what ecological changes have been brought about on these riverside areas by actions such as the taking down of dykes. The project partner and user of the results in this case was the Bundesanstalt für Gewässerkunde (Federal Institute for Hydrology).
It is responsible for practical action and planning in water-related construction work and for the protection of nature and supplies, in turn, the scientific and technical basic principles for the work of the ministries and the authorities in charge of administering the waterways and their shipping. ■

DR. MICHAEL RODE IS A HYDROLOGIST AND HEAD OF THE HYDROLOGICAL MODELLING DEPARTMENT.

Photo: Frank Dziock, UFZ

The hoverfly (Scaeva pyrastri) is a tiny but important link in the chain of a natural community on the banks of a river.

Bernd Klauer and Doris Böhme

All clear?

There was a time when many rivers had a crest of foam or stank so abominably that they had to be diverted underground. In the meantime, many of the sources of pollution have gone, the foam and the stink have disappeared, and the buried rivers are being brought back bit by bit into the light of day. In many places the water now looks clear. A reason to be pleased. A reason to sit back and relax? There is still a great deal to be done if the standards of the EU are applied. Because they require that the surface water not only looks clear but is also so clean that fish and other organisms can then live in it in the same way as in comparable rivers and lakes that are still in a natural state. They are the best indicators that the water is well and truly clean and also represents no health risk for man. But just as before, nutrients such as phosphates and nitrates from the use of fertilizers in agriculture and from water treatment plants still pollute many bodies of water. Algae grow, the oxygen content of the water drops, the conditions for the survival of fish and small creatures become worse. The water is also not entirely suitable for use as drinking water. Although the causes are known in principle, it is difficult to find a remedy. Almost all water and sewage treatment plants have already been upgraded at great expense and many

new ones have been built. Farmers now apply fertilizer with more care and more sparingly – if only for economic reasons because mineral fertilizers are costly. What can the water management authorities do to meet the stipulations of the European Water Framework Directive? UFZ scientists have been tackling this question as part of the project "Decision support for integrated river basin management", taking the example of the transboundary basin of the Weisse Elster river (White Elster).

Making choices is tough

In principle we already know what action can be taken in management. But what is not clear is what specific measures should be taken to attain a good level of water quality in the most cost-effective way. Should municipal and rural sewage treatment plants be optimised or should wastewater treatment plants be decentralised? Do "green" ecological farming methods or schemes to conserve the soil really help? What is to be done with abandoned areas or riparian buffer strips, and should less water be extracted? In order to select the right one from a wide variety of options, scientists have developed a procedure to assist in decision-making, on the basis of which the official authorities can set up programmes and management plans for all river basins.

The procedure comprises technically demanding modelling tools that are based on internet and geographic information systems that take into account the balance of water and matter and integrates socio-economic forecasting methods. With their aid it should be possible to estimate how effective the various management measures are, even if the data availability is sub-optimal, and that is the case in practice. But above all the procedures allows the decision-making process to be better structured. First of all, the most promising management measures should be pre-selected, and then their effect is estimated using modelling tools and expert knowledge. The measures are compared and evaluated. At the end the "best" option is chosen, this being the best in terms of the material effect and economy for the management plan. This structure is to serve as a guideline for decision-making processes in practice. The legal and institutional overall conditions and questions of acceptance are also to be taken into consideration when they are drawn up.

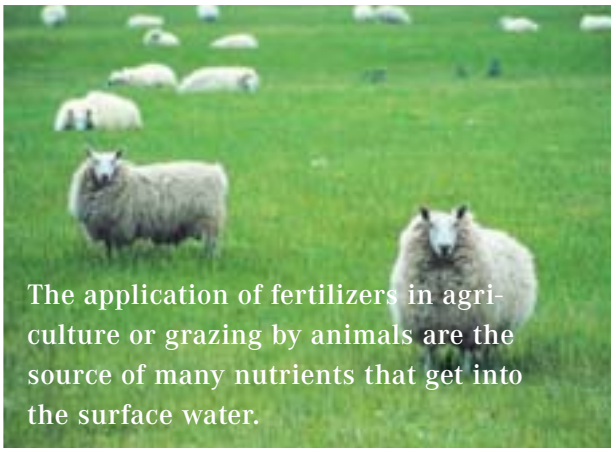
Teamwork

Given the multi-facetted nature of the task in hand, there was a need for experts from a wide variety of technical subjects; hydrologists, soil researchers and geographers of the UFZ are working on the modelling of flows of water and nutrients from the plant up to measuring level in the river. Geoinformation scientists from the university of Jena and the UFZ are providing the necessary programming skills for the model coupling. Economists of the UFZ estimate the costs and draft the architecture of the entire decision-making process. Legal experts from the UFZ and the University of Leipzig check whether the actions can be implemented from a legal point of view. One thing that is at least as important as the close cooperation between the scientists is the exchange of information with the practitioners. This procedure has been recently applied and tested in the federal state of Thuringia. If it is successful, then it can be made available in good time for the water management authorities for the management plans that are due to be implemented in 2009. ■

USEFUL INFORMATION

The **Weisse Elster (White Elster)** (pictured below) is a right-bank tributary of the Saale and is 257 kilometres long. Its source is in the Elstergebirge in the Czech Republic and it flows into the Saale at Halle. The (German) name Elster has nothing to do with the bird (in German, an Elster is a magpie). The word is of Slavonic origin and means "the one in a hurry". Important tributaries are the Weida and the Pleisse. Around 1.5 million people live in the 5,154 sq. km catchment area of the Weisser Elster. Larger towns located on the river are Plauen, Gera and Leipzig.

Photo: Photodisc Environmental Concerns



The application of fertilizers in agriculture or grazing by animals are the source of many nutrients that get into the surface water.

DR. BERND KLAUER, MATHEMATICIAN AND ECONOMIST, IS A SCIENTIFIC WORKER IN THE ECONOMICS DEPARTMENT.

Matthias Liess and Doris Böhme

Chemicals – what can our rivers stand?

Chemicals are a part of life just like the air we breathe. They are in cars, radios, computers and mobile phones, in clothing, cleaners, paints, medicaments and cosmetics, they increase agricultural output and enable food to stay fresh longer. Thousands of different chemicals are transported, processed and distributed around the environment in large quantities to maintain our standard of living. Many of these chemicals are more or less poisonous. They have an enormous potential to place at risk the basis for life for man and for animals and plants on a wide scale – and not only in theory. A number of chemicals pass intentionally into the environment, others do so without us knowing about it. Thus, for example, pesticides, industrial chemicals and pharmaceuticals are an unwanted burden on eco-systems – and also for rivers. Before chemicals are approved, their potential risk must be assessed. This is what the legislation prescribes. However, the procedures currently used for risk assessment show a great deal of uncertainty, because in current laboratory test systems the effect of individual chemicals is investigated under laboratory conditions. But the reality is otherwise. For that reason scientists at the UFZ have undertaken to design the processes used for estimating the risks posed by chemicals to be more realistic and more practical – at the level of eco-systems such as rivers, lakes and coastal waters.

Before chemicals are approved, their potential risk must be assessed. Many procedures currently used for risk assessment show uncertainty.

From the individual to the landscape

At what concentrations are toxic substances hazardous for living creatures in surface waters such as streams or rivers? The scientists start their search for questions in the laboratory and in the computer. They collate knowledge on what effect biologically active pollutants have on model organisms and refine computer models so that first of all the toxicity of a wide variety of chemicals can be predicted followed by the pollutant-specific sensitivity for a wide variety of organisms living in the wild. The prediction is based, among other things, on the relationship between the structure and the effect of the chemicals (Quantitative Structure Activity Relationship).

In the next step the researchers investigate artificial eco-systems. They quantify the effect of the pollutants in laboratory test systems or in flow channels (so-called meso-cosmoses) on plankton, biofilms and invertebrates under controlled conditions that are close to actual ones. In this way scientists can tell how the various organisms react to chemical and non-chemical stresses such as flooding or changes in their habitat. From this the researchers can, in turn, derive the essential parameters for a depiction of what actually happens in the models.

The real world

The step into actuality has been made by an international team of scientists under the leadership of the UFZ. It is investigating a large number of bodies of flowing water throughout Europe and the aim of finding out whether the make-up of the habit for invertebrates has been affected by pesticides. In order to exclude other

Using an artificial flow channel (meso-cosmoses) it is possible to study the effect of chemicals on organisms in their habitat in a way that is very close to reality.

Photo: Matthias Liess, UFZ

environmental factors as the cause, the individual types of organisms have been grouped into classes on the basis of ecological properties such as their sensitivity to organic pollutants, speed of reproduction and ability to recolonise; those affected by pesticides and those not affected by pesticides. The research did in fact have results; concentrations of pesticides that had been rated as harmless in the laboratory turned out to reduce a large number of sensitive species in their habitats and led at the same time to an increase in the species that were not sensitive. However, the scientists were also able to prove that negative effects could be compensated for by unaffected sections of the river lying upstream.

The complexity of the problems determines the wide range of disciplines of the scientists involved; chemists analyse substances that are present in microscopic traces; eco-toxicologists investigate the effect of toxic chemicals, while ecologists, modellers and geoinformation scientists have developed novel models that make it possible to predict a wide range of parameters in interactions. Here the harmful effects are identified and predicted at the landscape level. Legal experts check whether the measures to be taken to reduce pollution can be implemented legally. This is done by working in close collaboration with authorities and institutions such as the Umweltbundesamt (Federal Office of the Environment) or the Bundesamt für Verbraucherschutz und Lebensmittelsicherheit (Federal Office for Consumer Protection and Food Safety) and the European Commission. After all, the goal is not only to assess the risks but also to actually reduce them. ■

USEFUL INFORMATION

Pesticides are all types of substances applied to help or protect plants, being used either to combat pests or to regulate growth. In the narrower sense the term pesticides means a substance to deal with animal pests.

DR. MATTHIAS LIESS, AN ECOLOGIST, HEADS THE SYSTEM ECOTOXICOLOGY DEPARTMENT.

Knowing Governance and the acto politics

institutions
rs in industry, and our society

Who actually decides how our environment is used? P. 72
International water conflicts P. 76
Actors and conflicts in urban redevelopment P. 78

Economists, lawyers, sociologists and political scientists at the UFZ analyse how decisions on the use of landscapes are made and how these decisions can be improved. The first step here is to identify as well as understand the actors who decide how landscapes are used. In a second step scientists examine the negotiation and decision-making process between those actors. This process is often referred to as governance. In a third step researchers develop policy advice by creating adequate political instruments such as regulations, taxes or tradable permits. In a fourth step they identify who is to be informed in order to make sure that relevant knowledge and expertise are fed into the decision-making processes.

SPEAKER ON THE RESEARCH TOPIC "GOVERNANCE, INSTITUTIONS AND POLICY FOR SUSTAINABILITY":
DR HEIDI WITTMER, SCIENTIFIC STAFF MEMBER IN THE DEPARTMENT OF ECONOMICS.

Heidi Wittmer and Doris Böhme

Who actually decides how our environment is used?

Have you ever tried to find out who is responsible for a particular decision in a certain public authority or agency? Have you ever felt that you've been sent to Timbuktu and wasted a lot of time in the process? Now suppose scientists have made new discoveries as to how to make more sustainable use of landscapes in order to preserve the biological diversity, sustain water resources, reduce the area of sealed land, ensure sustainable urban development, thereby making sure that our children and grandchildren will live in an environment as favourable as we do today. How can we get knowledge to where it is needed when decisions on the use of our environment are made? Who is actually to be informed or advised in order to include this knowledge in the social decision-making processes? The question as to what kind of information is needed and who takes relevant decisions is far from trivial.

A large number of social actors from the state, private industry and civil society – for instance, municipalities, regional and traffic planners, water supply companies, private households, farmers and foresters, citizen's action groups or environmental associations – decide how environmental resources are used and landscapes shaped. It is a fallacy to believe that decisions are primarily taken by state authorities and that other actors in society simply accept their stipulations. Over the last ten years the limitations of such an understanding have become manifest. Nowadays, an increasing number of decisions are the result of negotiations among the aforementioned players. These decision-making processes, subsumed and discussed under the term "governance", have forced scientists and other circles involved to adopt new approaches. In order to know how the environment is used by whom and why, it is necessary for them to analyse the respective decision-making processes, identify the actors involved and establish how they interact within different social and political settings. It is on the basis of such findings that political measures and advice for a more sustainable use of environmental resources can be developed.

Networking is the be-all and end-all of environmental research

An individual person is likely to be guided by rules or institutions, i.e. by laws and regulations when deciding how to use the environment, but other political instruments, such as tax benefits for homeowners or the mileage allowance, also play a role. Laws and political instruments as well as individual or collective decisions are the subject of investigation in various social sciences. At the UFZ these include legal, political and planning sciences, sociology and economics. Social scientists involved in the research field of "Governance and Institutions" are working on ways as to how individual rules and instruments should be adapted as well as on improving the co-ordination between different areas of decision-making.

However, it is essential to take into consideration natural scientific knowledge in this process, thereby making it possible to implement more effective instruments and rules to overcome environmental problems. Such knowledge includes, for example, ecological know-how for the protection of species, hydrological models for the management of water bodies or findings regarding the diffusion and effects of pollutants, facilitating the clean-up of polluted areas.

This interface clearly illustrates the interdependence of the social and natural sciences. At the UFZ the conditions for such an exchange between the different disciplines are excellent as their facilities are all located under one roof.

Research areas ranging from conflict analysis to compensation payments

As part of the research in the field of biodiversity at the UFZ social scientists are investigating which instruments and coordination mechanisms in environmental protection are already in place and how such existing structures can be improved. For example, what are the necessary characteristics of a compensation system for the municipalities and land users that bear the costs of maintaining nature reserves where the beneficial effects can be felt far beyond their boundaries? The researchers are also engaged in building up a "national bio-platform" which will pursue three main objectives. The first is to produce a compilation of the current scientific output in Germany concerning nature protection and biodiversity. The second is to identify the questions political bodies and environmental protection authorities want scientists to answer. The third objective is to inform the public why there is a need to protect biodiversity and how this can be achieved.

Managing rivers or entire river basins is not a simple task. Whereas to manage relatively small river basins such as the River Weiße Elster (White Elster) flowing through Leipzig is already difficult enough, the task of managing large trans-boundary river basins such as the Elbe or the Jordan is all the more challenging. How is it possible to use the water resources of such rivers without putting an excessive strain on them? More often than not the various users have conflicting interests. The scientists analyse these conflicts, for example between upstream and downstream riparians. By doing so, they gain a detailed understanding, enabling scientists to propose ways of solving them. They further investigate the influence of political instruments such as water rights or water prices on the way people use water resources.

Every day the overall settlement and traffic area in Germany increases by approximately 120 hectares, which is equivalent to the area of about 120 football fields. It is the objective of the Federal Government to reduce the daily land consumption to 30 hectares. Scientists are therefore concentrating on identifying the most effective and efficient measures to achieve this goal. Should they include tradable permits for the dedication of building land, co-operation solutions, taxation or an amendment of the existing planning law? (See article on p. 16)

While in some regions we are faced with the phenomenon of mega-cities, in other regions, such as in East Germany - but also in other old industrial centres - we experience shrinking cities. How can a sustainable urban development be achieved despite a population decrease? Scientists examine what actors are involved in what way in urban redevelopment, what conflict structures exist and how policies can be adapted to these new problems.

Scientists are also analysing how participative decision-making processes should function in order to increase the involvement of both stakeholders and the general public in order to improve environmental decisions.

Research is vital

There is an increased demand to take scientific findings into account in political decision-making processes, in particularly where environmental issues are concerned. In order to facilitate the dialogue between science and policy governance research should form an integral part of every branch of environmental research, no matter whether such research is concerned with biodiversity, river basin management, land sealing or urban redevelopment. However, this growing interest on the part of political bodies also means that there will be an increased need for research to address the requirements of society.

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Ines Dombrowsky and Doris Böhme

International water conflicts

There are 263 international river basins worldwide. These important water resources are becoming more and more the focus of public as well as scientific debates. The reason for this interest is that they are increasingly exploited. As they stretch across political borders, increased competition for scarce resources may thus become a cause for international conflict. The situation is particularly critical in arid areas such as the Middle East. However, regulations surrounding the utilisation of international waters often lead to disputes in water-rich areas as well.
Do agreements and institutional arrangements actually contribute to international co-operation in the management of transboundary water resources? What are the interests and incentives of the respective riparian countries and water users? What are the characteristics of international water agreements already in force, and do they work as intended? Economists at the UFZ are pursuing these questions among many others. Their analysis of the problem is, however, not just limited to an economic and political analysis, but they also take account of natural scientific findings as well as the legal framework of international law in their investigations. The objective is to provide a scientific basis on which to provide advice to the relevant authorities in the drafting of such agreements.
In order to reveal typical patterns of international water conflicts, the scientists have analysed potential transboundary effects of different water uses. For example, water extraction from and sewage discharges into rivers or the over-fertilization of soils all have a negative effect. The effects of infrastructural measures such as water treatment or flood control measures, on the other hand, are positive. The decisive question, however, is for whom?

Upstream beats downstream?

Whereas the downstream riparians may be pleased with increased wastewater purification, less fertilizer usage and better flood protection by the upstream riparians, they will be less happy with the discharge of toxic agents. But why should upstream riparians be motivated to reduce water extraction or the discharge of pollutants any more than is absolutely required? Let us look at it from an economic perspective: any reduction of water usage by the upstream riparian also involves costs. In cases where the costs of implementing measures to reduce water usage are lower than the benefits gained by the downstream riparian, opportunities for negotiations are created, as the downstream riparian might contribute financially towards the implementation of such measures. In the case of building sewage works, contributions might be less feasible, since according to the polluter-pays-principle, the upstream riparian is solely responsible for the treatment of sewage water he produces in order to eliminate or prevent any negative effects. In the case of flood prevention installations, financial contributions by the downstream riparian are more realistic, at least where they enable him to gain influence over the planning procedures of the upstream riparian. As a result, both parties would benefit.

Water law and international law

The economic perspective mentioned above illustrates that as long as there is a consensus between the parties as to their respective water rights, there is potential for co-operation, even in cases where they deal with the negative effects of water

Water usage in Santiago de Chile

utilisation. Economic research is, however, unable to determine how these water rights agreements should look like. In that regard, international law prescribes the principle of equitable and reasonable utilisation. Nevertheless, the problem is that there is no international authority which specifically defines the water rights of states, meaning that riparian states have to negotiate water rights in the first place. Although international law provides some criteria, it is at the discretion of the negotiating states whether or not to consider them in their negotiations.

USEFUL INFORMATION

Water law is part of public law, regulating the use of water bodies. Use in this context refers to the arrangement of water bodies, water extraction for drinking water supply, irrigation in agriculture, industrial processes or for the purpose of cooling industrial water. The function of water law is to protect clean water – rivers, lakes, groundwater – from harmful interventions or pollution and to clean up polluted waters. A further function of this law is to protect people and their property from floods.

German water law is divided into water management law and waterway law. In the case of the water management law, the competence of the Federal Government is limited to framework legislation, since actual legislative power lies with the federal states. The german water law has been given new impetus by the **European Water Framework Directive** (WFD) which came into force in 2000, providing a new legal framework for the use and management of rivers. The foremost environmental objective is to achieve a "good qualitative status" in all European waters by 2015.

