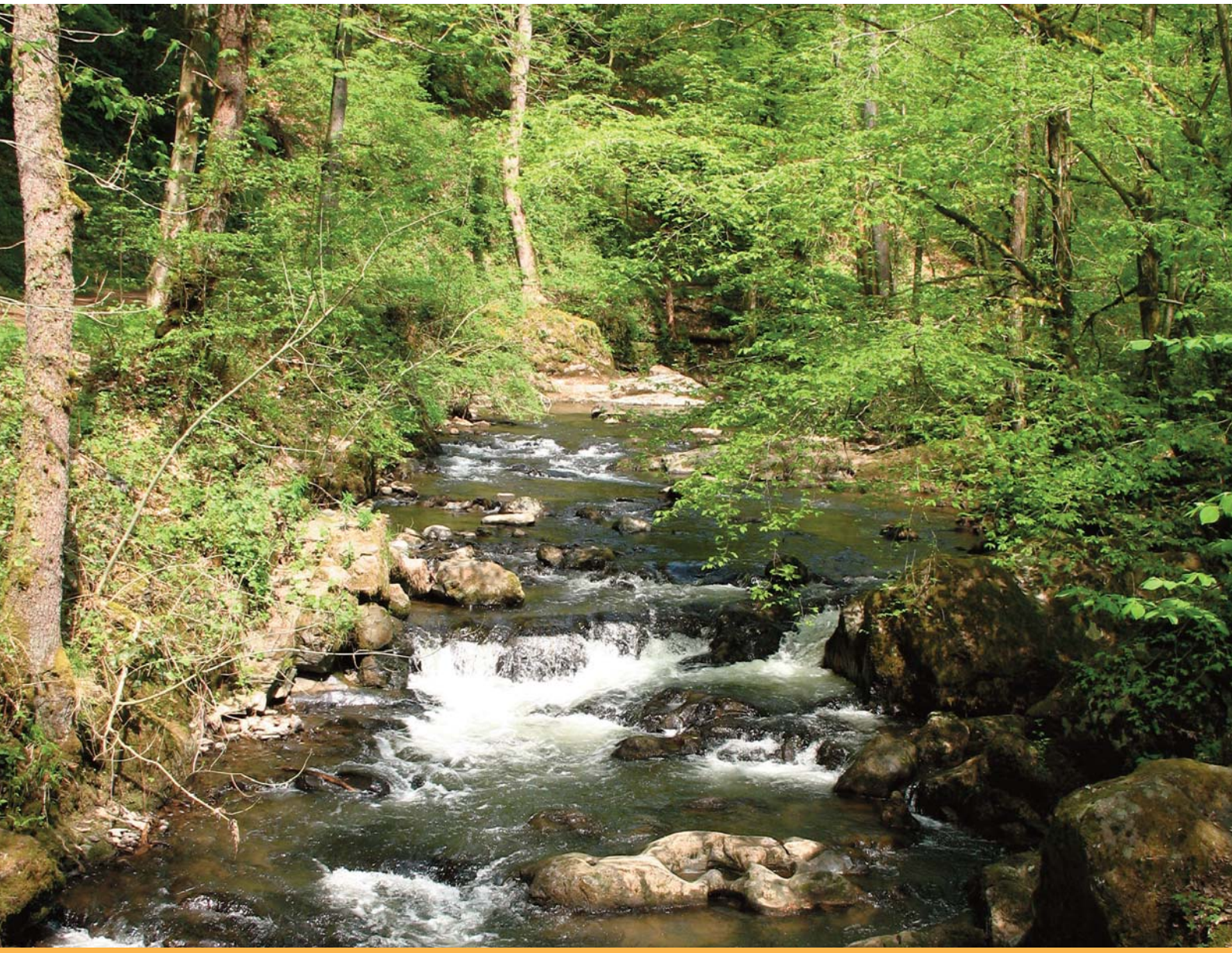
Federal Ministry
of Education
and Research

Water as a resource

Water research for a sustainable future



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Water as a resource

Water research for a sustainable future

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Water as a resource is one of the key factors in global sustainable development. Its protection is one of the most important tasks of the 21st century. Together with various players from politics and economics, those in water research are working on future-oriented solutions while simultaneously contributing to securing the wellbeing of the generations of today and tomorrow.

An accessible version of the article is available at
http://waterresources.fona.de/reports/bmbf/annual/2010/nb/English/10/welcome.html

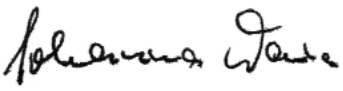
Global water consumption has tripled since the middle of the 20th century. In view of the world's growing population, this trend is set to continue. This not only affects emerging and developing countries, but also industrialised countries, where in some cases consumption exceeds natural supplies. In order to protect mankind's most important resource, experts from water research, politics and economics are working together to create solutions for the sustainable management of water supplies.

The aim is to guarantee water supply and wastewater disposal and to increase efficient usage. For this we need technical and structural innovations, as well as a systematic national and international exchange of scientific findings and practical applications.

Within the framework of the government's "high-tech strategy", the Federal Ministry of Education and Research (BMBF) is supporting the implementation of groundbreaking innovations within relevant fields of application. For the framework programme "Research for sustainable development" (FONA), the BMBF is set to provide more than two billion euro of funding by the year 2015. A major part of FONA is the water research that will be implemented within the BMBF's new principle "sustainable water management". BMBF is therefore promoting joint research projects with partners from the worlds of science and economics.

As well as enabling the exchange of knowledge, these projects are intended to provide emerging and developing countries in particular with support in training specialist personnel and thus ensuring they can deal with their ecological problems themselves in the long term. They also give German companies the opportunity to play a greater role in the global market in the fields of water and environmental protection. In this way, we are securing quality of life and at the same time promoting Germany as a business location.

This eBook presents a selection of completed and ongoing BMBF research projects. With such projects, we are making a significant contribution to expanding Germany's leading position as a development partner and exporter of environmental technologies.



Prof. Dr. Johanna Wanka ,
Federal Minister for Education and Research

An accessible version of the article is available at
http://waterresources.fona.de/reports/bmbf/annual/2010/nb/English/20/introduction.html

Water research for people, nature and the economy

Water is essential for all life. Be it in agriculture, industry or the home: this resource plays a crucial role in people's everyday lives and in the economy. Conscious handling of water is therefore a central pillar of sustainable development – and with the effects of climate change, population growth and a lack of drinking water this is one of the major challenges of the 21st century.

Funding water research and technologies has made a vital contribution towards German water management and research institutions being recognised and accredited for their development of future-oriented solutions that are helping secure and protect water resources worldwide.

Research for sustainable developments and high-tech strategy: the framework of the programme

The Federal Ministry of Education and Research (BMBF) is using its "Research for sustainable development" framework programme (FONA) and the government's high-tech strategy to tackle domestic and global challenges, particularly in relation to water. The focus is on research for sustainable water management. The topics covered within the principle of "sustainable water management" cover a broad range, including innovative technological approaches to protecting drinking water, supply and disposal, methods for river basin and flood management, cost-effective management concepts and measures to ensure an international transfer of knowledge. Water research has – like the entire area of environmental technology – undergone a paradigm shift over the last few years. While in the past the focus was on reacting to problems and developing "end-of-pipe" technologies, the emphasis is now on research and technology looking at forward-looking measures and the development of integrated problem-solving strategies.

On the way to a European research area

Multilateral initiatives are being supported at European level in order to intensify the funding of research in the European area. The aim is to create an internationally competitive European research and technology area. For example, the BMBF and its project co-ordinators are involved in the EU-funded ERA-NET (European Research Area-Networks) with regard to integrated river basin management and flood protection and precautions. This network makes it possible to co-ordinate research funding and develop harmonised concepts for future collaboration in the areas of research and technology.

Exceeding the boundaries of specialist disciplines

Water research involves many different fields of knowledge and combines a diverse range of approaches and objectives. Solutions in this broad field of research can thus only be found when the boundaries of specialist disciplines and sectors are exceeded and through intensified dialogue. Water engineers must work together with ecologists, economists and social scientists and must also consider the needs presented by politics, administration and consumers.

Networking to increase water management expertise

One of the central aims of the BMBF "Research for sustainable development" framework programme is to intensify dialogue between all the key players from economics, science, politics and society and to embark on new journeys together within water management. In doing so, Germany intends to retain and expand its position as a leading technology provider within the fields of climate protection and adapting to climate change, sustainable resource management and innovative environmental and energy technologies. The environment sector is also a major source of employment. By providing training in science and international project management, the research funding provided to universities, research institutes, major research facilities and industry makes a huge contribution to maintaining and intensifying water management expertise and thus securing jobs.

Transfer of technology and knowledge

One specific concern of the BMBF is the transfer of knowledge from research and development to company practice, with particular emphasis being placed on tapping into new markets. It is precisely through collaboration with emerging and developing countries, that successful water management can produce both short-term solutions for acute challenges and also consider long-term developments to deal with a lack of specialists and extreme climatic conditions. The principle of Integrated Water Resource Management (IWRM) within the sustainability research programme focuses on developing efficient measures for safeguarding and managing water resources in numerous partner countries, particularly within Asia, the Middle East and Africa. Measures within environment education and on-site capacity building play a key role in supporting the future sustainability of projects and processes.

International implementation

Many forms of technology have already proven their worth here in Germany. Now is the time to transfer them to other regions and to adapt them to the local conditions. Decentralised supply and disposal concepts and procedures for obtaining and treating water could also provide more and more people in emerging and developing countries with access to clean drinking water. Accessing water resources requires planning tools that assist in controlling consumption in accordance with need. As extreme weather events are on the increase, a forward-looking flood management policy is of growing global importance. The respective local conditions must also be taken into account, for example the composition of the untreated water, the infrastructure and cultural differences.

An overview

This brochure presents ongoing and completed examples of BMBF water research funding. Covering the main principles of "ecology, "technology" and "economy and education", the aim is to provide an overview of ideas and results produced and implemented by German universities and institutes together with commerce & industry and international partners.

An accessible version of the article is available at
http://waterresources.fona.de/reports/bmbf/annual/2010/nb/English/30/1_-ecology.html

Ecology

Water is the source and foundation of all life – a precious commodity that is increasingly endangered in many regions of the planet as a result of man's influence. This makes it all the more vital to ensure the sustainable handling and protection of water resources. The BMBF is working to achieve this goal through numerous research projects covering areas such as the restoration of domestic river basins, the biological clean-up of soil and groundwater, and flood management. The aim of integrated water resource management is to co-ordinate the social, ecological and economic aspects of this work.

Underground application – efficient in-situ ground water remediation methods

Toxic substances that escape from under disused, unsealed landfill sites, extensive contamination of the ground and soil from long-since closed industrial sites, widespread contamination from fuel and the aftermath of weapons: these are just some examples of hazardous abandoned waste in the soil that occur in great numbers and pose a threat to the quality of groundwater. Often no one knows precisely where this abandoned waste is located because toxic substances have been disposed of incorrectly or there are no longer any witnesses. Despite these difficulties, scientists are increasingly succeeding in tracking down abandoned waste, analysing it and using new methods – directly underground ("in situ") – to render it harmless before it reaches the groundwater. This is essential, as around 70 percent of Germany's drinking water is obtained from groundwater.

Germany is one of the world's most densely populated countries. Combined with the unchecked dumping of hazardous substances in the past and the intensive use of groundwater and soil resources, this all amounts to a large amount of abandoned waste and many suspected areas of contamination. With around 296,500 suspected abandoned waste sites recorded in Germany in 2009, there is a considerable need to treat this waste. Abandoned waste can be found underground at many disused and still active industrial sites. Its detection and efficient remediation presents a real challenge.

The Federal Ministry of Education and Research (BMBF) tackled this issue with new vigour as part of its "Research for sustainable development" programme, supporting selected research and development projects to solve the problem of abandoned waste. One of the aims of this is to develop pilot, transferrable solution examples.

Cleaning directly in the groundwater

Treating the groundwater and soil "in situ", i.e. making the hazardous substances harmless while still underground, is a promising approach. Be it the addition of nutrients, gas injection (project 1.1.08) or the introduction of micro-organisms – the range of in-situ procedures being (further) developed and tested by researchers and engineers in Germany is technically challenging and diverse. One advantage is the generally lower costs involved in on-site treatment. Unlike conventional methods, the contaminated groundwater and soil material does not need to be raised for treatment in plants above ground.

Groundwater remediation: a priority task

Germany places great value in developing efficient remediation procedures. There are numerous projects underway seeking to optimise these forms of technology in terms of practicality and transferability. Here are some examples of joint projects funded by the BMBF:

- Under the KORA principle (retention and degradation processes to reduce contaminations in groundwater and soil), tests were undertaken to determine how and whether remediation of abandoned waste could be improved through natural cleaning processes, (projects 1.1.01 and 1.1.02).
- The BMBF founded the RUBIN research programme (use of permeable treatment walls for site remediation) in May 2000 with the specific aim of developing in-situ treatment walls (projects 1.1.03, 1.1.05 and 1.1.06).
- SAFIRA (remediation research in regionally contaminated aquifers). Also the name of the Bitterfeld-based major research facility conducting the work, SAFIRA began researching new technologies and methods in 1999 for the in-situ remediation of groundwater contaminated with complex hazardous compounds (project 1.1.07).
- The BMBF and the state of Baden-Württemberg also provided funding to set up VEGAS (Versuchseinrichtung zur Grundwasser- und Altlastensanierung/ research facility for the remediation of groundwater and abandoned waste), the purpose of which is to develop innovative remediation methods that enable experiments to be performed under near-natural conditions (projects 1.1.09, 1.1.10, 1.1.11).

In-situ remediation of abandoned waste – making good use of biological cleaning processes

Experience has shown that conventional remediation procedures are often hit by technical or financial limitations, meaning that impurities cannot be fully removed from soil and groundwater. Natural processes for reducing hazardous substances could be of great support here. Research was undertaken under the BMBF KORA principle (retention and degradation processes to reduce contaminations in groundwater and soil) between 2002 and 2008 to determine how and whether these natural processes could be used in the remediation of abandoned waste.

In the past, more and more sites were being uncovered that were polluted with substances hazardous both to health and the environment as a result of previous production and storage activities. Before now, such abandoned waste was sanitised by digging up and removing the polluted soil or pumping out then treating the contaminated groundwater. Alternatively, safeguarding measures can prevent further spread of harmful substances or treatment (decontamination) with chemical or biological agents can be carried out. However, these conventional remediation methods are often subject to technical and economic limitations, e.g. due to deep aquifers◄, heterogeneous underground conditions, built-up areas, the type of toxic substances present and their often uneven distribution.

Building on natural processes

It has been determined at a number of sites that naturally occurring processes such as biological degradation, chemical precipitation◄, decomposition, sorption◄, dilution and volatilisation can render harmless or withhold hazardous substances in groundwater and soil under the right conditions. As such, contaminant plumes◄ expand only to a limited degree in the groundwater and diminish once the source of the toxin runs dry. Great emphasis has been placed on researching, evaluating and finally utilising these processes in a targeted manner for a sustainable way to handle our resources.

Systematic investigations at 24 reference sites

The natural retention and degradation of hazardous substances depends on the type of contamination and the conditions in the soil and groundwater. A few key questions must be answered to be able to assess whether natural processes for reducing contamination (referred to as "natural attenuation" (NA) processes) can be used or stimulated at a given location:

- Are the hazardous substances being effectively broken down or withheld by natural processes under the prevailing conditions underground?
- Are any (undesirable) intermediary products accumulating through biological degradation?
- Could degradation be stimulated through the targeted modification of on-site conditions?

The diverse range of issues related to NA processes was what prompted the BMBF to provide approximately EUR 20 million of support to the **"retention and degradation processes to reduce contaminations in groundwater and soil"** (**KORA**) principle between 2002 and 2008. In total, 74 projects were carried out at 24 typically contaminated sites representing a wide range of comparable cases in Germany, testing whether and under what

TN	Name of thematic network (industry-specific pollutants)	Investigated sites	Short name for working aid
1	Refineries, fuel tanks, fuels/mineral oil (TPH, BTEX, MTBE)	5	TN 1 guidelines (ISBN 978-3-89746-093-9)
2	Gas works, coking plants, coal tar processing (PAH, coal tar, heterocyclics)	4	TN 2 guidelines (ISBN 978-3-934253-50-6)
3	Chemical industry (VCHC, BTEX)	6	TN 3 guidelines (ISBN 978-3-00-026094-0)
4	Landfills, abandoned waste disposal sites (landfill pollutants)	4 (+ 2)+	TN 4 guidelines (ISSN 1611-5627, 04/2008)
5	Former munitions works (Compounds typically found in explosives)	3	TN 5 guidelines (ISBN 978-3-00-025181-8)
6	Mining, sediments (Trace metals, acidity/sulphate, pesticide)	2 (+ 1)+	TN 6 guidelines (ISBN 978-3-89746-098-X)
7	Modelling and prognosis	–	TN 7 synopsis (ISSN 1611-5627, 05/2008)
8	Derivation of MNA concepts, legal and economic issues, acceptance by the official bodies and the public	–	Handling recommendations with method collection (ISBN 978-3-89746-092-0)

+ Additional sites were investigated as part of associated projects

Overview of the thematic networks (TN) and working aids from the KORA funding principle

conditions natural degradation and retention processes could be put to effective use – in particular:

- Assessing the risks associated with contaminated groundwater and soil
- Calculating and performing hazard control measures (specific remediation)
- Calculating and performing follow-up measures.

In order to assess whether natural toxin reduction processes can be used and to monitor their effectiveness, regular soil and groundwater samples must be taken (monitored natural attenuation, MNA). The use of NA processes is therefore not a "do-nothing option". Quite the opposite: only through clear and thorough data collection (monitoring) and assessment (forecasting) can the anticipated processes be implemented effectively and natural methods of reducing contamination be a viable alternative or supplement to conventional remediation methods.

Toxin-related research

The aim of the research performed under KORA was to form the basis for considering natural processes for reducing contamination and to derive plausible opportunities and parameters for implementation from an ecological, economic and administrative perspective. This not only required the development of appropriate methods to prove the efficacy of the NA processes, but also the validation of tools for their assessment. Universities, engineering bodies and authorities worked together to develop MNA concepts for the 24 investigated sites with tailored solutions for each one, and in many cases these processes were implemented too. In doing so, they created reference sites to be used as examples of how NA processes can be recorded, assessed and considered in a graduated procedure. The experts further developed innovative in-situ remediation procedures based on stimulating natural processes for reducing contamination. They also investigated various measures that are to encourage acceptance of NA processes for abandoned waste remediation through (risk) communication.

Industry guidelines and handling recommendations for practical application

The results of this funding principle were documented in the KORA handling recommendations (with integrated method collection), in six sets of industry guidelines and in the KORA synopsis "Systemanalyse, Modellierung und Prognose der Wirkungen natürlicher Schadstoffminderungsprozesse" (systems analysis, modelling and forecasting effects of natural processes for reducing contamination) (see table). There is thus a variety of supplementary material available to assist authority representatives, engineering planners and those in charge of remediation. They can be used to check the potential ways in which NA processes and MNA concepts can be applied to treat abandoned waste. The working aids provide recommendations and assistance in using monitored or stimulated natural contamination reduction processes to treat abandoned waste in Germany and cover NA processes for groundwater that is already contaminated. Relevant existing (inter)national working aids, concepts and guidelines were considered during the compilation of the handling recommendations and industry guidelines. The working aids can be referenced at the website for this principle (www.natural-attenuation.de/bestellung) or downloaded in PDF format.

Project website ▶ **www.natural-attenuation.de**

DECHEMA e. V.
Dr. Jochen Michels, Christopher Frey
Theodor-Heuss-Allee 25
60486 Frankfurt, Germany
Tel.: +49 (0) 69/75 64-157, -440
Fax: +49 (0) 69/75 64-117
E-mail: michels@dechema.de, frey@dechema.de
Funding reference: 02WN0335

University of Stuttgart
Institut für Wasserbau (water engineering institute), VEGAS
Dr.-Ing. Hans-Peter Koschitzky
Pfaffenwaldring 61
70650 Stuttgart, Germany
Tel.: +49 (0)7 11/6 85-647 17
Fax: +49 (0)7 11/6 85-670 20
E-mail: koschitzky@iws.uni-stuttgart.de
Funding reference: 02WN0336

Keeping tabs on pollutants – recording and assessing natural degradation and retention processes

The former premises of a dry cleaner's for leather work clothing in the Harburg region of Lower Saxony was contaminated with perchloroethylene over a period of several decades. As the groundwater is extremely low down and the contamination is extremely difficult to access, conventional surveying and remediation procedures are not suitable for this abandoned waste. One of the projects within the KORA principle (retention and degradation processes to reduce contaminations in groundwater and soil) therefore aimed to use suitable monitoring and forecasting procedures to estimate the degree to which natural degradation and retention processes are sufficient in ruling out any risk to a neighbouring water conservation area.

Perchloroethylene (PCE)◄ was and still is used in trade and industry to remove paint, as a solvent and to degrease materials – as it was in a former specialist dry cleaner's for leather work clothing in Rosengarten-Ehestorf in Harburg. After use, the chemical along with the improperly cleaned wastewater filtered underground over the decades below the company's premises measuring approx. 3000 sqm.

An inaccessible aquifer

The surface of the affected aquifer◄ is 30 to 40 metres underground – unusually low down. With one stretch up to 230 metres deep, it is also extremely powerful. These factors – combined with the heavily built-up area – would make it extremely difficult and expensive to carry out remediation using conventional methods (pump-and-treat procedure◄). The Harburg authorities therefore looked at alternatives and opted to take part in the BMBF KORA principle. Run from 2003 to 2006, the project entitled **"Field-scale quantification of the potential of NA in deep large-scale aquifers – example: VOC contamination from a dry cleaners in Rosengarten-Ehestorf"** involved project planners determining the extent of natural attenuation (NA) in the soil since the introduction of contamination and estimating its subsequent course. The project partners included the Harburg authorities, the Institut für Gewässerschutz und Umgebungsüberwachung (institute for the protection of natural waters and environmental monitoring) in Kiel, the State Authority for Mining, Energy and Geology in Hanover and the Tübinger Grundwasser-Forschungsinstitut (Tübingen groundwater research institute).

A direct-push sounding device at work

In order to quantify the nature of the contaminant plume◄ and the natural degradation and retention process underground, the PCE introduction and its distribution had to be recorded first. Existing measuring points were upgraded and new ones set up in order to locate the precise location of the contamination source and the ensuing discharge.

Innovative systems for taking soil gas and groundwater samples

The site conditions made it extremely expensive to sample the groundwater using conventional wells, which is why only five were installed. The experts secured additional samples, but above all site surveys, using what is known as the direct-push procedure◄. This innovative drilling method is a faster, more flexible and considerably more cost-effective alternative to the conventional procedure. The direct-push procedure was further developed during the project so that the required underground depths

could also be reached. The scientists also expanded the wells to create multilevel measuring points to enable permanent sampling of soil gas and groundwater at various depths. This innovative procedure enabled a precise analysis of the vertical distribution of the contamination. Conversely, it proved difficult to determine the horizontal spread of the contamination by attempting to pump at the wells. The impenetrable soil did not permit any conclusions to be drawn regarding the overall breadth of the contaminant plume.

Steady introduction of PCE

Key results of the survey: the scientists measured the highest concentrations of PCE at a soil depth of five to ten metres below the surface. They determined that the soil continuously feeds PCE into the groundwater. However, the quantity continually drops over time until the discharge finally comes to a halt. Because the contaminant is primarily accessing the groundwater with the drainage water, the current and future amount of contaminant delivered and thus the lifetime of the pollution source is significantly affected by the amount of precipitation. On average, the total delivery over the non-sealed surface area of the company premises amounts to nine grams a day, of which over seven grams can get into the groundwater. The rest evaporates into the atmosphere, where it is broken down into harmless substances.

Pollution transport models

The project team made use of what are known as transport models to obtain a quantitative estimate of the future introduction of pollution into the groundwater. With their help the team ran through various versions of pollution spread since the assumed introduction of the contamination some 40 years ago. According to the most likely scenarios, which were determined by a comparison with the results measured on site, the PCE contamination plume in the aquifer has been stable and virtually unchanged for around 20 to 25 years. Calculations suggest that it is between 400 and 500 metres long. The results from the measuring points, which are extremely heterogeneous in part, lead to the conclusion that there may not be just one contaminant plume but it could have split into two or more branches.

Pollution source will be “clean” in around 40 years

Scientists expect that the source of the pollution – i.e. the PCE still in the soil above the groundwater – will have completely disappeared in around 40 years’ time. The PCE plume in the groundwater will completely break down over time due to the existing natural degradation processes.

These statements are indispensable for a legal assessment of using natural attenuation. They enable the authorities to dispense with the extremely expensive and frequently only partly efficient measures of active remediation without any risk. Overall, the procedure developed at the Rosengarten site for surveying and assessing the contamination situation has shown that decisions on whether and to what extent natural pollution reduction is taking place can also be made with sufficient certainty for deep aquifers.

Landkreis Harburg (Harburg County)
(Head of soil/air/water department)
Gunnar Peter
Postfach 1440
21414 Winsen/Luhe, Germany
Tel.: +49 (0) 41 71/6 93-4 02
Fax: +49 (0) 41 71/6 93-1 75
E-mail: g.peter@lkharburg.de
Internet: www.landkreis-harburg.de
Funding reference: 02WN0437

Permeable treatment walls – underground structures for successful remediation

Groundwater is an especially important and also vulnerable resource for our supply of drinking water. Often only the slightest amount of contamination is enough to render thousands of litres of water undrinkable. In order to dispense with the need to pump contaminated groundwater to the surface for cleaning, researchers in Germany and elsewhere have been intensively focussing on "in-situ" procedures for some years – technologies that can be applied directly in the aquifer◄. To drive forward new and further development of permeable treatment walls in Germany, the BMBF has been supporting the RUBIN research programme since 2000/2001.

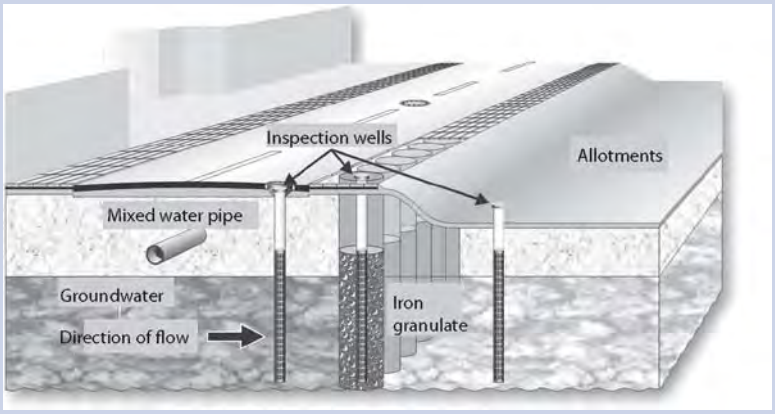
Cleaning polluted groundwater is a complex task. Most remediation procedures involve an active pump-and-treat method, active meaning that the water is pumped to the surface and treated there in downstream plants. This is an extremely expensive process, and as the water is then frequently channelled into the sewer system this results in yet more cost.

Remediation within the aquifer

Recent years have seen intensive work on the development and testing of passive forms of in-situ remediation technology using permeable treatment walls. These are installed in the groundwater flow from the source of contamination to eliminate the pollutants in the aquifer itself. A unique new procedure is thus saving costs as there is no longer a need to pump or discharge the groundwater. Two types of technology have been primarily introduced to practical applications: the all-over permeable treatment wall and the funnel-and-gate system, whereby the groundwater is fed via guiding walls (funnel) to a permeable reaction zone (gate).

An all-over permeable wall involves a ditch reaching down to the layers where the groundwater flows being filled with reactive material. Elemental iron or activated carbon◄ is primarily used for this purpose. The contaminated groundwater flows through the permeable barrier, and the reactive material operates like a filter to remove or break down the pollutants.

The technology involved in permeable treatment walls was primarily driven forward in North America. Germany had little practical experience with treatment walls.



Schematic representation of a fully permeable treatment wall (Mull u. Partner Ing. Ges. mbH, Hanover)

RUBIN – the project

The BMBF-funded research programme entitled **Use of permeable treatment walls for site remediation** (**RUBIN**) saw industrial companies and research facilities working closely together in an interdisciplinary fashion at various locations across Germany. The main task was to conduct a detailed, far-reaching and co-ordinated investigation into the potential and limitations as well as the environmental impact and economic viability of permeable treatment walls at a large number of locations in Germany. One key goal of the research programme was to develop generalised criteria for the application of permeable treatment walls, such as

- Layout, design, construction and operation
- Performance and durability (degradation of pollution, as well as for mixed contamination/reactor systems and reactive reactor filling materials)
- Framework conditions and limitations for use
- Economy (procedural costs) and ecology (environmental impact).

Results for practical application

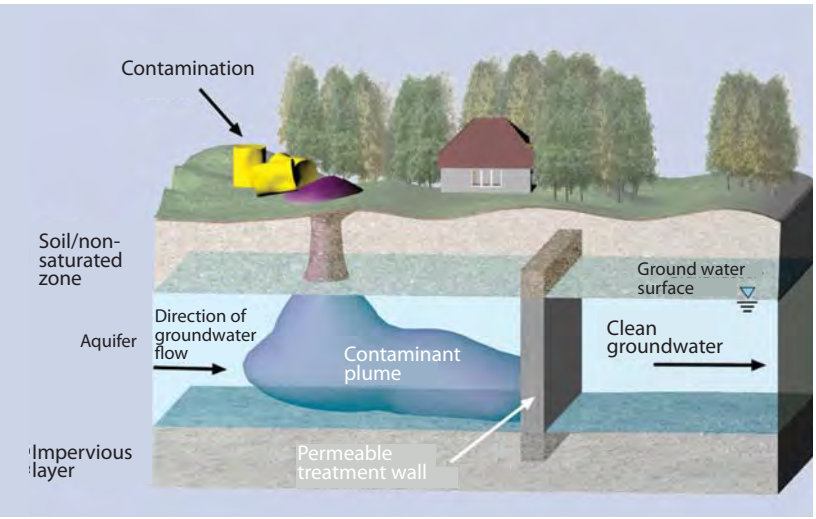
Projects were conducted at six sites to investigate durability, degradation levels, changes in material, material conversion processes, treatment wall systems, reactor filling materials and monitoring.

Another focus of the work saw employees from the University of Kiel set up and test quality management rules as part of the RUBIN project, with the aim of enabling reliable planning, execution and monitoring of standardised treatment walls in future. Experts from the University of Tübingen also compared the economic efficiency of the methods with conventional remediation procedures. These studies put those using this new technology in a position to carry out an in-depth cost comparison in future.