International law defines principles for the use of international water resources between states. In this respect, the UN Convention on the Law of the Non-Navigational Uses of International Watercourses was signed in 1997.

Scientific surveys conducted so far have revealed that treaties regulating international water usage have been concluded in almost half of the 263 transboundary river basins. Moreover, countries have set up specific commissions in about one quarter of these basins. It is open to debate whether these findings suggest that the glass is half full or half empty. ■

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Matthias Bernt and Doris Böhme

Actors and Conflicts in Urban Redevelopment

Urban shrinkage, a term which was almost unknown a few years ago, has emerged as one of the most topical themes in sustainable urban development. The continuing increase in unoccupied buildings is not just restricted to East Germany, but also affects a growing number of other areas in Europe and North America, like the Ruhr district, North of England and the Lorraine region. How can the problem of unoccupied housing best be resolved? What parts of a city will continue to be used in years to come? Where should new green areas

ideally be located? What adjustments need to be made to commuter traffic control measures or the water supply? What is to happen with unused plots of land? And who sits at the table when plans and decisions are made regarding future urban development? While unoccupied housing poses a number of problems on the one hand, urban shrinkage, on the other, presents an opportunity to restructure certain residential areas, thereby creating shorter commuting distances, more green areas and generally better living environments. The Federal Government and the states have developed a programme named “Stadtumbau Ost” (Urban Redevelopment East). The objective of the programme is to provide shrinking cities with the means to cope with fewer inhabitants.

The number of inhabitants living in Leipzig Grünau has shrunk from 90,000 to a mere 40,000. As many as 3,500 flats have been torn down in the last few years.

Whether more space with fewer buildings will be created as a result of the programme, or whether the wrecking ball will play a predominant role does, however, not just hinge on the good or bad ideas of city planners. Rather, a number of actors are involved in urban redevelopment, all with particular interests and goals. Whether sustainability objectives will actually be implemented, rather than just defined is not just contingent on clever concepts, but predominantly on how different interests can be reconciled. “Stadtumbau Ost” lends itself well to an almost paradigmatic study of such governance issues. As part of the programme, plans for a new type of city are being developed in more than 260 East German municipalities. Such a large-scale venture naturally involves a wide range of negotiation processes in which housing companies, banks and municipal authorities negotiate the redevelopment of entire residential areas.

Demolition or redevelopment?

In order to gain a better understanding of such negotiations, social scientists at the UFZ have for the first time conducted a detailed study of the political aspects of urban redevelopment based on the example of Leipzig’s district of Grünau. The study formed part of a larger project named “Actor constellations and conflict structures in urban redevelopment”. For two years scientists observed the redevelopment of Grünau, interviewed local govern-

"Urban redevelopment" is almost exclusively conducted in the form of demolishing unoccupied buildings, whereas no upgrading measures are taken.

ment employees, bankers and housing companies, analysed documents and took part in meetings of the decision-making bodies.

They discovered a considerable number of management problems. The result is that, so far, urban redevelopment is not as sustainable as it could be. Why is that? Sustainability in urban redevelopment is often talked about. In practice, however, there is little or no operationalisation of sustainability objectives. In order to retain as much flexibility as possible in the negotiation rounds, public as well as private actors refrain almost entirely from incorporating their declared willingness to make contributions to a "sustainable urban redevelopment" into concrete plans.

A further problem identified by the scientists is that a large number of important actors have so far not been involved in the planning process. Operators of infrastructure, private landlords as well as residents are not included in negotiations. As a consequence, their interests are also left out. The planning is incomplete and mainly limited to tackling problems of vacancy, that do harm to the big housing companies. Although new open spaces and green areas may be haphazardly created in this manner, they do not form part of the actual plans for green areas. Their design is thus subject to the imperative of low maintenance costs.

In addition, the demolition of unoccupied buildings is almost exclusively conducted under the label of "urban redevelopment", whereas no upgrading measures are taken. Grant programmes from the Federal Government and the states for urban redevelopment largely contribute to this negative mechanism, as they have been conceived in such a way that mainly the demolition of buildings is supported, while very few means are left for their conversion or renovation. A number of ambitious ideas by Grünau's cooperatives were quickly put back in the drawer for financial reasons.

Money alone will not do the job

Thus, as a result of financial pressures, little is left of the original objective of achieving sustainability. If urban redevelopment is to involve more than just tackling economic difficulties of housing companies and actually result in "sustainable cities" with more green areas, more quality of life, shorter commuting distances and less pollutants, a drastic change of course will be required. Sustainability objectives need to be defined in clear terms, the network of those involved in urban redevelopment expanded beyond housing companies and administrative bodies and the grant programmes revised. ■

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Finding the right soluti

Improving procedures P. 82
Competing for fish P. 84
The battle of semi-arid landscapes P. 86

Natural and social scientists at the UFZ are developing integrated assessment methods aimed at helping policy-makers reach important and complex decisions more easily and on a sounder basis. They are bringing together various established disciplinary and interdisciplinary methods, developing them further and analysing and structuring decision-making processes. This involves looking for suitable strategies to deal with complexity, uncertainty and lack of information. Scientists are working both theoretically and methodically as well as taking examples of actual decision-making processes, requiring an intensive dialogue with politicians and civil servants.

SPOKESMAN FOR THE RESEARCH TOPIC "INTEGRATED ASSESSMENT AND DECISION-MAKING SUPPORT":
DR. BERND KLAUER, A SCIENTIFIC MEMBER OF STAFF IN THE DEPARTMENT OF ECONOMICS

ons

Bernd Klauer and Susanne Hufe

Improving procedures

Photo: Photodisc Environmental Concerns

Planning on moving to Leipzig? With such a wide variety of attractive homes on the market, you will be facing a difficult choice. There is the one that is closer to work but a little more expensive, there are some imposing late nineteenth century villas but that will mean the kids will have to put up with a longer journey to school, and then there are others that have been expensively renovated but are a relatively long way from the city centre. Then there is the question of whether to have a house with four bedrooms and a small living room or one with two bedrooms and a very large living room. The decision is yours – which house should you choose? If it were only you deciding, then the choice might be easier to make, but your partner and every one of your children have their own ideas about what kind of house they want to live in... So how do you make the right decision? Which criteria are decisive ones and who should be involved in the decision-making process? What are the options available? What kind of financial burden does each alternative carry? As you can see, even when taken privately on a "small" scale, the procedure is hardly straightforward. Can you imagine what it must be like making far more complex decisions, of the kind that the state – that is, politicians and civil servants acting on behalf of society – has to make? Generally speaking, these involve enormous sums of money and may have an enormous effect on the lives of many people or permanently change a landscape's appearance.

It is precisely this field of research that a group of natural and social scientists at the UFZ, who have been questioning common decision-making processes, are analysing and seeking to improve. Part of their work is theoretical and methodical involving, for example, the examination of established disciplinary and interdisciplinary assessment methods. However, they also use actual case studies of decision-making processes from such policy areas as river basin management, environmental and biodiversity protection, federal transport planning and landscape planning.

Theoretical and methodical research

Theoretical and methodical research brings together existing procedures for decision support and develops them further. Biological and hydrological assessment models, cost-benefit analysis, multi-criterial analysis, optimisation and cost-effectiveness analysis are all examples of proven procedures in environmental research, economics and the planning sciences. Though they are widely used, in practice problems frequently still arise because communication between decision-makers and those affected by their decisions does not function satisfactorily. Proposals developed at the UFZ to improve this situation have attempted systematically to shape decision-making processes in such a way that assessments become transparent, helping interest groups to participate constructively while preserving the essential policy-making right of the authorities.

Furthermore, a basic problem of complex decision-making is incomplete knowledge of its effects. The quality of information on which decisions must be based can vary from the extremely reliable to the vague to the completely useless. Accordingly, there are many consequences of a given action that are simply not known. So how are decisions tackled in such conditions of general uncertainty? To answer this, scientists are studying strategies that go beyond the standard scientific application of probabilities, such as the so-called principle of caution. This states that actions carrying the risk of causing catastrophic damage should be avoided, even if the probability of this is extremely small.

German transport planning: a case study

Like many other policy planning decisions, German transport planning involves large amounts of money and can have enormous consequences for the economy and the environment. It controls the federal government's investment in transport infrastructure over a period of 10-15 years and has a volume of about 150 billion euros. Scientific assessment procedures - in particular cost-benefit analysis and environmental risk assessment - have been given a key role in the decision-making process that will determine which infrastructure projects will be classified as urgent. The results of these assessments form the basis for the political decision. In one case study scientists made a detailed analysis of the decision-making procedures involved in developing the river Saale for shipping. Whichever way one looks at it, this is a project that has important consequences for both the environment and the economy, and is in any event a matter of potentially enormous social and political controversy. What then were the effects of actually applying the procedure to the decisions taken? It transpired that despite all the procedural advances made by German transport planning over the last few decades assessments were still not transparent at certain crucial points. However, it is precisely the ability to comprehend assessments that is vital to reaching genuinely successful decisions in a political discourse between decision-makers and those affected by the decisions. The study presented several concrete proposals for improving matters. For example, expert opinions and traffic prognoses should be made available to the public in advance and in full - procedures that, as the scientists' studies revealed, were still very far from being standard practice at the time.

Putting research findings to use

The Helmholtz Association's environmental research project has been expected, quite reasonably, to come up with solutions to such urgent social issues as climate change, clean water shortage and the loss of biological diversity. A great deal of this involves policy consultation and decision support. This frequently proves to be difficult, as the results of research are presented in a manner that is too specialised or too difficult to understand. Consequently, scientists at the UFZ have devoted their time to the question of how the results of scientific modelling can be suitably used to influence policy decisions. This involves, on the one hand, combining models from such disparate fields of research as hydrogeology and plant physiology to produce general findings that can then be tailored to suit particular policy decision-making problems. On the other, information compiled must also be of the kind that politicians and civil servants will be able to understand and use. This means that not a long series of data or diagrams of processes on the microscale are required, but rather descriptions of whole river sections, nature preserves or rural districts that are capable of giving direct answers to questions. A model centre is currently under construction at the UFZ which will in future be dedicated to questions concerning model integration.

Developing ideas for the exchange of knowledge between science and society will remain an important challenge for applied research in the years to come. This means an exchange in both directions: on the one hand translating social problems into scientific tasks, and on the other making the results of research available to society. The research work at the UFZ towards integrated assessment and decision support is concentrated on this point of interface, and makes important strategic contributions towards the practical solution of environmental problems. ■

Shipping on the Elbe-Havel canal

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A cormorant (Phalacrocorax carbo sinensis) eats about 450 grammes of fish a day. Though they used to exist in only a few small colonies, their numbers have been growing rapidly for several years now.

Irene Ring, Reinhard Klenke and Susanne Hufe

Competing for fis

There is no getting away from nature programmes on television these days. And there is no mistaking that the main protagonists of these are often chosen for their endearing cuteness. Human beings, it seems, tend to be very fond of wild animals so long as they are only to be seen on far-off nature preserves or holiday safaris. What happens, though, when decades of environmental conservation suddenly meets with success, and species that formerly were rare start reappearing outside people's front doors in large numbers? When beavers are building their dams, wolves are wandering through forests or unexpectedly large numbers of cormorants are snatching anglers' fish, then old conflicts between humans and animals are often revived. How, though, are these conflicts to be resolved in a way that is as fair as possible to all sides?

Balancing ecology and development

In the meantime, it is clear that in cultural landscapes – that is, areas of land used by humans – conservation measures can only be successful over the long term if, alongside ecological considerations, they take into account the economic and social interests of the people they will affect. This means strategies are required that both point the way to successful management and offer solutions to conflict situations. For the last three years more than 60 scientists from nine European countries have been involved in developing such strategies.

They have been using a model case – the actual conflict between the protection of large fish-eating vertebrates such as cormorants, grey seals and old world otters and fisheries and aquaculture. This involves conducting comparative studies in Denmark and Italy for cormorants, in the Czech Republic, Germany and Portugal for otters and in Finland and Sweden for the grey seal. As well as ecological issues, the research team's investigations are taking into account economic, sociological and legal considerations. For example, they are determining the damage potential of such "conflict species" in relation to factors of landscape structure, resource use and geographical distribution, and are simulating the effects of a variety of management measures. What, for example, is the effect of compensation payments to

Old world otters (*Lutra lutra*) are musteline animals that live principally off fish, although they catch other small animals as well. Fish in ponds are easy prey to them – to the despair of fishermen.

fishermen? Is the controlled culling of cormorants effective and what are the long-term effects on the stability of species populations? Can the combination of technical changes to fish traps, restrictions on hunting and active protective measures help to reconcile conflicts with grey seals in the Baltic Sea without endangering their spreading into traditional breeding grounds? Does the erection of electric fences around small fish ponds prevent hungry otters from stealing fish, and can these animals be distracted by wild fish stocks in other lakes and streams? Using scientific analyses and computer-modelled scenarios scientists are assessing and discussing individual measures with regard to their effectiveness, efficiency and social acceptability. However, they are not just doing this among themselves; they are taking into account the various stakeholder groups involved such as fishermen, anglers and conservationists. Working with their conflicting perceptions is not only important to them but decisive for the success of the project. This is also true of the participation of conservation and fishing authorities, for in the end they are responsible for implementing environmental policy measures.

A patent remedy?

There is no patent remedy to these problems. The conflicts involved are too diverse. However, common and recurrent problems do gradually emerge from scientific research into, and comparison of, conflicts associated with competition over fish across the seven regions under study and the three species in question. And – at least in principle – possible solutions to them also emerge. Thus, sound scientific information, far-sighted action and the timely and constructive involvement of all interested parties seem to be the basis of potentially successful solutions. By the time the project ends in 2006 a set of guidelines should be available that can be used as the basis for concrete action plans for a wide variety of species and cases of conflict, using as examples results obtained from among cormorants, grey seals and otters. ■

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Karin Frank and Susanne Hufe

The battl of semi-arid lan

Semi-arid landscapes cover about two-thirds of the Earth's surface. They extend from Latin America through Africa, the Near East, Central Asia and Australia to southern Europe. Low but highly variable rates of precipitation make these regions extremely vulnerable to being misused by human beings. For years symptoms of decline in these regions, such as progressive desertification or the irreversible collapse of ecosystems, have been observed across the globe. The UNO estimates that on the continent of Africa alone almost three-quarters of semi-arid regions are affected. In developing countries especially this has not only been threatening important natural conditions for human life but also economic ones. The results are hunger, poverty and political instability the effects of which can be felt globally. When it comes to the sustainable use of natural resources, strategies, action plans and aids for decision-support are lacking – as well as the endurance to implement these.

Shepherd on a farm in Namibia more than 30, 000 hectares in size

Photo: Thorsten Wiegand, UFZ

Focussing on grazing strategies

The most common use of land in semi-arid regions is grazing with cattle, sheep or goats. For this reason, a group of young scientists from Heidelberg and Leipzig has been trying to investigate the basic principles that make grazing sustainable. Using special computer models, they simulate different grazing strategies and then see what effects these have on the ecosystem. Emphasis is placed here on the interaction of ecological and economic factors, since these substantially influence the farmers' management decisions. The starting point for the analyses are two specific case studies from Namibia: a commercial Karakul farm and subsistence cattle farming by the indigenous tribe, the Ova Himba. In both cases sophisticated grazing strategies have been practised for decades which appear to be sustainable. Using their computer models scientists put these to the acid test: are the strategies really sustainable? What aspects are essential for sustainability? Which circumstances require which grazing strategies? Preliminary results show that, despite their

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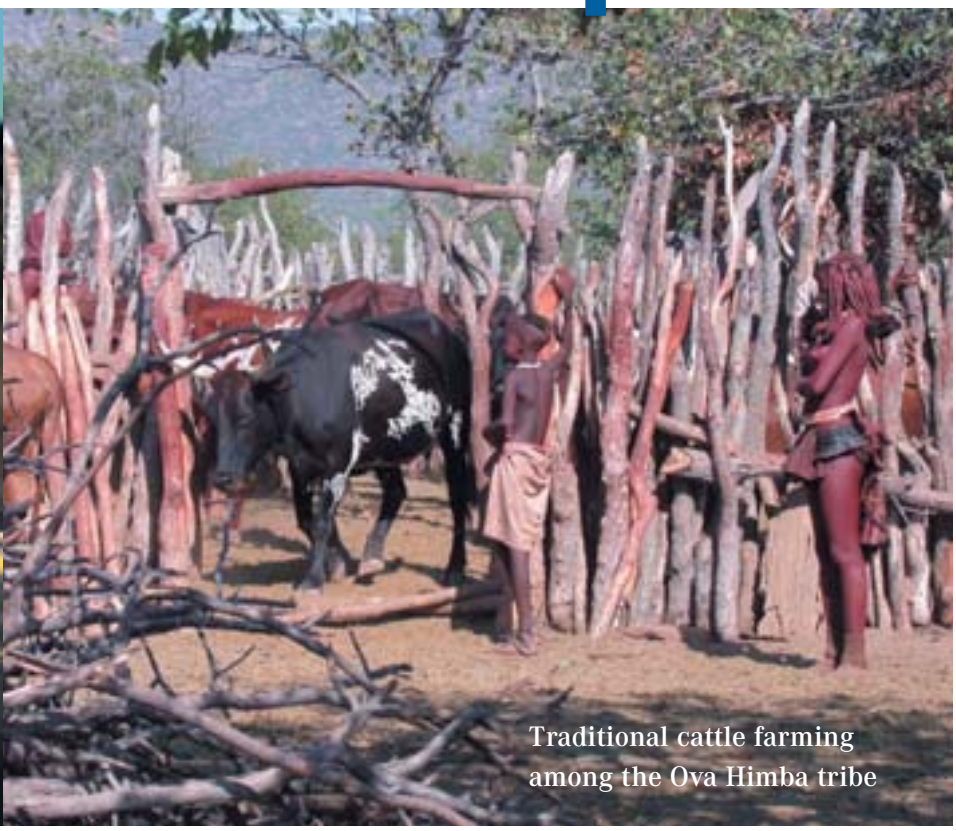

Traditional cattle farming among the Ova Himba tribe

Photo: Jula Zimmermann, UFZ

difference in structure and economic and social background, the grazing strategies of both the Karakul farmer and the Ova Himba were based on the same basic principle, namely that of giving rests to some parts of the pasture during rainy years. The pastures 'reward' this care taken of it during good years with a higher productivity during bad ones. In other words, resting pastures protects vegetation, animals and, hence, income from suffering sharp declines.

What happens, however, when farmers have access to insurance, loans or opportunities to save their money? What effect does this have on their choice of grazing strategy? Will their behaviour become less sustainable? These questions are of enormous relevance given how heavily involved international organisations are in introducing economic institutions to semi-arid regions that aim to insure against risk. So far it can be said that the effect of these financial insurance systems is heavily dependent on the business mentality of the individual farmers. If they have a tendency to think in the short term and are prepared to take risks, they will, given the existence of an insurance system, resort to less resting and environmentally more damaging grazing strategies. In these circumstances, financial buffer systems seem to have a rather counterproductive effect. If a farmer thinks in the long term and is concerned with security, no change in his behaviour can be discerned. To sum up: non-exploitative grazing leads to better ecological buffer effects over the long term and higher total income for the farmer than insurance schemes, which are only effective in bad years.

As a matter of course, the results of this research are intended to be made widely available. There are close contacts to scientists and decision-makers working in these regions. There are also plans to provide the results to Namibian students. ■

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Uncovering envi health probl

Environmental medical researchers, epidemiologists, natural scientists, biostatisticians, immunologists, cell toxicologists and sociologists at the UFZ are investigating whether and why environmental factors trigger allergic reactions and disorders, what effects environmental pollutants have on the immune system and what role genetic factors or the social milieu play. They are developing suitable procedures to be able to detect environmental pollutants in body fluids and in voids inside the body. Apart from volatile organic chemicals, it is primarily mould and its often toxic or allergy-provoking products of metabolism that cause the problems. The research is based on epidemiological and experimental studies.

SPEAKER ON THE RESEARCH TOPIC "ENVIRONMENTALLY-RELATED HEALTH PROBLEMS – THE EFFECT OF CHEMICALS IN THE ENVIRONMENT":
DR. IRINA LEHMANN, HEAD OF THE DEPARTMENT FOR ENVIRONMENTAL IMMUNOLOGY

ronmentally-related ems

Allergies – the epidemic of the 21st century? P. 90
Searching for causes with LARS, LISA and LISS P. 94
Does stress make you ill? P. 96

Mould spores, whose protein particles act as allergens, can be found in many houses. The fungi grow in flowerpots, on food, even in the refrigerator.

Irina Lehmann, Olf Herbarth and Doris Böhme

Allergies – the epidemic of the 21st century?

They are increasing worldwide, especially in the highly developed industrialised countries. It is estimated that a quarter of the population in Germany is affected by them. They are affecting children and young people more and more, and presumably there is a multitude of causes. Apart from genetically determined suspectibility, environmental factors and personal lifestyle also play a role in the emergence of such illnesses.
Whether hay fever, neurodermitis or asthma allergies not only disturb the actual sufferer but also society as a whole. This includes the fears of people regarding environmental hazards that unfortunately are repeatedly brought to the attention of the public in waves. Sometimes too loud and emotional, at other times too compliant, seldom reflecting the actual danger as scientists see it.
For that reason it is a social challenge for the environmental medical specialists, scientists and social researchers at the UFZ to uncover the causes and mechanisms of allergies and health problems caused by the environment. Among other things, this knowledge is a prerequisite for reducing the frequency of allergy-related diseases. Undoubtedly, there are good forms of medication to cope with the symptoms of these illnesses. However, the goal must always be to actually tackle and remove the causes.

Risk groups and risk factors

What environmental pollutants surround us? Where and when? And for how long? Are there even more risk factors that can lead to an allergy? And can these risks be avoided? Many questions that can best be answered by means of so-called epidemiological studies. The scientists of the UFZ are concentrating their studies in particular on infants and small children, since the first few months of life probably determine the tendency to suffer – or not suffer – allergic problems in later life. Furthermore, they are focused on pollutants that are found indoors, since children and adults alike spend the greater part of the day – around 21 hours – in enclosed rooms. Admittedly, people who look after their health can eliminate one or other item of food or particular materials from their daily life, but what can you do with the air that you breathe, for example? The quality of the air in indoors has a decisive effect on our health.
Whether or not an environmental pollutant actually leads to a risk of illness depends not only on the concentration of the pollutant. The dose is largely determined by the length of time of the load – the duration of exposure. In addition, indoor room exposure is always made up of a variety of kind of pollution: chemical, physical and biological. It has been known for a long time now that house dust mites or moulds are typical residents of indoor areas that can trigger allergies. But what of the chemicals that get into the air of the rooms in which we live or work being emitted from floor coverings, furniture or paint?

Photo: Norma Neuheiser, UFZ

Cigarette smoke contains more than 3,000 chemical substances, including benzene, formaldehyde, methanol, hydrocyanic acid and nicotine. The fact that smoking is bad for your health is well known. Scientists want to find out to what extent the poisonous and, to some extent, carcinogenic compounds affect the immune system and thus also allergic illnesses

Photo: N. Neuheiser, UFZ

Do they affect our overall well-being and increase the risk of allergies? Probably they do. Are psycho-social factors that initiate stress situations also in a position to do the same? The task of the environmental epidemiologists and immunologists is to test these hypotheses and to reveal mechanisms that set off allergies, chemicals and stress in our bodies.

An important constituent part of epidemiological studies is the determination of stressing and pollution loading. After all, the decisive factor is just what pollutants occur in individual people and in what quantities. To this end, scientists are investigating various kinds of body fluids such as blood and urine and are developing new procedures for detection that promise to be non-invasive, meaning that they do not stress the organism and yet are highly sensitive. The knowledge that has been gained forms an important basis for the work of the environmental medicine specialists. Thus, the individual patient benefits from the results of the epidemiological studies so that the doctor can then draw conclusions regarding the form of pollution and take this into consideration in the therapy concept. However, kindergartens, industrial premises, official authorities and organisations, too, are professionally advised.

The tiny difference

But why do certain people fall ill while others do not, even when they are exposed to the same pollutants? The cause of this probably lies in our genetic makeup. For example, our cells are equipped with various enzymes that change chemicals that have penetrated in such a way that they are quickly discharged. However, sometimes there are tiny differences in the genes that encode such enzymes. The result is that one enzyme works very quickly and effectively, while another one requires more time to eliminate a pollutant. Variations of this kind on the genetic

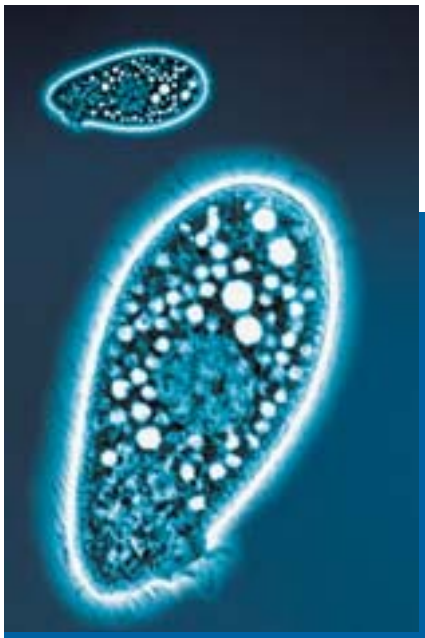

Photo: Andrea Müller, UFZ

Certain single-celled organisms can move with the aid of cilia (flagella). The cilia have the same structure and the same form of functioning as the cilia in the human trachea, where they are responsible for transporting away any foreign bodies such as dust particles. For that reason they are excellent test models for use in environmental medicine.

level are technically known as polymorphisms. Persons with certain polymorphisms are thus exposed to the pollutant for a longer period at the same level of concentration of the pollutant and thereby have a higher risk of falling ill. If it ever becomes possible to uncover these polymorphisms and bring them into context with these risks of falling ill, it would be possible to predict how high the risk of falling ill is for an individual person in a defined pollutant situation. It would then be possible to develop individual prevention strategies. Such investigations are also being carried out as part of the epidemiological studies.

The cell as model

With the help of various cell cultures that are subjected to the action of various pollutants, scientists at UFZ are attempting to estimate how great the risk potential is from environmental pollutants. These laboratory tests allow remarkably precise statements to be made as to how a particular cell type reacts to a pollutant and which important functions are adversely affected.

One of these cell models is based on an animal single-celled organism, the amoeba *Tetrahymena pyriformis*. In many respects this organism is comparable with the cells of higher organisms. It combines in one cell the complexity of a complete organism with a multitude of functions such as movement, feeding, digestion, fluid regulation and reproduction. The amoeba is therefore highly suitable as a model to test the toxic effects of a wide variety of chemicals with relatively little expense and effort.

Liver cells are used to study the role of the above-mentioned polymorphisms. Whether or not chemicals are able to restrict the ability of our immune system to react or else can change it in such a way that there is an increased risk for a tendency to allergic ailments, this is a question that is likewise being tested by the use of cell culture experiments. They involve cultivating lung epithelial cells or various immune cells that have been isolated from the blood and then exposed to pollutants in the laboratory. Although this requires a high level of technical complexity and time, it can replace animal experiments in many cases. ■

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Environmental physicians are developing and optimising analytical methods for air samples and body fluids as blood and urine.

Olf Herbarth, Irina Lehmann and Doris Böhme

Searching for causes with LARS, LISA and LISS

Environmentally-related illnesses in patients frequently cannot be distinguished externally from an illness that does not depend on environmental factors. Does the patient react in an allergic way because he or she is surrounded by indoor pollutants, pollutants from combustion processes or biological materials? Is this due to all factors concerned or as a result of their variety? Science can only make statements with any certainty regarding the interactions of environmental factors and health if valid epidemiological studies are available with hundreds or thousands of test subjects based on comprehensive questionnaires and studies of the surrounding exposure and various body fluids. Thus risk factors can be brought to light and risk groups found, and prevention or avoidance strategies developed. Two comprehensive long-term studies of the UFZ are the cohort study LARS, the Leipzig Allergy Risk Children Study and the repeated cross sectional study LISS, the Leipzig Infection, Allergy and Respiratory Ailments Study in children who are just starting school, in which more than 5,000 children were examined. These were carried out by the UFZ,

The scientists at the UFZ are concentrating their studies in particular on infants and small children, since the first few months of life probably determine the tendency to suffer – or not – to allergic problems in later life.

the University of Leipzig, the St. George Clinic teaching hospital and the Leipzig public health office under the overall guidance of the Environmental Medicine Centre [UMZ]. The LISA cohort study is devoted to the question as to how lifestyle factors affect the immune system and the allergy risk in children from eastern and western Germany. In addition to the UFZ there are also a number of other partners from various research institutes throughout Germany.

Allergy risk: renovating

LARS, LISA and LISS show that there is a risk of children falling ill from allergies that primarily affect the respiratory system, in particular when renovating. Many paints, varnishes, wood protection agents and adhesives contain volatile organic substances that remain in the air inside rooms for a long time, at least a quarter to half a year. In addition, scientists found evidence in the blood from the umbilical cord of newborn babies that a prolonged stay of pregnant women in recently renovated or freshly decorated rooms can have an unfavourable effect on the later development of allergic symptoms in their children. This will be researched in more detail in the LiNA cohort study of newborn babies that has just started. However, around 60% of future parents had renovated their apartments or houses, especially the child's room, in expectation of the arrival of their offspring. In 25 to 30% of these cases reference values were exceeded to a massive extent for a lot of volatile organic substances that are normally found for evaluation in the home and are therefore taken as guideline components.

60% of future parents renovate their apartments or houses, and in particular the child's room, in expectation of the arrival of their offspring. This increases the risk that the child will suffer from an allergy later in life.

The fact that infants, in particular, are exposed to the highest risk of developing allergies as a result of environmental pollution probably depends on the fact that both the metabolic activity is different compared with adults and the immune system is not yet fully developed at birth. A particular type of white blood cells, the so-called Th1 cells, are not present in infants or else only in small numbers. However, it is precisely these cells that can form protection against the development of allergic inflammatory responses.

As regards the allergy risk factor in children scientists have also proved that indoor pollution from mould spores represents a risk factor that depends on the genus. This applies both to infections to the respiratory tract and to illnesses causing obstructive bronchial and airway restrictions and a sensitisation to allergies.

> Scientists warn against making the hypothesis that unhygienic conditions would strengthen the immune system

Infections as a protection against allergies?

Further studies are required, primarily to be able to take preventive action on a scientifically founded basis. We read and hear with increasing frequency that "unhygienic" conditions would strengthen the immune system and protect us against allergies. Scientists warn against such hypotheses because we owe the fact that life expectancy has increased by around 30 years in the past century primarily to better hygiene. For that reason, they want to test whether and what kind of infections control the immune system in such a way that as few allergies as possible occur, and if so, which ones. Initial studies have revealed indications that, for example, microorganisms in the digestive tract could reduce the risk of allergy. The UFZ scientists also wish find out at what stage of the pregnancy the immune system of the child is decisively influenced by pollution from the environment.

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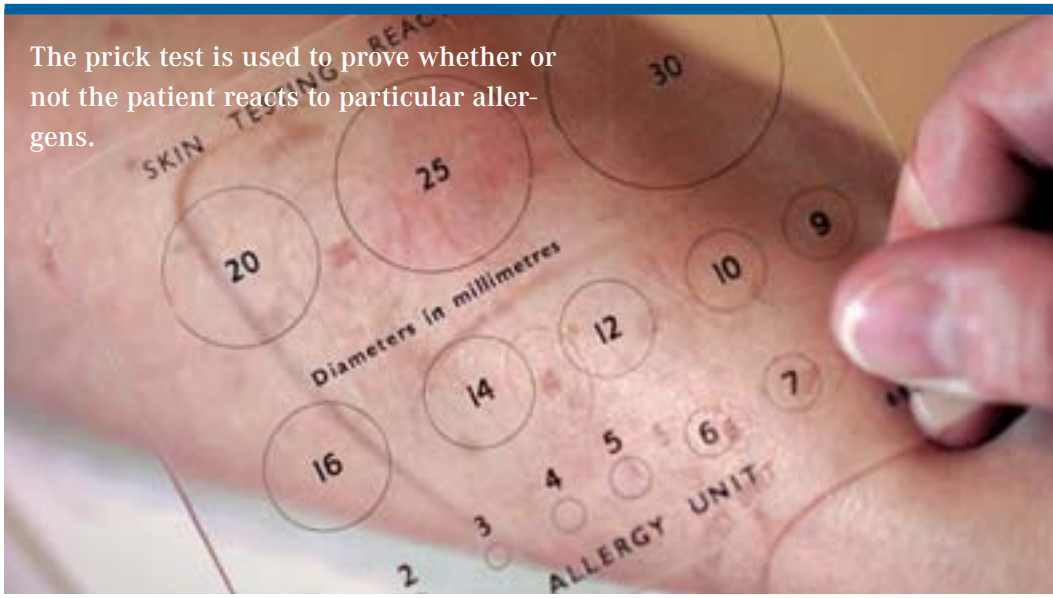
THE IMMUNOLOGIST, DR. IRINA LEHMANN, IS HEAD OF DEPARTMENT OF ENVIRONMENTAL IMMUNOLOGY.



The prick test is used to prove whether or not the patient reacts to particular allergens.

Stress makes you ill – who has not heard this saying? However, does stress really make you ill, or do many of us just imagine it to do so? This and other questions are being answered by a new health research project at the UFZ that crosses the boundaries of the individual disciplines involved. The aim is to find out whether health research can master the challenge of taking in hand a wide variety of ailments that are initiated by stress-related malfunctions of the immune system. First and foremost asthma, atopic dermatitis and other allergic ailments are among them. Nevertheless, many illnesses of the heart and circulatory system can also be traced back to the effect of stress.

Gunda Herberth, Horst-Dietrich Elvers and Doris Böhme

Does stress make you ill?

The marked increase in such ailments in recent years has been accompanied by an equally marked increase in psychological and social stresses placed on people. However, is there really a causal relationship? To what extent can psychosocial stress genuinely be taken into consideration as a factor causing these health problems? Stress is triggered off by a wide variety of environmental conditions that are perceived as overwhelming.

Going beyond the boundaries

To answer the question as to which forms of stress from our everyday environment affect the immune system and in which way it increases the risk for particular illnesses, it is important to go beyond the boundaries of the individual scientific disciplines. Above all, close collaboration between the social sciences and immunology is needed for in this case. This is no easy matter, but environmental sociologists and immunologists at the UFZ prove that it works. The prerequisite for this is an intensive dialogue, debates, finding a common language, and comparing the results of the research. Thus the sociologists and the psychologists are tackling, on the one hand, the question of what types of stress exist, through what environmental characteristics it is triggered – for example, by neighbourhood or traffic noise, conflicts in the family area, unemployment or pressure to perform at work – and how to record it as precisely as possible on the basis of questionnaires.

USEFUL INFORMATION

Translated from Greek, **epidemiology** means “the study of what has come over people”. It is not concerned with individual cases of illness but instead with the distribution of illnesses in the population as a whole, the frequency of occurrence, with physiological variables and the social consequences of the illness. In addition, epidemiology attempts to determine which factors affect the distribution. Findings from epidemiological studies are therefore not only important for healthcare for the individual, but also for decisions regarding policy. If risk factors are found, then the ones that are avoidable can be prevented or reduced. However, a knowledge of statistics is required to make the right conclusions and correlation from figures that have been gained. Thus there is a great deal of controversy among the public on epidemiological studies due to the fact that either the wrong statistical procedures were used or else that statistical statements had been interpreted incorrectly.

Immunologists, on the other hand, are attempting to trace at the molecular level the reactions that are initiated in the body as a result of stress, and thus to investigate the influence of environmentally-related stress factors on nerve and immune cells.

On the basis of data from the Lifestyle Immune System Allergy study LISA and the LiNA study of newborn babies that has just been started scientists are comparing external living conditions and the perception of environmental stress by people in relation to their immune function. This allows stressors that work immunologically to be distinguished from those that have no effect on the immune regulation of the human organism.

The successful collaboration between health researchers and the social sciences at the UFZ should be extended and funded further by these studies. This is the vital prerequisite for being able to give specific recommendations for structuring the human living environment in a way that is beneficial to our health and to reduce the frequency of numerous complaints on a long-term basis.