The quality management rules and economic efficiency observations are, along with the overall results of the programme, integral components of the handbook on the use of permeable treatment walls for site remediation, which presents the key results and findings of the project to interested parties. Created under the guidance of Ostfalia University, the co-ordination site of the RUBIN programme, this handbook is to serve primarily as a general orientation aid for users – e.g. authorities, those in charge of remediation, planners and environmental technology providers.

Scientists conducted further investigations to examine the results and findings at technical pilot facilities, with extensive planning, construction and trials involved. As a result, the technology was able to be rendered marketable and introduced to practical groundwater remediation within Germany. The BMBF funding therefore made it possible to develop a new, more cost-effective and more environmentally friendly method of removing pollution directly from the groundwater – one of the country's most significant sources of drinking water – ready to put into practice and thus enhance Germany's status within environmental technology.

Project website ▶ **www.rubin-online.de**



Schematic representation of a fully permeable treatment wall (source: Mull u. Partner Ing. Ges. mbH, Hanover)

Ostfalia –
University of Applied Sciences
Faculty of Civil and Environmental Engineering
Prof. Dipl.-Ing. Harald Burmeier
Prof. Dr. Volker Birke
Herbert-Meyer-Straße 7
29556 Suderburg, Germany
Tel.: +49 (0) 58 26/9 88-6 11 40, -6 15 60
E-mail: h.burmeier@ostfalia.de
v.birke@ostfalia.de
Funding reference: FZK 0271241 and 02WR0828

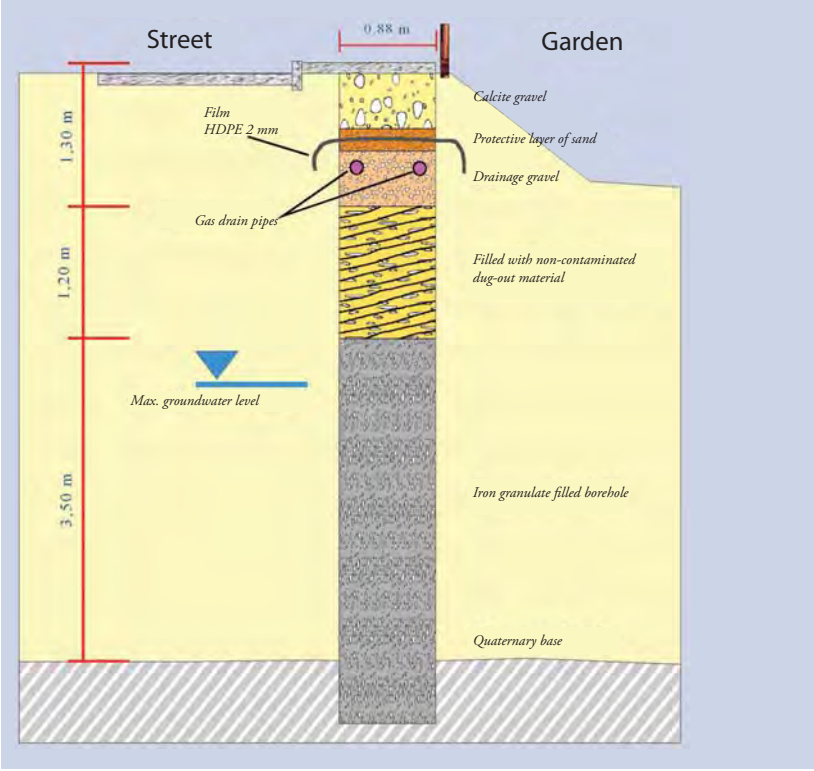
Reliable long-term effectiveness – in-situ treatment wall at the Rheine site

Treatment (reactive) walls are an extremely promising approach to sanitising or safeguarding contaminated aquifers◄. Germany's first all-over permeable reaction wall was installed as a pilot scheme at Rheine in North Rhine-Westphalia in 1998, in a quaternary aquifer polluted with chlorinated hydrocarbons (DBU project). In a subsequent, further-reaching research and development project funded by the BMBF, partners from science and economics worked together to investigate the durability of the treatment wall and the degree to which iron can be used as a reactive material at that particular site.

In June 1998, Hanover-based Mull und Partner Ingenieurgesellschaft mbH used funding from the Deutsche Bundesstiftung Umwelt (DBU, German environmental foundation) to erect a groundwater treatment wall as a field-scale project in order to remove volatile halogenated hydrocarbons (VHHC)◄ such as tetrachloroethylene (PCE)◄ or trichloroethylene (TCE)◄ from contaminated groundwater. This involved using a new porous zero valent iron (Fe^0), "iron sponge", as the reactive material.

Pollutants from a laundry

The reaction wall was installed approximately 700 metres downstream of a massive source of underground PCE contamination. The cause of this pollution is a laundry that once operated on the premises. The treatment wall is a structure enabling all-over permeability of contaminated groundwater and measures around 6 metres deep, 22.5 metres long and 88 centimetres thick. It is filled with two reactive materials up to a height of around 3.5 metres, i.e. above the maximum anticipated level of the groundwater. The materials used are an iron sponge supplied by MITTAL Steel Hamburg GmbH (formerly ISPAT Hamburger Stahlwerke GmbH) and a 70% pea gravel and 30% grey cast iron granulate blend from Gotthart Meier AG in Rheinfelden. This twin-layered effect allows the performance of the materials to be compared. This procedure has seen the amount of PCE reliably drop from its initial concentration of several thousand micrograms per litre by over 99% since 1998.



Vertical structure of the treatment wall at the Rheine site

Studies on long-term effectiveness

As well as the activity mentioned, the plant was also used for various long-term investigations. The BMBF funded the following projects: **Pre-investigation, monitoring and quality management regarding Reactive Walls** (Christian Albrecht University of Kiel), **Evaluation of the durability of an iron-reactive wall with the example of the site at Rheine** (Mull und Partner Ingenieurgesellschaft mbH) and **Biological processes in a reactive iron wall** (TU Berlin). The objective of the research activities was to observe the long-term behaviour of the treatment wall and to develop a monitoring programme to investigate the geochemical, hydro-geological and biological processes in and around the Fe^0 treatment wall.

Reliable for many years now

The reaction wall at Rheine has been providing assured constant remediation of the groundwater for over ten years now, with the two different materials producing different cleaning performances. The groundwater investigations have shown that the iron sponge achieved a

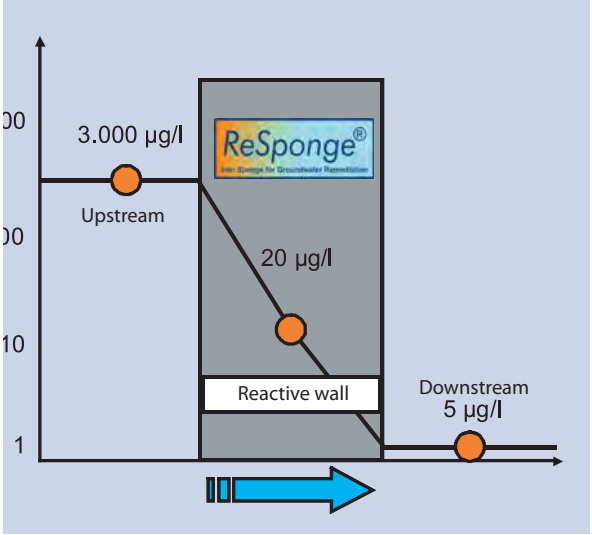
cleaning performance of around 70 to 80% in the first 6 to 12 months following installation, a figure that then rose to more than 99%. For several years now the concentrations of VHHC measured downstream have been under 10 micrograms per litre.

The concentrations of VHHC downstream of the section of wall filled with a mixture of grey cast iron granulate and pea gravel were somewhat different: an excellent cleaning performance of 99% was recorded at the start, but once the reaction wall had been in operation for around 8 to 12 months only around 80% of the inflowing VHHC content was still being broken down. This level of cleaning performance has remained virtually constant up to the present day. The scientists were able to determine from core drilling that a partial separation of gravel and iron was the cause of the reduced degradation in this section of the treatment wall.

Both flow modelling and pump-and-trace attempts clearly demonstrated that the permeability of the treatment wall is assured and nothing is flowing over or around it. The experts were also able to substantiate that hydraulic changes had taken place during the time of operation through precipitates◄ or gas formation.

Biological aspects

The scientists at TU Berlin also demonstrated during the project the appearance of bacteria in the two iron materials used after a few years. The description of the biological activities of all relevant physiological bacteria groups offered fundamental insights into the microbial colonisation. As it was discovered, there are no anticipated negative effects within a foreseeable timeframe on the long-term stability of the dechlorination performance of iron treatment walls as a result of the micro-organisms present.



Reducing the concentration of pollution by treatment wall permeation

Applying the results

The synopsis of all the research work clearly demonstrates that the pilot and demonstration treatment wall at Rheine can be successfully applied for long-term use. The project results also included Mull und Partner Ingenieurgesellschaft mbH registering a trade name for the iron sponge. It is marketed under the name "ReSponge" and has been registered with the patent and trademark offices in Europe (07/2005) and the USA (12/2005). The company also entered a contractual agreement with MITTAL Steel GmbH in Hamburg in 2003 for the marketing of iron sponge for remediation purposes.

Project website ► **www.rubin-online.de**

Mull und Partner Ingenieurgesellschaft mbH
Dr. Martin Wegner
Joachimstraße 1
30159 Hanover, Germany
Tel.: +49 (0)5 11/12 35 59-59
Fax: +49 (0)5 11/12 35 59-55
E-mail: wegner@mullundpartner.de
Funding reference: 0281238

Christian Albrecht University of Kiel
Institute of Geosciences
Prof. Dr. Andreas Dahmke
Dr. habil. Markus Ebert
Ludwig-Meyn-Straße 10
24118 Kiel, Germany
Tel.: +49 (0)4 31/8 80-28 58, -46 09
Fax: +49 (0)4 31/8 80-76 06
E-mail: ad@gpi.uni-kiel.de
me@gpi.uni-kiel.de
Funding reference: 02WR0208

Technische Universität Berlin
Department of Environmental Technology (ITU)
Environmental hygiene working group
Dr. Martin Steiof
Amrumer Straße 32
13353 Berlin, Germany
Tel.: +49 (0) 30/31 42 75-32
Fax: +49 (0) 30/31 42 75-75
E-mail martin.stelof@tu-berlin.de
Funding reference: 0271262

Funnel and gate – an innovative reactor concept successfully combating contamination

The Lang tar works in Offenbach prepared and processed tar from 1915 to 1929. After most of the buildings were torn down in 1930 and a period of various intermittent uses, the premises are now predominantly wasteland. However, the soil and groundwater are just as polluted with tar oil and tar-oil-related substances as they were before. What is therefore required is a straightforward, economically feasible and safe remediation procedure that also affects the surrounding office locations as little as possible. Scientists working under the RUBIN research programme used an innovative "funnel-and-gate system" with three built-in bioreactors◄ to develop a procedure to meet these requirements.

The impact of 14 years of tar production at the Offenbach site is still clearly measurable today: the contaminating tar oil and tar-oil-related substances have penetrated right through to the base of the quaternary, sandy-gravelly aquifer◄. Underneath this lies tertiary◄ clay (Rupelian clay), which has a blocking effect to prevent further penetration of the contaminants. Several measuring points indicate this pollution to be a 20 to 80 centimetre tar oil phase◄ at the base of the quaternary aquifer. Polycyclic aromatic hydrocarbons (PAH) are the dominant pollutants present; analyses indicated over 150 milligrams per kilogram of soil, and up to several grams in places. The researchers found BTEX◄ concentrations of up to 30 milligrams per litre at the source of the contamination.

Low maintenance and control requirements

After a detailed inspection of the site, experts estimated that it would cost around EUR 18 million to perform a conventional clean-up by means of digging up the soil. That led to a search for more cost-effective alternatives. In a study of the various options, scientists weighed up whether to clean up just some areas or to seal off the contaminated soil with a barrier and a surface seal. A funnel-and-gate system with bioreactor was discussed as an additional option. This solution should be simple to implement with low maintenance and control requirements, and would have minimal impact on the existing land usage. The estimated costs were comparatively low, coming in at EUR 1.5 million. However, there was a problem: such a reactor had never been built before; the feasibility of this proposal needed to be proven first.

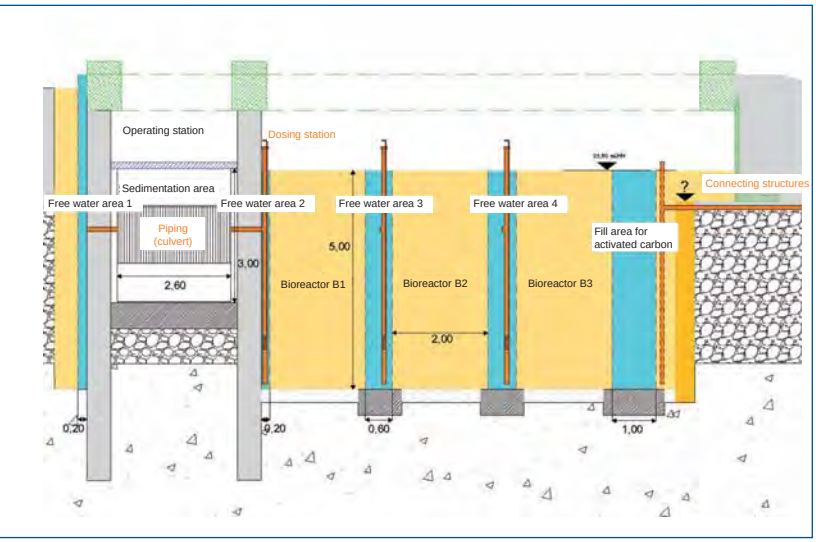
Funding from the BMBF smoothed the way from the initial idea through to the now obtained proof of functionality and effectiveness. Working under the RUBIN research programme (see project 1.1.03), a team of scientists performed the required experiments (in the lab and on site), produced the necessary models and implemented the construction and test run of the reactor on a pilot scale. Other key requirements for the success of the project were the approval of Darmstadt council, Department for the environment in Frankfurt, and the equipment provided by the state of Hessen.

Planning, construction and operation

The concept implemented on a pilot scale involved a heavily structured reactor: it comprised a baffle plate thickener to remove iron and other solids from the water, three in-series bioreactors and an activated carbon phase. Upstream of the baffle plate thickener and before each of the three bioreactors was an open water area (free water area) to distribute the groundwater over the entire flow cross-section of the bioreactors. Oxygen (as H_2O_2) and nutrients were also fed into the groundwater at several points within these free water areas to stimulate the biological degradation of the pollution. The reactor concept therefore took the general development away from passive, difficult-to-control systems to ones that enable intervention and control.

The pilot funnel-and-gate system was constructed between October 2006 and March 2007. The 30 metre long guiding walls (funnel) connect to the permeable reaction zone (gate) on the east and west flanks. They were designed as 550 millimetre thick walls in the mixed-in-place (MIP) procedure◄ and extend at least one metre into the Rupelian clay. The actual reaction areas between the free water areas were filled with a gravel with a grain size of 2 to 8 millimetres to serve as a growth body (carrier) for the pollution-degrading micro-organisms.

The reactor is operating during the pilot with a flow rate of 230 to 500 litres per hour, which cannot be achieved by the natural gradient of the groundwater alone. A pump is therefore necessary to achieve this. This active intervention ensures a constant throughflow and keeps feeding quantities and degradation conditions as constant as possible, leading to a clear reduction in operating and monitoring requirements compared with a passive approach. The flow rate control also enables modification to the hydraulic framework conditions at any time (e.g. groundwater sampling from the area).



Longitudinal cross-section of the innovative funnel-and-gate system

Oxygen and nitrate are added to the water in order to stimulate aerobic◄ and aerobic-denitrifying degradation of the pollutants. O-phosphate◄ also ensures that there is sufficient phosphorus present in the water. Nitrogen – another essential nutrient – is available to the micro-organisms in the form of naturally occurring ammonium within the groundwater. Hydrogen peroxide (H_2O_2) solutions, sodium nitrate and a mixture of monopotassium phosphate (KH_2PO_4) and buffer solution Na_2HPO_4 are buried to serve as working chemicals.

The microbial colonisation of the four gate modules was controlled by feeding in additives and monitored over 800 days across the entire bioreactor system using a microbiological monitoring program.

Effectiveness proven

In the baffle plate thickener, the addition of H_2O_2 converts the iron, which is then deposited as sludge through sedimentation. A large proportion of the pollutants is already broken down at this stage through the aerobic stimulation in the baffle plate thickener. The main reduction is that of PAH and BTEX aromatics (benzene, toluene, ethyl benzene, xylenes), to around 70%. The other contaminants relating to the tar oil (tar-oil-based pollutants) such as NSO-HET (NSO heterocyclic compounds)◄ and the other aromatic hydrocarbons◄ are reduced by around half.

The remaining aromatic hydrocarbons and PAH 2-16 are reduced to around 40% each in bioreactor 1 by the aerobic-denitrifying processes; the BTEX aromatics and NSO-HET to above 20%. The remaining pollutants are broken down in bioreactors 2 and 3.

The first time that no traces of tar-oil-based pollutants were recorded in the bioreactor process was in September 2009. The trialled funnel-and-gate system is removing the pollution from the groundwater by means of aerobic-denitrifying degradation alone. Other potential elimination processes such as retardation◄ and volatilisation are playing little or no role.

System expansion

The positive experiences with the test reactor are now leading the scientists to investigate the suitability of the system for treating the entire downstream contamination. They are currently comparing various versions with one or two gates and also passive and active components.

HIM GmbH, Remediation of Contaminated Sites Division
Dipl.-Ing. Christian Weingran
64584 Biebesheim, Germany
Waldstraße 11
Tel.: +49 (0) 64 28/92 35 11
Fax: +49 (0) 64 28/92 35 35
E-mail: asg.weingran@t-online.de
Funding reference: 02WR0293

CDM Consult GmbH
Dipl.-Ing. Jörn Müller
64665 Alsbach, Germany
Neue Bergstraße 13
Tel.: +49 (0) 62 57/50 43 15
Fax: +49 (0) 62 57/50 43 60
E-mail: joern.mueller@cdm-ag.de

I.M.E.S. GmbH
Dr. Hermann Schad
88279 Amtzell, Germany
Martinstraße 1
Tel.: +49 (0) 75 20/92 36 00
Fax: +49 (0) 75 20/92 36 04
E-mail: hermann.schad@imes-gmbh.net

DVGW Water Technology Center (TZW)
Dr. Andreas Tiehm
76139 Karlsruhe, Germany
Karlsruher Straße 84
Tel.: +49 (0)7 21/9 67 81 37
Fax: +49 (0)7 21/9 67 81 01
E-mail: andreas.tiehm@tzw.de

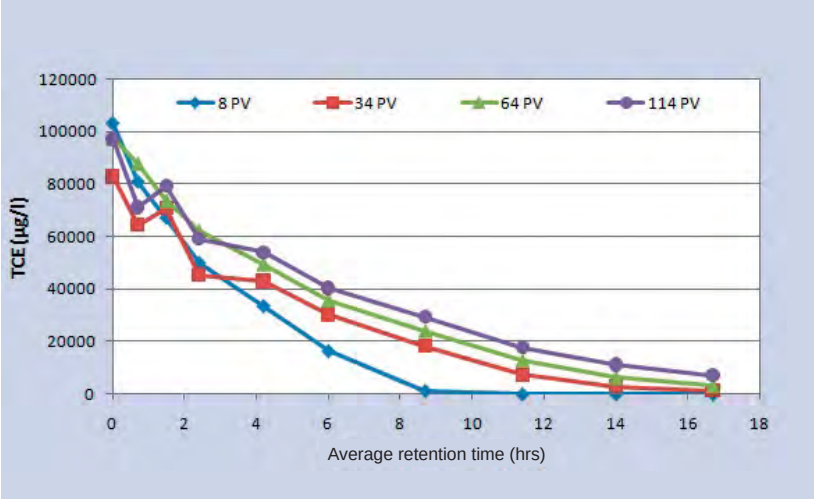
Application of treatment walls – combating high TCE concentrations

Iron granulate reaction walls have proven their cleaning effectiveness in several field studies to date. However, the effect of modified pH values◄ on the long-term stability of the reactive material was still unclear. Scientists from the use of permeable treatment walls (RUBIN) programme used the site of a former barracks in Berlin to test a corresponding pilot facility on the groundwater there, which was highly contaminated with trichloroethylene (TCE)◄. The result was overwhelming: the iron granulate was also highly efficient and economical in the long term and it was possible to remove all the TCE.

There are 11,000 known abandoned waste sites in Germany, all representing a significant risk to the groundwater. Quick remediation, e.g. through excavation or pumping out the polluted groundwater, has proven technically unfeasible or disproportionately expensive in many cases. This is especially true when the pollutants are organic substances such as volatile halogenated hydrocarbons (VHHC)◄ or tar oils, and when this pollution takes the form of a separate flow phase◄ under the ground. As such, technologies aiming to secure the contaminant plumes◄ being emitted from the sources of contamination are increasingly gaining favour. One example of such technology is permeable treatment walls. Development of this technology began in North America and it has since been funded in Germany via the BMBF's RUBIN R&D project (see project 1.1.03).

Testing long-term stability

A modular pilot facility was set up in 2001 on the site of a former Soviet barracks in Bernau (approximately 30 km north-east of Berlin) to treat the groundwater there, which was highly contaminated with trichloroethylene (TCE). The main aim of the project was to test the durability and degradation performance of an iron granulate treatment wall under quasi in-situ conditions. The procedure utilised the reduction potential of metallic iron coming into contact with water and halogenated hydrocarbons. The corrosion reaction of the iron served to dehalogenate◄ the partially carcinogenic substances. However, the oxygen reduction process increased the pH value, which triggered a string of secondary reactions restricting the long-term stability of the reactive material.



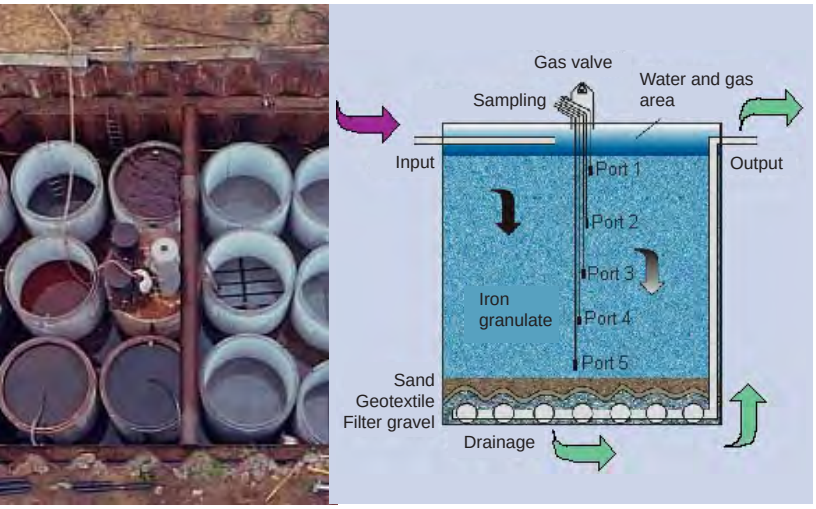
TCE degradation in lab with iron granulate

Project aims achieved

The scientists began by erecting a funnel-shaped barrier around the source of the contamination. This barrier borders the reactor, which is placed beneath the natural groundwater table and thus permits passive horizontal permeation. The reactor comprises 18 individual cylindrical modules measuring 2.8 metres in diameter and around 2.2 metres high; each module can be considered to be a standalone reactor. By coupling several modules in series or in parallel, it is possible to control flow lengths and thus the amount of time the water remains in the reactor according to requirements. The research project operated the modules in series.

The most important aims of the project were achieved in full:

- Efficient elimination of the high TCE concentrations remaining stable in the long term.
- Manageable volume flows and pollutant concentration/quantity over a long flow course in the iron reactor.
- Access to the reactive material to enable countermeasures to be taken against any unforeseen negative influences.



View of the reactor ditch with partly filled modules (left) and side view of a filled module

The grey cast iron granulate used as the reaction material achieved a cleaning performance of over 99.5%. It is both a highly efficient and economically beneficial prospect for field-scale projects where pollution concentrations are at least 25 milligrams per litre, as found at the Bernau site. Follow-up cleaning of the slightly contaminated reactor outlet with water activated carbon has proven to be highly effective over the three and a half years the reactor has been in operation and the most economic measure for remediation available. Running over several years, the research project saw a total of 450 kilograms of TCE removed from 15,000 cubic metres of water overall, and the treated groundwater cleaned up to the TCE detection limit.

Ready for practical application

The results of the research project have been implemented in site remediation since February 2007. The "east VCHC plume" is being cleaned using the iron granulate treatment wall. The requirements for this were:

- Upgrade/retrofit of the equipment. The iron granulate from 10 reactor modules had to be removed, mechanically processed and reinstalled.
- Installation of new piping plus measuring and control technology as a pump system to and from the reactor modules.
- Implementation of six pumping wells plus the necessary pumping technology.

As the cleaning performance of the reaction wall is insufficient for the cDCE degradation product◄, follow-up cleaning with water activated carbon is also required.

The contaminated groundwater is pumped at a speed of 2.4 cubic metres an hour from six wells. Ten parallel modules are used to clean the water contaminated with volatile chlorinated hydrocarbons◄ (VCHC, predominantly TCE). The treated water then flows through the follow-up cleaning system and is then fed back into the soil. The equipment is operated and monitored centrally.

The scientists have already modified the equipment several times during operation in order to optimise performance. The water now flows up through the modules in the A section. A mixture of iron and filter sand was placed in the feed area of the B section modules and a gas drainage system made from perforated polyethylene tubes has been installed.

In the last three and a half years, the cleaning installation at the Bernau site has removed approximately 3,200 kilograms of VCHC from around 55,000 cubic metres of groundwater underground. It has removed virtually all the TCE from this location, part of which was not fully dechlorinated but converted to cDCE instead.

Brandenburgische Boden Gesellschaft für Grundstücksverwaltung und -verwertung mbH
Martina Freygang
Waldstadt Hauptallee 116/6
15806 Zossen, Germany
Tel.: +49 (0) 33 77/3 88-157
Fax: +49 (0) 33 77/3 88-180
Martina.Freygang@bbg-immo.de
www.bbg-immo.de
Funding reference: 0251231

IMES Gesellschaft für innovative Mess-, Erkundungs- und Sanierungstechnologien mbH
Dr. Hermann Schad
Martinstraße 1
88279 Amtzell, Germany
Tel.: +49 (0) 75 20/92-36 00
Fax: +49 (0) 75 20/92-36 04
info@imes-gmbh.net
www.imes-gmbh.net

ISTEV GmbH
Peter Hein
Bismarckstraße 1
14109 Berlin, Germany
Tel. +49 (0) 30/80 94-15 76
Fax +49 (0) 30/80 94-15 78
hein@istev.com
www.istev.com

SAFIRA joint research project – remediation research using the Bitterfeld site as a model

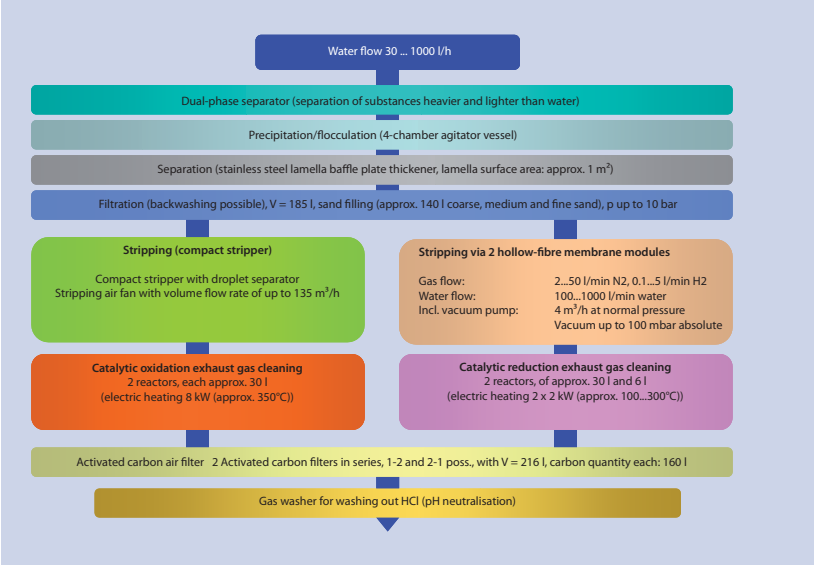
Coal mining and chemical industry have heavily contaminated the soil and groundwater in the Bitterfeld area. Experiences from the last 20 years indicate that hydraulic soil and groundwater remediation◄ is often ineffective – particularly on large abandoned waste sites if the source of the contamination either cannot be precisely located or is very difficult to remove. The remediation research in regionally contaminated aquifers◄ (SAFIRA) research project therefore used the sample model site at Bitterfeld-Wolfen to develop new technologies and methods for in-situ remediation of groundwater contaminated with complex pollutant compounds.

The Bitterfeld-Wolfen area is still suffering the effects of abandoned waste. The ground beneath the former industrial and landfill sites is polluted, the groundwater heavily contaminated in places with organic compounds, primarily chlorinated hydrocarbons (CHC◄), over an area of around 25 square kilometres. In Bitterfeld this contamination reaches a depth of 30 to 40 metres and affects an estimated 250 million cubic metres of groundwater. Conventional remediation procedures demand mainly protracted and expensive pump and treat measures. However, for such widespread contamination and such a complex mix of pollutants, in-situ cleaning is an appealing approach as it does not involve digging up and moving the soil.

Active and passive methods

In-situ remediation methods are divided into active technologies (e.g. soil gas suction) and passive methods, the latter requiring little or no energy feed during the remediation process. The most developed passive version is reaction walls. While this method is already successfully applied to simple combinations of pollutants, development is still needed to handle complex mixtures.

The **SAFIRA** research project investigated the hydro-geological and geochemical framework conditions for cost-effective in-situ procedures and tested these at the Bitterfeld site. Researchers at the UFZ centre for environmental research at Leipzig-Halle and the universities of Dresden, Halle, Kiel, Leipzig and Tübingen were able to use areas formerly home to the Bitterfeld chemical industry to develop and test the suitability of technologies for passive decontamination in a real-life situation.



Procedural steps carried out in the pilot scheme

The main objectives of the project were:

- Development and gradual implementation of efficient passive water treatment technologies for organic pollutant mixtures from the lab stage to a pilot phase.
- Technical-economic optimisation of the new technologies plus their combination.
- Demonstration of their long-term stability under field conditions.
- In addition, the actual operating costs and the environmental law and planning aspects of in-situ reaction zones were to be evaluated.