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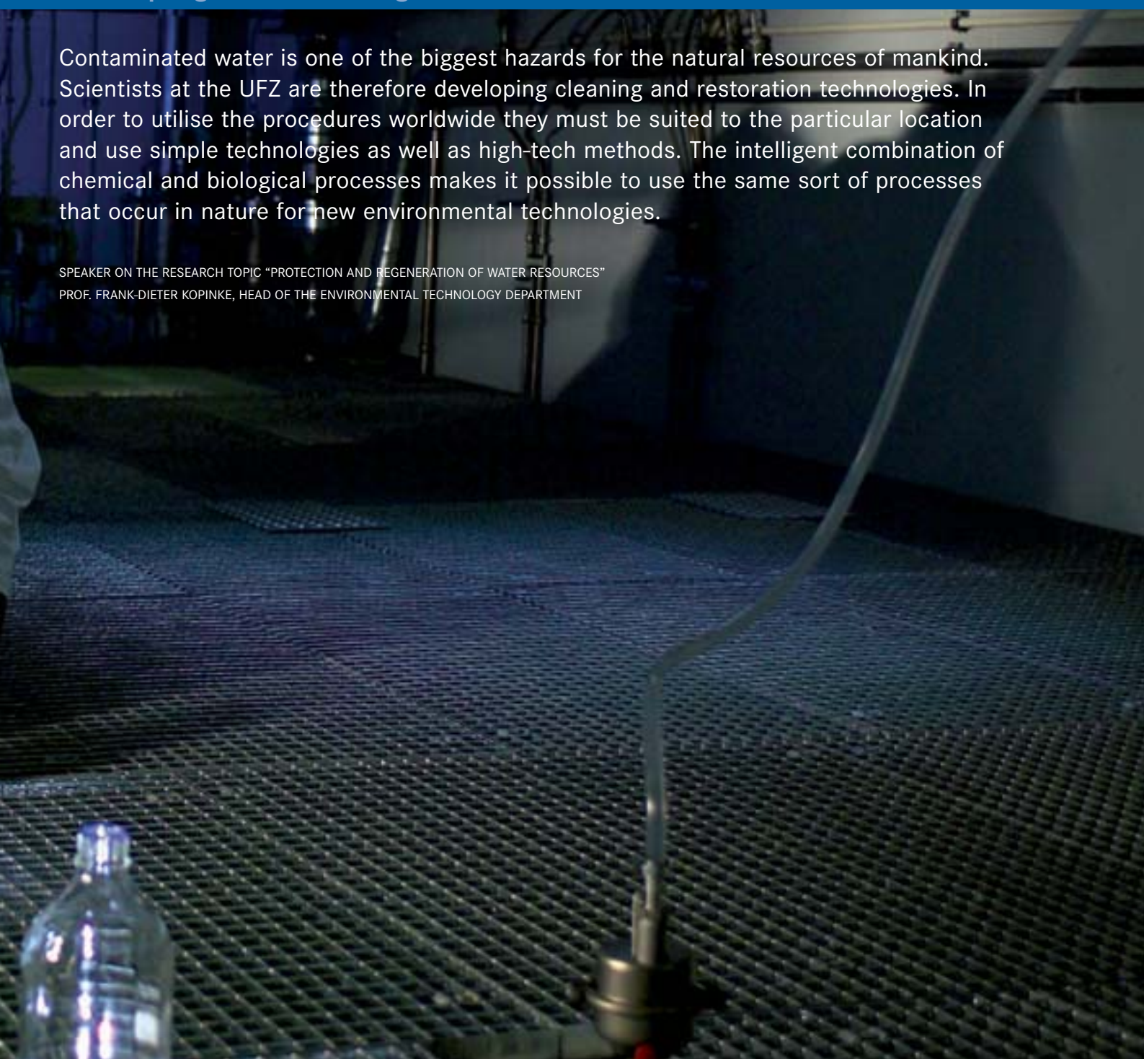
Protection and of water

regeneration resources

Protecting water, reviving water P. 100
Licence to heat the ground P. 104
Adapting and customising P. 106

Contaminated water is one of the biggest hazards for the natural resources of mankind. Scientists at the UFZ are therefore developing cleaning and restoration technologies. In order to utilise the procedures worldwide they must be suited to the particular location and use simple technologies as well as high-tech methods. The intelligent combination of chemical and biological processes makes it possible to use the same sort of processes that occur in nature for new environmental technologies.

SPEAKER ON THE RESEARCH TOPIC “PROTECTION AND REGENERATION OF WATER RESOURCES”
PROF. FRANK-DIETER KOPINKE, HEAD OF THE ENVIRONMENTAL TECHNOLOGY DEPARTMENT



Water and the soil are indispensable resources for our life. They are subject to a natural cycle. If they are managed in a sustainable way, they are not consumed but only used. However, flows of substances produced by man – especially emissions from industry and agriculture – mean that surface water and groundwater are constantly being contaminated, sometimes point-wise and sometimes in a creeping process. Despite all efforts made concerning sustainable forms of use and efficient technologies, this effect on the environment can only be reduced but not prevented altogether. Air, water and soil do indeed have a natural potential to purify themselves, but this is limited. In particular, a great many chemical and microbiological processes take place very slowly in the groundwater. A gradual accumulation of pollutants threatens the extremely sensitive and only slowly renewable groundwater resources of future generations. Preventive protection and monitoring of the groundwater is therefore a matter of strategic importance at the UFZ and in the Helmholtz community.

Frank-Dieter Kopinke, Doris Böhme and Tilo Arnhold

Protecting water, reviving water

Cleaning water efficiently and in an ecologically acceptable way is a scientific and technical challenge because there is no procedure that can be applied universally in view of the wide number of differing types of pollutants which exist in varying concentrations in the water. UFZ scientists are working on innovative technologies that must be appropriate to the location if they are to be used globally and cover the entire range from simple technologies to the latest high-tech. They range from in situ methods that copy those of nature to technically based ex situ procedures for the treatment of highly contaminated groundwater and waste water. There is a great need for development in particular of an intelligent combination of biotic and abiotic processes and the targeted use of biogeochemical processes in environmental technologies.

USEFUL INFORMATION

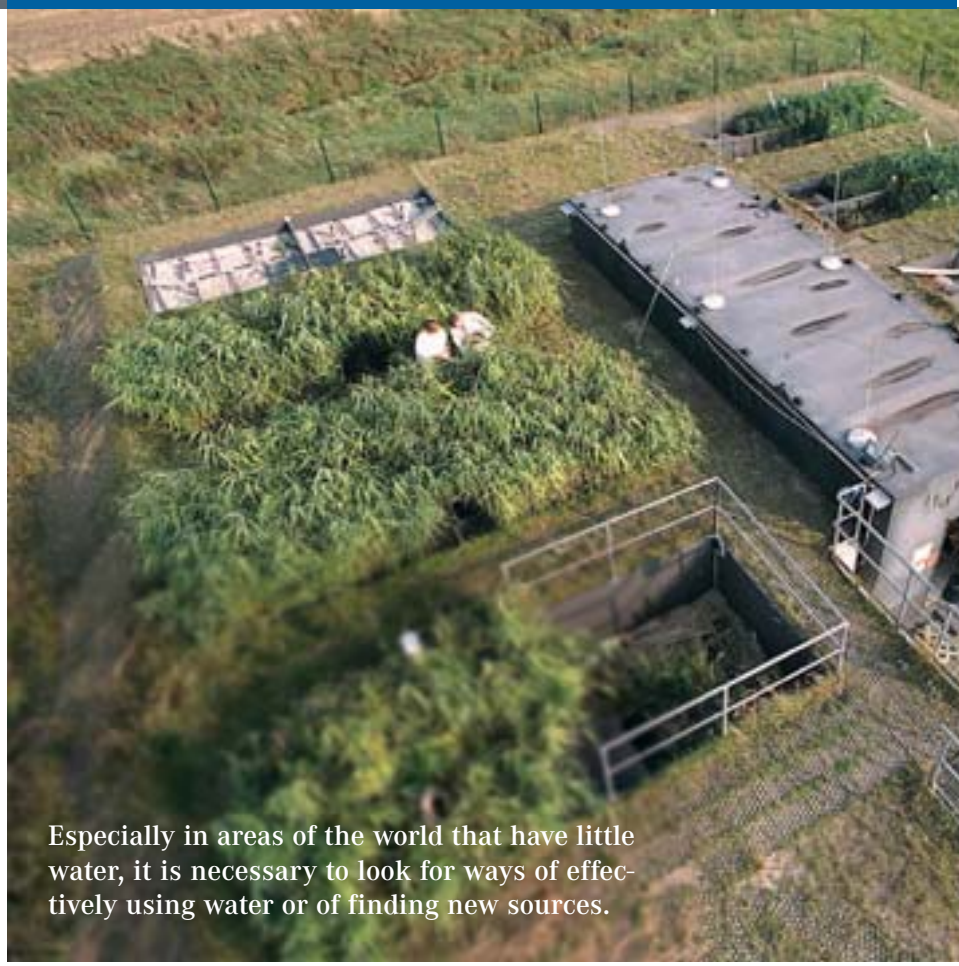
Biogeochemistry is an interdisciplinary system science that covers chemical, biological and physical processes, primarily the flows of substances in eco-systems and landscapes. These include, for example, the carbon, nitrogen or phosphate cycles.

From basic research to the application

The development of technologies is regarded at the UFZ as a complex task – one that is being carried out in collaboration with the Helmholtz research centres at Karlsruhe and Jülich - that ranges from an analysis of the problem up to the search for ideas and basic research and then on to implementation on a pilot scale or, if applicable, all the way up to practical testing in field use. There are scientists from the disciplines of chemistry, physics, biology and microbiology, geology, together with various forms of engineering and systems analysis. Their goal is both to gain knowledge and to obtain experience from actual practical action, whereby one

Photo: Robert Köhler, UFZ

Colloids (the picture shows finely ground activated charcoal) involve microscopically fine particles of a size of the order of 1 to 1000 microns. They play a major role in many biological and technical processes because they have a very large surface in comparison with their mass. Due to their small size, usually a liquid is used as a carrier medium (suspension) for colloids.



Especially in areas of the world that have little water, it is necessary to look for ways of effectively using water or of finding new sources.

without the other cannot be regarded as a satisfactory solution as a rule. The people who are addressed by the results of the research are the international scientific and engineering world together with the European environmental industry or the relevant responsible official authorities in Germany. The technologies are intended to satisfy the needs of both densely populated conurbations and rural areas of settlement with a decentralised infrastructure. The international experience of scientists, arising from collaboration arrangements with China, Taiwan, Brazil, Mexico and Turkey, also helps in adapting biological processes to other climatic conditions.

At the UFZ the scientists concentrate on four main topics concerning the treatment of water: environmental catalysis, rhizosphere processes, the use of radio waves and microwaves, and the production and application of active colloids. Two of these topics, environmental catalysis and the use of radio waves, are to be illustrated in more detail in the following articles. For this reason the basic concepts behind the two other topics are covered here.

Back to the roots

Chemists, biologists and process engineers at the UFZ work to make use of rhizosphere processes – areas involving the space around the roots of plants – in an intelligent way in order to clean up contaminated water. Here it is first of all necessary to recognise and to understand the biological processes of building up and breaking down that take place in the layer of soil between the roots of the plants and the microorganisms. Given this knowledge, it is then possible to control processes in a specific way, to combine them in a meaningful way, and to put them to practical use. A convenient control variable for the interaction within the "plant-microorganisms" community and the utilisation of the various substances is provided by the demand for oxygen and oxidants, such as nitrates and sulphates, in their capacity as the so-called electron acceptors. The scientists thus produce reducing or oxidising conditions in soil areas that are penetrated by roots and investigate how these affect the breakdown of pollutants.

Water and wastewater problems frequently occur in rural regions or in those that are characterised by a lack of water. Precisely in such cases it would be a good idea to make use of domestic and industrial waste water as a "new" water resource, but it needs to be cleaned to make this possible. For that reason these methods should be tested and used above all at locations with a decentralised infrastructure and in countries of the Third World

USEFUL INFORMATION

Humins are natural organic macromolecules that are formed by the breakdown of the residues of plants in the soil (humus). Sources for the production of humins are turf and geologically young brown coals

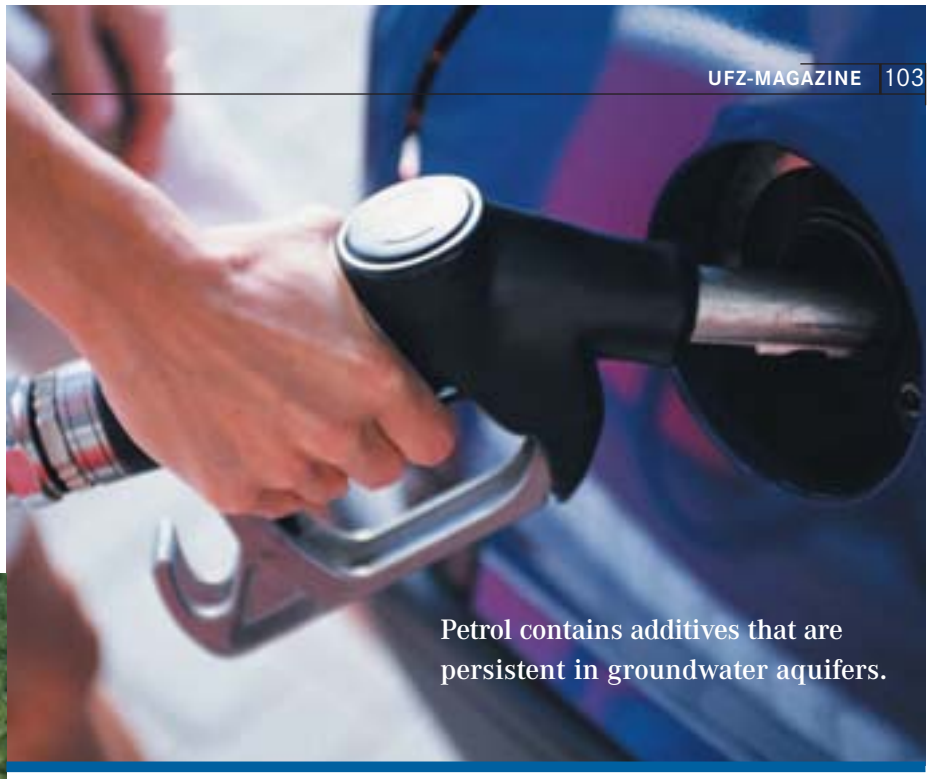


Photo: Photodisc Environmental Concerns

Petrol contains additives that are persistent in groundwater aquifers.

with various forms of soil filters being planted, i.e. as simple plant-based water treatment and cleaning units.

Small particles with a big effect

If contaminated groundwater is to be cleaned directly in the groundwater aquifer, it is necessary to mix a number of substances in such a way that they can react with one another. This is a difficult task that scientists wish to solve with so-called colloids. The pollutants and reaction partners are "collected" with these microscopically small particles that are to be introduced into the groundwater aquifer in the form of colloidal suspensions. Then, depending on their properties and the environmental conditions, the colloids can dock onto natural materials of the groundwater aquifer and so form a barrier that acts like a filter. When it passes this barrier, the pollutants in the groundwater are adsorbed, meaning that they are docked on, or else broken down. The UFZ is concentrating on colloids made from ecologically harmless materials: activated charcoal, iron and humic substances.

USEFUL INFORMATION

A **groundwater aquifer** is a rock formation with void spaces that is suitable to store and transport groundwater. There are three types of groundwater aquifer: porous groundwater aquifers are made up of loose or solid rock whose pore spaces allow groundwater to flow through them; creviced groundwater aquifers consist of solid rock that allows groundwater to flow through them through crevices and cracks in the rock; karst groundwater aquifers consist of weathered water-permeable carbonate rocks. A groundwater aquifer is delineated geologically by layers such as clays that are impermeable to water.

Surveying the groundwater is important when it comes to finding sources of potable water and regarding the effect of mines on groundwater.

Let loose into the air

A completely new way of tackling pollutants is based on the fact that the self-cleaning potential of various environmental areas is not the same for various pollutants. For example: methyl tertiary butyl ether (MTBE), which is used as an additive in petrol (see the article on page 23), is very difficult to break down in the groundwater. Its half-life is of the order of years. However, MTBE decomposes very rapidly in the atmosphere due to photochemical processes. Here its half-life is only of the order of about five days. Thus if MTBE is blown out of the groundwater, which in this case is the less reactive area, at relatively low technical cost and difficulty into the atmosphere, which is the more reactive area, you admittedly have the disadvantage of additional pollution of the atmosphere. However, this is only for a limited time. The advantages are that you save money, time and resources with this relatively simple procedure and so prevent the insidiously growing danger entailed by MTBE in the groundwater. What sounds simple is in fact a complex task in individual cases, since the assessment and weighing of the pros and cons requires close collaboration between scientists, economists and environmental lawyers. Precisely this is a special strength of the research at the UFZ and in the Helmholtz community. ■

PROF. FRANK-DIETER KOPINKE, A CHEMIST, HEADS THE ENVIRONMENTAL TECHNOLOGY DEPARTMENT AT THE UFZ.

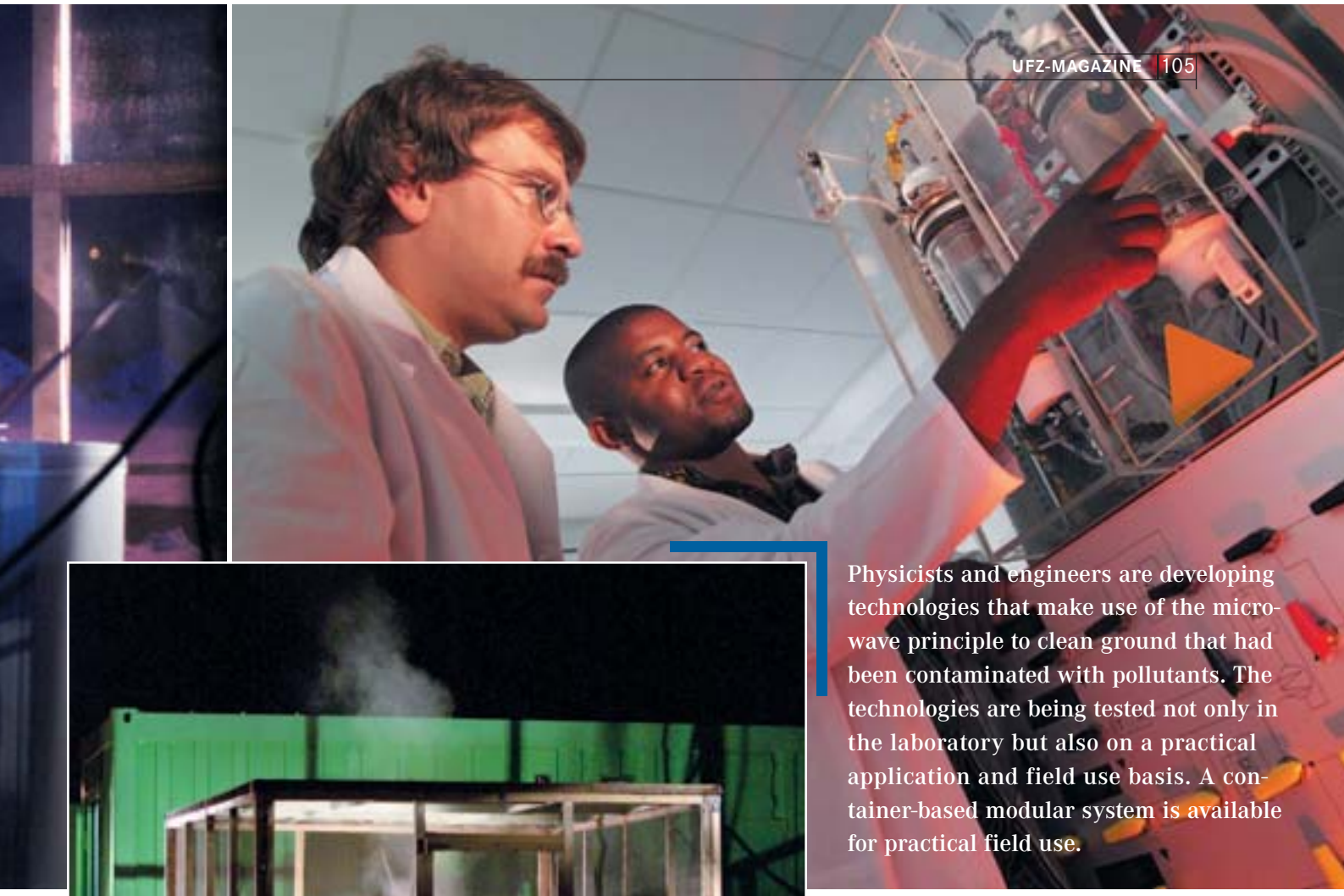
Licence to heat the ground

Ulf Roland and Tilo Arnhold

In practically all areas of life the temperature plays a decisive role – both for natural processes as well as for technical ones. While the heating of liquid media can be handled very well from a technical point of view, there is a need for in situ procedures that allow an even and easily controllable warming of solids. The problem is that solids, such as soil, can only be mixed with great difficulty, and their effective thermal conductivity is frequently very low. However, pollutants can be broken down in a significantly shorter time and sucked out with the ground air by raising the temperature in the ground. Microorganisms also like it warm, since the optimum temperature range for them to eliminate pollutants is 30 to 40 degrees Celsius. An established technical method to heat packed beds is through the use of hot air or steam. However, this has the disadvantage that the rigid linking of the gas flow and the amount of heat to be transferred often does not allow the desired concentrations of the substance to be reached.