Pilot facility for various procedures

At the heart of this project is a pilot facility installed in Bitterfeld's groundwater, 23 metres below the surface of the site. The scientists used this to investigate seven procedures that had been successfully tested in the lab and in small-scale field trials:

- Adsorption◄ and microbial degradation of pollutants with activated carbon◄
- Zeolite-supported palladium (PD) catalysts◄
- Oxidation all-metal catalysts◄
- Oxygen-reducing combination reactors◄
- Membrane-supported palladium (PD) catalysts◄
- Adsorption with activated carbon
- Anaerobic◄ microbial degradation

Transferring these procedures to a larger pilot scale proved problematic in some cases. Although the microorganisms at the site are in a position to break down chlorobenzene◄ under anaerobic conditions, the rates of degradation were insufficient in practice so procedures for adding oxygen also had to be developed. The scientists also ascertained that although palladium catalysts were suitable for quick reduction dechlorination◄ they needed better protection in groundwater containing sulphates against the products used for the microbiological reduction of sulphate such as hydrogen sulphide. Conventional adsorbents (such as activated carbon) help to remove pollutants. The operating life of treatment walls can be significantly extended through microbiological colonisation. The project also showed that oxidation catalytic procedures can also be used to treat complex pollutant mixtures. Methods for reactivating the surfaces of the catalysts is an area where optimisation was required.

Implementation in specific remediation concepts

In additional investigations, the project partners adapted their research to the extremely diverse composition of pollution at each site, in particular the many different substances and the high concentrations of individual substances at Bitterfeld. The new projects focused on three areas promising huge benefits for future remediation concepts at Bitterfeld-Wolfen:

- Innovative remediation technologies (catalysis◄)
- Coupled systems (hydrochemistry/microbiology)
- Spatial effect (digital area model, visualisation, models)

Within innovative remediation technologies, the project team developed a new method that uses vacuum strips◄ through a hollow-fibre membrane to convert pollutants from the liquid phase◄ to the gaseous phase, which enables a highly efficient level of destruction through catalysis. This technology deals with a broad range of contaminants in high concentrations. Once the procedure had been successfully used in a pilot scheme, it was developed further at various locations. The focus of this development was on removing and destroying crucial substances from a procedural perspective. A new form of technology will now make it much easier to treat the specific contaminated groundwater in the Bitterfeld-Wolfen region. It was tested in a pilot scheme that included a procedural stage for stripping◄ out pollutants with hollow-fibre membrane modules and devices for applying innovative procedural steps for removing the sulphur from the stripped-out gases (UFZ patent). The facility aims to demonstrate alternatives for complex groundwater contamination where there has previously been no economically viable cleaning concept. The "treatment train" approach was followed to achieve a sufficient overall cleaning performance, in other words the intelligent interlinking of modular standard and/or innovative individual processes.

Another focus was on the combination of different microbiological degradation paths in corresponding conditioned aerobic◄/anaerobic zones permitting the successive degradation of certain pollutants or groups of pollutants. The third area of focus looked at the creation of a digital database for Bitterfeld, which included a geological structure model, a description of regional groundwater qualities at various periods and remediation scenarios based on land usage.

Helmholtz Centre for Environmental Research – UFZ
Prof. Dr. Holder Weiß
Prof. Dr. Frank-Dieter Kopinke
Permoserstraße 15
04318 Leipzig, Germany
Tel.: +49 (0)3 41/2 35-12 53
Fax: +49 (0)3 41/2 35-18 37
E-mail: holger.weiss@ufz.de
frank-dieter.kopinke@ufz.de
robert.koehler@ufz.de
Internet: www.ufz.de
Funding reference: 02WT9911/9

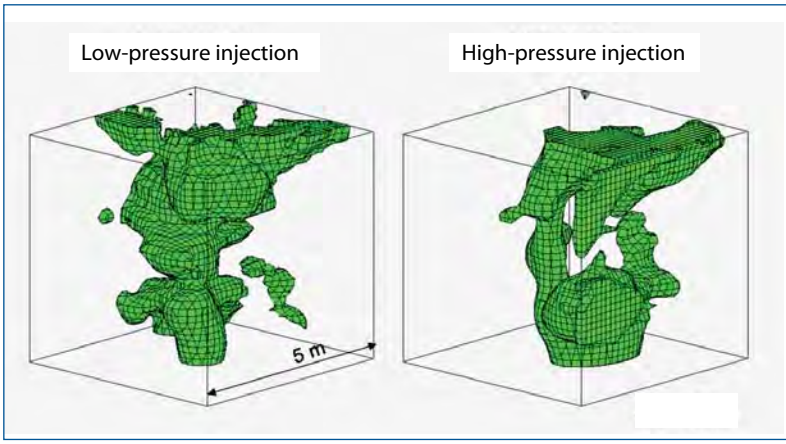
Direct oxygen injection – measuring and modelling dynamic gas accumulators

Many organic pollutants in groundwater are biodegradable under aerobic◄, or oxygenated, conditions. Adding oxygen can accelerate the degradation process; a relatively cost-effective way of doing this is to use direct gas injection. A project team investigated the processes determining the efficiency of such direct gas injections in porous media (aquifers◄), and developed forecast models for use within remediation. Several demonstration projects have already been successfully completed on the basis of the research results.

One way to accelerate the degradation of pollutants underground is to use direct gas injections – an in-situ remediation procedure. Injection lances moving both horizontally and vertically are used for the targeted introduction of oxygen into the stream of contaminated groundwater, where it establishes itself in the aquifer in the form of small, finely distributed bubbles. Low-permeability layers of sediment prevent the gas from dissipating upwards; sideways-expanding oxygen-flow capillary networks◄ form instead. The immobile gas phase◄ acts hydraulically and biologically like a reactive oxygen wall that cleans the groundwater flowing through it. This means the bubbles dissolve slowly and add oxygen to the groundwater passing by, supporting the process of degrading the pollutants it contains, while new oxygen is constantly fed in from above.

Controlling the spatial effect of the gas accumulator

Between 2000 and 2010, the BMBF financed the **SAFIRA**, **PROINNO** 1 and 2 and **ZIM** demonstration projects in order to research this procedure. The research sites included the site of a former chemical plant in Leuna and the Auensee recreation area in Leipzig, which is under threat from the groundwater being contaminated with PCE-TCE◄. Conventional technologies for direct gas injection are based on homogeneous gas distribution through lances. The distribution itself is not measured, meaning that these technologies operate "blind". Basically, the gas distribution at the injection lances behaves like a dynamic gas accumulator comprising branch-like and inter-related (coherent) channels of gas and non-related (incoherent) gas clusters. The injection or release processes cause these either to expand or draw closer together.

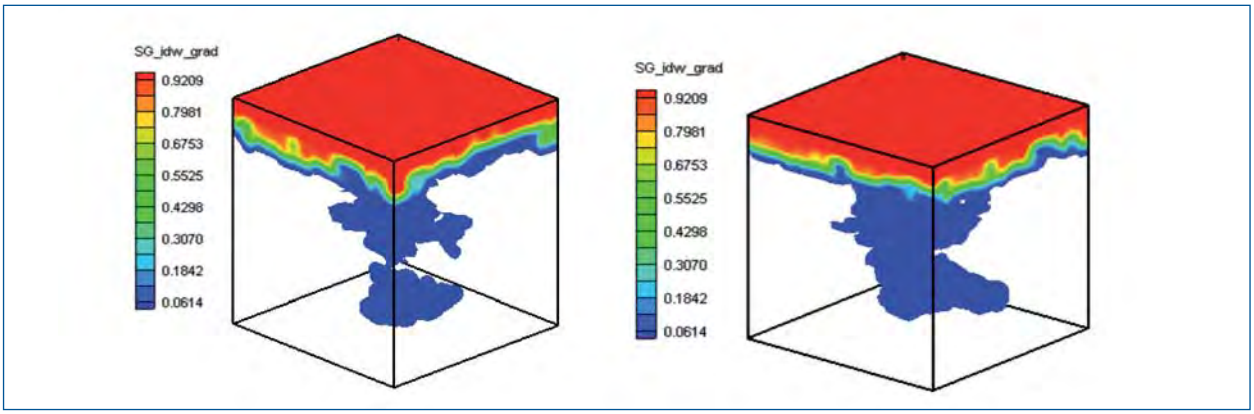


3D representation of gas distribution underground with LPI and HPI direct gas injection

The heart of the innovation and the scientific challenge of the projects lay in the small-scale metrological recording of the gas dispersion and accumulation processes in the heterogeneous conditions underground and the interpretation and control of these using computer models. The aim was to control the spatial effect of the gas accumulation. As well as conventional low-pressure injection (LPI), the scientists also experimented with high-pressure injection (HPI) for the first time.

Improved monitoring

Sensatec in Kiel worked together with the UFZ centre for environmental research at Leipzig-Halle to develop a new systems technology for coupled LPI-HPI direct gas injection. This involved both a reliable in-situ gas measurement system and a dynamic gas dispersion model on the basis of which the new injection process can be controlled and optimised. The measuring system features an innovative set of sensors (sensor array), which enables it to measure and store large amounts of data extremely quickly. This makes it suitable for recording changes in the gas transport and accumulation processes in the otherwise heterogeneous conditions underground. As this is much faster than typical groundwater transport processes, standard systems are unsuitable for this type of monitoring. With regard to the measurement data, the scientists used suitable geostatistical processes to calculate intermediate values (interpolation) and visualised all the data in 3D. These 3D data fields formed the basis for developing the gas dispersion model.



Example 3D computer simulation of gas distribution with LPI and HPI direct gas injection

Technologically relevant results

The research projects produced the following results:

- Independent measuring of horizontal and vertical hydraulic conductivity is essential for model-supported forecasting of dynamic gas accumulation underground. Thin clay layers in particular can significantly influence the dynamics of the gas flows reaching vertically upwards. In existing groundwater models, the vertical conductivity was calculated from the horizontal conductivity using an empirical factor (<1). However, this basic approximation breaks down when it comes to predicting the dispersion behaviour of dynamic gas accumulators.
- A fine-scale site survey is required to ensure the optimum vertical and horizontal positioning of injection lances and sensors. As a minimum, monitoring must involve dynamic drilling◄ and injection logs◄ in order to determine hydraulic conductivity and geoelectric profile recordings◄.
- The gas must be measured in a sealed in-situ sensor net adapted to the local conditions (approx. 60 measuring points per injection lance; 1 sensor per m^3), which is essential for successful predictions of gas dispersion in heterogeneous sediments.
- The experts derived from the laboratory experiments a working hypothesis that low-pressure injections lead to incoherent gas transport and high-pressure injections lead to coherent gas transport. This finding is important when it comes to ascertaining the correct dimensions for the gas barriers.
- A sensor system must be able to measure and store lots of data in a short period of time and to differentiate between coherent and incoherent gas transport.
- LPI scenarios and combined LPI/HPI scenarios with an extremely low injection rate of 0.18 cubic metres an hour lead to an incoherent accumulation of gas. Conversely, LPI scenarios with an injection rate ten times higher than this and pulsed HPI scenarios lead to a coherent accumulation of gas. This means that it is clearly the injection rate and not the injection pressure that predominantly affects the various gas distribution patterns. The only significant difference between the two injection methods is that high-pressure injection achieved a higher level of gas saturation in the lower range.
- A 3D gas dispersion model for optimising the coupled LPI/HPI gas supply procedure must:
  a) be a multi-phase model,
  b) factor in heterogeneous horizontal and vertical permeability◄ and capillary pressure fields◄,
  c) use parameter fields conditioned for the measurement data.
- The experiments regarding the gas dispersion processes conducted in the lab and the field are also of great interest to CCS technology, i.e. the underground accumulation of greenhouse gases.

Project website ► **http://safira.ufz.de**

Helmholtz Centre for Environmental Research – UFZ
Hydrogeology department
Prof. Dr. Helmut Geistlinger
Theodor-Lieser-Straße 4
06120 Halle, Germany
Tel.: +49 (0)3 45/5 58-52 20
Fax: +49 (0)3 45/5 58-55 59
E-mail: helmut.geistlinger@ufz.de
Funding reference: 02WT9947/8

VEGAS research facility – ecological remediation without digging up and shipping out

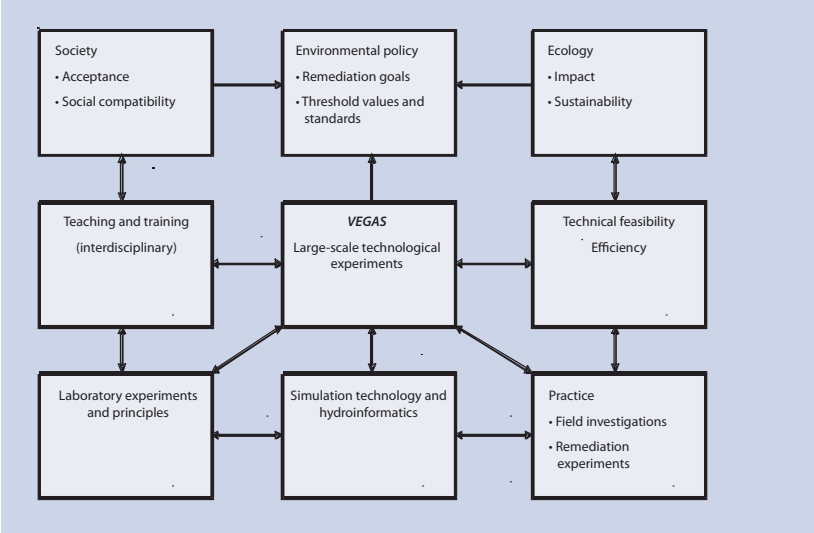
Pollution is contaminating soil and groundwater all over the world. Land affected by this is difficult to use and hard to sell because remediation of the soil and groundwater is extremely complex and expensive. It therefore often remains unused. At the same time, an area of around 90 hectares a day in Germany alone is being redeveloped as green-field land. The specialists at the Versuchseinrichtung zur Grundwasser- und Altlastensanierung (research facility for the remediation of groundwater and abandoned waste, VEGAS) are therefore developing technologies that enable efficient surveying and remediation of contaminated land to render it marketable once more.

The soil and groundwater at many former industrial sites and also in numerous urban areas has been contaminated through improper disposal methods, accidents, the effects of war and careless handling of hazardous substances. Consumers have also worsened the problem in the past: household chemicals, paint and other toxins that are now dealt with as specialist waste were disposed of at unsecured landfill sites with permeable ground underneath. For example, exhausted gravel pits were filled with all kinds of refuse and then planted over.

Conventional in-situ remediation techniques are often protracted and expensive. The physical properties of the pollutants means that they collect in the soil pores and are difficult to remove with traditional flushing methods. However, if contaminated material is dug out and disposed of at a dump, this only serves to delay the problem. Built-up land or land with deep-lying, hard-to-pinpoint sources of pollution cannot be dug up in any case. One of the most important tasks we face today therefore is to develop new technologies offering economical and ecological remediation before the abandoned waste poses a threat to both people and protected natural resources.

The VEGAS concept

With support from the BMBF and the Ministry of the Environment in Baden-Württemberg, the major research facility **VEGAS** was established by the University of Stuttgart in September 1995 (size: 670 m²; large-scale test rig surface area 18 x 9 m, height 4.5 m, divisible into three compartments). The engineers and scientists there develop surveying and remediation technologies and operate field applications and technology transfers. The large-scale test rigs are used to perform experiments under near-natural conditions, their dimensions being somewhere between conventional lab equipment and actual field conditions. There are good reasons for such middle ground: conventional lab tests are not directly transferrable to actual conditions "in the field", and the results from time and cost-intensive field studies at existing pollution sites are only meaningful to a limited extent. This is because more often than not the remediation specialists are unaware of both the overall amount of pollution and its precise spatial distribution. The few distributed measurement points do not produce a sufficiently detailed overview. Furthermore, environmental protection laws currently in force prohibit the injection of remediation chemicals into the aquifer◄ if it cannot be guaranteed that they are harmless. However, such a guarantee cannot be given when testing new technologies under development.



VEGAS – Contributing to research, practice and teaching

Innovations in technology

Abandoned waste in the soil can either be cleaned up or safeguarded. The remediation approach involves removing the source of the contamination or the plume through chemical, biological or hydraulic methods. Safeguarding prevents the further spread of the pollution, e.g. by containing the source. In the last few years, VEGAS has concentrated primarily on source surveying and remediation. Appropriate procedures, some of which have already been put into practice in the field in collaboration with companies include:

- Thermal remediation technologies: Energy feeds – either in the form of vapour or a vapour-air mix or as a fixed source of heat – increase the temperature of the contaminated soil and groundwater areas. This reduces the surface tension◄, viscosity◄ and density of the pollution while simultaneously increasing its vapour pressure. This boosts its transformation into gas and enables it to be sucked out via the soil gas.
- In-situ reduction of pollution through minute pieces of iron (nanoscale iron) in treatment walls: this remediation procedure is applied to CHC plumes. Experts are currently examining how this technology could also be applied within built-up areas. This involves injecting nanoscale iron directly into the source of the contamination by means of suspension◄. The issues of transportation, reactivity, and long-term stability and also economics still need to be clarified; these too must be answered through the pilot sites within various research consortia.

Other types of technology (further) developed by universities, companies, local authorities and institutes within VEGAS involve procedures such as the injection of tensides, alcohol cocktails or microemulsions. Other new options included special remediation wells, in-situ chemical oxidation (ISCO◄) and reduction (ISCR◄), immobilisation of heavy metals and improvement of the natural degradation processes within the aquifer (enhanced natural attenuation, ENA) through the addition of nutrients.

Focus on measurement technology

The field of measurement technology has been consistently expanded within VEGAS:

1. Surveying: The position and concentration of a pollution source must be precisely identified in order to implement remediation. The VEGAS researchers have therefore developed new methods, e.g. based on sensors and fibre optics, to enable a quick and cost-effective way of pinpointing sources of pollution.
2. Monitoring: New instruments for on-site measurement technology enable a prompt return of information on the distribution of and decrease in pollution, thus lowering the cost of remediation.
3. Long-term observation: Once remediation is complete, the experts must use automated long-term observation to prove that the concentration of pollution is not rising again and that the threat is therefore effectively neutralised.
4. Geothermal energy: To date there has been little research on the influence of geothermal systems on groundwater. The monitoring of water temperature and quality in the vicinity of geothermal probes is intended to contribute to their safe use in the long term.

Transfer of technology and knowledge

In order to ensure sustainable protection for soil and groundwater, it is not enough simply to develop technology. That is why the research facility holds regular training events for specialists working at authorities and engineering bodies. The technologies developed are conveyed to a broad specialist audience through pilot schemes conducted at actual pollution sites.

Project website ► **www.vegasinfo.de**

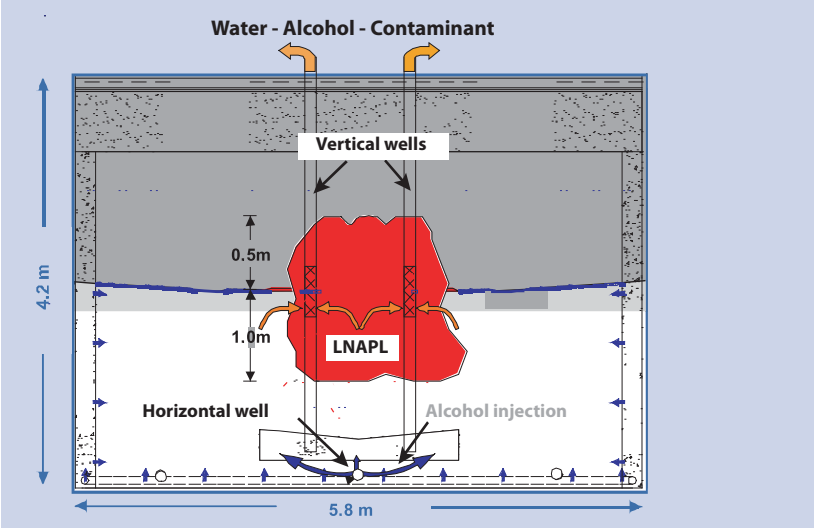
University of Stuttgart
Institut für Wasserbau (water engineering institute), VEGAS
Pfaffenwaldring 61
70550 Stuttgart, Germany
Tel.: +49 (0)7 11/6 85-6 47 17
Fax: +49 (0)7 11/6 85-670 20
Funding reference: 02606861

VEGAS scientific manager
Dr. Jürgen Braun
Tel.: +49 (0)7 11/6 85-6 70 18
E-mail: juergen.braun@iws.uni-stuttgart.de

VEGAS technical manager
Dr.-Ing. Hans-Peter Koschitzky
Tel.: +49 (0)7 11/6 85-6 47 16
E-mail: hans-peter.koschitzky@iws.uni-stuttgart.de

Remediation using alcohol – using methods from the crude oil industry as a model

Using methods from the crude oil industry as a model for protecting the environment? A research team from the Versuchseinrichtung zur Grundwasser- und Altlastensanierung (research facility for the remediation of groundwater and abandoned waste, VEGAS) at the University of Stuttgart has shown that this is indeed possible. Experts at the institute for water engineering (IWS) there and the institute for hydromechanics at the University of Karlsruhe (IfH) developed an alcohol-based form of remediation technology for treating contaminated aquifers◄. They concentrated primarily on contamination through hydrocarbons of varying density and medium to low solubility (LNAPL/DNAPL◄). Their work has resulted in a procedure that enables aquifers contaminated in this way to be cleaned "in situ" – i.e. in its existing location.



Alcohol flushing of aquifers contaminated with LNAPL

The crude oil industry first of all managed to use traditional pumping methods to extract around 40% of the accumulated crude oil from the discovered source. The main reasons for the low yield were the surface tension◄ and the different viscosities◄ and densities of water and oil. The specialists at the oil company then injected alcohol and tensides into the oil fields as solubilisers to test their effect. These substances reduced the surface tension and significantly increased pumping efficiency.

However, certain types of alcohol prevent the CHCs from moving freely. This put alcohol flushing back in the picture for use in in-situ groundwater remediation. This method is only economically viable though if alcohols can be found that enable a quick and controlled discharge of contaminants in dissolved form or as a free phase◄ and that can be recovered and reused several times during remediation.

Large-scale tests

The BMBF-funded project entitled **"Development of an advanced groundwater remediation technique for the removal of anthropogenic chlorinated hydrocarbons with high density (CHC) by alcohol injections"** saw scientists from IfH and VEGAS testing whether alcohol flushing was suitable for remediation and investigating how to determine the relevant dimensions. The research focused on efficiency, stability of the cocktail (separability), production costs and above all hydraulic control. On the one hand, this means that a cocktail of alcohol with its specific physical properties must be transported in a targeted manner to the source of the contamination; on the other, that uncontrolled mobilisation of the contamination must be avoided. The IfH investigated what happens when alcohol cocktails are injected in a spatially targeted manner into a contaminated aquifer and whether the effects can remain under control. To clarify these questions, the experts from both institutes performed two large-scale tests among others in realistic conditions.

The researchers produced a mixture of hydrocarbons (BTEX◄) of low density (LNAPL) in a 6 x 3 x 4 metre tank so that the pollution lay in residual saturation – i.e. captured through capillary forces – beneath the surface of the water and as a floating phase. They then used a horizontal well to target injection of a mixture of alcohol and water (isopropanol and water at a ratio of 60:40) into the artificial aquifer. The alcohol permeated the contaminated region and dissolved the pollution, which could then be pumped out via two vertical wells. The result: almost 90% was removed.

In further tests, the scientists introduced a source of CHC contamination (TCE) to a heterogeneous artificial aquifer in a large tank (9 x 6 x 4.5 m). They used a groundwater circulation well to inject a cocktail of alcohol into the lower regions of the aquifer. At the same time, the same well was

Large VEGAS well (alcohol flushing for DNAPL contamination)

used to draw out the mixture of alcohol, water and pollution from the upper regions. Scientists managed again to remove over 90% of the contamination – in dissolved but also mobilised form. It must be emphasised that no uncontrolled downwards vertical displacement of the pollution took place.

The alcohol used was recycled in order to reduce costs and the amount of wastewater. The project team designed and built a wastewater treatment facility for this purpose.

Alcohol cocktails for tough cleaning

These successful tests meant that the researchers could now make more accurate statements on which alcohol cocktails are suitable for which types of remediation. For example, a cocktail of 2-propanol (54% volume), 1-hexanol and water (both 23% volume) is recommended for CHC contamination. This mixture enabled the soil material to be cleaned safely and efficiently in all tests. The required initial concentration of the mixture depends on the flow conditions and the heterogeneity of the soil. It must be noted that the higher the proportion of alcohol, the more expensive the remediation process. The lower the proportion, the greater the risk that the cocktail will separate.

Complex use cases

Finally, the project partners used the test data to produce mathematical equations for the dependency of the density, viscosity and surface tension on temperature and the mixture ratio. They are currently being used to expand the MUFTE-UG (Multiphase Flow, Transport and Energy Model – Unstructured Grid) numeric model at the department of hydromechanics and modelling of hydrosystem at IWS with a module that can simulate a complex multi-phase/multi-component flow.

Project website ▶ **www.vegasinfo.de**

Karlsruhe Institute of Technology (KIT)
Department of Civil Engineering, Geo and Environmental Sciences
Institute of Hydromechanics
Prof. Gerhard H. Jirka
Kaiserstr.12
76128 Karlsruhe, Germany
Tel.: +49 (0)721/608-2200
Fax: +49 (0)721/608-2202
Funding reference: 02WT0065

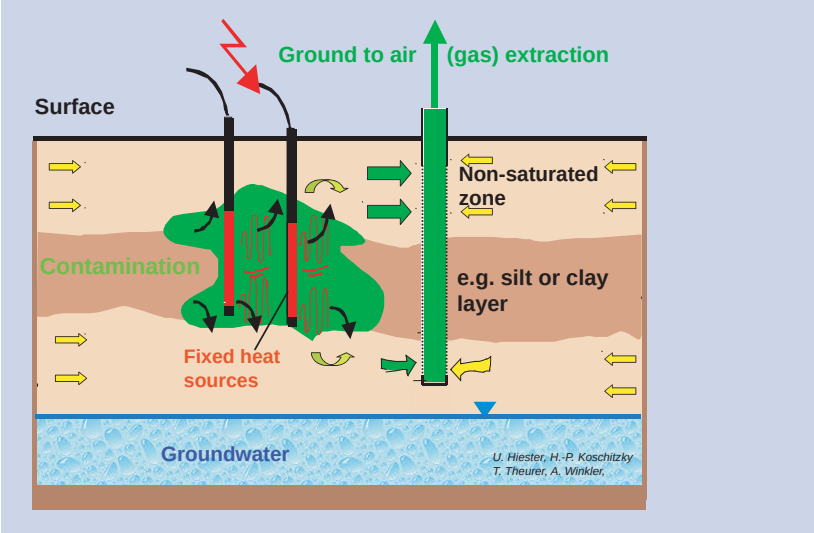
University of Stuttgart
Institut für Wasserbau (water engineering institute), VEGAS
Pfaffenwaldring 61
70550 Stuttgart, Germany
Tel.: +49 (0)7 11/6 85-6 47 17
Fax: +49(0)7 11/6 85-6 70 20
E-mail: vegas@iws.uni-stuttgart.de
Funding reference: 02WT0064

VEGAS scientific manager
Dr. Jürgen Braun
Tel.: +49 (0)7 11/6 85-6 70 18
E-mail: juergen.braun@iws.uni-stuttgart.de

VEGAS technical manager
Dr.-Ing. Hans-Peter Koschitzky
Tel.: +49 (0)7 11/6 85-6 47 16
E-mail: hans-peter.koschitzky@iws.uni-stuttgart.de

Heat as an accelerator – heat lances turning soil pollutants into vapours

High temperatures are a good way to extract pollution from contaminated soil. This has been proven by researchers at the Versuchseinrichtung zur Grundwasser- und Altlastensanierung (research facility for the remediation of groundwater and abandoned waste, VEGAS) within the University of Stuttgart's water engineering institute. Their thermal in-situ remediation technology (THERIS) – just one of the procedures used for thermal remediation – uses a strong infeed of heat to clean out contamination from underground, which is faster than the conventional means of "cold" soil gas suction. Experts at the VEGAS research facility (see project 1.1.09) have compared both processes with each other as part of a research project – with very clear results.



Principle of the THERIS procedure

Medium to low solubility liquid hydrocarbons (LNAPL/DNAPL◄) contaminate soil and pose a risk to groundwater. Landowners frequently turn to a process called soil gas suction (SGS) for remediation. This involves the pollutants, which convert into gas at a sufficiently high natural temperature, being sucked out of the contaminated ground together with the air within through pipes (soil gas level). A discharged air treatment facility filters out and removes the pollution from the contaminated soil air on site and the system then releases the cleaned air into the atmosphere. However, this method quickly reaches its limits: the organic pollutants only convert from liquid to gas◄ in very small amounts at the usual soil temperature of about 10°C, which makes the remediation process much slower and much more expensive. Furthermore, fine-grain soils – in which pollutants most often accumulate – are not permeable enough for this process. The soil gas is then very difficult to suck out. After several years, it is still uncertain whether many of these facilities are achieving their remediation objective.

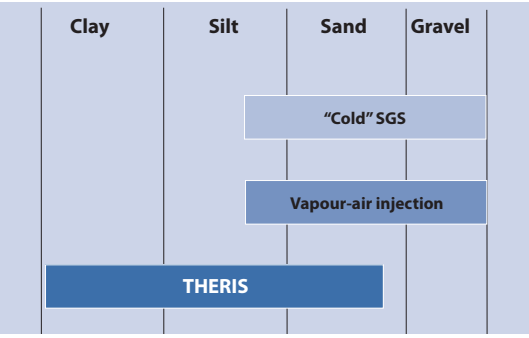
Heat infeed boosts contaminant discharge

These problems can be overcome by applying heat, e.g. via fixed sources of heat such as the electrical heat lances on which the THERIS procedure is based. The soil heats up, pollutants convert more quickly to gas and are also discharged from smaller areas of permeable soil. SGS sucks out gaseous contaminants directly from under the ground along with the soil gas. The suctioned, contaminated soil gas is then cleaned on site. THERIS can be used with various soil types, particularly those with loose stones (sand, silt, clay) in the soil zone above the groundwater, i.e. the non-saturated soil zone.
Unlike thermal in-situ remediation procedures – vapour or vapour-air injection – no heat medium is injected during the THERIS process. This makes THERIS also suitable for heating and cleaning large, low-permeability soil layers. Comparative experiments in the large tank at the VEGAS research facility and at a field site should now clarify the differences between SGS and THERIS in terms of remediation time, degree of effectiveness and energy consumption.