The long or short of it?

In recent years direct heating procedures have been developed as highly promising alternatives, not bound to the flow of a substance. Warming with microwaves has established itself in everyday use. This is based on the interaction of an electrical alternating field with molecular dipoles such as water within the medium. You can find the corresponding microwave devices in practically every household. However, microwave heating has some crucial disadvantages for many technical processes. On the one hand, the microwave radiation can often only penetrate a few centimetres into the material to be warmed, with the result that larger quantities cannot be heated evenly. On the other hand, the use of energy is not efficient with many materials because a large amount of the energy that has been beamed in is then reflected away. Physicists, chemists and engineers at the UFZ have developed an alternative heating procedure that is based on the use of radio waves and have tested it in various areas. It combines the advantages of microwave heating, such as the direct input of the energy into the medium, with the possibility of heating in a more



Physicists and engineers are developing technologies that make use of the microwave principle to clean ground that had been contaminated with pollutants. The technologies are being tested not only in the laboratory but also on a practical application and field use basis. A container-based modular system is available for practical field use.

homogeneous way due to the markedly greater depth of penetration. In addition, the energy can be input almost without any losses into a large variety of media. It can therefore be used for, among other things, dry and damp soil, activated charcoal or catalysts. The solution lies in the shifting of the frequency range from the GHz range to the MHz range, or in other words, from relatively short to long waves.

Success in the field

Due to its high degree of relevance to environmental and process technology, this particular technology has been tested on activated charcoal, silicate minerals and various types of soil in the laboratory and in practical application in the field. This included a number of successful field tests to implement thermally-supported extraction of the ground air, thermally-supported microbial cleaning of the ground, and the targeted warming of sources of pollutants at various reference locations. A container-based modular system has been made available in the interim for applications on a technical scale, this having all the components for a thermal treatment of soil and other solids built into it. A first licence agreement to make use of the technology has been made. However, there is a considerable application potential for radio wave technology in more than just the various procedures for cleaning up. It is also of interest for chemical process technology. Radio waves allow in principle the selective heating of individual components in a packed bed, which opens up completely new perspectives for established technical processes.

USEFUL INFORMATION

Radio waves are electromagnetic waves such as those used in broadcasting. From a physical point of view, electromagnetic waves involve oscillations of an electromagnetic field that is disseminated, this being made up of an electrical component and a magnetic component. These properties are used to transmit data or energy. Electromagnetic waves are divided into various ranges of wavelength. The shorter the wavelength, the higher the frequency, and hence the number of cycles at which the wave oscillates.

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Katrin Mackenzie and Tilo Arnhold

Adapting and customising

Frequently it was “chemistry” that contaminated the groundwater, for example, under industrial locations – but chemistry can also cure the problem. The reaction conditions for the cleaning of water are, however, stipulated by nature and are generally unfavourable for a chemical form of treatment. Warming up large amounts of water is simply not feasible from an economic point of view. Consequently, the temperature cannot be used as a parameter to control the speed of the reaction. There is a further hurdle in the form of the concentrations of the pollutants. Even low concentrations of a few milligrams or micrograms per litre can be dangerous for humans but concentrations of this level are often too low for effective chemical reactions. Furthermore, the spectrum of chemicals involved in each case of pollution is generally complex. The treatment methods should therefore be capable of being applied simultaneously to various classes of substances. In environmental chemistry catalysts are therefore an indispensable tool to allow chemical reactions to be completed quickly and selectively.

Selecting the right strategy in a responsible manner

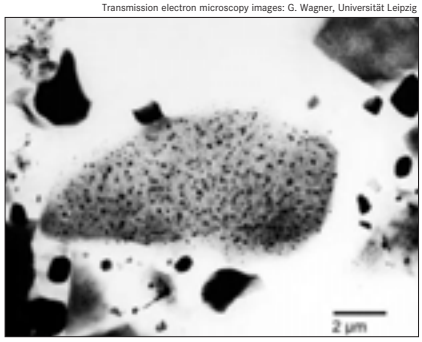
Which chemical reactions are available and where do the problems crop up? Organic pollutants can be oxidised, preferably to carbon dioxide and water. Reduction also comes into consideration for the detoxification of water with certain classes of pollutants such as chlorinated hydrocarbons (CHCs). Both types of reactions have advantages and disadvantages. An incomplete chemical conversion of the pollutants can actually increase the toxicity of the water instead of reducing it. For example, an incomplete oxidation of organic phenols also produces the well-known dibenzodioxins and furanes that are related to the poisons which were released at Seveso. For this reason, oxidative forms of treatment are regarded critically when it comes to the treatment of CHCs. Depending on the type of contaminant in each particular instance, it is necessary to choose the appropriate treatment strategy in a responsible manner.

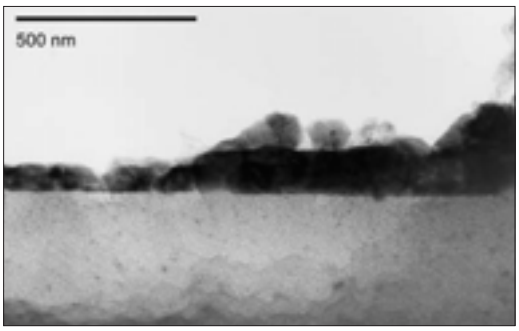
The adaptation of known reactions and catalysts to the relevant environmental conditions represents the current challenge for the development of catalytic procedures that will function in practice.

The UFZ is exploring several ways to reach this goal as part of the “environmental catalysis” project. Pollutants can be enriched by adsorption on catalytic

substrates such as activated charcoal such that their chemical conversion is carried out in an adsorbed state. The pollutants on the catalytic substrate – and hence close to the location of the reaction – are "collected" and thus the water is purified. The chemical conversion into harmless by-products is then carried out at the catalytically active centre. Adsorption and chemical reaction should thus work together. However, the adsorbed substances should not only be taken out of the water but must also be made available for the chemical reaction. For this purpose scientists must find or develop from scratch adsorption reaction systems for reductive and oxidative catalytic procedures.

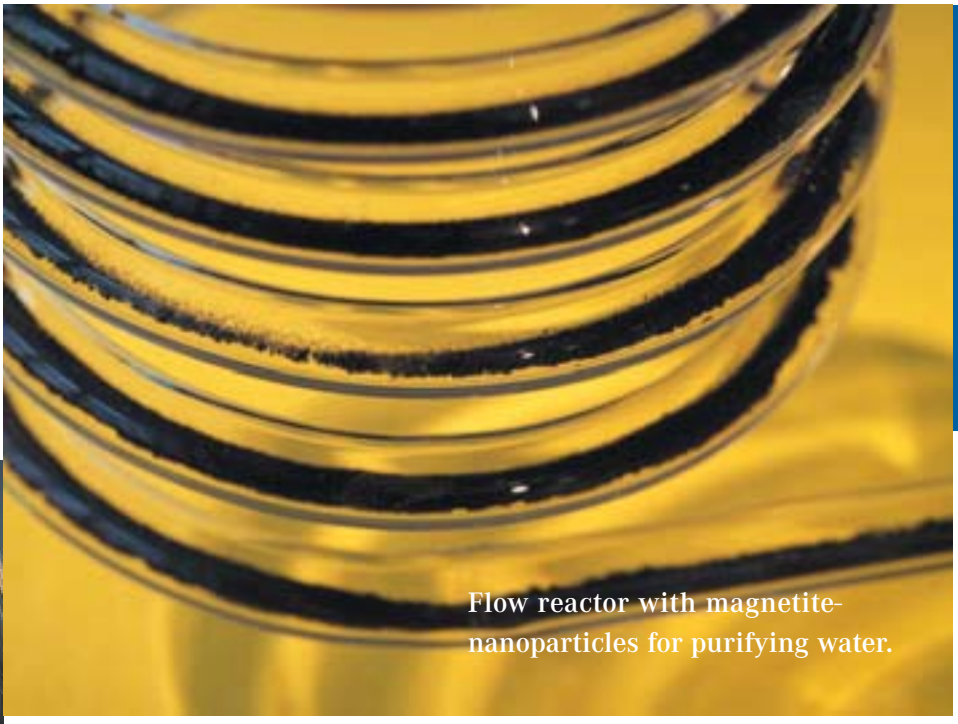
Transmission electron microscopy images: G. Wagner, Universität Leipzig





Activated charcoal particles under the electron microscope

The picture on the left shows larger iron crystallites (black) and small nanoparticles on activated charcoal (middle of the picture). The picture on the right shows a cross-section through a particle of activated charcoal and metallic iron that has been separated out.



Flow reactor with magnetite-nanoparticles for purifying water.

USEFUL INFORMATION

Chlorinated hydrocarbons is the collective term for organic compounds containing chlorine. Chlorinated hydrocarbons are regarded as basic materials in the chemical industry.

Both new and old, well-proven methods

The use of nanoreagents and nanocatalysts is a completely new direction in environmental technology. Nanotechnology has thus made an entry into the environmental sector. For example, nanoparticles of metallic iron, so-called iron colloids, have already been used successfully to purify groundwater. Chemists and process engineers are testing a variety of different nanocatalysts, on the one hand in adsorption reaction systems that are to be used to clean up groundwater in situ, and on the other hand for special applications in the treatment of waste water using extremely active palladium catalysts on ferromagnetic carrier colloids that can then later be separated elegantly from the purified water with the aid of permanent magnets. In this case a study of the risks of this process, such as potential penetration into cell walls and possible unwanted effects produced by these microscopic particles in living cells, is also essential. This question is being tackled in close cooperation with cell toxicologists at the UFZ.

However, the use of old and proven technologies is also indispensable in the search for suitable methods of treatment for contaminated water. A possible way to improve the reaction conditions for environmental catalysis is to transfer the highly diluted volatile pollutants from the "unfavourable" water phase to the "favourable" gas phase. Many organic compounds are highly concentrated in the gas phase when they are blown out with air – a so-called stripping process – which makes treatment of the pollutant-laden streams of gas at higher temperatures economically feasible. If stripping is combined with the heterogeneously catalysed gas phase reaction, this then greatly extends the range of possible applications for catalysis in water purification.

Adapting and customising – these are the keys to effective chemical processes in environmental technology. ■

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Creating a sustaina and catalysi

Microbiologists, biotechnologists, chemists and engineers at the UFZ are researching potential microorganisms to use them in a targeted way for biosynthesis and biotransformation processes. They wish to find new ways to create valuable materials and active agents. For example, they are developing methods to modify yeasts genetically in such a way that that they can produce the modules for industrial chemical processes from renewable raw materials. Or they are studying the thermodynamics of biological systems so that they can better predict the behaviour of biocatalysts.

ACTING SPEAKER ON THE RESEARCH TOPIC “SUSTAINABLE SYNTHESIS AND CATALYSIS”:
DR. BEATE STREHLITZ, A SCIENTIFIC STAFF MEMBER AT THE ENVIRONMENTAL AND BIOTECHNOLOGY CENTRE (UBZ).

able synthesis
is

Spinning gold from straw P. 110
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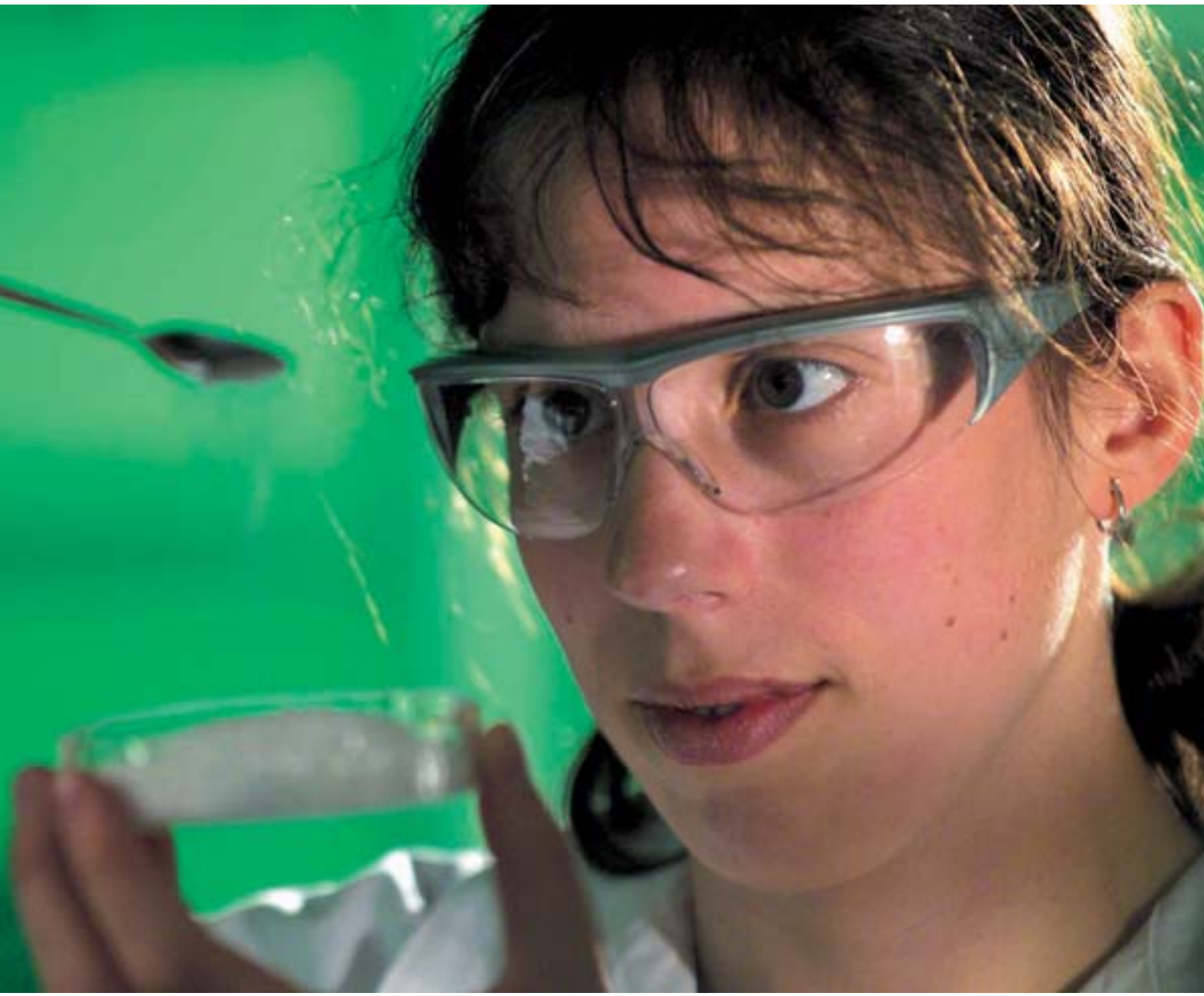
Sour from sweet P. 116

Beate Strehlitz and Doris Böhme

Spinning gold from straw

Everybody knows the fairy tale of Rumpelstiltskin and the pretty miller's daughter, whose promise to spin straw into gold nearly sealed her fate. Johann Friedrich Böttger had promised the king of Saxony, Augustus the Strong, that he could make gold out of base metal. Of course he did not succeed. Nonetheless, today he is regarded as the joint inventor of porcelain, which is also called white gold, because it was rated on the same level as silver and gold in terms of value. While "white biotechnology" – a branch of environmental biotechnology – does not have the aim of producing gold, it has developed methods that allow, for example, certain fine chemicals to be produced from waste and which in themselves are more expensive than gold. The tools for this, the so-called biocatalysts, are provided by nature. Finding and improving them, understanding how they function, developing procedures, optimising and controlling them to manufacture important products in an environmentally-friendly way – these are all tasks that are being tackled by environmental biotechnologists at the UFZ.



Biotechnological processes are interesting alternatives to chemical, physical and mechanical processes for both economic and ecological reasons. Chemical processes are often associated with high pressures, high temperatures, environmentally-damaging solvents or catalysts containing heavy metals and not inconsiderable quantities of waste, which to some extent is toxic. Biotechnological processes, on the other hand, work with highly selective and efficient biocatalysts. These are polymer biomolecules, without which life would be unthinkable, since they make possible the biochemical reactions and physiological processes in living forms that are necessary for life. Since they themselves come unchanged out of the reactions, they can always be used again and again. If a biocatalyst is made up of a chain of amino acids, it then belongs to the substance class of proteins and is described functionally as an enzyme.

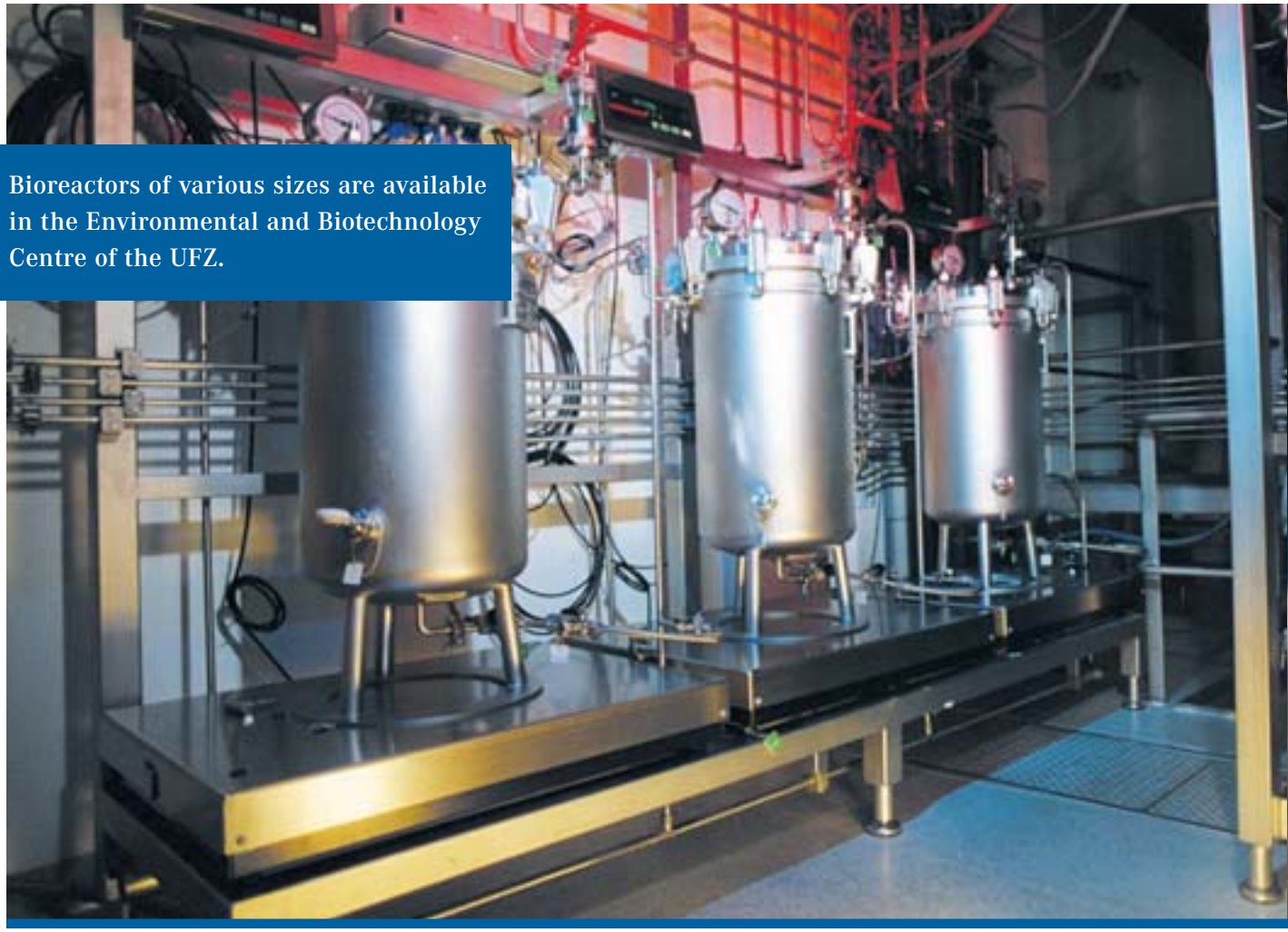
As a rule, microorganisms and enzymes work under normal conditions and in aqueous media, and use natural raw materials or even waste as substrates for catalytic processes. Biocatalytic processes generally require fewer process steps than corresponding chemical processes. The processing steps to extract the pure products can be integrated into the process. These are many benefits which biotechnologists wish to better understand and make use of.