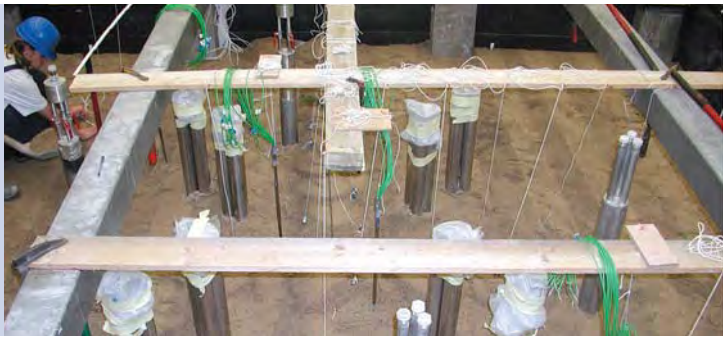
Experiment in the large VEGAS tank

The researchers began testing the THERIS procedure in a 150 cubic metre tank at the VEGAS research facility, which was filled with a layered soil structure and equipped with measuring instruments. They added 30 kilograms of trimethylbenzene (TMB, flash point 169°C) to a localised area of a one-metre thick layer of fine low-permeability sand.

To begin with, they applied cold soil gas suction for two months. They then put four quadratically arranged, fixed heat sources (THERIS) into operation in this fine-structured layer, which heated up to 500°C. The SGS continued to deliver a constant rate of suction. As the TMB was fully removed after just 20 days, the soil temperature between the heating elements had not even hit 100°C.



THERIS procedure: areas of application



Heat lances and soil gas suction level being installed in the large tank

Remediation in the field test

The researchers also began a field test: an approximately 3.5 metre thick clay-marl layer over an area of around 80 square metres still contained high concentrations of CHC◄ after several years of cold SGS, primarily perchloroethylene◄ (PCE, flash point 121°C). To begin with, the SGS was left to continue without any change. Then 22 heat lances from the THERIS system were implemented, equipped with the latest measuring, control, data recording and transfer technology. They heated the soil evenly and in a way relatively uninfluenced by differences in geological structure. After just one month the temperature was around 80°C, and largely over 90°C after two. The researchers sucked out the gaseous pollutants mobilised by THERIS using SGS.

THERIS has the edge

The evaluation of the tests showed that THERIS cut the remediation time by about 90% compared with cold SGS and reduced the amount of energy required by two-thirds. Differences in the absolute values between the tank and the field test were traced to location factors such as geology, the type of contamination and its distribution plus system-specific details (e.g. the well arrangement).

THERIS takes just a few weeks to clean even low-permeability soil quickly, reliably and with sustainable results. The significant increase in performance is predominantly attributable to:

- the increased gas permeability and more effective diffusion as a result of the dried soil
- the accelerated conversion of liquid hydrocarbons to gas as a result of the higher temperatures.

The THERIS facilities are robust, enabling them to be installed quickly and operated safely whatever the weather. Due to the cost of putting the heating elements and monitoring systems in place, the installation costs are higher than for cold soil gas suction. However, these additional costs are compensated for by the shorter remediation time, lower operating costs (energy, equipment rental etc.) and lower personnel costs.

Project website ► **www.vegasinfo.de**

University of Stuttgart
Institut für Wasserbau (water engineering institute), VEGAS
Pfaffenwaldring 61
70550 Stuttgart, Germany
Tel.: +49 (0)7 11/6 85-6 47 17
Fax: +49 (0)7 11/6 85-6 70 20
E-mail: vegas@iws.uni-stuttgart.de
Funding reference: 02WT0266

VEGAS scientific manager
Dr. Jürgen Braun
Tel.: +49 (0)7 11/6 85-6 70 18
E-mail: juergen.braun@iws.uni-stuttgart.de

VEGAS technical manager
Dr.-Ing. Hans-Peter Koschitzky
Tel.: +49 (0)7 11/6 85-6 47 16
E-mail: hans-peter.koschitzky@iws.uni-stuttgart.de

Maintaining lifelines – fully integrated, sustainable river basin management

Rivers are the lifelines of nature. They collect together the continents' water and transport it to the seas, they provide structure to landscapes and are a home for many different types of animal. They also fulfil a key economic function as transport routes, energy suppliers and sources of drinking water. When flooding occurs, it poses a risk to both life and property. Pollution also remains a problem in many regions of the world. This wide variety of aspects and their interaction can only be managed through sustainable river basin management.

River basin management refers to a water economy bordered by a natural drainage basin (rather than city, regional or other administrative borders). Its spatial field of activity is thus where the natural interrelations of the water cycle can be detected and where they have a direct impact.

A new understanding of water resource management

European Parliament and Council directive 2000/60/EC, generally referred to as the EU Water Framework Directive (WFD), came into force on 22 December 2000. It draws heavily on the idea of river basin management, its core objective being the protection of aquatic ecosystems with a view to sustainable environmental development. Unlike the previous method of categorising waters on a basis of usage, measures and sectors, the WFD places the focus on an all-embracing, integral view of the groundwater and surface water systems (watercourses, standing waters, transitional waters and coastal waters).

As such, water management in future will no longer be based on administrative borders but on river basins. This opens up the way to a fully integrated method of viewing natural water systems and their use from source through to mouth. A co-ordinated approach across state and country borders will serve to ensure waters are used sustainably and are protected.

Instruments for sustainable river basin management

These requirements make river basin management a complex task from both a scientific and practical perspective. The Federal Ministry of Education and Research (BMBF) is supporting research projects focussing on river basin management so that new handling guidelines can be developed within this field. As well as researching the complex interaction between rivers and their basins, land reclamation and conservation are other issues of scientific focus. Focal points from the last few years have included research on the Elbe ecology (project 1.2.01), river basin management (project 1.2.02), risk management for extreme flood events and integrated water resource management. The sediments in flowing waters were considered as part of the BMBF joint research project entitled "sediment dynamics and pollutant mobility in river basins" (SEDYMO) (project 1.2.03), the aim being to contribute towards ecological maintenance dredging of federal watercourses, sustainable management of contaminated flood sediment and the planning and implementation of sediment clear-ups to improve the structure and ecology of bodies of water. A joint research project funded by the BMBF and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) resulted in the requirements necessary for the successful reintroduction of sturgeon (project 1.2.04).

Funding has also been provided at European level, for R&D and networking projects on river basin management and integrated water resource management (IWRM) within EU research programmes. One such example is the EU "IWRM Net" project, representing 21 institutions from 14 countries including the BMBF with its two project co-ordinators in Karlsruhe (PTKA) and Jülich (PTJ). This project is pursuing training and intensification within European river basin management. IWRM Net gives the participating countries the opportunity to exchange both the conditions within their location and their experiences at European level, launch joint projects and even develop future concepts where necessary for co-operative research and development.

The Elbe basin – a research model for river management in the future

The Elbe river basin is an extremely exciting field of research for scientists in ecological disciplines. Whereas the quality of the Elbe's water was extremely poor some years back, the flood plains for the river formerly serving as an international border were able to sustain the versatile structure that most rivers of a similar size lose as a result of construction. This means the 1091 kilometre stretch of river and its basin◄ has the potential to survive as a near-natural river habitat in future. The Elbe basin therefore serves as a model region where experts can research usage conflicts and develop solution concepts.

The structure and history of the Elbe have made it the subject of many research activities within a whole host of different scientific disciplines – wholly within the intent of the EU Water Framework Directive◄. This directive demands river basin management◄ aimed at achieving sustainability. Development concepts for large-scale river habitats with their diverse forms of interaction have only emerged to some extent previously – including on an international front. In the meantime, it has become apparent that preservation of river habitats requires a fully integrated approach that must support a complex assessment of the ecological and commercial situation within the river basin.

As such, the BMBF provided around EUR 20 million of funding for 28 scientific projects within the joint research programme on the ecology of the Elbe between 1996 and 2005. Experts within the individual projects examined ecological and economic connections and developed solution concepts for the various usage requirements of farmland, conservation, water management and shipping.

Natural areas rather than administrative units

The researchers should not only gather scientific findings, they should also devise instruments and handling recommendations for politicians and planners. The requirements of the EU Water Framework Directive state that the river, its flood plains and the basin should be considered as a functional unit. The effects of the Elbe flood of 2002 and the extreme drought of 2003 have already clearly shown in dramatic fashion that ecological phenomena must be considered not within the confines of administrative borders but by those of natural areas.

View of the Elbe and its flood plains (Source: Federal Institute of Hydrology)

Three focuses for research

Topic 1: The ecology of flowing waters

Key phrases such as "creating retention basins◄ by installing dykes" and "guaranteeing minimum waterway depths through tailored river-engineering maintenance measures" are on everyone's lips in the wake of the floods. However, such measures have an effect on water levels, affect the hydrodynamics◄ and morphodynamics◄ of the waters and influence the living conditions of fish and micro-organisms. The micro-organisms in the Elbe are especially important for material conversion and thus for the quality of the water. The researchers investigated these connections by examining the morphological◄, hydraulic◄ and biocoenotic webs of interaction◄. The main focus was on which processes control the composition and dynamic of the living communities within the Elbe. The results of in-depth field tests and devised models provided the answer, the end product being a contemporary, comprehensive overview of the research on water quality, which also included decision-making supports for planning water engineering measures.

Topic 2: The ecology of the flood plains

Engineering rivers and changing land usage within flood plains are actions that have ecological consequences. Public discussion has seen an increased demand for the clearing of flood zones and the reclamation◄ of river flood plains. This poses the question as to what an environmentally appropriate development of the flood plains in the Elbe river basin might look like. The consequences for the affected farmland, the population and the flora and fauna must be taken into account. The projects within this topic indicate handling recommendations to ensure conservation and formulate overall concepts for the ecological development of flood plains while also factoring in eco-

The joint Elbe ecology research programme

nomic aspects. This meant that current research results on control factors, bioindication◄ and the prognosis for living communities within the Elbe and its flood plains had to be brought together. Alongside this, a considerable proportion of the work involved indicating the benefits and costs of intervention as this is ultimately what influences political decisions. So, for example, the results of the research have also provided key bases for planning procedures for dyke relocation around Lenzen. It is the largest national project of this type to date, and has since been implemented.

Topic 3: Land usage within the river basin

Diffuse nutrient loading from agriculture is one of the key negative factors in the quality of the Elbe's water today. The causes of this loading vary greatly from region to region due to the natural properties and usage structures within the Elbe river basin. The projects within this topic involved scientists examining how the water quality in the Elbe and thus also the North Sea could be improved through a modified use of the land or other agricultural procedures. They used water and matter balance models to show which measures are ecologically desirable and economically feasible for controlling land usage and the water balance in the Elbe basin. This was then used as a basis to develop and propose strategies for reducing water contamination. The conserving soil processing procedure is one worth particular mention: this management system has a positive effect on soil-physical, hydrological and biological properties, reduces soil loss and therefore also lowers the amount of phosphate entering the water.

Representation of the results in various media

The results of the joint Elbe ecology research programme were prepared in three types of media for varying needs:

- The Internet-based Elbe Information System (ELISE) provides information on the research into the Elbe's ecology and supports co-ordination of the project work.
- The five bands within the publication series on concepts for the sustainable development of a river landscape (entitled "Konzepte für die nachhaltige Entwicklung einer Flusslandschaft") summarise the findings across the projects and present concepts for use in practice (http://www.weissensee-verlag.de/verlagsprogramm/04_niw_flusslandschaft.htm).
- The "Elbe-DSS◄", a decision support system for river basin management, provides a basic structure for the specialist knowledge and the computer models and data relating to the Elbe basin. Such systems could help authorities to plan river management in future. They enable the complex effects of individual measures to be identified in advance in view of the objectives to be achieved. The Federal Institute of Hydrology (BfG) has made the developed prototypes for the Elbe DSS available free of charge over the Internet (http://elise.bafg.de/?3283).

Federal Institute of Hydrology (BfG)
Dr. Sebastian Kofalk
Mainzer Tor 1
56068 Koblenz, Germany
Tel.: +49 (0)2 61/13 06-53 30
Fax: +49 (0)2 61/13 06-53 33
E-mail: kofalk@bafg.de
Internet: www.bafg.de, http://elise.bafg.de
Funding reference: 0339542A

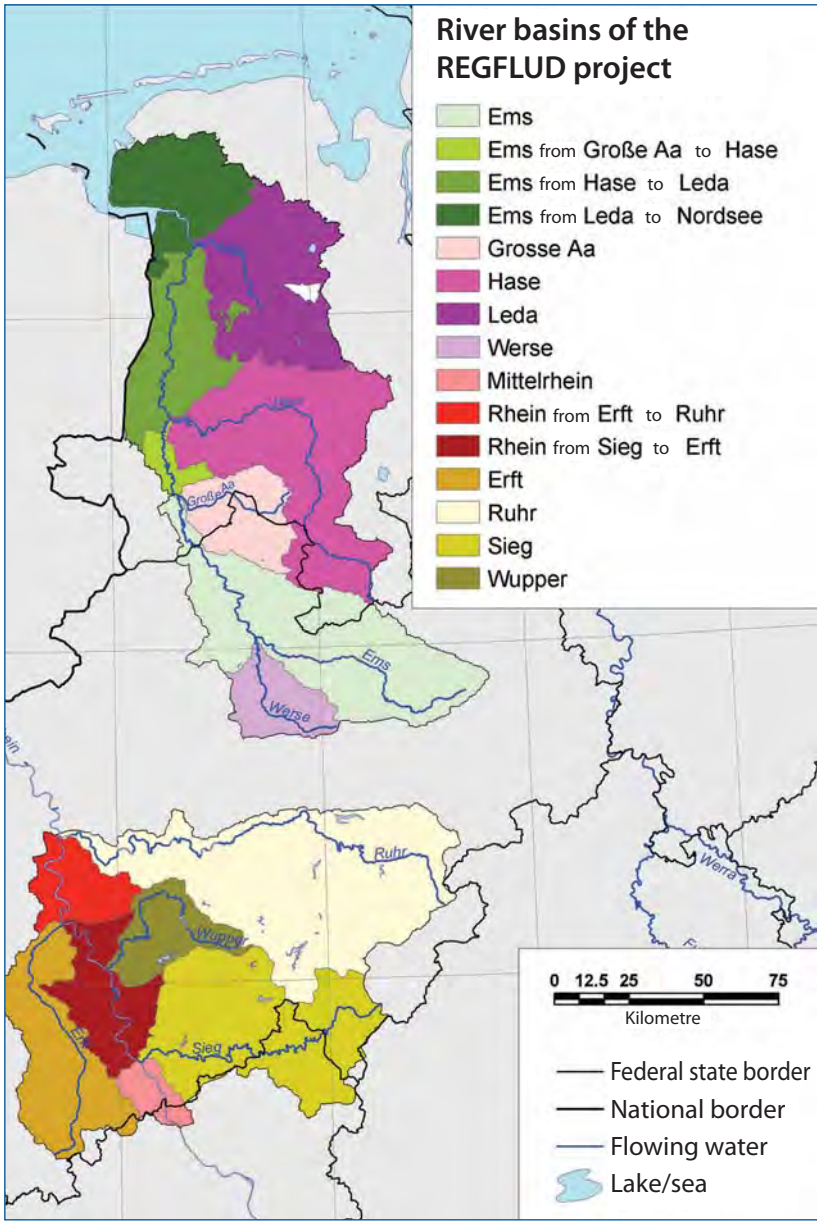
Examining the Rhine and Ems – management systems for water quality in river basins

Rivers form a crucial part of the water cycle. Among other things, they need to be protected from nutrient loading to guarantee their function in the long term. The European Water Framework Directive (WFD◄) calls for this safeguarding measure with the demand for corresponding environmental development. The REGFLUD project saw an interdisciplinary team tackle these requirements and adopt a scientific approach to studying the systematic management of regional river basins. Using the examples of the Rhine and Ems rivers, the experts investigated agricultural measures to improve the quality of the water.

German waters are not as heavily loaded with nutrients as they were in the past; they have undergone a substantial clean-up over the last few decades. The biggest contributions to this positive development are an improved procedure for cleaning up wastewater and a reduction in the amount of phosphates used in detergents. Despite this success in water protection, there are still equally large sections of water suffering to a greater or lesser extent from nutrient loading. The majority of nutrients in rivers originate from diffuse sources – i.e. they are impossible to pinpoint precisely – predominantly as a result of farming. Agricultural production introduces nitrogen and phosphorus, which have an impact on the ecological balance and the usability of water and seas. As a further step towards improving the water balance, the 2000 EU Water Framework Directive◄ calls for management systems to be established for all river basins.

New requirements

Many public bodies in charge of water usage and protection are entering new territory when it comes to diffuse nutrient loading. Unlike isolated loading, neither the cause nor the effect can be clearly identified. This is primarily due to the diverse natural conditions such as water balance and soil properties that affect the transportation, bonding and degradation of the nutrients underground and in the groundwater. In many cases, the authorities lack the tools and methods necessary to decide on efficient strategies or measures to reduce diffuse water loading through agriculture.



The river basins involved in the REGFLUD project

Different regions undergoing investigation

This is where the BMBF-funded REGFLUD research project stepped in to assist (full name: **"Management regionaler Flusseinzugsgebiete in Deutschland (REGFLUD) – Rahmenbedingungen und Politikoptionen bei diffusen Nährstoffeinträgen (Stickstoff und Phosphor) der Landwirtschaft"** – management of regional river basins in Germany – framework conditions and policy options for

diffuse nutrient loading (nitrogen and phosphorus) in agriculture). The aim of the project was to devise scientific methods that could be used to help determine efficient measures for reducing the diffuse nutrient loading of river basins as a result of agriculture. The investigations took place between July 2001 and October 2005 and focused on two river basins: a section of the Rhine basin between the Sieg, Erft, Wupper and Ruhr tributaries, and the entire basin◄ of the River Ems. The regions investigated differed in terms of both agricultural usage and local conditions.

Interlinking systems and models

The focus of the REGFLUD project was on interlinking the Regional Agricultural and Environmental Information System (RAUMIS) for Germany with the hydrological GROWA98 and WEKU models. RAUMIS enables the analysis of the regional effects of various agricultural and agri-environmental policy measures on agricultural land usage, production and income and on diverse agri-environmental relationships, e.g. excess agricultural nutrients. The GROWA and WEKU models use this as a basis – while factoring in a whole host of local conditions such as soil, climate and topography – in order to map nutrient loading of water by area. The deriving of efficient measures to reduce nitrogen loading from agriculture using the combined model was tested with a nitrogen tax and a restriction on livestock density.

Tailored measures required

The model results show that the different regional conditions lead to very different proportions of excess nitrogen from agriculture being found in the groundwater and surface water. The proven effects of a nitrogen tax and a restriction on livestock density, strongly deviating from each other within areas, document that only tailored measures to provide a sustainable solution to the nitrate problem will help in a given area. The integrated consideration of local conditions and the complex interaction through the combined model makes it possible to develop more efficient water protection measures.

Muck spreading in agriculture
(Source: www.oekolandbau.de)

Putting into practice

The AGRUM-Weser pilot project run by Germany and neighbouring countries is developing other regional solutions using the REGFLUD approach. The combined model has been expanded to include the MONERIS model, which factors in all relevant loading paths. The work is being conducted in collaboration with those responsible for executing the requirements of the WFD in the Weser river basin and also takes country-specific procedures into account. The aim is to analyse and evaluate operational measures for reducing the effects of diffuse nutrient loading from agriculture. As such, the decisive step has been taken to put the REGFLUD research project into practice.

Project co-ordination
Institute of rural studies within the
Federal Agricultural Research Centre (FAL)
Dr. Heinrich Becker
Bundesallee 50
38116 Braunschweig, Germany
Tel.: +49 (0)5 31/5 96-55 03
Fax: +49 (0)5 31/5 96-55 99
E-mail: heinrich.becker@fal.de
Internet:
www.vti.bund.de/de/startseite/institute/lr.html
Funding reference: 0330037 to 0330040

SEDYMO research project – effects of sediment dynamics on the quality of flowing waters

Many pollutants released by man into the environment end up in the water. The contamination directly discharged gathers together here, along with solids washed away by precipitation and floods and dissolved compounds. Some pollutants tend to bind to particles and are deposited with the sediments on the water bed. From there they can get back into the water, for example if they are stirred up by deepening of the waterways or flooding, or are re-dissolved as a result of chemical processes. A research project is tackling these important problems and working on supplying the currently lacking foundation and process knowledge.

Taking sediment samples at the Rhine

Using an in-situ erosion tester at the Elbe

Although the amount of contamination entering Germany's rivers is constantly falling, the sediments◄ they contain are still heavily loaded with environmental chemicals in many areas. These substances do not only enter the waters through wastewater; other causes of this pollution are contributions from the air, precipitation and floods, and contaminated solids from landfill sites and slag heaps. River mouths are especially affected by this, as this is where the pollutants from the entire course of the river gather.

Fine sediment is of particular interest to those researching water pollution. It contains relatively large amounts of pollution and the large particle surface makes it very reactive from a chemical and physical perspective. Pollution in this regard does not only relate to directly toxic environmental chemicals such as heavy metals and specific organic compounds; it also covers substances that can indirectly affect water quality, such as organic substances or nutrients such as nitrogen and phosphorus. The degradation processes and widespread algae growth reduce the oxygen levels in the water.

Dynamics of pollution release

Depending on the flow speed and the chemical and biological state of the water, solids and parts of dissolved substances transported by rivers are deposited on the riverbeds and flood plains. The sediments therefore also indicate the water pollution of the last few days, but their components can also be released again. If solids are present (mineral or organic particles), then either natural or artificial erosion processes are involved. Triggers include flood water, movement caused by ships or maintenance dredging to keep the waters navigable. Soluble pollutants that in the meantime have bound themselves to the sediment◄ can be released through (micro)biological and chemical processes.

Knowledge on the dynamics of pollutant-bearing sediments is becoming increasingly important with the implementation of the European Water Framework Directive (WFD)◄, which focuses on measures to improve water quality across entire river basins.

Statements to date on the means of pollution entering water have predominantly referred to known sources outside the water itself. This includes diffuse sources such as agriculture and isolated sources such as landfills and industrial sites. However, this approach omits an extremely important factor: the re-release of harmful particles within the sediment on the riverbed.

The BMBF **"sediment dynamics and pollutant mobility in river basins" (SEDYMO)** research project was launched in May 2002 to drive forward this aspect of sediment research. The project aims to make a contribution towards the ecological optimisation of maintenance dredging within federal waterways, the sustainable management of contaminated flood sediments and the planning and execution of sediment clear-up operations to improve the structure and ecology of the water.

Interdisciplinary approach

The research project co-ordinated by the institute of environmental technology and energy economy at the Hamburg University of Technology together with 12 other partners (see TUHH project website) combines two key issues: the dynamic erosion/depositing behaviour of the fine sedi-

Taking sediment samples at the Salzach

ment and the mobility of pollutants and loads in sediments and suspended matter. As the two aspects are closely interlinked in practice, a joint research approach between technical and natural-science disciplines is required.

The first phase◄ of the project saw the project team examining the erosion and transportation of fine-grained sediment using the Neckar and the Elbe as an example. The researchers used the flow channel, microcosm and turbulence column as measuring devices. The methodical work was accompanied by physical-chemical and microbiological analyses. Other sub-projects involved comparative investigations of the transportation of fine-grained sediment performed under near-natural conditions in docks and their inlets. Another sub-project investigated the mixture of fine-grain particles in the Elbe. The second phase primarily saw the scientists investigating the transportation of nutrients and pollutants. The interactions occurring in natural conditions between aggregates, pollutants, water and soil were quantified, classified as control factors of biological, sedimentological and chemical processes and consolidated into models. Six more sub-projects helped the scientists gain fundamental knowledge of the physical-chemical and biological properties of solids within water.

Broad application range

The investigations showed that the speed at which the organic pollutants are sorbed (bound) to the sediment and then desorbed (released) depends heavily on hydrodynamic conditions. Conversely, changes to the hydrochemical composition of the flowing water, e.g. due to flood events, have less influence on the binding behaviour of pollutants than previously thought.

The instruments and models developed during the course of the project to characterise and predict the erosion stability of sediments has already been put to practical use. For example, areas flooded by the severe Elbe flood in August 2002 were examined. Scientists from the research programme have also taken part in the "Iffezheim barrage" risk assessment: the shifting of 300,000 cubic metres of heavily contaminated Rhine sediment has sparked an international controversy.

The SEDYMO results are also being directly input into the work of the technical committee on managing contaminated sediments at the German Association for Water, Wastewater and Waste (DWA) and the BMBF-funded "Risk Management of Extreme Flood Events" (RIMAX) programme. They will be of particular relevance when further measures are implemented in accordance with the WFD to combat pollution sources in waterways. Reducing emissions from historically contaminated sediments will be a key task within this work.

The publication entitled "Sediment Dynamics and Pollutant Mobility in Rivers – An Interdisciplinary Approach" is the frame of reference for the interactions in both technical engineering and natural sciences of contaminated sediment in flowing waters and was compiled as part of the SEDYMO project from the contributions to the "International Symposium on Sediment Dynamics and Pollutant Mobility in River Basins".

Hamburg University of Technology (TUHH)
Institute of environmental technology and energy economy (IUE)
Prof. (i. R.) Dr. Ulrich Förstner
Eissendorfer Straße 40
21071 Hamburg, Germany
E-mail: u.foerstner@tu-harburg.de
private:
Stöversweg 6 a
21244 Buchholz, Germany
Tel.: +49 (0) 41 81/3 67 90
Internet: www.tu-harburg.de/iue/sedymo

University of Stuttgart
Institut für Wasserbau (water engineering institute, IWS)
Prof. Dr.-Ing. habil. Bernhard Westrich
Pfaffenwaldring 61
70569 Stuttgart, Germany
Tel.: +49 (0)7 11/68 56 37 76
E-mail: bernhard.westrich@iws.uni-stuttgart.de
Funding reference: 02WF0315 – 0318, 02WF0320 – 0322, 02WF0467 – 0470

The sturgeon is making a comeback – repopulation of a former river resident

The sturgeon was a typical resident of North-German rivers that then disappeared from these waters. Its eradication is a symptom of the conditions of the water: migrating fish in particular find it difficult to locate suitable conditions in obstructed and contaminated rivers. An ongoing research project conducted by the BMBF and the BMU has been working since 1996 to meet the necessary requirements for the successful repopulation of the sturgeon. The scientists have already established parent stock for North Sea and Baltic Sea sturgeon and released the first set of young into the Oder and Elbe as part of an experimental stocking measure. Fish from French and Canadian rivers constitute the germ cell for the offspring.

At the end of the 19th century, sturgeon were widespread along the entire European coast and they had spawning grounds in all the major European rivers. Today, this breed of fish is threatened with global extinction. The rivers have become obstructed and contaminated, destroying their habitat, and intensive fishing has simultaneously decimated the population. Individual catches of sturgeon were registered in Germany as late as 1992. After that, the sturgeon was deemed to have died out in Germany.

It is not just the sturgeon that has suffered the destruction of its habitat; other migrating fish have also been affected, e.g. the salmon, sea trout, houting, allis shad and twait shad. The experience gained in the reintroduction of the sturgeon and possible reclamation measures◄ is therefore also of benefit to other fish populations.

Residents of different waters

The sturgeon is a migrating fish that leaves the sea and moves far upriver in order to breed, laying over a million eggs in fast flowing water. Once the larvae have hatched and grown up among the pebbles, the offspring drift downstream to sections of the river rich in food. At the end of their first year, the fry progress to the brackish water of the river mouth and then go on to reside in the sea for the next two to four years. After 10 to 20 years, the sexually mature fish return to the river of their birth in order to breed.

Reintroduction research project

The quality of the water in rivers has improved greatly in the last 20 years – providing an opportunity to reintroduce sturgeon, which was seized by the Gesellschaft zur Rettung des Störs e. V. (society for saving sturgeon) in 1994. The federal ministries for research and the environment have given over EUR 1.8 million since 1996 to support a research project on the reintroduction of sturgeon to the feeder rivers of the North Sea and Baltic Sea. Entitled **"Genetische Populationsstruktur, Zuchtplan und künstliche Vermehrung einer süßwasseradaptierten Zuchtgruppe des Europäischen Störs** (Acipenser sturio) **als Voraussetzung einer erfolgreichen Wiedereinbürgung"** (genetic population structure, breeding plan and artificial reproduction of a freshwater-adapted breeding group of European sturgeon (Acipenser sturio) as a prerequisite for successful reintroduction), the project involves the German Federal Agency for Nature Conservation (BfN), the Berlin Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), the Landesforschungsanstalt für Landwirtschaft und Fischerei Mecklenburg-Vorpommern (Mecklenburg-Western Pomerania state research facility for agriculture and fisheries) as well as other research facilities.

Trial stock in the Elbe river basin, young sturgeon (Acipenser sturio) with marking

Suitable sturgeon were bred

If the waterways are to be repopulated, it is essential to have sufficient numbers of fish that correspond to the former native breeds. A significant sub-project is therefore the establishment of a parent stock for producing a stock of offspring suitable for the respective habitat. The European Atlantic sturgeon (Acipenser sturio) from the Gironde in south-west France was selected for the offspring to be introduced to the North Sea and its feeder rivers. From a genetic perspective, this very small fish population is virtually identical to the fish that once lived in the North Sea. The IGB has been obtaining a few samples with the co-operation of Cemagref in France since 1996 in order to breed stocking fish for the Elbe and Rhine. As sturgeon are not sexually mature until the age of 10 to 12 at the earliest, the first offspring of fish formerly of

Ultrasound to determine gender in Born/Darß

French stock became available in 2007. The fish produced from this reproduction were marked, fitted with telemetric transmitters and released in the middle of the Elbe so that their migration could be tracked.

The sturgeon that once lived in the Baltic Sea differ from those of the North Sea both genetically and in appearance. They are the descendants of the American Atlantic sturgeon (Acipenser oxyrinchus), which migrated to this location around 1,000 years ago. A breed that is genetically very similar to the Baltic Sea sturgeon lives in the Rivers St. Lawrence and St. John in Canada. The Gesellschaft zur Rettung des Störs brought some sexually mature fish to Germany for breeding purposes in 2005 and 2006 with the aim of founding an initial parent stock. The release of offspring from controlled reproduction in Canada into the Oder river basin◄ has been taking place since 2006 for telemetric examinations and to determine the use of the habitat◄.

Offspring from controlled reproduction were reared in order to build up parent stocks. These fish were characterised using genetic screenings, particularly via microsatellites developed by the University of Potsdam, and breeding plans were created in order to optimise genetic diversity. 2010 saw the first successful reproduction from the A. oxyrinchus parent stock in Germany, so now early live stages can also be examined.

Catching an American Atlantic sturgeon (Acipenser oxyrinchus) for reproduction in Canada

Development of alternative fishery techniques

To ensure that the growing sturgeon population does not become a victim to fishing, the project has also driven forward the further development of gillnets for coastal fishing. The aim is to minimise the unintended catching (bycatching) of sturgeon and simultaneously to optimise the catching of zander and perch in the Szczecin Lagoon. Trials with newly developed nets have shown that the bycatching of sturgeon can be almost completely eliminated by implementing simple changes. But as the amount of target breeds entering the net was also somewhat lower, uptake within the fisheries is still rather low.