Coming clean

The proportion of chemical products manufactured by biotechnological processes is still only around 5%. In the McKinsey study on the "Contribution of biotechnology to the chemical industry", experts came to the conclusion that we can reckon with an increase in this figure up to 10 or 20% by the year 2010 – and the tendency is for the proportion to grow. The importance of White Biotechnology is also growing together with the dramatic increases in the price of oil since they can help to shift many chemical processes that are based on oil over to others that use different raw materials, such as renewable ones, for example. But branches of industry, such as food, textiles, cosmetics and paper, are also looking hard for new, more competitive and more environmentally-friendly procedures and products. To take just one example, the use of enzymes in washing processes in the textiles industry or in detergents gives the same results while reducing the amount of energy and water required by up to 50%.

The cleaning of wastewater by the use of bacteria or the utilisation of raw materials from renewable sources are likewise fields of application in biotechnology. Products, such as biodiesel and bioplastic, are already well known and have a very promising career ahead of them.

Scientists at the UFZ are also aiming to develop products and processes that place less strain on the environment and can compete in economic terms with conventional solutions. They do this by researching phenomena and details that start off in basic research and cover investigations on a technical scale. The required technical infrastructure in the form of bioreactors of various sizes is available to them in the Environmental and Biotechnology Centre (UBZ) of the UFZ. Thus, for example, they are developing and optimising procedures for the manufacture of organic acids such as citric acid, isocitric acid or ketoglutaric acid, products for the food industry or so-called modules for chemical syntheses. Other products that are of interest to business are biopolymers and protector molecules. Biopolymers have similar characteristics to the chemically produced PVC or polyethylene polymers that are widely known everywhere, but in contrast to their chemical cousins they are biologically degradable. Protector molecules are sugars that also exist in nature and are produced by microorganisms. As the name implies, protector molecules have a protective function. They stabilise living materials such as microorganisms. For that reason scientists are attempting to isolate and make use of these protector molecules.



Bioreactors of various sizes are available in the Environmental and Biotechnology Centre of the UFZ.

Little and large helpers

The basis of biotechnological processes is, on the one hand, renewable resources and agricultural leftover and waste materials which can be used as substrates – in other words, as sources of energy or food for microorganisms. On the other hand, high-performance biocatalysts are required to do the work and convert the substrate into the desired products. This is done by using, for example, extremophile bacteria that have been adapted accordingly to their environment, or "non-conventional yeasts". Since yeasts are not able to do this when still in their original state, they are genetically and phenotypically optimised by the UFZ microbiologists. They implant specific genes into the strains from the wild to allow them to make use of the substrates that are being offered.

However, the road to the final product is long and often not very effective. A further task of the scientists is thus to find out where and why the process hits snags and how to do away with these bottlenecks. However, not all parameters can be measured directly in the options that have been available commercially up to now. For that reason they are developing new methods for process control and optimisation, for example, biosensors for online control. Since microbiological processes are still associated with warmth, scientists measure temperature changes with the aid of so-called calorimetric processes which, in turn, provide information on the rate of growth of the microorganisms or the speed of conversion. A further method in modern biology that is used at the UFZ is flow cytometry. The behaviour of cells can be characterised by using it.

Biotechnology is a perfect case for interdisciplinary collaboration. New discoveries in genome research and system biology are leading to a deeper knowledge of the physiological and regulatory processes in microorganisms. They thus allow the targeted use of biological systems in biotechnological processes. However, this presupposes that chemists, microbiologists, genetic engineers, microbiologists, computer scientists and process engineers can work together closely. ■

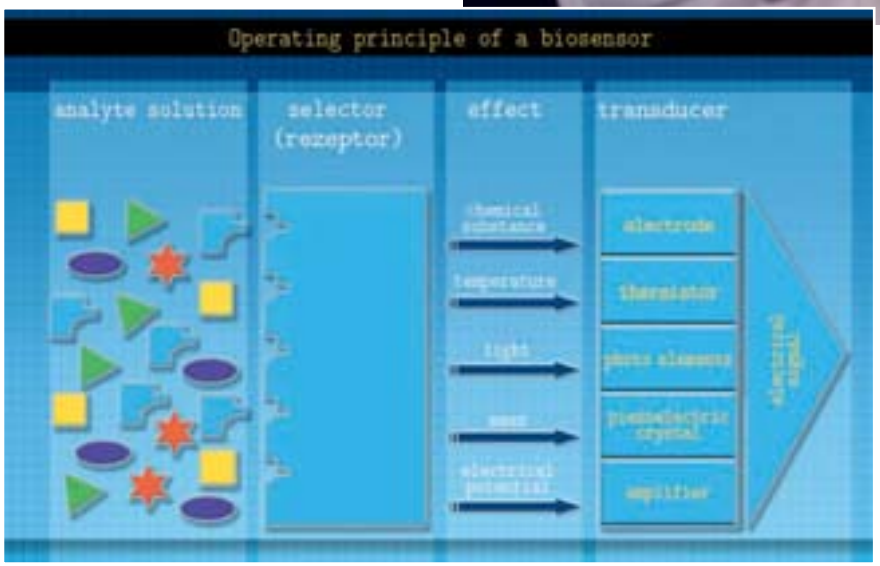
DR. BEATE STREHLITZ IS A SCIENTIFIC MEMBER OF STAFF AT THE ENVIRONMENTAL AND BIOTECHNOLOGY CENTRE (UBZ).

Scientists at the UFZ intend developing products and processes that have less adverse effects on the environment.

Regina Stoltenburg, Beate Strehlitz and Doris Böhme

If it doesn't fit, it is mad

Anyone who has a diabetic in the family or is a diabetic himself very likely knows what a device to measure blood sugar levels is. The test strips that are used to measure the concentration of sugar in the blood of the diabetic are called biosensors in scientific jargon. They are based on biological receptors. This means that a biological component – for example, an enzyme or microorganism – works interactively with the analyte to be measured. This produces physio-chemical changes in the biosensor that are translated into a signal that can be measured by means of a signal converter, a transducer. Subsequently, the starting state of the measuring system is restored. Biosensors find application in particular in cases where the parameters being searched for either cannot be measured directly by conventional chemical analysis or only with great effort and difficulty. They are highly selective and sensitive, and can



be used several times, require no elaborate preparation of samples as opposed to most chemical analysis methods, and do not create any toxic waste. Since they are simple to handle, biosensors have advanced into many areas: apart from clinical chemistry or medicine, they are also used in food and environmental analysis as well as for process control in pharmaceuticals and biotechnology.

The needle in the haystack

However, up to now for many parameters which you would like to measure

e to fit

Handheld multi-analysis device - the test strip is nothing other than a biosensor, which was developed by the Leipzig-based company Senslab.

Fruit juice producers need to deal with the problem of the formation of lactic acid as part of their quality control. Special biosensors allow the production and storage processes to be more efficient and secure.

quickly, easily and if at all possible on site there have not been any biological receptors that have been suitable for application in biosensors. For that reason UFZ scientists have been developing so-called DNA aptamers, which purely theoretically could be found to suit any molecule. This works in roughly the same way as searching for a needle in a haystack. Structures matching the target molecule are "searched for" for an artificially produced library of around 10^{15} different oligonucleotides with a length of from 50 to 150 bases. This figure of 10^{15} different oligonucleotides is an unimaginably large number of 10 million times 100 million. This means that the variety of structures available is also huge and you can be quite sure that among them there are a number of oligonucleotides that match the target molecule closely. Nevertheless, how can you find the right aptamers? Using the SELEX process (Systematic Evolution of Ligands by Exponential Enrichment), in which the molecules that match most closely – meaning those that have a certain affinity for the target molecule and so to speak feel themselves attracted to the target molecule – are searched for step by step. The procedure has been modified by the UFZ in such a way that it is now possible to develop aptamers according to the needs or wishes of users. Scientists at the UFZ have developed aptamers for streptavidin and ethanolamine, for example, with their FluMag SELEX. Streptavidin is important for test systems in immunology and molecular diagnostics, since it has a strong affinity for biotin. Consequently, it is used for coupling processes to fix molecules onto surfaces. Biotin plays an important role in the metabolism of fats and sugars and is also called vitamin H or B7. Ethanolamine is a substance that is enriched and normally decomposed in the body, in the pancreas or the liver. People lacking the necessary enzyme suffer from the rare hereditary illness ethanolaminosis, which has been discussed as a possible cause of death in children. The UFZ researchers are also searching for aptamers to provide proof of moulds and neurodegenerative ailments. Here they are working together with partners from the University of Leipzig and from industry.

DR. BEATE STREHLITZ IS A SCIENTIFIC MEMBER OF STAFF AT THE ENVIRONMENTAL AND BIOTECHNOLOGY CENTRE (UBZ).
DR. REGINA STOLTENBURG, A MICROBIOLOGIST, IS A SCIENTIFIC MEMBER OF STAFF AT THE UBZ.

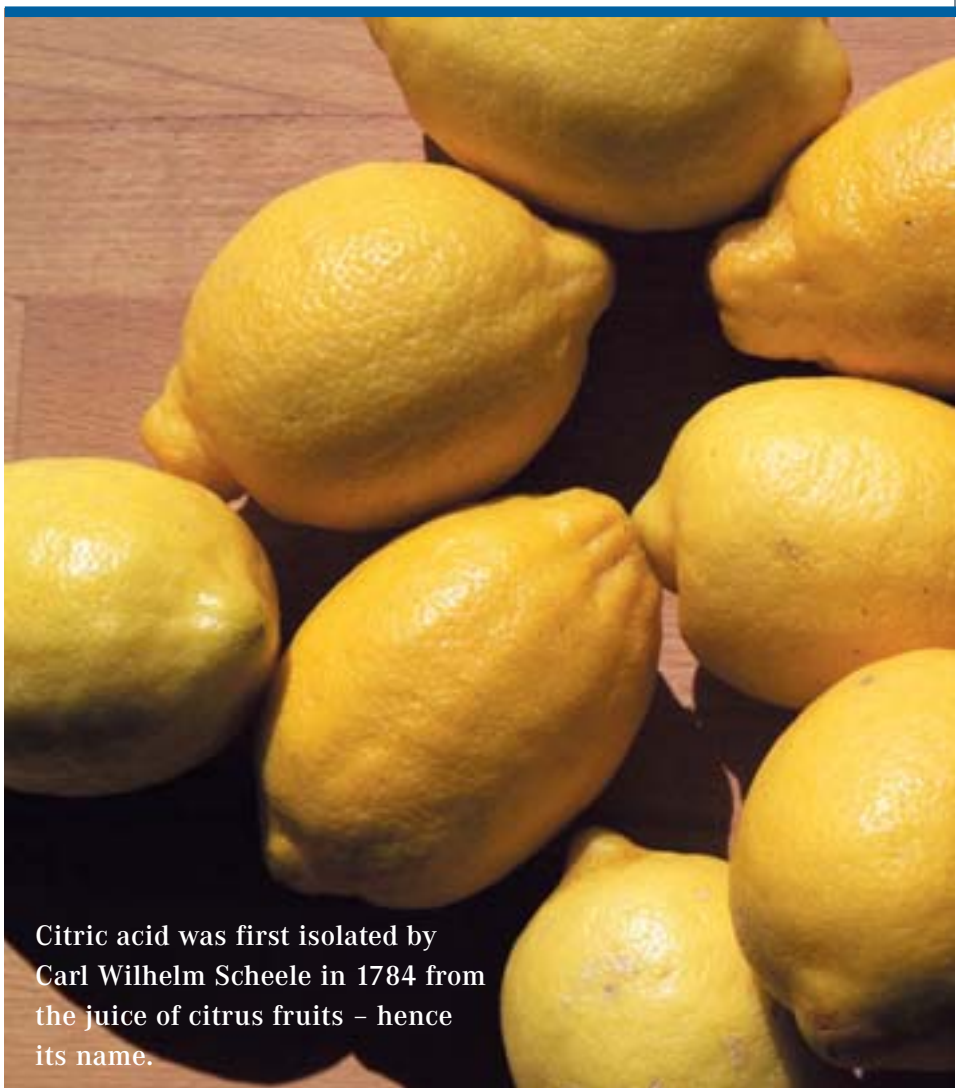
Lucie Moeller, Andreas Zehnsdorf, Andreas Aurich and Doris Böhme

Sour from sweet

We encounter citric acid almost every day. It can be found in all organisms as a product of metabolism. It occurs in apples, pears, raspberries, in coniferous trees, mushrooms and fungi, in wine and even in milk. We encounter it in an everyday context as a constituent of sweets, drinks, detergents and limescale removers or as an additive used in so-called tooth-whitening toothpastes. In the pharmaceutical industry it is used as a means to prevent the blood clotting in blood for transfusion. At the moment around a million tons of citric acid are produced worldwide every year, and an increase in the sales volume of 3.5 to 4% has been forecast in the coming years.

Citric acid was first isolated by Carl Wilhelm Scheele in 1784 from the juice of citrus fruits – hence its name. Lemon juice contains around 5 to 7% citric acid. Up until around 1920 it was solely produced from lemons, although it had already been known at the beginning of the 19th Century that certain moulds could produce citric acid. The first patent for the production of citric acid from sugar containing waste such as molasses by the mould *Aspergillus niger* was applied for in the USA in 1913.

This efficient biotechnological process has been used up to the present day. The disadvantage: the procedure that consists of a great many stages produces in addition to wastewater contaminated with heavy metals large amounts of heavily contaminated gypsum that cannot be used in any way and so needs to be disposed of. For that reason citric acid is not produced currently in Germany and needs to be imported.



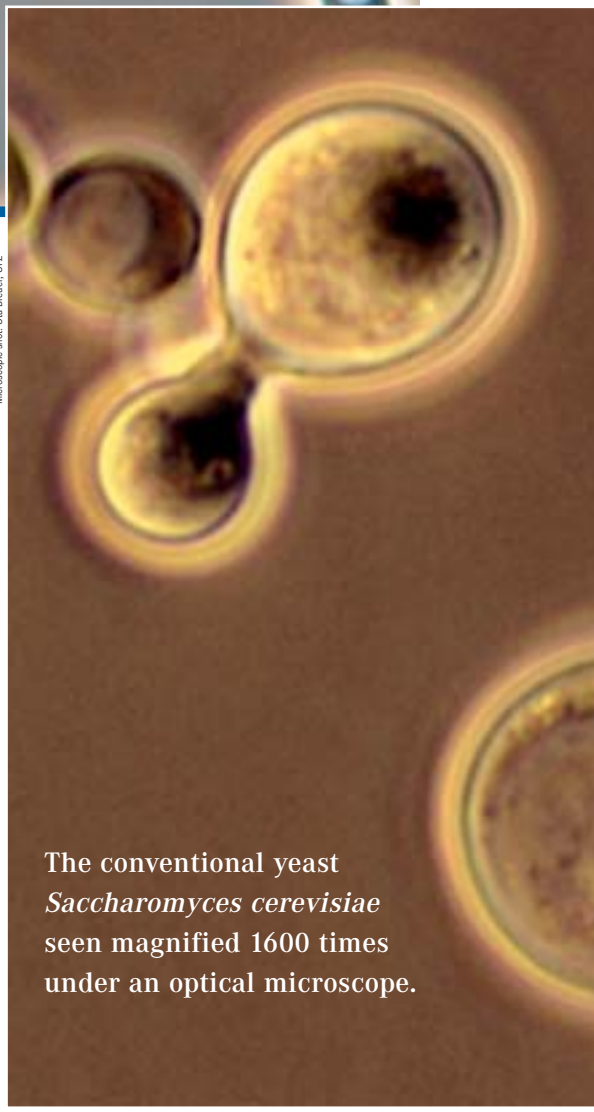
Citric acid was first isolated by Carl Wilhelm Scheele in 1784 from the juice of citrus fruits – hence its name.

Be more friendly, please!

A more environmentally-friendly method uses the yeast *Yarrowia lipolytica*, since less wastewater and no gypsum is required thanks to the use of clean raw

Microscopic shot: Andreas Aurich, UFZ

The wild strains of *Yarrowia lipolytica* yeast forming the citrate when growing on glucose.



Microscopic shot: Uta Breuer, UFZ

The conventional yeast *Saccharomyces cerevisiae* seen magnified 1600 times under an optical microscope.

materials and closed process circuits. Scientists in Leipzig had been researching back in the 1970s and 80s the production of citric acid by using *Y. lipolytica* from n-alkanes. Today, renewable raw materials, such as plant oils or glucose, are used as substrates for this process. Working in conjunction with the Institute for Microbiology of the University of Dresden, scientists at the UFZ are primarily concentrating on the strains of the yeast *Y. lipolytica* that have the best properties regarding the formation of citric acid. These have been genetically modified in such a way that they can also convert sucrose, which we know as table sugar. The unmodified wild strains cannot do this because they are lacking the enzyme that is required. The goal of UFZ scientists is to optimise the procedure so as to increase the quality of the citric acid and the efficiency of the process so that the procedure can be used on an industrial scale. But how can the product formation and substrate breakdown processes be monitored as they occur, both quickly and cost-effectively? For example, by using biosensors as quasi-online measuring systems. With the aid of a biological system consisting of enzymes or cells (see also article on p. 114), the substrates, by-products and the product itself can be identified and quantified.

An interdisciplinary scientific team is working on optimising the process for the Yarrowia procedure. Microbiologists are responsible for the modification of the yeasts, biotechnologists and engineers supervise the cultivation and process control in the bioreactors of the Environmental and Biotechnology Centre (UBZ), chemists and biologists provide the required measuring systems on the basis of biosensors, and microbiologists and chemists investigate and analyse the by-products and products of the intermediate reactions that can arise under various experimental conditions.

In the industrial world it is always easiest to make a change in a manufacturing procedure if the demand for the product exceeds the capacity of the plants that produce it or if the existing plants need to be renewed. From this perspective it is conceivable that the established but highly polluting *Aspergillus* procedure will be replaced in stages by the environmentally-friendly *Yarrowia* procedure – and thus allow the manufacture of citric acid to return to Germany. ■

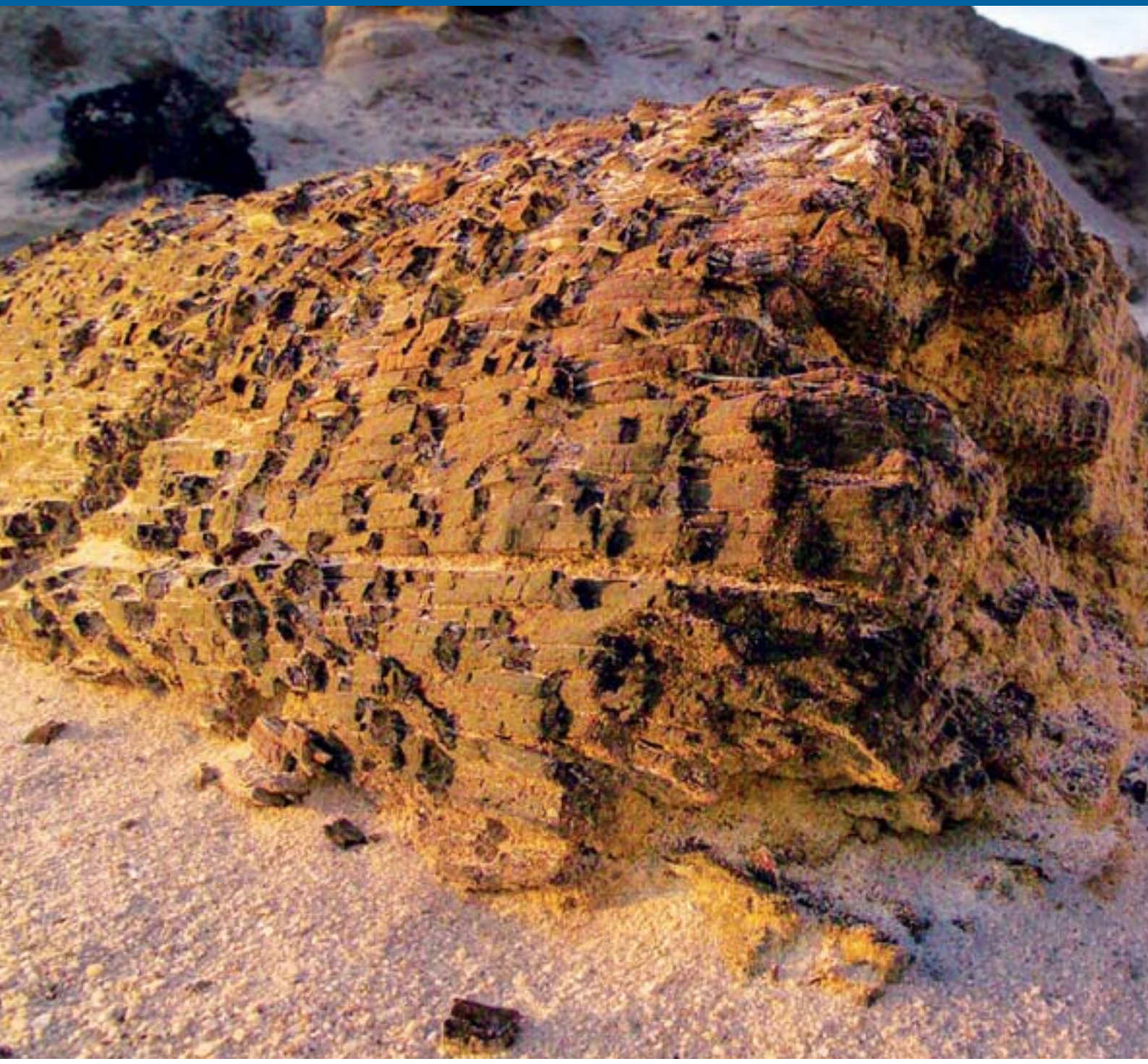
USEFUL INFORMATION

Glucose is a simple sugar (monosaccharide) with the formula $C_6H_{12}O_6$. Sucrose is the scientific name for table sugar. The double sugar (disaccharide) consists of one molecule of glucose and fructose (fruit sugar) respectively and has the formula $C_{12}H_{22}O_{11}$.

LUCIE MOELLER IS WORKING FOR HER DOCTORATE AT THE UBZ.

DR. ANDREAS ZEHNSDORF AND DR. ANDREAS AURICH, BIOTECHNOLOGISTS, ARE SCIENTIFIC MEMBERS OF STAFF AT THE UBZ.

Comparing climatic space and throug



trends across h time

Climatic archives – learning for the future from the past P. 120
When will the next Ice Age come? P. 124
Trees never forget P. 126

Climatic changes are a significant factor for the dynamics of landscapes. Isotope researchers and geoscientists at the UFZ are therefore analysing lake sediments and the annual growth rings of trees with the aid of isotope methods so as to be able to reconstruct the climate of key regions such as northern and western Europe, for example, and for selected important time windows. This covers periods of time ranging from a few months up to thousands of years. In order to find out how climatic changes have affected the hydrology of continents, South American and Japanese lakes have been included in the long-distance research work.

SPEAKER ON THE RESEARCH TOPIC "COMPARING CLIMATIC TRENDS ACROSS SPACE AND THROUGH TIME"
DR. STEPHAN WEISE, HEAD OF DEPARTMENT FOR ISOTOPE HYDROLOGY

Stephan Weise, Tatjana Böttger, Walter Geller and Tilo Arnhold

Climatic archive learning for the fu from the past

We have been experiencing an increasing degree of global warming for some decades now. This means, in all probability, desertification, a rise in the sea level to the extent that we can say even now that some island states will disappear in the foreseeable future, and extreme climatic events such as hurricanes and typhoons of a size not experienced before will devastate wide areas of land and make hundreds of thousands of people homeless. Processes, both on a local scale as well as globally, must be understood in order to be able to take useful steps. Predictions of changes have been possible for some years on the basis of elaborate computer models. However, the value of the results they give depends entirely on an understanding of the processes and trends that determine the climate. Thus if new calculations always seem to add yet more confusion, then this is also due to the fact that our knowledge of climatic history and thus the scientific basis for these climatic models still has many gaps in it that are slowly being closed. The climate is undoubtedly one of the most complex “machines” that man has ever had to deal with.

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The memory of our planet

Information on the climatic conditions at the time of their creation can be found in, for example, sediments from oceans and lakes or the annual growth rings of trees. The trick is to be able to decipher this information. Many specialists such as geologists, botanists, dendrochronologists, isotope chemists or archaeologists are needed to understand this climate puzzle because the picture can only been seen once all the many parts of the puzzle have been put together.

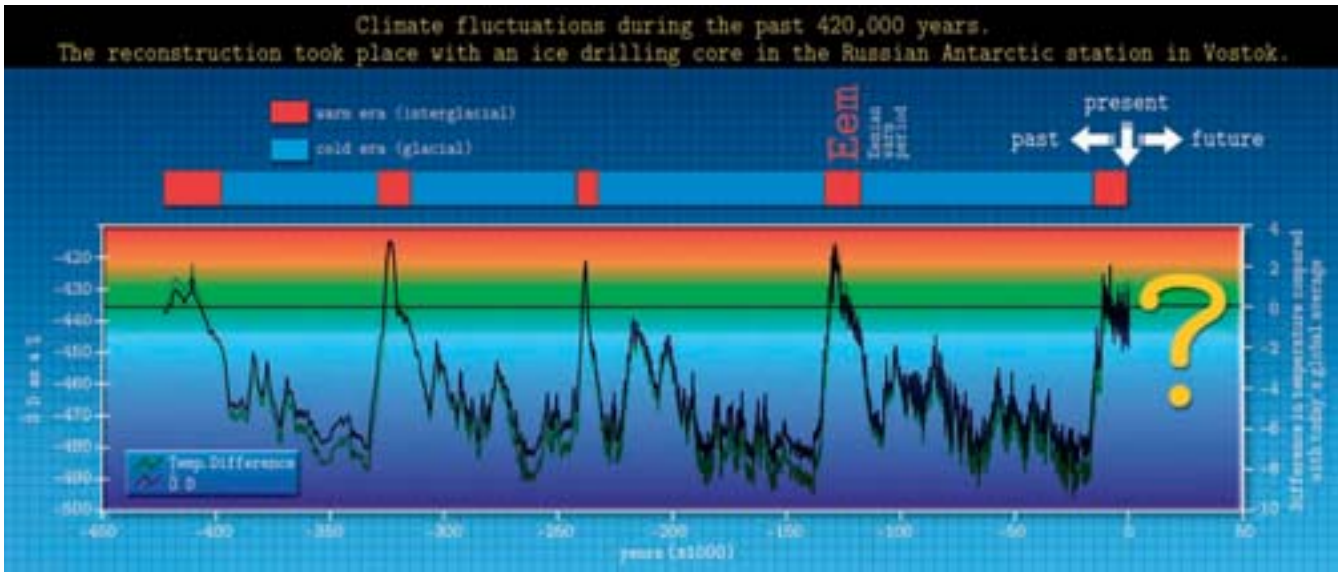
The results show that, even without the influence of man, nature in the past experienced climatic changes that went far beyond any of the events of the past few decades and what has been predicted so far for the next hundred years. It is therefore important to try to understand this "natural experiment" of the past so as to learn how to correctly assess the present climatic trends. For that reason hydrologists, isotope researchers and geoscientists at the UFZ are researching in collaboration with the GeoForschungsZentrum Potsdam (GFZ) and the Forschungszentrum Jülich [Research Centre Jülich] the climatic relationships in the course of various phases within around the past 140,000 years by investigating tree material and sediment cores from lakes. Within this time span there are two warm periods, the so-called Eemian that occurred around 120,000 years ago, and the present Holocene that has lasted for around 10,000 years, plus several cold periods.

Old trees and new methods

The increase in the level of carbon dioxide in the atmosphere that is harming the climate is regarded as the major contribution of mankind to climatic change. A cause of this has been the burning of fossil sources of energy. But it is precisely this that could indirectly help us to understand the history of our climate, because many climatic archives have come to light in Germany as a result of the search for lignite. Important places for investigation are connected with the names of open-cast coal mines such as Reichwalde in Lusatia and Groitzsch in the vicinity of Leipzig. Fossilised trees whose annual growth rings could be investigated with the modern isotope-based methods were found there. Thus isotope researchers at the UFZ,

Photo: Photodisc by Getty Images

Source: modified from Petit et al. (1999) Nature 399, 429-436



working in collaboration with the Saxon Academy of Sciences at Leipzig, have been able to track changes in the climate going back to the last warm era, the Eemian Interglacial, and even further back before that. At Reichwalde in Lusatia they found a "paleo-forest" that originated from the time of the transition phase from the last cold period up to the present-day Holocene warm period that has lasted around 10,000 years so far. The direct effects of the actions of man on his environment can be seen in trees that have been examined to compare the relative climatic information of pines from Reichwalde that are around 14,000 years old with those of the present time. It is possible to tell from the ratio of the stable carbon isotopes $^{12}C/^{13}C$ that the carbon balance of trees that are in the area of the exhaust gas plume of power stations burning lignite has evidently been greatly affected by the emissions of sulphur dioxide from these power stations. Possibly the isotope method can also be used for regional monitoring of the amount of pollutants.

Lakes as a mirror of the weather

Global climatic changes can have different consequences in different regions. For that reason reference objects from other regions were added for comparison with the areas being investigated in Germany. The continental climatic trends in connection with the Eemian warm period are being researched on the basis of lake sediments at locations in Poland and Russia along a European east-west transect.

The mechanisms of the changes in climate differ significantly between the continentally-dominated northern hemisphere of the Earth and the oceanically-dominated southern hemisphere. It is therefore important to take a look at the other side of the globe in order to be able to get a truly comprehensive understanding of climatic events. Sediments that had been obtained from core drillings from lake beds in Chile were used to make the comparison between the northern and southern hemispheres. On the basis of findings to date, it is possible to look back over at least the past 10,000 years with these sediment cores. The Chilean lakes were also investigated together with Argentinean lakes so as to observe current climatic changes as well. They run like a string of pearls along the Andes in a north-south direction and represent the entire spectrum of temperate zones.

Due to their special properties, the main focus of investigation of the UFZ lake

USEFUL INFORMATION

It is possible to track the climate in Europe on a regional basis back to the last Ice Age around 16,000 years ago with the aid of tree rings, which faithfully reproduce seasonal climatic variations in their structure. Modern techniques based on stable isotopes are the basis of this research.

Photo: Photodisc Environmental Concerns

researchers in Magdeburg has been the so-called warm-monomictic lakes of the northern and southern hemispheres. Since these do not form a covering of ice there, the water of the lakes is mixed completely once a year in the form of full circulation. The temperatures of the deeper waters thus correspond to the temperatures of the entire water column and the end of the period of full circulation in late winter. The temperatures in the depths are influenced less by short-term changes arising from current weather conditions as the lake gets deeper. In a number of lakes in Europe that have been investigated over a large number of years, such as Lake Constance, the lakes of central Switzerland and the Italian lakes at the foot of the Alps, increases in the temperatures in the depths have been found and correlated with one another. The course of climatic oscillations, such as those of the Gulf Stream in the north Atlantic and of El Niño in the south Pacific, can also be observed directly through the progression of these temperatures over many years. ■

DR. STEPHAN WEISE, A PHYSICIST, HEADS THE DEPARTMENT OF ISOTOPE HYDROLOGY.
PROF. WALTER GELLER, A BIOLOGIST, HEADS THE DEPARTMENTS OF LAKE RESEARCH AND RIVER ECOLOGY (THE LATTER ON A TEMPORARY BASIS ONLY).

Sediment core drilling at Caviahue in Argentina.

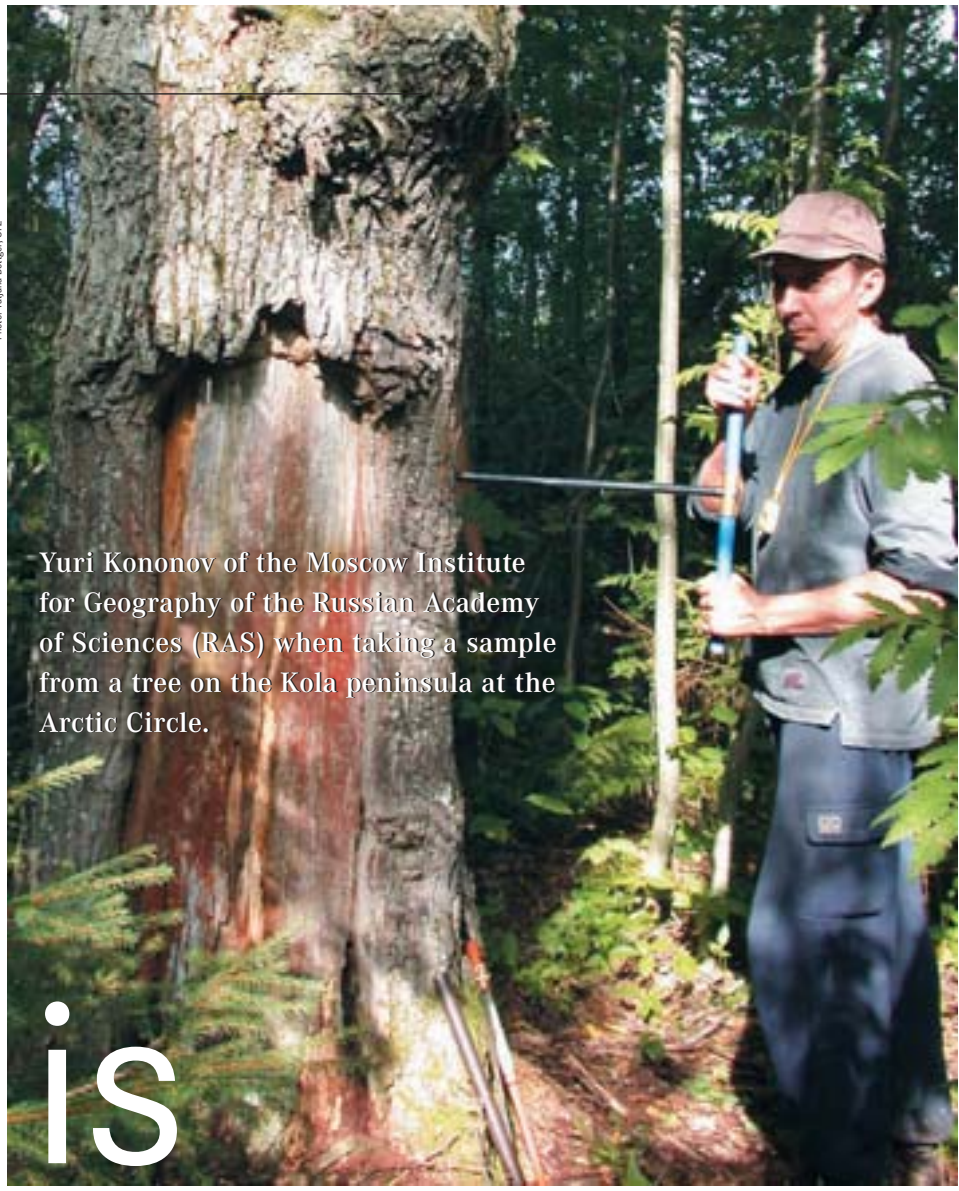


Photo: Tatjana Böttger, UFZ

Yuri Kononov of the Moscow Institute for Geography of the Russian Academy of Sciences (RAS) when taking a sample from a tree on the Kola peninsula at the Arctic Circle.

Tatjana Böttger and Tilo Arnhold

When is the next Ice Age coming?

What took place around 118,000 years must have been dramatic indeed. Within a short time the temperature dropped markedly. After that, the amount of precipitation was also reduced drastically as the temperatures fell. The broad-leaved trees such as linden trees disappeared. Central Europe became a cold steppe area very much like the Siberian tundra of today. The last warm period before the present warm era came to an end. This is proven by investigations of sediment cores from inland lakes ranging from the Eifel to Russia.

The work was carried out as part of the DEKLIM national climatic research programme in which the UFZ is participating. Drill cores from the Antarctic show that our Earth goes from a warm period to a cold period roughly every 100,000 years. In purely statistical terms we are probably “due” for another cold period, and hence falling temperatures should be the order of the day. But when does that happen and what are the first signs of it coming? Or will these natural effects be overlaid by the influence of man? What processes are responsible for this?

European ISONET network.
Red indicates the sites under investigation by UFZ.