Sturgeon under observation

Once the sturgeon have been released, they remain under intense observation. Markings and transmitters are used in order to research the migration of the fish, the aim being to identify and describe suitable habitats and to determine the risks posed to them. This monitoring is to form the basis for further releases and possible reclamation measures in rivers. If the quality of the sturgeon habitats is improved, then other animals will also benefit. The sturgeon can therefore also become a precursor for the resettlement of other breeds with similar ecological requirements.

Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB)

The scientists at the Berlin IGB are dedicated to ecosystem research of limnetic systems (inland waterways). The findings serve as the basis for ecological restoration, remediation, management and protection concepts. At the IGB, hydrologists, chemists, microbiologists, limnologists, fish ecologists and fisheries biologists all work under one roof. www.igb-berlin.de

Leibniz Institute of Freshwater Ecology and Inland Fisheries
Dr. Jörn Geßner
Müggelseedamm 310
12587 Berlin, Germany
Tel.: +49 (0) 30/64 18 16 26
E-mail: sturgeon@igb-berlin.de
Internet: www.igb-berlin.de
Funding reference: 0330718

Creating synergies through international co-operation – integrated water resource management

Integrated Water Resource Management (IWRM) is generally defined as a process for co-ordinated development and management of water, land and the associated natural resources. An IWRM process such as this pursues the goal of effecting economic and social well-being along with a sustainable way of managing ecosystems.

In the last few years, the principle of integrated water resource management has been the overlying concept for water management in Germany and Europe; not least through the implementation of the European Water Framework Directive concluded in the year 2000. The IWRM process puts the focus on water basins as units: if interacting stationary surface waters, aquifers and – where present – coastal waters are considered with an integrative approach, sustainable management will be achieved. Social framework conditions, the ecosystem and various usage requirements are all weighed against each other and discussed with all user groups and interest groups.

The Federal Government dedicated funding to IWRM in 2004 as part of the research for sustainable development programme being run by the Federal Ministry of Education and Research (BMBF). The overriding goals of using IWRM in developing and emerging countries are:

- Ensuring the population has on-site access to clean drinking water and secured means of sanitary disposal
- Improving the positioning of German companies within the international water management markets
- Supporting bi and multilateral collaboration within water as a scientific field
- Promoting interdisciplinary, transdisciplinary and international co-operation between science, industry, administration and supply/disposal practice
- Boosting Germany's standing as a location of economics, education and research among international competition.

Eight research projects are currently being funded, taking place in China (project example 1.3.06), Indonesia (project example 1.3.05), Iran, Israel-Jordan-Palestine (project example 1.3.01), Mongolia (project example 1.3.04), Namibia, South Africa and Vietnam (project example 1.3.02). German and international researchers and companies are working together to establish the prerequisites for sustainable use of water supplies, frequently backed up by German monitoring and plant technology. The projects are being supervised by project co-ordinators Karlsruhe Water Technology and Waste Management Division (PTKA-WTE) and Jülich (PTJ-UMW).

Topic-based programmes and projects

Within the various funding programmes, the BMBF is supporting IWRM-related projects in partner countries that are not actually classed as developing or emerging but are also focused on fields such as developing and adapting water technology or sustainable land use. Examples of these are the International Water Research Alliance Saxony (IWAS) or concepts for sustainable development on the Volga and its tributaries. The transdisciplinary project entitled "Water related Information System for the Sustainable Development of the Mekong Delta" (WISDOM) intends to provide local authorities with a information system to help them use the resources available in a sustainable manner (project 1.3.08).

With the aim of developing comprehensive water management concepts for five hydrologically sensitive regions of the world, around 40 scientists from the Helmholtz Centre for Environmental Research – UFZ and the Technical University of Dresden have joined forces with Stadtentwässerung Dresden GmbH, the Institute of Hydrobiology (itwh), Dreberis GmbH and other partners from science, economics and politics to form the "International Water Research Alliance Saxony" (IWAS) (project 1.3.07).

The funding priority of IWRM and the results obtained are available on the BMBF website dedicated to IWRM (www.bmbf.wasserressourcen-management.de).

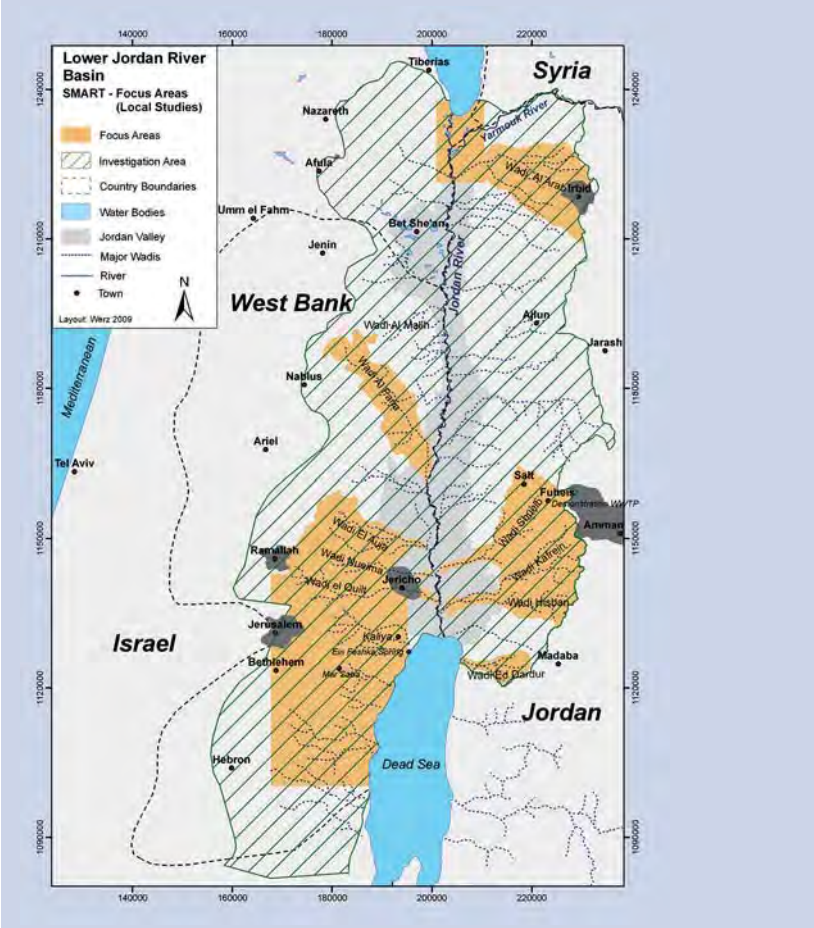
Lack of water in the valley of the Jordan – finding cross-border solutions

Just 50 years ago, the River Jordan was abundant with water. These days, the lower course of the river is merely a trickle and the water level of the Dead Sea is falling by a metre every year. Diversions for the Israeli coast and the highlands around the Jordanian capital Amman have decimated the water supplies. It is thus virtually impossible to ensure economic and social development of the Jordan valley – especially as the population is exploding at the same time. A cross-border management concept could help ensure the resources available are used more efficiently. An international team of scientists is now recording previously unused water supplies, developing technologies for cleaning and storage and assuring the necessary infrastructures and expertise are in place in the affected regions.

In the spirit of the Millennium Goals◄ and the UN "Water for Life" decade, the BMBF is supporting the international research project entitled **"Sustainable Management of Available Water Resources with Innovative Technologies" (SMART)** within the basin◄ of the Lower Jordan. The project is being implemented under the scientific leadership of the Karlsruhe Institute of Technology (KIT) together with German, Israeli, Palestinian and Jordanian partners.

Assessing and managing water supplies

The key focus of the project is to conduct a comprehensive assessment of all water resources in the area of investigation – including groundwater, wastewater, extremely saline waters and floodwater – and to incorporate this into an integrated cross-border management system. In order to achieve this, the scientists must survey and assess all resources that until now have never been considered for use for quality reasons or due to a lack of storage facilities. The intention is to determine suitable treatment techniques and develop intermediate storage capabilities in accordance with subsequent use and the local conditions. This integrative approach is new to the field of water management; apart from new technologies, a regional infrastructure and institutional capacities are required in order to implement integrated water resource management (IWRM).



Map of the SMART investigation zone between the Sea of Galilee in the north and the Dead Sea in the south

Regional characteristics of the area under investigation

This region is typified by stark contrasts in climatic conditions, changing from Mediterranean (semi-arid) on the coast through to highly arid◄ in the south-east. The precipitation within the Jordan basin varies from 800 millimetres a year in the northern mountainous regions (approx. 1,000 metres above sea level) to less than 100 millimetres a year in the Lower Jordan valley (250 to 420 metres below sea level). The latter lies within a major lineament comparable to a deep trench, where the Arabian Plate is shifted in a northerly direction. The flanks of the trench consist of carbonate rocks and sandstones, and it is filled with fluvial◄ and marine sediments. The ever-growing population, predominantly based in the major cities in the upper-lying regions (Jerusalem, Ramallah and Amman-Salt), is producing large amounts of wastewater

in isolated areas that is either infiltrating the aquifers◄ or flowing towards the Jordan via deep and mainly dry riverbeds – known as wadis. Economically, the Lower Jordan valley is in a period of agricultural, tourism and also industrial development. The high temperatures and fertile soils provide conditions for all-year-round farming and shape the region as a "natural greenhouse".

Research with an application approach

During the first phase of the project (2006 to 2009), the researchers established extensive infrastructures such as the "SMART-Wastewater Treatment and Reuse Site" in Fuheis and environmental monitoring systems (climate, effluent, groundwater quality and quantity) in several sections of the basin. They also identified other sites for various forms of technology. Pilot systems are now being installed there in consultation with local ministries, development co-operation bodies and the industrial partners involved.

The second funding phase is ongoing and aims to implement the successful activities from the first phase within demonstration projects, with a strong application approach being taken. The German Water Partnership has already registered interest, particularly in the fields of wastewater treatment, membrane procedures◄, artificial groundwater enrichment and software-supported decision-making tools; several members of the umbrella organisation for German water management are involved in the SMART project. Discussions are also taking place with the Kreditanstalt für Wiederaufbau banking group (KfW), which sees great potential in decentralised wastewater treatment in the region.

Key results from the research programme have found their way into the Jordan National Strategic Water Plan 2008–2022, which means important political steps have already been taken to prepare a systematic solution for decentralised water management.

View of the Jordan valley with irrigation cultures on the eastern Jordanian side

Information from school children on the use of clean wastewater for irrigation in agriculture

Building up structures and expertise

During the second phase of the project, the scientists will continue to characterise the available water resources and to expand into other areas. The key question is how the water quality can be developed in a closed basin in the medium and long term when increasing amounts of wastewater are being reused. The research team is investigating how hygiene-related micro-organisms can be eliminated and how organic trace elements◄ accumulate and biodegrade in arid to semi-arid conditions.

All activities are fed into IWRM scenarios for the sections of the basin, in which the various forms of adaptation are represented in terms of demographic, climatic and economic change and compared in analyses. Confirmed IWRM scenarios are then made available for the entire project area taking into account the new technology and management concepts.

Overall, the build-up of local capacities has played a major role within SMART II: this is crucial for the implementation of integrated water resource management. It was already evident in the first phase that there is huge interest in the specifically developed further education programmes. They received particular support from the major planning authorities (Palestinian Water Authority, Jordan Ministry of Water and Irrigation) and proved themselves to be a good opportunity to raise awareness for the IWRM process and the use of sustainable technologies.

Karlsruhe Institute of Technology (KIT)
Institute of Applied Geosciences
Prof. Dr. Heinz Hötzl
Adenauerring 20 b
76131 Karlsruhe, Germany
Tel.: +49 (0)7 21/60 84 30 96
Fax: +49 (0)7 21/60 62 79
E-mail: heinz.hoetzl@kit.edu
Funding reference: BMBF-PTKA 02WM1079

German-Vietnamese collaboration – researching a sustainable way to deal with water

Vietnam is a country rich in water resources. With an average annual precipitation of just under 2,000 millimetres and a dense water network of 2,360 rivers spanning over ten kilometres, the water supply is generous. Yet despite these favourable conditions, water management is a challenge in Vietnam: a lack of infrastructure and knowledge and increasing water consumption through agriculture and industry are just some of the problems. German and Vietnamese researchers are working together on a BMBF research project to establish the prerequisites for a sustainable way of managing the water supplies.

The distribution of precipitation and waterways in Vietnam varies greatly from region to region. Extended dry seasons lead to temporary supply problems in certain areas of the country. Much of Vietnam is also "downstream territory", i.e. the rivers have already travelled some distance before flowing into the country. So, for example, the quantity and quality of the water resources in the Mekong and the Red River depend heavily on the usage along the upper courses in neighbouring countries. Furthermore, the necessary infrastructure for water supplies, wastewater treatment, flood protection etc. is not in place nationwide. In addition to all this, the economic development of the country with advancing urbanisation, industrialisation and intensive farming is leading to an increase in water consumption and thus to growing amounts of wastewater. The authorities are not currently in a position to implement effective water management in the face of these challenges.

Careful management of water resources is essential if the water-related problems in Vietnam are to be solved. Technical, judicial and social tools must be developed and conceptual measures for the respective river basins implemented. These activities are intended to harmonise the somewhat contradictory requirements of the water supply and provide sustainability. Several BMBF-funded projects under the collective title **"IWRM Vietnam"** are supporting this process in three representative Vietnamese regions with different natural, socio-economic and ecological characteristics:

- Red River Delta, Nam Dinh province: The key challenges for integrated water research management (IWRM) are intensive farming and the wastewater from the textile industry, metalworking and aquaculture. The freshwater is also being depleted through excessive groundwater extraction and increasing salt-water intrusion◄.

The Red River Delta in the Nam Dinh province of Vietnam

- Dong-Nai basin, Lam Dong province, Hoa Bac district: Intensive tea and coffee cultivation is resulting in large quantities of fertilisers and pesticides entering the waterways that supply over 9,000 people with their day-to-day water.
- Mekong Delta, Can Tho province: The main problems here are the deficient water supply, flood events and deposits from intensive livestock farming.

The "IWRM Vietnam" research project is being led by the chair of environmental engineering and ecology in civil engineering at the University of Bochum with the co-operation of the Universities of Bonn and Greifswald and a network of German and Vietnamese partners in universities, research institutes, authorities and companies. The scientists are developing methods for implementing integrated water resource management for river basins in Vietnam. To date, they have produced the following results at two planning levels:

River basin level: planning and decision-making support tools

Tools have been developed that will help to establish sustainable water management and to reduce or even completely eliminate the risks posed to water quality. One of the results is a planning atlas for integrated water resource management.

The scientists examined the water resources in the aforementioned example regions as well as the current economic, social and ecological situation of the basin◄ in question. The aim was to cover both current and future

Location of the three project regions

usage conflicts and water management issues. The results of the investigations are to help decision-makers in future in implementing measures for sustainable water management and for protecting the water resources against contamination. The tools were developed in close collaboration with the Vietnamese authorities and tested in the three example regions.

Local level: environmental technology

The experts have also developed technical and conceptual solutions for specific water-management problems at local level for the three project regions. This involved adapting German environmental technologies to local conditions and putting them to use.

The scientists developed a tool for the Can Tho province that is designed to reduce the amount of nutrients in the waters of the Mekong Delta. A web-based geo-information system (GIS) was set up for this purpose in order to monitor the water quality. The researchers also developed solutions for treating agricultural wastewater.

The researchers designed a central water supply system for the Lam Dong province. This involved creating a balance between conflicting interests within an agrarian community. The adverse effect of agriculture on the water quality played a significant role here. The experiences gained are being fed into the development of a province-scale IWRM system.

The scientists developed concepts for treating domestic and industrial wastewater in the Nam Dinh province. They are examples of a possible solution for the water management problems faced there.

One key component of the project is what is known as capacity development◄. This involves training for the Vietnamese partners in environmental administration and research, master's theses, joint research activities, workshops and conferences.

Continuing need for co-operation

The Vietnamese government has recognised the importance of integrated water resource management and is working on improving the framework conditions. The institutions that need to implement IWRM on site are being strengthened – beginning with the river basins with the biggest water management problems. The diverse range of challenges means the Vietnamese government requires continuing support, e.g. in the development of planning tools, monitoring strategies and wastewater treatment procedures, and in the intensifying of environmental administration and personnel training. There is still great demand for scientific and technical collaboration between Vietnam and Germany where IWRM is concerned.

University of Bochum
Faculty of Civil and Environmental Engineering
U+Ö: Environmental engineering and ecology in civil engineering
Prof. Dr. Harro Stolpe
Universitätsstraße 150
44801 Bochum, Germany
Tel.: +49 (0)2 34/3 22-79 95
E-mail: harro.stolpe@rub.de
Funding reference: 02WM0815

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Wastewater disposal in Vietnamese industrial zones – a case study for holistic concepts

Vietnam is one of the up-and-coming former developing countries experiencing strong economic growth and rapidly increasing environmental problems. Most of the country's 300 or so industrial zones have no regulated forms of wastewater disposal. There is a lack of modern technology, the necessary expertise and assertive authorities. It is clear that a holistic approach is essential for this complex issue to be successfully resolved in the long term. Research facilities are working together with German companies within the BMBF research project entitled "integrated wastewater concept for industrial zones" (AKIZ) to develop new solutions – and are therefore simultaneously creating a future market for Germany's environmental technology.

Vietnam produces around 20% of its exports in state-run industrial zones. There are currently around 250 national registered industrial zones covering more than 60,000 hectares of land plus an additional 15 economic zones. Factoring in the industrial zones registered at regional and district level, this figure is likely to be way over 300 and 90 more are planned by the year 2015.

In preparation for the project, experts determined that only around a quarter of the investigated industrial zones had any sort of central sewage facility whatsoever, of which only a quarter again operated satisfactorily from a western perspective. Existing facilities were often out of commission due to insufficient financing or a lack of maintenance.

Integrated approach

A research project with around EUR 8 million of funding from the BMBF intends to indicate possible ways out of this precarious situation. Scientists working on this "flagship" project are using an industrial zone in the Can Tho province within the Mekong Delta as an example to develop an integrated wastewater concept. The expected results include the specifications for work at a central sewage plant. Working on the AKIZ research project are four German industrial partners and a total of five German universities together with Vietnamese universities and research institutes. The Institute of Environmental Engineering and Management at the University of Witten / Herdecke gGmbH (IEEM) is responsible for overall co-ordination.

Workers in a Vietnamese pesticide plant

The BMBF project is being conducted together with German development collaboration.

Finding tailored solutions

Before high-tech solutions that have proven themselves in industrial countries can be implemented, they must be tailored to the specific working conditions and tropical climate conditions within the project area. The scientists used container testing facilities at German industrial

TP 1	**Integrated management concept/co-ordination** Institute of Environmental Engineering and Management at the University of Witten / Herdecke gGmbH (02WA1060), Hanoi University of Science, National Economics University
TP 2	**Elimination of toxic substances** HST Hydro-Systemtechnik GmbH (02WA1061), University of Stuttgart (02WA1062), Hanoi University of Science
TP 3	**Anaerobic industrial wastewater treatment with energy recovery** Passavant-Roediger GmbH (02WA1063), Leibniz University Hanover (02WA1064), Southern Institute of Water Resources Research
TP 4	**Recovery of valuable materials by membrane filtration** EnviroChemie GmbH (02WA1065), Technische Universität Darmstadt (Technical University Darmstadt) (02WA1066), Hanoi University of Civil Engineering, Vietnamese-German University
TP 5	**Development and operation of a containerized laboratory and monitoring concept** LAR Process Analysers AG (02WA1067), Institute of Environmental Engineering and Management at the University of Witten / Herdecke gGmbH (02WA1068), Passavant-Roediger GmbH (02WA1063), Vietnam Institute of Industrial Chemistry, Can Tho University
TP 6	**Sewage sludge management concepts** Technical University Braunschweig (02WA1069), Vietnamese Academy of Science and Technology, Institute for Environment and Resources at the Vietnam National University

Topic areas and partners within the AKIZ research project

partners to do this and to further development. Sample companies in the Tra Noc industrial zones were used to present decentralised solutions for wastewater pre-treatment with pollution close to the source and recovery of energy and resources.

In Vietnam – as in many other developing and emerging countries – there have never been any sustainable concepts for eliminating effluent sludge. The scientists had to begin by devising suitable concepts for its disposal and recycling. Most emerging countries have effluent limits that are even comparable in part with western wastewater standards. However, they often do not contain any toxicity parameters◄ or are not implemented due to a considerable lack of enforcement. Nevertheless, it is a fundamental prerequisite that applicable environmental standards and quality requirements be implemented when using high-tech facilities. Specific training in this regard (capacity building◄) is being implemented as part of the AKIZ project. An innovative monitoring system will also supply key data for determining requirements for technological adaptation and for the administrative and financial aspects of cleaning wastewater.

Concepts with a future

All the aforementioned aspects must be fed into a single all-encompassing management concept that maps out the technical and economic operation of the wastewater system in the industrial zone. It covers the decentralised technological approaches to pre-treatment and the central sewage plant, beginning with the monitoring system (tropicalised laboratory unit) and extending to the calculation and financing models to ensure sustainable wastewater cleaning. The intention is to use other industrial zones to verify the transferability of the project results.

A wastewater channel in the Tra Noc industrial zone in Can Tho

The resolution of the precarious wastewater situation in many industrial zones in developing and emerging countries requires a strictly holistic approach that must ensure the sustainable and efficient operation of the entire system along with all technical, economic and ecological factors. The AKIZ project deals with these aspects with an integrative approach and uses German expertise to develop tailored solutions. As an emerging country experiencing strong economic growth and rapidly increasing environmental problems, Vietnam is also increasingly becoming a market for quality-oriented environmental technologies from Germany.

Institute of Environmental Engineering and Management at the University of Witten / Herdecke gGmbH (IEEM)
Prof. Dr. Dr. Karl-Ulrich Rudolph
Ms Dipl.-Ing. Sandra Kreuter
Alfred-Herrhausen-Straße 44
58455 Witten, Germany
Tel.: +49 (0) 23 02/9 14 01-0
Fax: +49 (0) 23 02/9 14 01-11
E-mail: mail@uni-wh-utm.de
kreuter@uni-wh-utm.de
Internet: www.uni-wh-utm.de

Project co-ordination
AKIZ Project Office
Dipl.-Ing. René Heinrich
Lot 12A, Tra Noc Waterplant, Industrial Zone Tra Noc II
Can Tho City, Vietnam
Tel.: +84/71 03/74 40-03
Fax: +84/71 03/74 40-04
E-mail: heinrich@uni-wh-utm.de
Funding reference: 02WA1060 (TP co-ordination)

Model Region Mongolia – the path to sustainable water management

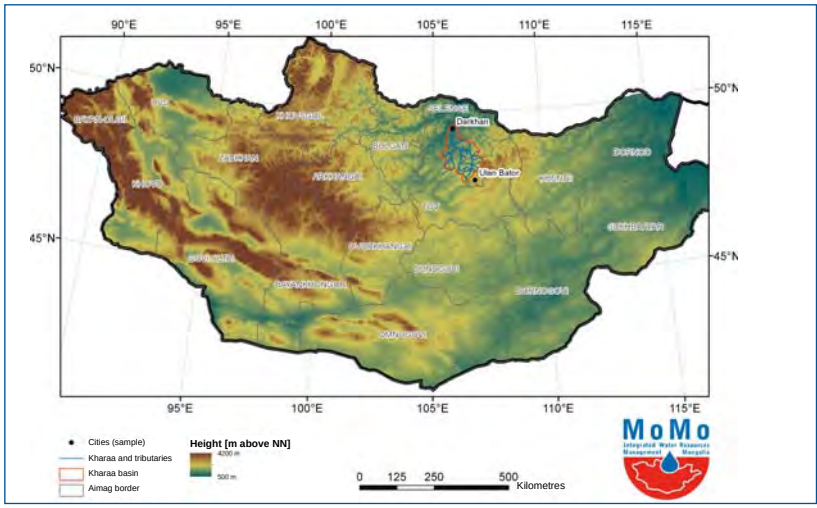
Mongolia is faced with some major water management challenges. Global change, droughts, widespread contamination from mining and outdated water supply and disposal infrastructures have led to a dramatic decline in living conditions over recent years. The problems are so closely interlinked that only integrated system solutions can help. A consortium of scientists and engineers is now developing an overall concept using German expertise and technologies to implement sustainable management of the water supplies.

Mongolia has a population of around three million people, around 60% of whom have no access to clean drinking water and safe methods of wastewater disposal. The broad, dry and cold steppe regions and the boreal coniferous forests◄ of central Asia are typified by a general water shortage and an extremely variable climate that brings great annual and seasonal fluctuations in water availability. With a rapidly growing population, the traditional nomadic nature and the expansion of agriculture and mining (predominantly gold and copper), more and more water is being consumed. The situation is not expected to improve in future either.

The research project entitled **"Integrated Water Resources Management in Central Asia: Model Region Mongolia"** (**MoMo**) has a team of scientists developing innovative solutions to provide the people with a sustainable water supply. Numerous German and Mongolian cooperation partners are involved in this inter and transdisciplinary research, which is being co-ordinated by the Helmholtz Centre for Environmental Research (UFZ) in Magdeburg.

Reliable basic data required

Between 2006 and 2009, the researchers created key foundations for integrated water management for the city of Darkhan (approx. 100,000 inhabitants) and the surrounding Kharaa river basin in north-east Mongolia. They developed the new concepts in close collaboration with local partners. This initial phase of the project examined the key components of water management: climate change and hydrology◄, groundwater, land use, nutrient cycles, ecology, supply of drinking water and treatment of wastewater. The scientists used scenario techniques to form long-term strategies for managing water resources, developed with the key local players and adapted and fine-tuned to the situation on site. This enabled them to propose a useful range of measures. Mongolia is exhibiting a great deal of interest in the implementation; with the national water law of 2004 and the creation of a national water agency, there are excellent institutional framework conditions in place in order to achieve this.



Location of the model region in Mongolia (Cartography: Daniel Karthe)

Steps towards implementation

Since the three-year implementation phase began (running from 2010 to 2013), the scientists have been implementing the first elements of integrated water resource management (IWRM). For example, several pilot sewage plants are being set up to adapt selected technologies to the local conditions. Gaps in knowledge on the qualitative and quantitative condition of the water resources are to be closed and a comprehensive environmental monitoring system set up covering the surface water, groundwater, soil, drinking water, wastewater and land coverage. The planned monitoring network is being set up in collaboration with the environmental authorities and adapted to local needs.

With regard to domestic water management, the researchers are implementing an integral concept covering the introduction of locally optimised technologies and strategies for the settlements in question. These include the urban sector with its ailing central drinking water and

The Kharaa basin in northern Mongolia
(Source: Daniel Krätz)

In the suburban yurt settlements, the residents obtain their drinking water from central water kiosks (Source: Lena Horlemann)

Project partners in Germany:
Helmholtz Centre for Environmental Research – UFZ, Leipzig, Magdeburg
Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), Berlin
Fraunhofer Application Center System Technology, Ilmenau
Bauhaus University Weimar, chair for urban water and sanitation, Weimar
University of Kassel, Center for Environmental Systems Research
Heidelberg University, Institute of Geography, Heidelberg
p2mberlin GmbH, Berlin
Vista Geowissenschaftliche Fernerkundung GmbH, Munich
terrestris GmbH & Co. KG, Bonn
Bergmann Clean Abwassertechnik GmbH (BCAT), Penig
Seeconsult Deutschland GmbH, Osnabrück
Passavant-Roediger GmbH, Hanau
GEOFLUX GbR, Halle (Saale)
Project partners in Mongolia:
At national level:
Mongolian ministries for the environment, education, construction, agriculture and finance
National environmental monitoring authorities
National water agency
At regional level:
Darkhan Uul Aimag provincial government
Regional environment agency, Darkhan Uul Aimag
Meteorological institute of Darkhan
USAG, drinking water and wastewater company, Darkhan
Scientific institutions in Mongolia:
National University of Mongolia, Ulan Bator
Mongolian University of Science and Technology, Ulan Bator and Darkhan
Agricultural University, Darkhan
Mongolian Academy of Sciences
German partners in Mongolia:
German embassy, Ulan Bator
GIZ, Ulan Bator

Research project partners: **MoMo**

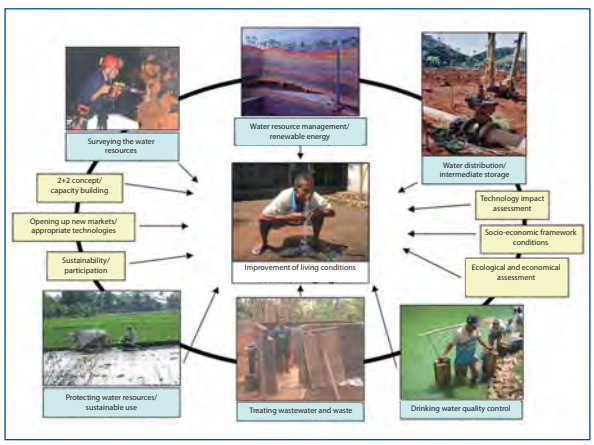
wastewater treatment system, the suburban yurt settlements where the residents have no prospects of a connection to central supply and disposal systems through the authorities and smaller localities in the country, which instead of sewage facilities often only have sluice systems taking the waste away. The second phase of the project will also see capacity development measures significantly increased to make a sustainable contribution to improving living conditions and to increase the sense of personal responsibility in affected areas.

Helmholtz Centre for Environmental Research – UFZ
Department Aquatic Ecosystem Analysis
Prof. Dr. Dietrich Borchardt
Brückstraße 3a
39114 Magdeburg, Germany
Tel.: +49 (0)3 91/8 10 97 57
Fax: +49 (0)3 91/8 10 91 11
E-mail: dietrich.borchardt@ufz.de
Internet: www.iwrm-momo.de
Funding reference: 033L003

Model region Gunung Kidul – integrated water resource management in karst regions

Gunung Sewu on the southern coast of Java is characterised by its tropical climate. In the dry season, the karst region◂ suffers an acute lack of water; this weakens this agricultural area so badly that it is also referred to as the poor house of Java. The region also suffers from an appalling supply system and completely insufficient means of wastewater disposal. Supported by the BMBF, scientists over recent years have already set up an underground reservoir and used regenerative hydropower to supply cave water. The follow-up project is now opening up additional water supplies and developing a concept for integrated water resource management. The quality of life among the inhabitants is set to improve long term with these measures.

The Gunung Kidul district near the city of Yogyakarta is one of the poorest regions on Java. One reason for this is the fissured karst ground, which soaks up the surface water straightaway. On top of this, there is a lack of adapted technologies to obtain and distribute drinking water and to treat wastewater. This is where the BMBF project entitled **"Integrated Water Resource Management (IWRM) in Gunung Kidul, Java, Indonesia"** comes in: the aim of this project is to secure a supply of drinking water for the region; this necessitates tapping into the underground water resources in the Gunung Sewu cave systems ("1000 hills") and the karst groundwater of the Wonosari Plateau, and sanitising existing water distribution systems. Newly developed technologies are intended to help supply the population with sufficient clean water all year round, without placing an additional burden on future generations or neighbouring regions.
The research project is being run by the Institute for Water and River Basin Management (IWG) at the Karlsruhe Institute of Technology (KIT) and involves the collaboration of German and Indonesian partners from universities, research facilities, industry and public authorities.



Basic design of integrated water resource management (IWRM)

Location of the Gunung Sewu karst region on Java, Indonesia

Surveying and managing the water resources

The basis of an IWRM project is sound knowledge of all the conditions affecting the water within a given region. The data already gained for the basin◂ of the Gua Bribin cave in the precursory project is to be expanded and optimised with the new findings within management and distribution systems, and strategies to protect precious water resources are to be developed.

A barrage installed in the precursory project retains the inflowing water within the Gua Bribin cave. This generates sufficient pressure to operate pumps to deliver the water. The scientists are now planning to implement another pumping facility within the Gua Seropan cave; the energy to drive this is to be produced via a wooden pressure line. The two facilities will provide valuable practical experience for the use of regenerative pumping technologies in karst regions.

Distribution, treatment, quality assurance

The existing water distribution systems in the rural areas of Gunung Sewu must be improved as a matter of priority. Alongside a cost-efficient network and operating concept, the scientists also intend to develop a concept for decentralised energy recovery within the distribution network and to implement this at selected example sites.

The Gunung Sewu karst region during the dry season

A management tool is to support and assist the local authorities in their decisions in order to optimise the operation of the network.

Another vital aspect is assuring the quality of the water. Researchers are therefore developing a monitoring system to keep a permanent watch on the quality of the untreated water and the water in the distribution systems. They are installing a pilot water treatment facility in the Wonosari hospital, which if successful will serve as a template for further decentralised facilities in the region.

Treating wastewater and waste

With regard to treating wastewater and waste, the intention is to develop adapted technologies for separating, treating, using and returning flows of wastewater and waste. The ultimate aim is an enclosed nutrient cycle and assurance of the scarce water resources available. The scientists must develop a "substance flow model" as part of the preparatory work for devising a sustainable disposal concept. This maps all the relevant, water-related nutrient flows within the region, depicts existing problems and helps determine the areas on which the work should focus. The stark differences between the urban and rural sections of the model region mean that solution approaches must differ depending on the area.

Socio-economic evaluation and technology impact assessment

A socio-economic analysis can be used to determine the living conditions and problems relating to water supply and wastewater disposal within the region of investigation according to the different areas and to develop possible solutions. The systems analysis and technology impact assessment – supplemented by the life-cycle assessment◄ and life-cycle costing◄ are also used to evaluate economic, ecological, social, cultural and acceptance-related aspects. The results facilitate decision-making with regard to designing and implementing water management facilities, enable the effect of this system to be judged in terms of sustainable development within the affected region and support the overall IWRM project in making such a contribution.

Expanding knowledge

Technical concepts are only sustainable if the target groups accept the concept in question and are involved in all phases of the project. The design and implementation of technical concepts within this project are therefore accompanied by workshops, familiarisation campaigns and an intensive transfer of knowledge. The scientists have worked together with the Indonesian partner institutions on all tasks and have involved NGOs and the local population to some extent. Also planned is a comprehensive teaching and education programme for the staff operating and maintaining the water management facilities. This is also intended to form the basis for the transfer of the IWRM concept to other locations and trigger its multiplication with as diverse a base as possible.

Strategies to combat water shortage

The new underground flowing water system and IWRM concept for Gunung Kidul will provide significant approaches to overcoming the shortage of water in karst regions but also in non-karst regions. Significantly, the project is also making a contribution to intercultural understanding, which is of vital importance in light of the global political situation.

Project website ► **www.iwrm-indonesien.de**

Karlsruhe Institute of Technology (KIT)
Institute for Water and River Basin Management
Prof. Dr.-Ing. Dr. h. c. mult. Franz Nestmann
Dr.-Ing. Peter Oberle
Dr.-Ing. Muhammad Ikhwan
Kaiserstraße 12
76131 Karlsruhe, Germany
Tel.: +49 (0)7 21/6 08-63 88
Fax: +49 (0)7 21/60 60 46
E-mail: peter.oberle@kit.edu
Funding reference: 02WM0877

Example region Shandong – concepts to combat avoidable water shortages

The northern provinces of China have severe water shortage and pollution problems, the consequences of which are stagnant socio-economic development, a decrease in the quality of life and damage to the environment. And yet there is no fundamental lack of water; it is the rapid growth in population, industry and agriculture plus the uncoordinated water management measures that are often leading to water conflicts. Integrated water resource management using German monitoring and plant technology is intended to resolve the major problems experienced in the Shandong province and simultaneously serve as a sustainable concept for use in other regions of the world.

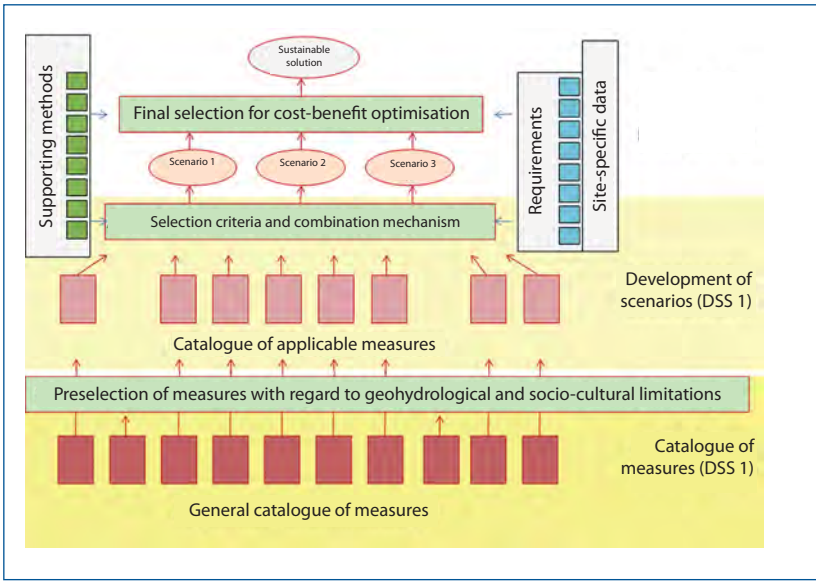
The basin◄ of the Huangshuihe river is 1,034 square metres in size and situated in the north-east of the Shandong province on China's Pacific coast (64 kilometre coastline). Agriculture is one of the main sources of income in this region, but its development has since been heavily curtailed due to a shortage of water – and the same applies to the region's industry. The excessive strain being placed on resources has also become apparent, with overuse of groundwater sources leading to saltwater infiltration.

As part of the bilateral research project entitled **"Sustainable Water Resources Management in the Coastal Area of Shandong Province, PR China"**, an international team of scientists is now developing an integrated water resource management (IWRM) system to solve the major problems faced in this region. The aims of IWRM are:

- Integration of social, economic and environmental aspects
- Integrated consideration of groundwater and surface water (quantity and quality)
- Optimisation of the water balance for the entire basin.

German-Chinese research team

The research project is being funded by the Chinese Ministry of Science and Technology (MOST) and the BMBF, bringing together German expertise, the latest developments in connection with the WFD◄ and the research efforts of Chinese experts in the coastal region of the Shandong province. Using Longkou as an example area, German and Chinese scientists are working together with local authorities and research facilities to develop an application-oriented strategy for optimising water management. Ideally, it should help relieve the water shortage when applied to the entire Shandong province.



Construction diagram for the planned decision support system (DSS)

The project is divided into four sub-projects:

1. Socio-economic decision-making criteria for a decision support system (DSS)◄
2. Development of a method for planning sustainable measures within IWRM
3. Integrated concept for saving, reusing and recycling water in the home, industry and agriculture
4. Development of a water monitoring concept for the Huangshuihe basin

Development of a decision support system

Scientists are developing a DSS as part of this project. This system is intended to help optimise sustainable water management and to devise a monitoring concept. Socio-economic decision-making criteria are input into the system; these were initially determined by the Institute for Ecological Economy Research (IÖW) recording the present water usage in the project area (report: "Assessment of current water uses"). The analysis of the socio-economic and institutional framework conditions in the water sector formed part of a master's thesis. The scenarios for future water usage developed therein were determined through linear projection of current usage; a different

Testing sampling technology at a groundwater measuring point

procedure is currently not possible. However, the greatest gap in information within the framework conditions lies in the socio-economic institutions and institutional tools. Despite close collaboration with the Chinese partners, it is still just as difficult to acquire actual data and figures for agriculture, households and institutional measures.

Another element of focus was on the collation and quantitative description of measures to serve as a basis for the DSS. During close collaboration between DHI-WASY GmbH and the Ruhr University of Bochum, experts put together a comprehensive catalogue of potential water management tools. Questions relating to the selection method are currently being discussed. For example, a preselection stage will make it possible to reduce the large number of potential measures (or combinations of measures) in advance. A newly developed interactive water balance sheet and a groundwater model devised as part of the project have already been able to indicate that the water balance in the project region has almost balanced out over the last year. It would therefore appear, as already suspected, that there is no fundamental lack of water and that this is purely a management problem.

Pilot project plans complete

In the meantime, scientists have completed concepts and design plans for the use of rainwater in the Songfeng settlement and for efficient irrigation for the Weilong Wine Company, which have been transferred to the Chinese partners. Reactions to these are still pending. Plans for pilot projects to enrich the groundwater with treated wastewater in the Dongcheng sewage plant and to reuse process waters in the Yulong paper plant are still underway.

Monitoring system under construction

The scientists were also able to make significant progress in implementing the monitoring concept. A rough analysis of the project area undertaken before the project highlighted clear weaknesses in the existing monitoring system, particularly in the recording of groundwater levels and water quality parameters. The Chinese partners have now built two new measuring points, and a third is planned. The first measuring point is equipped with a solar multi-parameter remote probe, which continually measures five different values and transmits these daily to a website. A facility with additional measuring and sampling technology plus regular sampling for chemical analysis are in the preparatory stages.

There also weak spots in recording the amount of effluent. Of particular importance is the fact that the effluent data for the Huangchengji – the largest tributary in the project region – is missing. The scientists have in the meantime designed a measuring system in co-ordination with the Chinese partners; it is to be installed just before the mouth of the Huangchengji in the main river and will provide data for the groundwater model.

Project website ▶ **www.dhi-wasy.de**

DHI-WASY GmbH
Prof. Dr. S. Kaden (Project Co-ordinator)
Waltersdorfer Straße 105
12526 Berlin, Germany
Tel.: +49 (0) 30/67 99 98-0
Fax: +49 (0) 30/67 99 98-99
E-mail: s.kaden@dhi-wasy.de
Internet: www.dhigroup.com
Funding reference: 02WM0923-6

International Water Research Alliance Saxony – building blocks for sustainable water management

There are currently almost a billion people living without clean drinking water and over three billion without sufficient sanitation – with serious consequences for health and the economy. It is in response to this that the United Nations devised the Millennium Goals◄ in 2002, which commit the member states to halving the number of people without access to clean drinking water and sanitary facilities by the year 2015. Research projects such as the "International Water Research Alliance Saxony" (IWAS) can help deliver specific solutions in this regard. Scientists working on this project are developing comprehensive water management concepts for five hydrologically sensitive regions of the world.

The world's population is rapidly growing and with it the need for food and clean water. This poses a major problem: up to 90% of the expected increase (by 2050) will be in developing and emerging countries. Irrigation farming is required in order to produce the amount of food required within these regions. This worsens the already prevalent lack of water – taking up around 70% of global water consumption, agriculture uses far more water than anything else.

Around 40 scientists from the Helmholtz Centre for Environmental Research – UFZ and the Technical University of Dresden have joined forces with Stadtentwässerung Dresden GmbH, the Institute of Hydrobiology (itwh), Dreberis GmbH and other partners from science, economics and politics to form the **"International Water Research Alliance Saxony"** (**IWAS**) in order to address these challenges, by tackling the most pressing water issues in five strongly affected regions of the world.

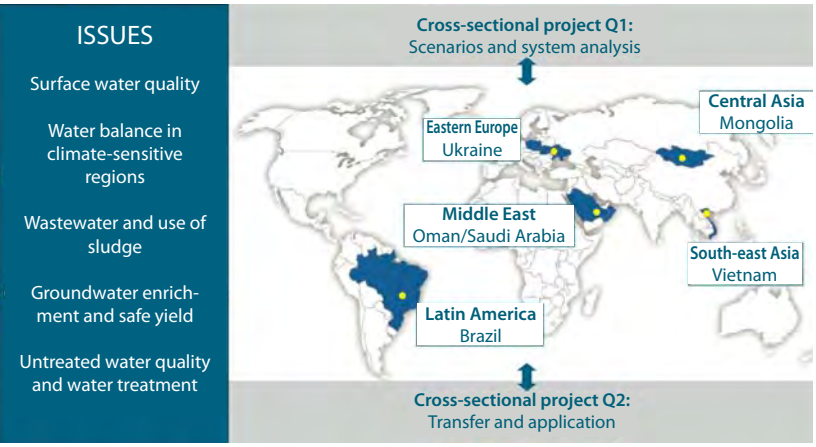
Working in the model regions

Funded by the BMBF as part of the "Spitzenforschung und Innovation in den Neuen Ländern" programme (top research and innovation in new countries), scientists working on the IWAS project are developing system solutions for the respective water problems. The solutions are to serve as elementary building blocks for holistic and sustainable integrated water resource management (IWRM), the aim being to establish this in the affected countries in the years and decades to come. The reasons for the water problems that are occurring are as diverse as the profiles of the regions under investigation:

Model area in Saudi Arabia: water in the dessert (Source: GIZ IS, Riyadh)

Eastern Europe/Ukraine: The focus in this region is on improving the quality of the surface water in line with the EU Water Framework Directive (WFD◄). The model region is the basin◄ of the Western Bug. Previous studies have shown that the river basin is heavily contaminated. An extensive range of technological improvements and changes to institutional framework conditions are required if European standards are to be achieved in this area. The scientists analysed the water management structures within the urban and rural areas, mapped the water cycle and the established forms of land use in computer models and recorded the climate data in a database. Intensive relationships were also established with representatives from science, the authorities, water management and the relevant ministries.

Central Asia/Mongolia: This project region is dominated by an extreme climate and the environmental conditions are currently undergoing significant change. The most important task here is to develop adaptation strategies, with new technologies to safeguard water quality playing a major role. The scientists have already begun constructing a measuring device that will quickly detect bacteriological impurities and pollutants. They have also worked in close collaboration with the "MoMo" IWRM project (see project 1.3.04) in analysing the available administrative structures and stakeholders. This will enable potential improvements to social framework conditions to be applied and thus pave the way for the sustainable implementation of the IWRM concept.



Research approach of the International Water Research Alliance Saxony (IWAS)

South-east Asia/Vietnam: The work in this project region focuses on a district of Hanoi (Long Bien). Extremely rapid growth in this region has led to the improper disposal of wastewater. The aim is to develop a concept for a sustainable drainage system and to integrate it into the existing water system. The scientists have analysed ways to supplement the groundwater artificially with cleaned wastewater to counteract its reduction. A demonstration facility is to be erected on a plot of land provided by the city authorities and a water competence centre is also in the pipeline.

Middle East/Saudi Arabia, Oman: Arid regions◄ like the Arabian Peninsula primarily obtain their water resources from the groundwater. The risk of over-exploitation of this source of water is especially high. The focus of this regional project therefore is a complex modelling of groundwater regeneration and the negative effects on its quality, e.g. through the infiltration of saltwater along the coast. Then there is also the question of sustainable management; among other things, the project is examining the influence of climate change and climate extremes on crop yields.

Latin America/Brazil: The Brazil model region is typified by rapid, unchecked urbanisation. It is expected that the need for water supplies and system capacities will soon increase dramatically. IWAS is working together with the water supplier and other Brazilian partners to develop appropriate strategies. This is to be combined with other complementary BMBF projects in order to establish an IWRM system for the region. The regional water suppliers are planning to invest millions over the next few years in land use and the development of a technical infrastructure; the project results will make a significant contribution to devising sustainable solutions in this regard.

Cross-sectional activities and outlook

The development of sustainable management concepts requires future scenarios and forecasting models. These are combined for all regional projects in a central "IWAS toolbox" to enable transferability to other regions. Other key components of the IWAS projects are the transfer of knowledge (capacity development) and the setting up of sustainable water management structures. This is intended to help implement the developed solutions and strategies in the respective regions in such a way that ensures their longevity.

Following the completion of the two-and-a-half-year pilot phase, a follow-up project was launched (2011 to 2013). This phase will continue the work undertaken, increase the focus and implement the developed management concepts in collaboration with the respective partners.

International Water Research Alliance Saxony – IWAS
Helmholtz Centre for Environmental Research – UFZ
Department Aquatic Ecosystem Analysis and Management
Prof. Dr. Dietrich Borchardt
Brückstraße 3a
39114 Magdeburg, Germany
Tel.: +49 (0)3 91/8 10 91 01
E-mail: dietrich.borchardt@ufz.de

Technical University of Dresden
Institute for urban water management
Prof. Dr. Peter Krebs
01062 Dresden, Germany
Tel.: +49 (0)3 51/46 33 52 57
E-mail: pkrebs@rcs.urz.tu-dresden.de

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Helmholtz Centre for Environmental Research – UFZ **02WM1027**
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WISDOM research project – a water information system for the Mekong Delta

Climate change, rapid economic development and a quickly growing population have all put increased pressure on water supplies in the Mekong Delta. This makes living and farming in a region already blighted by natural events such as floods and droughts even more difficult. German and Vietnamese scientists are now developing an innovative information system in a project funded by the Federal Ministry of Education and Research (BMBF), which is designed to help local authorities to adapt water management to the changes in environmental conditions and to use the resources available in a sustainable manner.

At a length of 4,500 kilometres and with a basin◄ of 800,000 square kilometres, the Mekong is one of the world's largest rivers. It starts at the Tibetan Plateau and winds its way down to the southern end of Vietnam where it flows into the South China Sea via nine larger channels and forms the 70,000 square kilometre plus Mekong Delta. Both living and farming in the region of this mighty river mouth are dominated by natural events: intermittent flooding and droughts, saltwater penetration from the tides, but also through advancing climate change, which turns the soil saline. The rapid population growth and progressive economic development have also put extra pressure on resources, and regulatory measures implemented in neighbouring countries upriver have had far-reaching effects within the region. The consequences are: changed flood patterns, increasing numbers of extreme events such as floods and droughts, a deterioration in the quality and availability of drinking water, acidified and saline soils and a loss of biodiversity.

These developments all bring great challenges to farming and water management, and yet the administrative and planning sectors in the regions in question only have isolated environment-related information at their disposal and this information is rarely exchanged. Duplication of and gaps in responsibilities make it even harder to implement a sustainable strategy.

German-Vietnamese collaboration

"Water related Information System for the Sustainable Development of the Mekong Delta" (WISDOM) is a transdisciplinary research project aimed at establishing integrated water resource management for the Mekong

BMBF delegation visits the WISDOM workshop in Vietnam – WISDOM project co-ordination presents project results

on three scales (basin, delta, three selected subject regions in the delta) and is being co-ordinated by the German Remote Sensing Data Center (DFD) of the German Aerospace Center. German and Vietnamese institutions are together establishing a transferable information system (IS) for the Mekong Delta as part of the project. The aim is to support plans and decisions relating to sustainable land management and integrated water resource management (IWRM) and to make a contribution towards adapting to climate change. The project is being conducted in close collaboration with the relevant regional and national institutions.

More information for improved planning

The focus in the design of the WISDOM information system is on the constant integration of existing and newly generated results and data. This will enable user-oriented analyses in order to develop sustainable solutions within resource management. The system collates data from various disciplines such as hydrology◄ (water quantity, sediment load), socio-economics (socio-economic statistical data, analyses of legal framework conditions, institutional databases etc.), geography (land use, soil, vegetation, water resources and changes to these), modelling (salt infiltration◄, spread of pollution, flooding scenarios), information technology (data from in-situ measuring networks◄ on salt content, water level, pH value◄, nutrients) and earth monitoring (land use, soil humidity, non-sealed areas etc.). The planning tool enables the user to conduct analyses in regard to specific issues.

User-friendly online tool

The WISDOM-IS features an innovative and complex data infrastructure based on various licence-free software components. It is – visually speaking – a bit like a "mini Google-Earth" for the Mekong Delta, and makes all project results available. Not only does it provide visualisation of all data and research results and their combined retrieval and intersection, users can also call up documents, legal texts, address databases, image material and presentations. This is an easy-to-use online tool so the decision makers do not need any experience with geo-information systems (GIS) or other Geo-IT-related knowledge in order to use the system. As the IS provides data on a regular basis it can also support certain monitoring tasks within sustainable land and water resource management. Still a prototype at present, the system is to be made ready for practical application and implemented in the region by the end of the project (2013).

Reuse and transferability

Involvement in the German-Vietnamese WISDOM initiative provides excellent opportunities to establish German technology and expertise in Vietnam. Assuming the project runs successfully, there are good scientific and economic opportunities for reuse, particularly within environmental monitoring and decision-making for water and land management and land administration. There is also great potential within capacity building ◄ and institutional-level training – both nationally (ministries, research programmes) and regionally.

The planning-based information system enables data of any type (remote sensing, GIS or sensor data, digital maps, field maps, reports, statistics etc.) to be fed in and retrieved

WISDOM training workshop

Fieldwork in the Mekong Delta

in relation to specific problems. Furthermore, many of the methods developed during the project for the specific conditions in developing countries can be adapted and transferred. The initial results of the WISDOM project are already being transferred to the CAWA (Central Asian Water) project financed by the Federal Foreign Office. Both Central Asia and China have shown great interest in the WISDOM approach.

Project website ► **www.wisdom.caf.dlr.de/**

German Aerospace Center, DLR
German Remote Sensing Data Center DFD
of the DLR
Dr. Claudia Künzer
Münchner Straße 20
82234 Wessling, Germany
Tel.: +49 (0) 81 53/28 32 80
E-mail: claudia.kuenzer@dlr.de
Funding reference: 0330777

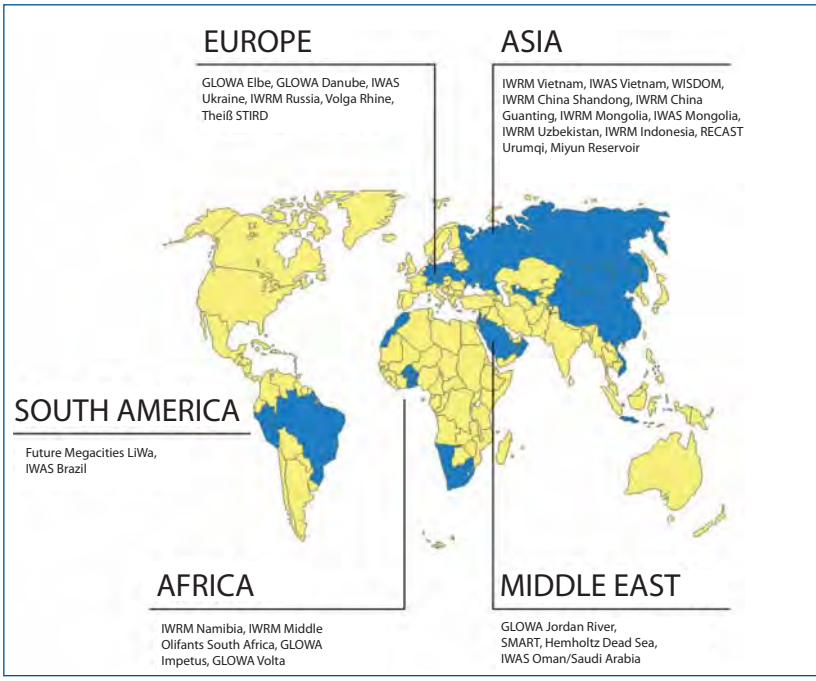
Integrated water resource management – global networking to ensure transfer of knowledge

Sustainable management of water resources is one of the greatest challenges of the 21st century. One of the focuses of Federal Ministry of Education and Research funding involves scientists, engineers and practitioners working on concepts for "integrated water resource management" (IWRM). IWRM is a process that implements sustainability concepts and interlinks ecological, social and economic objectives. An accompanying scientific project is supporting networking among those involved.

There is no escaping the escalating global water crisis. Many emerging and developing countries are suffering from an inadequate supply of drinking water and insufficient means of wastewater disposal. Roughly one in six people in Asia currently has no access to a central supply of drinking water, and 50% have no regulated means of wastewater disposal. Four in ten people in Africa have to get by without a guaranteed supply of drinking water or means of wastewater disposal. In many semi-arid and arid regions◄ of the world, a chronic water shortage is a factor restricting economic development. The explosion in the world's population and the consequences of climate change and differences in land use will intensify these problems in future on a global scale. The impacts of climate change – such as flooding, drought and desertification◄ – pose major challenges to water management in the future.

Foundations laid in 1992

There are great expectations that the concept of "integrated water resource management (IWRM)" will solve the world's water problems. The international foundations for this as a concept were laid back in 1992 with the "Dublin Principles" and "Agenda 21", and many international conferences have signed up to the IWRM concept since then. IWRM is an iterative, adaptive and evolutionary process aiming to maximise social and economic well-being without negatively affecting vital ecosystems, which involves interlinking ecological, economic and social objectives. This requires various public and private entities to get actively involved and work together on the planning and decision-making processes for handling water.



Countries and regions receiving BMBF IWRM project funding

The IWRM approach was introduced by the European Union (EU) as the Water Framework Directive in the year 2000 and is currently being implemented in the EU member states. The management cycles put forth by the EU Water Framework Directive◄ are intended to serve as an international example. This framework – when adapted to the respective local conditions – provides excellent opportunities to overcome existing water problems, both within and outside the EU.

The focus since 2006

The Federal Ministry of Education and Research (BMBF) has been funding IWRM projects since 2006, developing and testing new procedures, technologies and management concepts in model regions outside the EU. The aim of this: to ensure water supplies and the preservation of ecosystems in settlements and river basins and to enable sustainable management through integrated concepts that can be transferred to comparable regions. The solutions derived from this work will also make it easier for German companies working in the water sector to tap into new markets. This particular focus is accompanied by additional measures to improve the prospects of infrastructure investment through multilateral financing and funding agencies.

A boy looking for water in Jordan (Source: André Künzelmann, UFZ)

The BMBF is currently funding IWRM research projects in China, Indonesia, Iran, Israel-Jordan-Palestine, Mongolia, Namibia, South Africa and Vietnam. Synergies are being produced from the results of funding focused on "Global Change and the Hydrological Cycle" (GLOWA) and "Research for Sustainable Development of the Megacities of Tomorrow".

In the meantime, many research projects and initiatives have been working on adapted IWRM concepts. However, one key question is whether generally applicable frameworks and benchmarks for integrated management approaches can be derived from the country-specific activities. The relevant scientists and decision-makers from politics and administration therefore need to enter into an intensive dialogue about the experiences gained from the projects – and draw conclusions from the results.

Networking co-ordination centre set up

To provide support for networking among those involved in this work, the BMBF set up a co-ordination centre at the Helmholtz Centre for Environmental Research – UFZ in 2009. The networking activities involve many representatives from science, politics, administration and economics. As many of these representatives as possible need to participate in this networking to enable sustainable concepts to be developed and to establish integrated water resource management as an intelligent management concept.

The aim of this supporting project is to improve meaningful dialogue among those involved, and furthermore to provide contextual and organisational support for IWRM funding measures – including the transfer of technology and knowledge – in order to draw synergy effects from the national and international research activities.

Various cross-cutting themes have been addressed as part of the networking project, where they have been discussed and worked through in workshops and working groups. These themes, which play a central role in the implementation of IWRM, include capacity development, information and data management, water governance◄, stakeholder participation, financing strategies and implementation concepts. An international conference on IWRM is planned for 2011 for scientists, engineers, administrative bodies and companies to present and to discuss their experiences and research results in this area.

Project website ►
www.bmbf.wasserressourcen-management.de

Helmholtz Centre for Environmental Research – UFZ
Department Aquatic Ecosystem Analysis
Dr. Ralf Ibisch
Dipl.-Loek Christian Stärz
Dipl.-Pol. Sabrina Kirschke
Prof. Dr. Dietrich Borchardt
Brückstraße 3a
39114 Magdeburg, Germany
Tel.: +49 (0)3 91/8 10 97 57
Fax: +49 (0)3 91/8 10 91 11
E-mail: ralf.ibisch@ufz.de
Internet: www.ufz.de

Combating floods together – targeted approaches towards countering the risks

Homes destroyed, assets wiped out, existences under threat: it would seem residents in flood-risk regions are increasingly having to stand by and watch water taking away their property. The risk comes not only from swollen rivers that flow over or break their banks; because the groundwater level increases so much during a flood this puts cellars and underground infrastructures under threat too. Professional risk management is essential if the dangers posed to business and residential areas are to be avoided.

Both floods and low waters form part of the natural dynamic of all river landscapes. However, the impact of global climate change has given rise to a trend of extreme meteorological events in Central Europe, such as droughts and extreme rainfall. There has also been an increase in so-called "hundred-year floods". Floods are already the most widespread natural threat in Europe. As the soil is increasingly being sealed off, ever decreasing amounts of precipitation are filtering down. Measures to shore up river flood plains and to channel waters have also led to a loss of natural retention areas. This increases the flow speed during floods, makes flood waves higher, and causes the prospects of damage to rise too. The advanced age of some dykes also presents a risk as breaches can occur.

Transdisciplinary research activities

There is to be an improvement in the options available in future to detect dangerous situations in advance and reduce damage. This requires comprehensive risk management in both the planning and operation stages. Research in this area must develop transdisciplinary examination approaches, obtain results from these and then prove they can be applied by means of example. In order to ensure that results can be transferred into practice, the Federal Ministry of Education and Research (BMBF) is involving representatives from economics and administration in its research projects on flood protection. The participants come from universities, national authorities, state authorities, local authorities, private companies, water boards and insurance firms.