Isotopes – the key to the past

Up to now it has only been clear that the climate became unstable before it changed radically and temperatures plummeted. Smaller variations could therefore point to a larger collapse. For that reason the climatic history of Europe in the past 400 years has been examined more closely. This period also includes the so-called "little Ice Age" in the 17th century. Apart from written records, there are also still a large number of old trees from that time that have objectively stored information on the weather. The main focus of the ISONET EU project are studies on pines and oaks, since they are typical and widely distributed types of deciduous and coniferous trees. For the first time a uniform network makes it possible to systematically investigate the influence of regional environmental conditions on the ratios of the stable isotopes in the annual growth rings and so to reconstruct the climatic changes on a European scale. The isotopes of carbon, oxygen and hydrogen that are of various masses follow the laws of physics: they are taken up at different rates into the biomass according to the temperature and amount of rainfall. A search is being made in the annual growth rings of trees from Scandinavia to the Mediterranean and from the Iberian peninsula to the Alps for signs left by the various climatic conditions. This is done by extracting the tree ring cellulose in the laboratory and analysing it in a mass spectrometer to determine the ratios of the isotopes. The data for the past 100 years is especially important because it can be compared with the meteorological data obtained with the instruments of that time. These calibrations are more complicated, but they are the key to reconstructing with the aid of still older trees those climatic phases from times when people did not keep detailed weather records. It is therefore a question of sharpening the tools so as to get more precise results. In the meantime the UFZ has become the standard laboratory for all ISONET partners.

The UFZ researchers have already found some interesting results; the tree growth rings from the Kola peninsula on the Russian-Finnish border are the most sensitive indicator for the range of the Gulf Stream. Temperature variations can be observed most clearly here at the extreme end of the heat pump that characterises the climate in Europe. It is necessary to investigate key regions such as these in order to understand the climate pattern better. The results will help to interpret the changes of the past 400 years and so allow more accurate forecasts to be made for the future. ■

DR. TATJANA BÖTTGER, AN ISOTOPE CHEMIST, IS A SCIENTIFIC WORKER IN THE ISOTOPE HYDROLOGY DEPARTMENT.

USEFUL INFORMATION

Isotopes and the climate – Isotopes of a chemical element are atoms that differ in their mass but not in their chemical properties. For example, with carbon there are the two stable isotopes ^{12}C and ^{13}C that only differ from one another by an extra neutron in the atomic core of ^{13}C. However, the difference in mass becomes visible in all kinds of processes such as the metabolism of trees: carbon dioxide (CO_2) with the lighter carbon isotope is taken up for preference in photosynthesis, whereby the degree of preference depends to a certain extent on climatic factors such as the temperature, air humidity and the CO_2 content of the atmosphere. Since this dependency is not 100%, the isotopes can only make relative statements. They are therefore called climate proxies, besides other indicators.

The fossilised trunk of a coniferous tree (*Doliostroboxylon priscum*) in the open-cast coal mine of the Groitzsch triangle. The find is around 37 million years old. At that time there was a river delta there. The wood was well preserved in the sand because air was wholly excluded.

Tatjana Böttger and Tilo Arnhold

Trees never forget

The late glacial era is still a mystical epoch for researchers. During this transitional phase from cold to warm ended the glaciation of large parts of Europe and the forest came back. The Neanderthals had probably already died out several thousand years before this happened. Instead, it was now modern man that took possession of central Europe. The hunters and gatherers slowly settled down and began to tame animals. The agrarian age arrived. An example of how climatic change not only affects the appearance of the landscape but also human culture.

Photo: Stephan Weise, UFZ

Mummies

Normally dead wood rots relatively quickly. However, it is preserved if there is no oxygen because the wood is located under water, sand or a thick layer of earth. This is precisely what happened in the open-cast mine of Reichwalde in northern Upper Lusatia. There, many trees from the Allerød period – a warm phase in the late glacial time – have been well preserved underneath a layer of turf. Specialists from a number of different disciplines (archaeology, geology, dendrochronology, botany, ecology and isotope geochemistry) are working together in the “Reichwalde paleoforest” DFG project to investigate the late glacial landscape history with the individual phases of forest development and development of moors. The link to research on tree rings and sediments allows the climate to be reconstructed especially well here. Researchers have taken and evaluated about 3,000 samples. They have deduced from the residues of pollen and large remnants that there already was a

Photo: Stephan Weise, UFZ

Dr. Achim Brauer from the GFZ Potsdam working on the preparation of a sediment core from the Eemian period in the open-cast coal mine at Gröbern. This is a joint project of the Saxon Academy of Sciences at Leipzig (SAW), the GFZ Potsdam and the UFZ.

USEFUL INFORMATION

The **Allerød** is a short warm phase at the end of the first Ice Age before the Holocene warm period began. This climatic phase is named after a place in Denmark. During the Last Glacial Period Weichselian from around 115,000 to 14,000 years ago many parts of northern Europe were glaciated. At that time the ice extended all the way up to present-day Brandenburg. The most recent epoch on the history of the Earth began when the glaciers retreated and the breakthrough of the Atlantic into the Baltic occurred. This was the Holocene, a warm period that has lasted until today.

Between 1540 and 1850 there was a so-called Little Ice Age when it was, on average, 2 degrees Celsius colder than it is today.

birch-pine forest here around 14,000 years ago. The finds of trees in Reichwalde are of ones that pine forest grow in this region over a period of around 800 years. This gives a unique view into one of a major climatic warming of our planet. The researchers have identified stable phases, but also a number of disturbances in the development of the forest. These were due to temperature variations, dramatic changes in the groundwater, and forest fires, especially in late summer. As each season can be read from the growth rings of the tree, they give considerably more precise information than any other climatic archive. The properties of the annual growth rings give information on how well the tree was able to grow – in other words, whether the conditions were warm or cold, damp or dry. At that time the conditions in Upper Lusatia must have been similar to those we find today in northern Scandinavia. Later the forest turned into moorland again. The region had turned into tundra before the actual warm period began, around 400 years after the last tree find.

Living

The UFZ researchers also took samples from trees of today for comparison. Here they hit upon some surprising results, since the isotope signature of the pines has changed distinctly since the 1990s. There can only be one explanation for this. Old brown coal power stations were shut down or were equipped with filters around this time. The scientists have found a new way to monitor pollution. However, the discovery was not greeted with unreserved joy because this effect represents another risk factor for the measurements. The isotope signature is not only affected by temperature and humidity but also by pollutants in the air. And this makes it clear that it will be difficult in the near future as well to unlock the climatic information from the tree rings.

DR. TATJANA BÖTTGER, AN ISOTOPE CHEMIST, IS A SCIENTIFIC WORKER IN THE ISOTOPE HYDROLOGY DEPARTMENT.

Glossary

Sustainable urban development

Urbanisation is the concentration of a population in cities. Nowadays, half the population of the world and about 80 per cent of Europeans live in cities – and this trend is on the rise.

Reurbanisation means the reutilisation and further utilisation of inner city residential areas on the basis of specific housing requirements corresponding to the various needs of different household types. It is carried out by encouraging people to move within the city or to return to it from areas just outside it.

Microcontaminants are impurities that are present in very low concentrations (nanogrammes or microgrammes) per litre. They can enter our environment through e.g. sewage systems. Examples include the ingredients of medicines, bodycare products (deodorants and scents), biocides and a wide variety of industrial chemicals.

Modelling is undertaken by means of abstracting, i.e. by simplifying and generalising reality. In so far as it imitates a model, it does not necessarily have to be made in a solid three dimensional form; it can also appear as an abstract mental operation. Using a model can help us to reach conclusions that have general validity

Simulation models are special models where the object, content and mode of representation are constructed for the purposes of simulation. Particular features of the system are modelled which are important in order to solve a certain problem. In urban development this can be e.g. age structure, land use or the number of people employed. By contrast, other features which are of less importance to the immediate question are ignored.

Managing contaminated soil and groundwater

Cometabolism is the biological degradation of substances where microorganisms require additional substrates as an energy source. Mineralisation into carbon dioxide and water is not generally caused by cometabolism.

Organisms that require pure oxygen for life are defined as aerobes or as **aerobic** (from the Greek aer or air). Organisms that require no oxygen or that can even be inhibited or killed by it are defined as anaerobes or **anaerobic**.

NGO stands for non-governmental organisation, i.e. an amalgamation of individuals constituted for a particular period of time that is not profit oriented and either independent of, or not organised by, any branches of the state, and which is involved on a voluntary basis in areas such as social work, environmental protection, animal welfare, free educational work or human rights.

WHO is the abbreviation for The World Health Organisation, a United Nations body that has its headquarters in Geneva in Switzerland. It was founded on 7th April 1948 and has 192 countries among its members. It is the coordinating authority for the United Nations and international public health bodies.

Remediation and using mining lakes on a long-term basis

Eutrophication is the increase in a water body's biological productivity that is based on photosynthesis and the consequences that arise from this increase. It is caused by an excessive supply of plant nutrients (phosphorus and nitrogen from sewage and farming). After dying, the biomass produced by this increasingly growing biotic community sinks to the bottom of the lake and consumes oxygen as it decays. If oxygen consumption exceeds oxygen reserves in the deep waters of a lake fish begin to die and the lake can be said to reach a "tipping point".

Enclosure refers to separate tube-shaped areas in lakes where scientists can test remediation methods on a small scale before using them on the entire lake

LMBV (Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft mbH) This state-owned company was founded in 1994 to remediate the areas impacted by brown coal mines and brown coal processing plants in East Germany. Remediation activities are financed by the federal government, regional states and by the Federal Agency for Employment

Anoxic describes a stratum of water that contains no dissolved oxygen. Many microorganisms use nitrates, iron (III) or sulphates in these strata to break down and live off organic material

Using microbiological diversity for the environment and health

Microorganisms (also microbes) are organisms that are not normally visible to the naked eye. In their broadest definition they include, among other organisms, bacteria, algae, fungi and protozoa.

Decomposition refers to the breakdown or reconstruction of organic molecules. Typically this involves breaking down organic compounds containing inorganic substances such as carbon dioxide and water. In water and in soil biological disintegration is primarily carried out by microorganisms (especially bacteria and fungi). Aerobic decomposition (with oxygen) is distinguished from anaerobic (without oxygen).

DNA is the abbreviation for deoxyribonucleic acid (sometimes written as DNS in German), a macromolecule. It carries the codes that are vital for heredity transmission and which determine how proteins are constructed. DNA consists of two molecular chains that wind about each other in a spiral form (the "double helix"). A gene is a section of a DNA molecule.

Arsenic is a semi-metal that occurs everywhere in the environment and consequently also in organisms. However, arsenic is principally known for its toxic qualities, not least due to its role in crime novels. Acute arsenic poisoning results in sickness, vomiting and, within a few hours, severe diarrohea. Death is then normally caused by the resulting loss of electrolytes and water. It can also cause kidney failure. If consumed regularly small doses of arsenic can also cause health problems. Discolouration of the skin can be observed in cases of chronic arsenic poisoning, and this can lead to tumours. Disorders to the nerve tracts can also result, manifesting themselves in lack of sensation in the skin and incidents of paralysis Those afflicted complain of headaches, difficulty in concentrating, weakness and exhaustion, as well as muscular degeneration. Though arsenic (or more precisely arsenic trioxide) remains a popular murder weapon in crime novels, it has actually been long out of use. In exhumed bodies the poison remains detectable for a long time after death

Biofilm It is estimated that in nature 90 percent of all microorganisms are associated with the outer layers of substances where they form biofilms or microbic communities. Such outer layers can be the surfaces of hard materials, the meniscus separating oil and water or even the surfaces of bodies of water. Biofilms can vary in thickness, from a few micrometres to several centimetres.

Uncovering environmentally-related health problems

atopic dermatitis is a skin disease where the main symptoms are red, flaking eczema of the skin that sometimes also produces a discharge, and an often unbearable itching. Its other common names are **neurodermitis** and endogenous eczema. Neurodermitis is thought to be incurable, although it can be treated. It can appear at any age of life.

Exposure is the medical term for the body's degree of exposure to environmental factors, especially harmful ones. For example, a passive smoker is exposed to cigarette smoke.

Protection and regeneration of water resources

Suspension refers to a suspension of very fine particles in a liquid. Depending on the size of the particles in them, suspensions can remain stable for long periods of time and/or demulsify relatively quickly by depositing - sedimenting - these particles.

Humic substances are naturally occurring macromolecules that form when plant remains decompose in soil (humus). Sources for the extraction of humic substances are peat and young brown coal.

Electron acceptor (electron receiver) is an atom, molecule or ion that is capable of absorbing electrons. This process is also called reduction; the electron acceptor is also known as the oxidising agent.

in-situ / ex-situ In-situ procedures refer to clean-up procedures where contaminated soil or groundwater is removed directly at the site of the contamination. By contrast, in ex-situ procedures the contaminated material is transported and treated elsewhere.

Biotic is the term used for those environmental factors where organisms are recognisably involved. By contrast, abiotic environmental factors are those in which no organisms are involved – for example subterranean geology, atmosphere, light, temperature or heat. The distinction between these and biotic factors is rarely hard and fast.

In chemistry, **phenols** refer to aromatic compounds consisting of a benzene ring and one or several hydroxyl groups attached to it.

Oxidation is a chemical reaction. In this process the substance being oxidised transmits electrons to the oxidising agent. The latter is reduced by electron absorption (reduction). Reduction is therefore always linked to oxidation.

In **Adsorption** atoms or molecules from a gas or a liquid are deposited on the inner surface of an adsorbent (e.g. activated or gas-absorbing coal). Related to this process is absorption, where atoms or molecules are released into the open volume of a substance.

Chlorinated hydrocarbons (CHCs) are a collective term for organic compounds that contain chlorine. Chlorinated hydrocarbons are used as basic materials in the chemical industry.

Stripping This process is used in the petroleum industry and in chemistry to distil highly volatile water components such as ammonia or organic solvents. The properties of the stripping materials are decisive factors, such as e.g. their vapour pressure.

Creating a sustainable synthesis and catalysis

An **oligonucleotide** is a molecule that is made up of a few (=oligo) nucleotides. A **nucleotide** is the smallest module in nucleic acids and is also used in genetic codes. The giant molecules DNA and RNA are made up of five different types of nucleotides in total.

An **enzyme** is a protein that acts as a catalyst to chemical reactions and regulates the metabolic process of all living organisms. For example, the enzyme pepsin is responsible for digestion, while invertase can break down sucrose into glucose and fructose.

An organism's **phenotype** is its outward appearance or form.

Alkanes are a group of simple hydrocarbons where the atoms do not form multiple compounds. They consist only of the elements carbon (C) and hydrogen (H).
The simplest alkane is methane (CH_4).

Comparing climatic trends across space and through time

The **Eemian** was the last interglacial period before the present one. It lasted for about 11,000 years and is named after the river Eem in Holland. During this climactic period, which occurred between about 128,000 to 115,000 years ago, the temperature was on average 5 degrees warmer than it is today, a fact vividly attested to by the bush elephant found near Gröbern (Germany). At the end of it, the mixed forest of Central Europe was replaced by tundra.

The **Allerød** is a short phase of less than 1,000 years that took place at the end of the Last Ice Age, shortly before the Holocene warm period began. This phase, named after the Danish town of Allerød, marked the end of the Weichselian glaciation of about 115,000 to 14,000 years ago, when large parts of northern Europe were covered by an ice sheet. At that time ice extended from Scandinavia to present day Brandenburg.

The **Holocene** is the most recent period of geological history - a warm period lasting from about 10,000 years ago until the present day. It began with the retreat of the ice sheet from central Sweden and the linking up of the Baltic Sea with the Atlantic Ocean. The rising temperatures caused an increase in sea levels by about 120 metres. The British Isles were separated from the continent and the Mediterranean linked up with the Black Sea at the Bosphorus (straits of water at Istanbul), causing parts of the Black Sea to flood – a modern explanation for the legend of the Flood

The **Little Ice Age** is a colder phase that took place within the last 1000 years of the Holocene Period. Between about 1540 and 1850 it was on average almost two degrees colder than it is today. The frozen canals in the paintings of Dutch masters give testimony to this. Since the middle of the 19th century, the beginning of industrialisation, temperatures have begun to rise again.

Paleoclimatology is a branch of climate research that is concerned with reconstructing climate history. It makes use of a variety of climate records, including tree rings (see dendrochronology), corals, mussels, sediments and ice cores.

Dendrochronology (Greek for 'tree' and 'time') is the science of dating tree rings. Back in the last century during the Twenties scientists began measuring the width and number of tree rings to gain information about the age of the wood and the climactic conditions in which it grew. The best known record is Hohenheim tree ring calendar which documents over 12,000 uninterrupted years. Over the last 20 years this procedure has been broadened by isotope research.

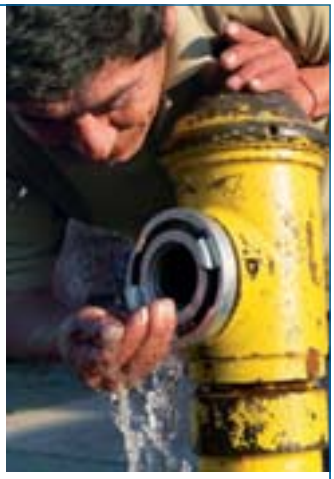
DEKLIM is the acronym for German Climate Research Programme. It was founded in 2001 with the aim of reaching a better understanding of the climate system so that strategies for action on climate change could be developed.

The **DFG** is the abbreviation for the German Research Association. It is the central funding organisation for research in Germany and is financed by the Federal Government and the states.

Warm monomictic lakes are lakes where the entire body of water circulates only once a year (in winter). They are to be found in temperate maritime climates and in mountainous or subtropical regions. Lake Constance is an example of this kind of lake.

Sediments i.e. deposits on the bottoms of lakes or seas provide information about climate history. For example, they contain the remains of plants or ashes from volcanic eruptions. By studying and measuring these, inferences can be drawn about the climactic and environmental conditions prevailing at that time of sediment formation.



PEER - An Environmental Partnership for a Sustainable Society

In 2001, with the aim of developing and expanding the "European environmental research area", leading European environmental research centres set up the **Partnership for European Environmental Research (PEER)**. Seven centres with around 4,700 staff work together and with many other partners throughout Europe to find solutions to complex environmental problems. Key research themes are:

- Halting the loss of biodiversity
- Solving global water problems
- Assessing the risk of pollutants
- Sustaining multifunctional landscapes
- Adapting to the impacts of climate change
- Developing Earth observation systems for sustainability
- Seeking for promising new technologies

The work is based on interdisciplinary approaches to environmental research and combining knowledge from natural sciences and humanities. PEER aims to develop joint strategies in European environmental research; to support national, European and international policy; to enhance the competitiveness of European environmental research; to promote staff exchanges and training of young scientists; to make joint use of infrastructure; and to harmonise, plan and undertake research projects on a long-term basis.

The PEER members are:

Alterra, Netherlands
Cemagref, France
CEH, the Centre for Ecology and Hydrology, United Kingdom
NERI, the National Environmental Research Institute, Denmark
SYKE, the Finnish Environmental Institute, Finland
IES, the Institute for Environment and Sustainability of the Joint Research Centre of the European Commission in Ispra, Italy
UFZ, the Helmholtz Centre for Environmental Research, Germany

More information: www.peer-environment.eu • secretary@peer-environment.eu

PEER | Partnership for European Environmental Research

The UFZ was founded in 1991. It employs around 830 people at its locations in Leipzig (04318 / Permoserstraße 15), Halle/Saale (06120 / Theodor-Lieser-Straße 4) and Magdeburg (39114 / Brückstraße 3a). The UFZ receives 90 per cent of its funding from the Federal Ministry for Education and Research (BMBF), five per cent from the Ministry of Science for the state of Saxony, and five per cent from the Ministry of Culture for the state of Saxony-Anhalt. **The new name of the UFZ is: Helmholtz Centre for Environmental Research - UFZ.**

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