The BMBF was funding flood research projects even before the flood disasters involving the Oder and Elbe, but these events intensified those efforts. Here are some examples of the subject areas receiving BMBF funding: the acute pollution as a result of the August 2002 Elbe flood was the subject of investigation (project 1.4.01) and also served to clarify the consequences of the extremely high groundwater level in Dresden even long after the Elbe flood through the use of models (projects 1.4.02 and 1.4.04). Important findings were also obtained through monitoring and stabilising dykes with drainage elements (project 1.4.05) and using sensor-based geotextiles inside (project 1.4.06). To prevent floodwater from getting through windows and doors in extreme events, scientists from the Saxon Textile Research Institute in Chemnitz have developed self-sealing water barriers that can also be fitted in old buildings with uneven walls and are removed just as easily (project 1.4.07). The MULTISURE ("Development of Multisequential Mitigation Strategies for Urban Areas with Risk of Groundwater Flood") project focuses on how to estimate the potential for damage and risk as a result of rapidly rising groundwater in urban areas (project 1.4.03).

Sustainable protection against flood events

In 2004, the BMBF established flood protection as a focus for its research funding. Since then, the "Risk Management of Extreme Flood Events" measure (RIMAX, see project 1.4.06) has been combining skills and driving forward further development (www.rimax-hochwasser.de). Funding of around EUR 20 million in total has been channelled into 38 projects between 2005 and 2010, the aim being to detect pending flood events at an earlier stage in future and to be quicker and more effective in preventing damage. RIMAX thus made a significant contribution towards the implementation of the government's five-point programme for flood protection and also forms part of its high-tech strategy. Through RIMAX, the BMBF has also formed an early basis for the national implementation of the EU Floods Directive dated 23 October 2007 (Directive 2007/60/EC of the European Parliament and of the Council on the assessment and management of flood risks). (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:288:0027:0034:EN:PDF)

The consequences of a hundred-year flood – pollution following the flooding of the Elbe

When extreme flood events mobilise pollutants as in the Elbe basin◄, large amounts of harmful sludge and wastewater are distributed over the flood plains – and also residential areas and farmland. A team of scientists investigated the pollution left behind and evaluated the ensuing risks. The result: pollution levels within the soil were generally no greater than they were prior to the flood. Nevertheless, the experts recommend a comprehensive water and risk management system for future use.

In August 2002, heavy rainfall caused extreme flooding of the Elbe and its tributaries, leading to significant contamination of the flooded area. The floods released pollutants from old sources, expanded contaminated river sediments and carried along polluted soil and excavated material from industrial areas and mine dumps. Oil flowed from tanks on private property and both communal and industrial wastewater escaped from overcome sewage plants into the rivers. The water infiltrated residential areas, gardens and farmland, where the solids were deposited and formed a layer of sludge contaminated with heavy metals, organic pollutants and harmful germs. As such, the risks posed to health needed to be clarified as soon as possible.

The first stage saw numerous research institutes and authorities independently examining the effects of the flood on the pollution levels in the groundwater and flooded areas. So that these measurements could be combined and an analysis gained of the overall situation, the BMBF initiated a research project called "**Schadstoffuntersuchungen nach dem Hochwasser 2002 – Ermittlung der Gefährdungspotenziale an Elbe und Mulde**" (Pollution investigations after the flood of 2002 – determining the potential risk at the Elbe and Mulde). 28 partners worked under the guidance of the centre for environmental research at Leipzig-Halle to investigate the river basins of the Mulde and Elbe from the Czech Republic to Hamburg.

Chronic pollution of river sediment

The numerous pollutants in the Elbe come from many sources. Elements such as arsenic and heavy metals occur naturally across the entire basin and have always been carried down from the bordering low-mountain regions. Depending on the river dynamics, they are deposited or carried further and cause the "geogenic background contamination◄" in the waterways. Other sources of pollution include mining and other industrial activities within the region.

Oil tank torn off by the Elbe flood (Source: Thomas Egli)

Virtually no changes as a result of the flood

The substantial (in part) concentration of heavy metals and organic pollutants exhibited by the rivers during the flood quickly dropped again as the waters receded according to tests. With just a few exceptions, the flood did not significantly increase the amount of pollution in flood plain soils and sediments. However, this should not take away from the fact that the regularly flooded land beyond the dyke beneath the confluence of the Mulde and Saale is heavily contaminated. As the recommended values for use as pasture were way exceeded in terms of dioxin and mercury in many samples, experts recommend the implementation of consistent use management. This would mean that the heavily contaminated hollows and watering holes

Sediment deposits after the 2002 Elbe flood (Source: Dagmar Haase)

should not be used and that grazing should only commence after cleaning through precipitation.

The great flood of 2002 also affected locations normally protected by dykes. In the researchers' view, no acute risk is posed to the health of the population: the analyses indicated only disparate increases in the concentration of pollution. Nevertheless, the measurements indicated that the basic pollution load of the researched area was already pretty high before the flood occurred. (See UFZ final report: Schadstoffbelastung nach dem Elbe-Hochwasser 2002 (pollution load after the Elbe flood of 2002) at www.ufz.de/data/HWBroschuere2637.pdf).

Introducing risk management

Floods and the associated hazards are not going to go away. However, the intensity of the events and the extent of the damage can be reduced. As such, the researchers propose employing preventive water management and land usage in a far more consistent manner than before and consolidating fragmented areas of responsibility for flood-related issues. The aim is to ensure integrative and interdisciplinary water management in the river basin, which is also to include flood risk management. The researchers view integrated pollution management – particularly for the Mulde and Saale – as a potential basis for long-term remediation within central Germany.

A recently developed pollution distribution model is the first step in this direction. The coupling of a hydraulic model with a land and pollution distribution model for the first time enabled scenarios for moderate to extreme flood events to be determined and then fed into a decision support system◄ – a system already in use within Anhalt Bitterfeld. It is also used for current flood exercises and for resettlement operations in order to assess the risk of pollution ingress during flood events.

In order to reduce the risk posed by toxins and harmful germs during future floods, the experts also advocate the creation of handling instructions for dealing with flood sediments, installing pollution sources such as private oil tanks and heaters and commercial chemical stores in locations secured against flooding and devising measures to enhance protection of industrial facilities, sewage plants and other similar installations. The scientists also recommend compiling research results through a database-supported decision support system (DSS)◄ so that the necessary information is available when making decisions in future.

The legacy of a century of mining: slag heaps in Muldenhütten near Freiberg. Around 9,000 tonnes of high-grade lead and arsenic-loaded material were eroded here during the flood of 2002 (Source: Günther Rank)

Greater efforts should also be made to keep flood zones free from buildings and inappropriate use as a preventive measure (preventive land use). Abandoning farmland and planting greenery is an effective way to counteract erosion of contaminated soil on river flood plains. Undeveloped land also provides natural retention areas◄; this method all but eliminates damage to buildings.

In a second project funded by the BMBF called "Flood risk mitigation based on non-structural land use schemes in runoff generation and flood plains" (MinHorLam), scientists investigated the influence of non-structural land use measures on flood risks. One of the topics covered was the risk potential for producers and consumers when pollution contaminates the plant stocks and soils on land used for agriculture and forestry. The researchers devised damage-limitation measures such as changing land use, introducing special types of plant, accumulating pollution in only small amounts and compensation for leaving land uncultivated. The findings gained are being made available to the general public through an Internet platform.

UFZ-Umweltforschungszentrum Leipzig-Halle GmbH
River ecology department
Dr. Wolf von Tümpling, Prof. Walter Geller
Brückstraße 3a
39114 Magdeburg, Germany
Tel.: +49 (0)3 91/8 10-93 00
Fax: +49 (0)3 91/8 10-91 11
E-mail: wolf.vontuempling@ufz.de,
hochwasser@ufz.de
Internet: www.ufz.de/hochwasser
Funding reference: 0330492

3ZM-GRIMEX project – coupled models simulate flood scenarios

When a flood occurs, the danger is not only posed by submerged land but often by rising groundwater as well. This spreads out under the earth and can cause a great deal of damage. Up to now, most water flow simulation systems have treated these processes separately or as two components, and it has not been possible to map surface water, the sewage system and groundwater together. A research project led by the Dresden Groundwater Research Center interlinked computer-aided models to provide a better assessment of how these components interact during flood conditions.

Flooding in Dresden: Water flowing out of the sewage system onto Terrassenufer

Floods in recent years have caused a terrible amount of damage. The amount of damage in Dresden alone amounted to around a billion euro in August 2002 – roughly 10% of the total damage nationwide. Groundwater counts for 16% of the damage to property in Saxony: it has therefore become apparent that floods can affect groundwater even in urban areas. The floodwater generally takes two courses as it spreads beneath the earth:

- Surface water getting into the groundwater and spreading. The groundwater flowing into the receiving waters◄ from the hinterland backs up.
- Surface water spreading via infrastructures such as the wastewater sewage system (technogenous regions◄) to areas outside the region flooded directly.

Researchers at the Dresden Groundwater Research Center used model support to begin mapping the interaction between surface water and groundwater in flood conditions immediately after flooding occurred. The aim was to assist the clean-up in the wake of flooding and to improve prevention measures. At that time however, only individual technical model solutions were available for interactions between surface water and groundwater and between groundwater and the sewage system: they were based on simulation programs relating to a single component – surface water, the sewage system or groundwater.

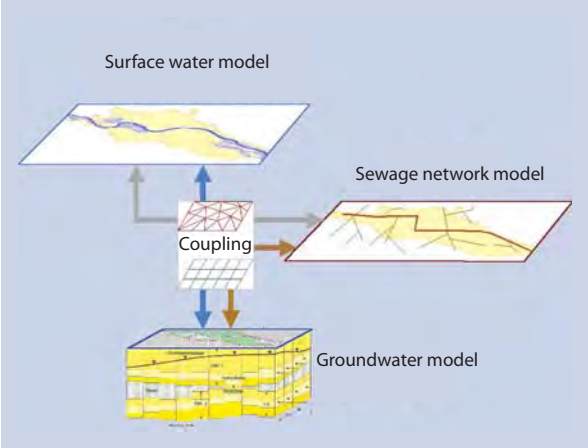
Coupled modelling: three zones – one system

This is where the BMBF project **"Development of a 3-Zone model for groundwater and infrastructure management after extreme flood events in urban areas" (3ZM-GRIMEX) was able to help**. The scientists making up the project team developed an innovative modelling tool for the state capital Dresden that maps the interactions between the following hydraulic components in extreme flooding on the basis of existing models: surface water effluent, effluent in the technogenous zone and groundwater. This coupled modelling system enables the development of solution strategies for designing and safeguarding the underground infrastructure networks, for managing groundwater-related flooding and for supporting town-planning decisions.

The experts used coupling software from the Fraunhofer Institute to link together simulation programs with a proven record in mapping significant flows of water during a flood. In doing so, they had to take into account both the time and spatial differences between the individual model components. To ensure that the coupling was successful, full awareness of the fundamental connections within the system – comprising sewage network, surface water and groundwater – and the time and spatial scales of the flow processes was required. A scale determined how a certain feature of a process was recorded and rendered measurable.

Computer-aided coupling process

Computer-aided coupling is based on the strategy that the individual modules – models for surface water, the sewage network and groundwater – calculate their respective water levels and throughflows as separate instances and then exchange these calculations. Each module then supplies these "coupling variables" to the others. The coupling software ultimately combines the information from the individual modules (blending). If, for example, sewage elements, groundwater levels and flooded surface areas are blended together, it is possible to determine which residents are affected by adverse weather and warn them in good time.



Schematic of the model coupling within the 3ZM-GRIMEX project

The programs used provided the project team with different challenges depending on the field of application. Take the sewage network for example: the hydrodynamic sewage network calculation did not require an especially high level of performance from the computers and the level of data in most areas was also very good. However, the only way to integrate the effect of the sewage system on the dynamic of the groundwater was to use greatly simplified approaches.

Advance calculation of flooded surface areas through realistic modelling (Map background source: city of Dresden)

Practical application in Dresden

The focus of the first processing phase was on the individual models. This depended on harmonising their spatial relationships and recording all relevant water flows that have an effect during flooding and need to be mapped in the modelling system. The researchers created a general water flow schematic for this purpose, which formed the basis for the coupling activities. The main thing was to ensure adequate mapping of temporary components such as flood relief wells, flooded surface areas and overly backed-up sections of sewer. These algorithms were tested in a synthetic test model, which involved the team of experts trialling first the couplings and then all three instances.

The entire system has since been implemented in Dresden. The coupled modelling has enabled the exchange of water between surface water effluent, effluent in the sewage system and groundwater to be calculated for a variety of flood scenarios. Experts also used the new system to identify hotspots with latent flood risks due to emergent sewer water. The transfers from groundwater into the sewage system were able to be localised and quantified. The influence of emergent sewer water on groundwater only has a local effect during flooding, but depending on the intensity can lead to a significant rise in groundwater in the hotspots.

Project website ▶ **www.gwz-dresden.de/dgfz-ev/forschungsbereich/3zm-grimex.html**

Dresdner Grundwasserforschungszentrum e. V.
Project co-ordination
Dr. Thomas Sommer
Meraner Straße 10
01217 Dresden, Germany
Tel.: +49 (0)3 51/40 50-6 65
Fax: +49 (0)3 51/40 50-6 79
E-mail: tsommer@dgfz.de
Funding reference: 02WH0557

Flood events – the forgotten groundwater

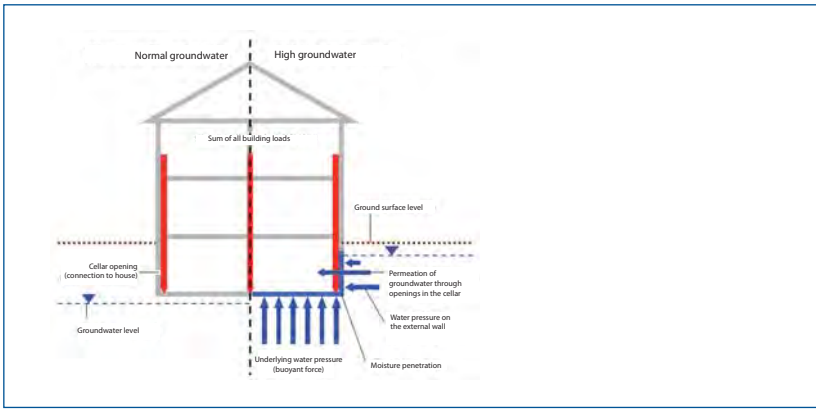
What are the consequences of a groundwater level raised by a flood, particularly for built-up areas near rivers? The MULTISURE project has been seeking answers to this long-neglected question. The scientists involved developed models to enable potential risks and damage to be more accurately pinpointed in future, using Dresden — which is located on the Elbe – as an example.

The specialist community most often perceives a flood as an event involving extreme effluent over the surface of the ground. In addition to flooded surface areas, a rise in groundwater as a result of flooding can also be observed – especially after long periods of flooding in wide valley flood plains. Before now, science rarely factored in the risk to underground structures and infrastructures posed by fast-rising groundwater as a consequence of extreme flooding.

So, how can the risk and damage potential from fast-rising groundwater be estimated? What is the required make-up of models that can predict underground damage due to extreme flooding? These questions were the focus of the project entitled **"Development of Multisequential Mitigation Strategies for Urban Areas with Risk of Groundwater Flood" (MULTISURE)**, led by the Dresden Groundwater Research Center (DGFZ), involving several institutes and running from 2006 to 2009. The aim of the project was to develop tools used to map and assess the hazards, potential damage and risks arising from the interactions between flooding, groundwater and underground infrastructures. The site chosen for investigation was Dresden along with the Elbe valley aquifer and both existing and planned underground building developments.

Two damage models developed

The project partners began by investigating how approaches for estimating damage through flooded rivers can be applied to groundwater-related flooding, and how the two events interact and overlap. The German Research Centre for Geosciences (GFZ) modified the meso-scale damage model developed for river flooding called FLEMOps (top-down approach) in order to estimate the damage caused by rising groundwater. This involved conducting telephone surveys with those affected — specifically regarding damage that occurred outside the flooded surface areas or were caused solely by groundwater. As such, findings could be obtained on handling the groundwater-related flooding individually and on the material and financial damage.



Threat from below: effects on the building structure

A bottom-up approach involved describing damage for types of building and infrastructure in relation to age — and depending on the groundwater dynamic. This enables the remediation measures required to rectify the damage to be determined, and also their costs. Expanding on this, the Leibniz Institute of Ecological Urban and Regional Development (IöR) is developing the new GRUWAD model (damage simulation model for building damage related to groundwater).

Multiple scenarios created

The groundwater risk assessment and depiction used both the above modelling approaches (top-down and bottom-up). FLEMOps and GRUWAD were used for a GIS-based◄ determination of damage caused by groundwater at different spatial resolutions. The basis for this were the scenarios created by the Dresden Groundwater Research Center for the highest groundwater levels under various flood conditions in the Dresden Elbe valley and the implementation of various protective measures (database previously was flood events plus current planning within Dresden).

Threat from below: groundwater escaping to the surface

Interviews conducted

Intensive communication and co-operation among everyone involved is key in ensuring efficient flood risk management: this includes city and state authorities, associations, scientists and residents. MULTISURE has analysed and evaluated these processes.

The basis for co-ordinated public action in flood prevention is meaningful information – and this also increases risk awareness and personal prevention measures among citizens. The interviews conducted during the course of the project and the analysis of existing means of information and communication were co-ordinated by the Institute for Environmental Communication at the Leuphana University of Lüneburg. The resulting brochure – primarily aimed at the general public – deals particularly with the personal responsibility of those affected and is therefore intended to intensify risk prevention.

The project results were fed by Görlitz/Zittau University into the city of Dresden's information system. This enables internal access within authorities to key project results. As such, the results can be used to improve authorities' internal analyses and decisions and to provide the public with information on the risks posed by groundwater-related flooding.

Dresdner Grundwasserforschungszentrum e.V. (DGFZ)
Dr. Thomas Sommer
Meraner Straße 10
01217 Dresden, Germany
Tel.: +49 (0)3 51/4 05 06-65
Fax: +49 (0)3 51/4 05 06-79
E-mail: tsommer@dgfz.de
Internet: www.dgfz.de
Funding reference: 0330755

The underestimated threat posed by groundwater – damage assessment and prevention after the hundred-year flood

In the wake of the flood of August 2002, Dresden had more to tackle than damage to buildings and infrastructure: the groundwater had also risen by up to six metres in places and was taking a long time to recede. A team of local researchers and engineers therefore set about investigating the consequences of the flood beneath ground. The aim was to enable early detection in future of risks to underground facilities and the groundwater so that protective measures can be implemented. To achieve this, the experts modelled the dynamics of the rise in groundwater and analysed the nature of the groundwater as a supply of drinking water and the potential risks due to infiltrating pollution.

During the flood of 2002, groundwater levels underneath the Elbe valley way exceeded anything observed in decades. The triggers for this were the heavy rainfall over 12 and 13 August, the ensuing overflowing of the Elbe tributaries and the flood of the Elbe itself. The groundwater had an impact on building structures both above and beneath ground – their functional capability and stability were significantly affected by the fast-rising levels. As the surface floodwater receded, it was then possible to assess the impact of the underground floodwater on the body of groundwater beneath the city of Dresden. This groundwater is a major source of drinking and process water and plays a major role in the stability of buildings and the urban environment. Scientists and engineers from TU Dresden and the Dresden Groundwater Research Center joined forces with local engineering firms and dedicated themselves to achieving this task through the research project entitled **"Hochwassernachsorge Grundwasser Dresden"** (Dresden groundwater: cleaning up after the flood), which was led by the city's Environment Office. The experts started with short and medium-term consequences, and investigated them in line with the following focus points:

- Further development of the groundwater model to determine the effects of the groundwater dynamic on buildings and potential damage to buildings,
- Investigation of changes to the nature of the groundwater in the wake of significantly risen levels,
- Analysis and evaluation of potential groundwater-related damage ensuing – as a result of flooding – from contaminated areas (abandoned waste), sludge deposits or waste,
- Evaluation of the risks posed by unsealed wastewater channels (contaminant discharge).

The Elbe flood at Kaditz. Groundwater measurement points are engulfed by the flood.

The aim was to use Dresden as an example to evaluate flood-related damage to a body of groundwater underneath a city for the first time and to use this to derive action recommendations for administration, affected companies and citizens.

Model recording the groundwater dynamic

The nature and course of the groundwater flooding differed throughout the city, with wide areas – mainly more than a kilometre away from the receiving waters◄ – displaying a rise in the groundwater level after the flood wave that was then extremely slow to recede and others showing a brief significant rise that then dropped back down rapidly. The experts developed a computer groundwater model to record these different dynamics, which also factored in the basic structure of buildings beneath ground – primarily the historical town centre and the infrastructure. This enabled the project team to simulate the effect of different flood protection measures on the groundwater too.

The investigations of the nature of the groundwater took place on three levels: the working group took samples from a wide area in autumn 2002 and then spring and autumn 2003 to see how the quality had progressed. Investigations also found isolated pollution ingress at abandoned waste sites. The third element took the form of sample site-specific investigations of the natural sediment◄, conducted in the lab. This should enable statements to be made on the discharge and conversion of substances where polluted wastewater reaches the groundwater from the sewage system. The researchers simulated scenarios with different water levels and pressures in the sewers and the aquifer◄.

Protecting the building structure against rising groundwater at a Dresdner school (Source: www.benno-gym.de)

Drinking water unaffected

The experts were able to dispel fears regarding the nature of the groundwater by comparing the readings of specific water characteristics and pollutants values taken prior to the flood. The changes as a result of the flood were then only detectable for three months afterwards; they posed no threat to the drinking water.

The results at the abandoned waste sites investigated varied depending on the substances present and the flow conditions. Increased groundwater levels and flow speed released contaminants from their respective source. The experts detected slight increases in pollutant concentrations in the upper groundwater, plus vertical displacement within certain groups of substances. No significant lateral spread of pollution as a result of the flood was observed.

To enable them to investigate risks posed to the aquifer from unsealed channels, the project team simulated a local unsealed sewer system under pressure and flow conditions akin to a flood. This showed that the ammonium load typical of municipal wastewater only spread a small amount as a result of the flow speed and limited amount of unsealed areas.

Identifying risks, developing protective measures

The experts used the distances between the groundwater table and the surface of the terrain ◄ (depth to groundwater table) from August 2002 to December 2003 to develop a method for detecting risks posed to underground building areas. The parameters used included the intensity and duration of the groundwater flooding, the highest water levels, the speed of the rise in level and the minimum depths to the groundwater table. As a result, it was possible to determine the risk potential for 68 measurement sites within the city.

The assessment of the nature of the groundwater and the flow modelling based on various flood scenarios enabled conclusions to be drawn for use in town planning. According to the project team's findings, town planning should always factor in the threat posed by a rise in groundwater. The investigations also confirmed the effectiveness of the planned protection measures, namely mobile shoring with inner-city Dresden and flood relief wells.

In light of the results of their investigations, the researchers recommend that the processes of groundwater rising be constantly factored into the preparation and execution of measures to tackle flooding, with building precautions forming an essential component. The identification of "danger zones", where increased groundwater levels can be expected, forms the basis for this. As such, prompt measurements of the groundwater dynamic and the identification of the highest groundwater levels using a current groundwater flow model are required.

Project website ►
www.hochwasser-dresden.de/HWGWDD

Project management
City of Dresden, Environment Office
Dr. Kirsten Ullrich
Grunaer Straße 2
01069 Dresden, Germany
Tel.: +49 (0)3 51/4 88 62 78
E-mail: kullrich@dresden.de
Internet: www.dresden.de/Hochwasser
Funding reference: 0330493

Project co-ordination
Dresdner Grundwasserforschungszentrum e.V.
Dr. Thomas Sommer
Meraner Straße 10
01217 Dresden, Germany
Tel.: +49 (0)3 51/4 05 06 65
E-mail: tsommer@dgfz.de

Avoiding dyke breaches – monitoring methods and safeguarding concepts for river dykes

Floods in recent years have increasingly led to dyke breaches as these – in part historical – structures have not been able to withstand the hydraulic loads placed upon them. For financial reasons, thorough remediation of all affected dyke areas can only take place in the long term at best. As such, scientists working on two research projects funded by the BMBF have developed a monitoring system for the reliable detection of dykes in critical condition and a procedure for stabilising endangered dykes using drainage elements◄. The efficacy of these developments was confirmed through pilot tests.

A state-of-the-art three-zone dyke comprises a surface seal on the water side and a supporting body in the centre of the cross-section. A drainage body on the land side ensures that drainage water is captured in the dyke and safely diverted away. However – as in other parts of Europe – Germany has old dykes running along stretches of rivers and streams spanning hundreds of kilometres, dykes that do not meet today's safety standards. They have previously been filled, mainly after floods, with materials available locally. Dyke bodies such as these take in water during a flood due to a lack of a sealing layer; this causes progressive moisture penetration that in the worst case can lead to a breach.

Using time domain reflectometry to monitor dykes

The development of moisture penetration over time is crucial to stability, particularly in old dykes such as those mentioned above. A monitoring system is required in order to obtain reliable information on this, and needs to deliver data on the current hydraulic situation of a dyke body along the stretch of a given dyke. Time domain reflectometry (TDR) has proven to be a suitable procedure when used in conjunction with cable sensors. This involves implementing ribbon-cable sensors in the dyke body; a voltage pulse fed in at the sensor start and reflected at the sensor end can be used to determine the distribution of moisture along the cable sensors. This enables sufficiently accurate detection of the drainage line (boundary between moist and dry material) and thus the area penetrated by the moisture. The benefit of this procedure is that the dyke body only needs to be accessed at sensitive spots.

Scientists from the Materialforschungs- und -prüfanstalt (institute of material research and testing, MFPA) at the Bauhaus University Weimar and the Institute of Soil Mechanics and Rock Mechanics (IBF) at the Karlsruhe Institute of Technology (KIT) developed a monitoring system based on the TDR method specifically for flood protection dykes as part of the project entitled **"Bewertung und Prognose der Standsicherheit von Hochwasserschutzdeichen mittels Time Domain Reflectometry"** (evaluation and prognosis of the stability of flood protection dykes using time domain reflectometry).

At the heart of the monitoring system is a forecasting model that uses the moisture distributions measured within a dyke, the predicted course of flooding and the expected precipitation to predict the onward progression of the dyke's moisture penetration. An evaluation model was developed both for the moisture distribution measured during a flood and for the predicted moisture conditions to permit a stability analysis of the outer slope of the backed-up dyke. The developed monitoring system is able to use its own power supply to perform self-sufficient measurements and send data to a central server via remote transmission. The analysed and predicted moisture distributions are made available online along with the stability evaluation. This could then be an effective tool for those responsible for flood management for arranging safeguarding measures or evacuations quickly in the event of a threat. It was not possible to transform the monitoring system into a fully automated monitoring tool during the funding period of this project.

Stabilising dykes with drainage elements

Sections of dyke that are at risk of a breach need to be stabilised in the lower section of the outer slope during flooding; this involves a great deal of labour and materials (e.g. sandbags). The surface of the slope on the river side is to be sealed with films or other materials, but this is only useful if there are weak spots leading to a concentrated throughflow. Otherwise, such measures are not able to reduce the drainage line by any significant amount. If it is not possible to avoid water getting into the dyke, it is then a matter of capturing the drainage water in the dyke body and safely diverting it away. Otherwise, it can emerge from the outer slope; increased flow forces could then lead to a breach.

Standard drilling is to be applied to implement the linear drainage elements in the model dyke (Performed by: Morath GmbH, Albbruck)

The model dyke on a natural scale (height: 3 m) proved the technical feasibility of the stabilisation procedure (viewed from land side)

This is the area that the second BMBF project addressed, entitled **"Stabilisierung bruchgefährdeter Flussdeiche mit Dränelementen zur Sickerwasserfassung und Bewehrung"** (stabilising river dykes at risk of breaching with drainage elements to capture drainage water and for reinforcement) and involving the Institute of Soil Mechanics and Rock Mechanics (IBF) of the Karlsruhe Institute of Technology, the Department of Geotechnics at the University of Kassel and the Saxon Textile Research Institute (STFI) in Chemnitz. During this project, a concept was developed to safeguard backed-up dykes in the event of a flood. An emergency measure like this can also be used as a short or medium-term method for strengthening old dykes.

Effectiveness of the procedure proven

The emergency safeguarding measure specifically intends to apply drainage elements by machine to sodden dykes at risk of breaching, which will then intercept the running drainage water at the foot of the dyke. Standard equipment (e.g. from the construction industry) readily available from multiple locations is to be used for the installation wherever possible. The practicality of the procedure and the tools required for installation were tested on a natural scale using standard drilling equipment. The true-to-life tests confirmed that the stability procedure is indeed effective. A trial on a proper stretch of dyke would also be invaluable in gaining acceptance within standard construction practice; however, this was not possible as part of the research project.

Karlsruhe Institute of Technology (KIT)
Institute of Soil Mechanics and Rock Mechanics
Dr.-Ing. Andreas Bieberstein
Engler-Bunte-Ring 14
76131 Karlsruhe, Germany
Tel.: +49 (0)7 21/6 08-22 23
Fax: +49 (0)7 21/69 60 96
E-mail: andreas.bieberstein@kit.edu
Internet: www.ibf.uni-karlsruhe.de
Funding reference: 02WH0479 / 02WH0585

Integrated warning system – monitoring and stabilising dykes with sensor-based geotextiles

The condition of dykes has almost exclusively been monitored visually up to now. With the appearance of their insides hidden from inspectors, damage is often not noticed until it is in the advanced stages. This means it is generally too late to implement targeted support for sections at risk of breaching in crisis situations. Automated monitoring within the dyke could prove to be helpful here: with funding from the BMBF, the Saxon Textile Research Institute (STFI) has worked together with the Federal Institute for Materials Research and Testing (BAM) and other partners to develop special geotextiles that both secure and monitor dykes at the same time. In the meantime, the research has produced a new spin-off company◄ called fibrisTerre GmbH as well as three marketable patents.

Conventional dyke inspections in Germany monitor the surface and are not always able to detect damage with sufficient speed or reliability. Round-the-clock monitoring would be required during times of flooding, and this is hardly feasible from a manning perspective. There are actually electronic measuring systems already available on the market, but they are expensive and as such are rarely used. Cue the BMBF-funded research project entitled **"Entwicklung von multifunktionalen, sensorbasierten Geotextilien zur Deichertüchtigung, für räumlich ausgedehntes Deich-Monitoring sowie für die Gefahrenerkennung im Hochwasserfall bei der Deichverteidigung"** (development of multifunctional, sensor-based geotextiles for reinforcing dykes, dyke monitoring over greater areas and hazard detection to defend dykes in the event of flooding). Scientists from the Saxon Textile Research Institute in Chemnitz worked together with the Federal Institute for Materials Research and Testing in Berlin and other partners to develop an innovative material with built-in sensor technology as a part of this project.

Geotextiles: a versatile construction material

Geotextiles are heavy-duty fabrics specially designed for outdoor use; they can be made of woven, non-woven or knitted fabrics, and from natural or synthetic materials. They are used within geotechnical and structural engineering – generally to stabilise ground constructions and prevent soil erosion, e.g. in constructing roads and railways or waterways and dykes. Depending on their purpose, geotextiles are either permeable – when installed on steep slopes, berms or embankments – or impermeable, e.g. when used at landfill sites.

Controlled measuring on an area of sensor-based geotextile as part of the application process: field test in Swienna Poremba (Poland)

Automated dyke monitoring

The idea behind the project was to develop a multifunctional geotextile that, as well as being able to secure the dyke slopes, could also be used to monitor dyke stability. Fibre-optic sensors were therefore incorporated into non-woven structures during the manufacturing process itself to serve this precise purpose. These sensors feature the standard, low-cost glass fibres used within telecommunications and use special optical measuring procedures to detect even minimal stretching of the textile structure as well as temperature fluctuations so that dyke deformities can be registered during a flood. The detected changes can then be routed to central measuring and monitoring stations, where they can be called up at any time so that the alarm can be raised promptly in the event of any damage.

A new basis for measuring devices was developed for obtaining and evaluating the readings, work primarily undertaken by the BAM. Based on Brillouin frequency range analysis◄, the new measuring technology developed and patented during the BMBF's **RIMAX** project (Risk Management of Extreme Flood Events) clearly had so much potential that the EXIST research transfer programme approved the application of three young scientists to set up their own company. Founded in January 2010, fibrisTerre GmbH is the first spin-off company from the BAM.

Field test on a full-scale lab dyke at the Franzius Institute of Hydraulics, Waterways and Coastal Engineering in Hanover

Producing the geotextiles

How should textiles be made in order to ensure sufficient protection of the optical fibres? Which materials are most suitable? How can the glass fibres be worked into the textile? To answer these questions, the scientists at the Saxon Textile Research Institute conducted numerous tests on a non-woven Raschel machine. The method used is a conventional production procedure for geotextiles that has been specially modified for this purpose; new test methods have also been developed to determine the sensor and mechanical performance profile of the multifunctional geotextiles. The STFI is obtaining patents both for the production process and for the use of geotextiles with built-in sensors within dykes.

Field test in Solina (Poland)

In the meantime, the functional capability of the geotextiles has been demonstrated in various field tests. Various studies using a trial full-size dyke on the premises of the Franzius Institute of Hydraulics, Waterways and Coastal Engineering at the University of Hanover have shown what the new procedure can achieve. Simulations of different crises and loads were run, proving the functional capability of the sensor-based geotextiles under conditions of practical relevance. BBG-Bauberatung Geokunststoffe GmbH is currently working on marketing the sensor-based geotextiles together with rg-research, which was founded by Rainer Glötzl (http://rg-research.de).

Benefits of the procedure

Comparatively speaking, sensor-based geotextiles are a cost-effective alternative to other dyke monitoring approaches. The optical procedure lowers the costs per measuring point considerably, and provides data for the entire area rather than just isolated spots or along a chain of sensors. This also makes it possible to monitor extremely long sections of dyke with little personnel expenditure and enables precise mapping of damage. Only a monitoring system enables observation of both short-term changes such as cracks and scouring and long-term effects such as dyke subsidence. Finally, the procedure is also financially beneficial when it comes to constructing dykes, as securing the structure and integrating the monitoring system becomes a single-step process.

Project co-ordination
Sächsisches Textilforschungsinstitut e.V. (STFI)
Elke Thiele
Annaberger Straße 240
09125 Chemnitz, Germany
Tel.: +49 (0)3 71/52 74-0
Fax: +49 (0)3 71/52 74-1 53
E-mail: elke.thiele@stfi.de
Internet: www.stfi.de
Funding reference: 02WH570

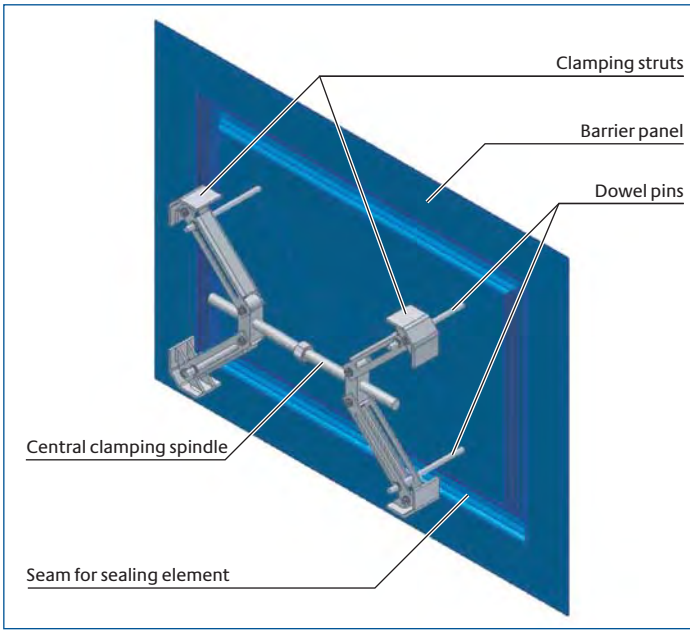
Building security for all – self-sealing water barriers for windows and doors

A large number of towns and communities have been affected by flooding in recent years. The floodwater gets into houses and often destroys all the furnishings inside. Windows and doors must be sealed in good time to prevent water escaping over banks from getting into buildings. There are already various protection systems available on the market, yet experience has shown that old buildings in particular are not sufficiently sealed. Scientists from the Saxon Textile Research Institute in Chemnitz therefore developed self-sealing water barriers for windows and doors for flexible and straightforward installation – even in old buildings with uneven walls – that can also be removed without any problems.

Conventional flood protection systems for windows and doors generally comprise protection panels that are either affixed directly to the masonry with pins and screws prior to a flood or inserted into pre-installed rails. The crucial thing here is that the gap between the panel and the wall is perfectly sealed so that there are no little openings or cracks for the water to access the inside. And yet – as experience from recent floods shows – this prevention is hardly ever implemented, a trait particularly prevalent among a large number of old buildings as the uneven masonry does not enable precise, impermeable sealing to be installed. Even rubber itself is not elastic enough in such cases, and silicone is not easy to remove from plaster, windows and door frames once the barrier system has been taken down.

Mineral sealing material

In light of the above, scientists at the Saxon Textile Research Institute in Chemnitz have been seeking more efficient and effective alternatives as part of the work on the BMBF-funded research project entitled **"Selbstdichtende Wassersperren für Fenster und Türen"** (self-sealing water barriers for windows and doors). And their solution? Mineral sealing materials that can be moulded by adding fluid and can thus flexibly adapt to unevenness. Loam and clay are examples of mineral substances that swell up when moistened and can be moulded into any shape. Used to fill special textile tubes and moistened before use, they can adapt to match the masonry perfectly. Tests have shown that bentonite is an extremely suitable sealant for this purpose. This stone is a mixture of various clay minerals and is particularly effective at absorbing



Barrier system with specially developed clamping struts for increased stability.

water and expanding. The clay granulate used is extremely fine (grain size of 0.1 to 2 mm), making it easy to dispense and helping to prevent the funnel from blocking when filling the textile tubes (bridge-building). This granulate was therefore selected for use in the subsequent tests.

Produced in a single process

The textile tubes are to be filled with bentonite granulate during production so that the complete product is made in a single process. The scientists worked with representatives from Umwelt- und Maschinentechnik GmbH in Pöhl to test special machines used in textile processing that would be suitable for this. These included a circular loom, a circular knitting machine and a "Kemafil" machine. The latter of these can be used to implement a special procedure developed and patented by the Saxon Textile Research Institute, which enables a wide range of materials to be coated with a three-dimensional mesh structure. The sealing system is produced by shaping a non-woven material into a tube and securing with meshed threads, and simultaneously filling this with the mineral substances. The tests showed that a right-left small circular knitting machine was best at producing the seal for the barrier system.

Sealant tube made from a small circular knit with integrated BENTONITE granulate

Modified R-L small circular knitting machine with feed, metering and filling equipment

Additional scouring protection

It has been demonstrated that textile tubes filled with mineral granulate are suitable for balancing out minor and major unevenness in walls and providing perfect sealing. This sealant must be moistened before application between the wall and panel. If a significant flow speed is encountered, additional scouring protection should be applied prior to sealing. A tube made from soft, recycled textile is suitable for this; it does not prevent water gradually seeping through to the seal, but it reduces the flow speed such that the mineral components are not washed away.

Benefits of the self-sealing water barrier

The self-sealing water barrier system is quick, flexible and straightforward to install without any pre-installation work required; it can be applied to all building types and removed again without any problems. As well as the mineral seal and scouring protection, the system includes metallic or non-metallic front panels affixed using a quick-release mechanism. This dispenses with the need to secure directly to the masonry with pins and screws. The perfect seal also means there's no need for laborious resealing once floodwater has come up against the barrier.

Sächsisches Textilforschungsinstitut e. V. (STFI) at the Chemnitz University of Technology
Dept. Technical Textiles/Woven, knitted and composite products
Dipl.-Ing. Ulrich Herrmann
Annaberger Straße 240
09125 Chemnitz, Germany
Tel.: +49 (0)3 71/52 74-2 16
Fax: +49 (0)3 71/52 74-1 53
E-mail: ulrich.herrmann@stfi.de
Internet:
www.stfi.de/de/projekte/rimax_wassersperre.pdf
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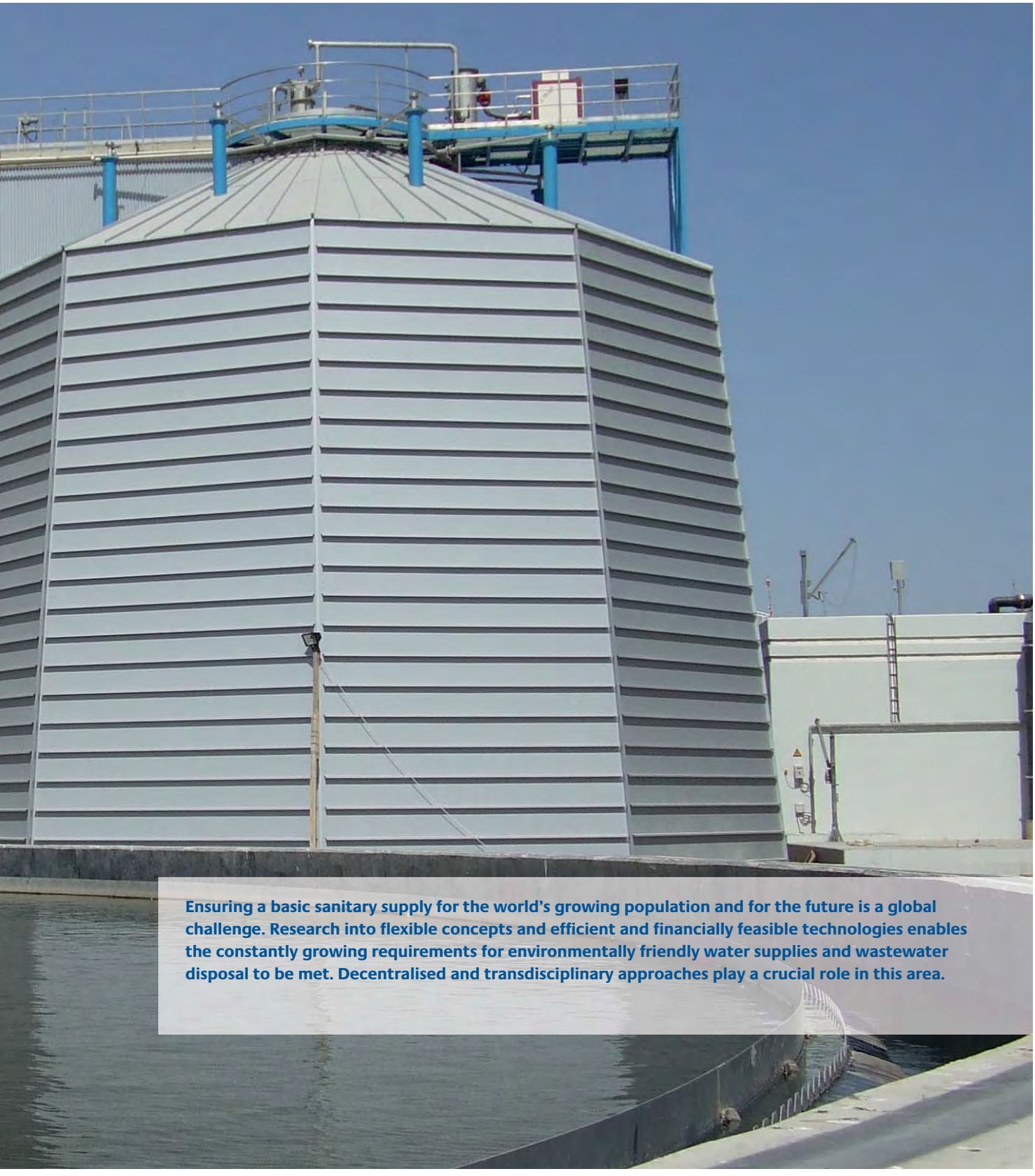
http://waterresources.fona.de/reports/bmbf/annual/2010/nb/English/40/2_-technology.html

Technology



Ensuring a basic sanitary supply for the world's growing population and for the future is a global challenge. Research into flexible concepts and efficient and financially feasible technologies enables the constantly growing requirements for environmentally friendly water supplies and wastewater disposal to be met. Decentralised and transdisciplinary approaches play a crucial role in this area.

Global sustainability through customised local solutions – recycling and resource efficiency

Around a billion people still have no access to clean drinking water, and around 2.5 billion are without regulated wastewater disposal. The 2002 UN summit in Johannesburg highlighted the huge importance of drinking water supplies and wastewater disposal: the proportion of people having to live without clean drinking water and basic sanitation is to be halved by the year 2015. A simple direct transition of our methods to affected areas will not work as demographic change is storming ahead; adapted and efficient technologies and concepts are therefore required.

Designed decades ago for a much greater consumption of water, conventional, central supply and disposal systems depend on a high flow of water. However, household water consumption in Germany has been decreasing for years now, and the country's demographic change suggests that this trend is set to continue further over the next few decades. To generate the pressure required to prevent solids from being deposited in the sewer systems, many areas are already having to pump in additional water. Smaller, decentralised concepts that can adapt to changing needs are therefore essential for the future.

Areas with a lack of water and ecologically sensitive regions can also implement customised, decentralised procedures so the available resources are used efficiently. However, this approach requires the entire local water system to be considered as a single entity, from water collection, treatment and distribution through to wastewater cleaning and recycling. Through integral examination and management, household wastewater can be treated and used as process water, and solids can be processed and used as fertiliser or converted into biogas for energy. Numerous projects funded by the Federal Ministry of Education and Research (BMBF) have investigated how tried-and-tested methods can be combined on site to form system solutions.

Example of China. "Semi-centralised": this was the name given to a structure extending beyond individual building units, thus different from conventional centralised solutions. The "Semizentrale Ver- und Entsorgungssysteme für urbane Räume Chinas" project (semi-centralised supply and disposal systems for urban areas in China) primarily investigated the potential of this approach in China's large, fast-growing cities (project 2.1.01).

Example of Germany. The "Sanitary recycling Eschborn" (SANIRESCH) project focussed on how to reduce water consumption for toilets and how the resultant urine water can be used in an environmentally compatible manner (project 2.1.02). The KOMPLETT project (2005 to 2009) was able to demonstrate that reusing all domestic wastewater and solids of a high yield density (e.g. in hotel complexes) could be made economically viable (project 2.1.03, Development, combination and implementation of innovative system components of process engineering, information technology and sanitary equipment to create a sustainable key technology for closed-loop water systems). "Production integrated measures for environment protection in hotel and catering industry in special consideration of existing built volumes" investigated how the concept described in its title could be implemented (project 2.1.04). "Recycling of Phosphorus – Ecological and Economic Evaluation of Different Processes and Development of a Strategical Recycling Concept for Germany" (PhoBe) is a project funded by the BMBF to see how scarce phosphorus can be efficiently recovered from effluent sludge; the researchers are also determining the production costs of the procedures involved (project 2.1.05). When it comes to connecting new building developments, local areas need to consider whether to expand existing sewer systems. At a new building development in Knittlingen near Pforzheim, a "Decentralised Urban infrastructure System 21" (DEUS 21) was drafted and implemented (project 2.1.08).

Example of Vietnam. The issue of resolving contamination through mineral fertilisers and human excrement is being investigated under a German-Vietnamese project called "Closing Nutrient Cycles in Decentralised Water Treatment Systems in the Mekong-Delta – SANSED" (project 2.1.06).

Example of Turkey. Environmentally friendly waste and wastewater disposal or energy supplies are a rarity among tourist facilities. One solution could be "Integrated modules for high-efficient wastewater treatment, solid waste disposal and regenerative energy production in touristic resorts" (MODULAARE) (project 2.1.07).

Semi-centralised supply and disposal systems – dynamic solutions for China's growing major cities

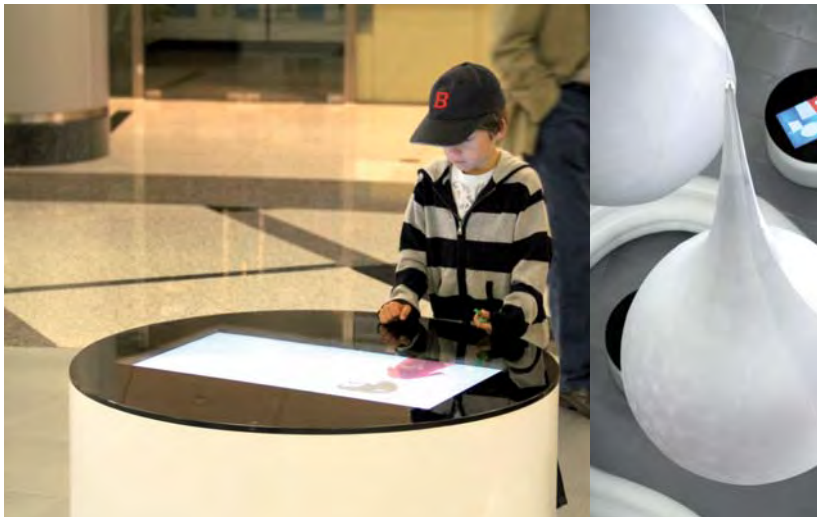
China's cities are growing at a rapid rate: hoards of people are drawn to these overcrowded areas in search of work. The supply and disposal infrastructure is not designed to cope with this, and high pollution levels are the result. "Semi-centralised" concepts for water supplies and the treatment of waste and wastewater in rapidly growing urban areas are one solution to this: they are flexible and can be adapted to the population growth within cities.

With growth rates of up to 1,000 people a day, conventional centralised and above all sectoral-based supply and disposal strategies in urban areas are quickly hitting their limits. This problem is also evident in the People's Republic of China: the rapidly expanding cities have outgrown the water supply, waste and wastewater treatment and spatial planning; the environmental problems are equally acute.

This is the area tackled by the project cluster **"Semizentrale Ver- und Entsorgungssysteme für urbane Räume Chinas"** (semi-centralised supply and disposal systems for urban areas in China), which was led by the IWAR institute at the Technische Universität Darmstadt (Technical University Darmstadt) and ran from 2004 to 2010. "Semi-centralised" is still new in terms of spatial reference planes; it is a structure that extends beyond individual building units and is thus different from conventional centralised solutions. The aim of this: to enable flexible adaptation of supply and disposal units to the dynamic development of major cities, which in China are characterised by rapid growth and quickly changing structures.

An initial subproject in 2004/2005 tackled the structural and legal frameworks; subsequent projects investigated technical aspects in pilot facilities in both Germany and China, conducted public relations (EXPO 2010 in Shanghai) and produced a cost comparison between examples of a conventional and an integrated semi-centralised supply and disposal unit.

The aim of the second phase of the project (which ran from 2005 to 2008) was to develop supply and disposal systems that could actually achieve sustainable use of resources through an extensive water and energy cycle. This required integrated planning for the technical facilities. The project team developed a modular system for supply and disposal (water, wastewater, waste) that is flexible enough to adapt to local conditions and applies both technical and organisational synergies. The wastewater-related research involved investigations into greywater treatment◄ and inner-city water recycling. Various procedures were examined in terms of the achievable drainage qualities, space and energy requirements and more.



"Semizentral" exhibition stand at EXPO 2010 in Shanghai

Integrated approach

Semi-centralised supply and disposal systems provide a consistently high level of quality for water infeed and drainage, a secure way to treat sewage sludge and waste and autonomously produce enough energy to run the systems independently. The concept combines the various technical infrastructure elements for water, wastewater and waste both with each other and within spatial planning. This needs specific legal, socio-cultural, ecological and economic considerations to be taken into account, as well as the administrative and technical structures and resources available locally. In order to promote synergies, it is important to make efficient use of interfaces between spatial and infrastructural planning and also between the individual technical modules. For example, this could be energy recovery through integrated treatment of waste and sewage sludge or reusing inner-city water to flush toilets (integrated infrastructure planning).

Proven technologies

The main aims of combining various modules to form one overall technical system are to achieve a material flow cycle and to reuse nutrients and energy found in wastewater and waste. Proven technology is used in these modules: aerobic and anaerobic wastewater treatment◄, fermentation◄ and mechanical-biological waste treatment◄, energy and material recycling◄ and **water collection and treatment**. Industrial-scale test facilities were also used to examine new technical challenges such as membrane cleaning via ultrasound and industrial greywater treatment using a variety of treatment procedures.

The semi-centralised approach has attracted immense global interest in the meantime; this was reflected at its appearance at EXPO 2010 in Shanghai, where it was presented within the "Urban Planet" pavilion as a forward-looking infrastructure solution for cities of the future.

Project website ► **www.semizentral.de**

Technische Universität Darmstadt
IWAR Institute
Prof. Dr.-Ing. Peter Cornel
Prof. Dr.-Ing. Martin Wagner
Dr.-Ing. Susanne Bieker
Petersenstraße 13
64287 Darmstadt, Germany
Tel.: +49 (0) 61 51/16 27 48
Fax: +49 (0) 61 51/16 37 58
E-mail: v.wawra@iwar.tu-darmstadt.de
Internet: www.iwar.bauing.tu-darmstadt.de
Funding reference: 02WD0398, 02WD0607, 02WD0998

Wastewater as a resource – the promising SANIRESCH demonstration project

Knowledge of new sanitary systems is growing in Germany. However, further research and development is required for all system components before production can begin. The "Sanitary recycling Eschborn" is helping to achieve this: the focus of its work is on how to implement the alternative solution approach and use wastewater in an environmentally compatible manner. A federally owned company is being used for the demonstration, and the initial results of the project are coming in.

The current level of knowledge within Germany about innovative sanitary systems is not yet sufficient to allow large-scale implementation: many of the technologies involved must be developed further (e.g. diversion-flush toilets), and approval is not yet in place for recovered products such as urine and struvite◄ to be used in farming. A research and demonstration project is looking into how this situation could be amended: **"Sanitary recycling Eschborn" (SANIRESCH)** is being run by the Deutschen Gesellschaft für Internationale Zusammenarbeit (GIZ, German association for international co-operation) with scientific support from RWTH Aachen University, the University of Bonn, Gießen university, Huber SE and Roediger Vacuum (period of study: 2009 to 2012).

The GIZ installed a sanitary system for the separate collection of urine, brown water and greywater◄ when it modernised its main building in Eschborn near Frankfurt in 2006. This system includes diversion-flush toilets, waterless urinals, separate piping systems for urine, brown water and greywater and urine storage tanks. SANIRESCH is looking at how to treat and recycle wastewater, examining both staff acceptance of the new sanitary system and also how urine could be used in farming. Economic efficiency and ability to transfer the approach to other countries are additional considerations.

Numerous project modules

The project consists of various components, with the project partners working on these alone or in collaboration.

Sanitary and in-house installations: The GIZ headquarters features 25 waterless urinals (Keramag) and 48 diversion toilets (Roediger Vacuum) to separate the wastewater – the latter are being tested in continuous operation.

Production tests using urine on test fields by the University of Bonn: fertilising (March 2010)

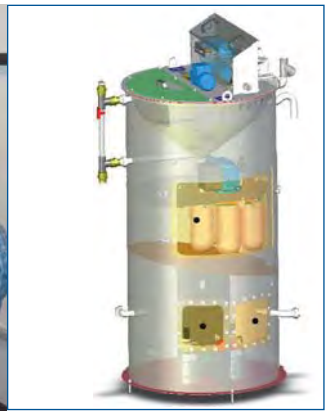
Plant technology: A precipitation reactor is treating the collected urine using a chemical-physical process; magnesium oxide is added to produce solid magnesium ammonium phosphate (MAP), which is a valuable fertiliser for use in agriculture. Brown water treatment◄ takes place in a membrane bioreactor (MBR), once the solids have been removed. The MBR uses ultrafiltration◄ to remove solids and bacteria, as well as almost all viruses. The resultant filtrate is then hygienic enough to use for irrigation. An MBR is also used to treat greywater (water from the kitchen sink/hand-washing), with the resultant process water being used to flush the toilets.

Operation and monitoring: The facilities in question are maintained and optimised on site. Remote technology◄ is used to control and monitor the systems and to analyse the basic parameters of the wastewater.

Quality of the products / Storage of urine: When urine is stored, the pharmaceutical substances can degrade; this degradation is to be quantified. Lab tests are also being used to adapt the storage conditions (e.g. by varying the pH value◄) so that urine storage can be improved in terms of removing harmful substances.

Agricultural production SANIRESCH is conducting fertiliser tests using stored urine and MAP in the open field. The primary focus is the effects on renewable raw materials (miscanthus) and crops. The legal framework conditions for recycling urine in Germany are being clarified and recommendations are being developed for authorities.

Project partners inspecting the MAP reactor



MAP reactor with view of the inside

Acceptance: Studies intend to determine the level of acceptance of urine as a fertiliser among users and cleaning staff at GIZ and also farmers and consumers.

Economic feasibility: One project module is dedicated to determining the costs of investment, operation and reinvestment, and also the amortisation point. The project also seeks to make an economic comparison of this concept with other technical solutions.

International adaptability: The objective is to determine regions particularly suited to the sanitary concept and the technologies used and to identify the ways in which they can be used. The necessary adaptation to be able to implement the technologies successfully in specific cases in emerging and developing countries is also being determined.

Initial project results

The research project was launched in July 2009; the following results relate to the first year of the project.

When it comes to employees, the urinals and toilets are the only visible components of the system. The state of the sanitary facilities is thus crucial to their acceptance. It became evident that the Roediger diversion toilets need to be modified: the valve responsible for diverting the urine has already been improved in order to facilitate installation and improve throughflow.

The urine storage tests showed that the urine contains pharmaceutical residues that even at the end of the six-month storage period were not completely eliminated. Initial measurements showed concentrations of heavy metals to be beneath the limits of the German Drinking Water Ordinance (TrinkwV, 2001); it is therefore assumed that this could be used within agriculture without any issues. Tests on the urine precipitated as MAP indicated that no active pharmaceutical agents were included within the precipitated product. Analysis is still required to determine whether agents are adhering to the surface of the MAP crystals and forming part of an organic matrix.

Regarding the effect of the fertiliser, an ongoing field test is fertilising parcels of land containing wheat and broad beans with urine. These crops have displayed good growth, equivalent from a visual perspective to those on parcels of land receiving mineral fertiliser. Although more detailed results are still pending, it is expected that there will only be slight differences in comparison with mineral fertiliser.

The economic feasibility study analysed the investment and operating costs of the sanitary installations implemented within the building (toilets, urinals, piping systems, urine tanks) compared with the conventional system, which was installed in the wings of the building at the same time. The sanitary installation costs for the SANIRESCH version were EUR 0.088 per use, compared with EUR 0.071 for the conventional version. This difference is due to the considerably higher investment costs.

Project website ▶ **www.saniresch.de**

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Sustainable sanitation – ecosan
Dr.-Ing. Martina Winker (project management)
Postfach 5180
65726 Eschborn, Germany
Tel.: +49 (0) 61 96/79 32 98
Fax: +49 (0) 61 96/79 80 32 98
E-mail: martina.winker@giz.de
Internet: www.giz.de/ecosan
Funding reference: : 02WD0947 to -52

Domestic wastewater in a cycle – the "KOMPLETT" system

The objective of the "Komplett" project was to separate out domestic wastewater for treatment and to reuse virtually all of this resource. The project also intended to develop new sanitary ceramics for WCs that are lighter (and thus save resources during production), reduce water consumption and possess antibacterial properties.

There are still around 1.1 billion people without access to clean drinking water and around 2.5 billion with no sanitation facilities – meaning that a considerable proportion of the global population has either no or insufficient access to basic human needs. According to forecasts produced by UNESCO, between two and seven billion people worldwide – depending on the scenario – will suffer from a lack of water by the middle of the century. Regions particularly affected are those that supply tourists in addition to their native population (at approx. 400 litres per person per day, tourist water consumption is extremely high). The provision of hygienic, problem-free water is also one of the major future tasks faced by states in central and southern Europe. Reusing treated domestic wastewater has the potential to make a vital contribution to this.

A research project funded by the Federal Ministry of Education and Research (BMBF) saw practical tests conducted for a concept involving almost entirely closed water cycles. The project was run by sanitation firm Villeroy & Boch from 2005 to 2009 and was called **"Development, combination and implementation of innovative system components of process engineering, information technology and sanitary equipment to create a sustainable key technology for closed-loop water systems – Komplett project"**. The objective was a system that enables the reuse of all the wastewater produced domestically and also all solids.

The project comprised a preliminary testing, pilot-plant and full pilot phase. Phase one involved tests to characterise the two different wastewaters (greywater and blackwater◄). Lab tests were then performed in order to evaluate and improve individual system components (the biological treatment of wastewater in particular). Initial tests to compost the solids were also conducted, and new sanitation products were developed. The project enabled the development of new sanitary ceramics and lighter sanitary items.

Presenting the KOMPLETT project at the 2008 IFAT environmental trade fair in Munich under the patronage of the German Water Partnership.

Test facility in Kaiserslautern

The pilot-plant phase used a testing facility on a semi-technical scale to treat the two partial flows of greywater (from showers, hand basins, washing machines) and blackwater (from toilets) from a block of flats in Kaiserslautern for ten months. As well as biological treatment stages, the trial tested process stages for additional chemical-physical water treatment and the disinfection and elimination of trace elements◄. Functional tests of the sanitation products, the system's measuring technology and the software for displaying the readings took place at the same time. The project team also tested vermicomposting◄ (which is processed using special worms) of the remaining substances.

Pilot facility in Oberhausen

The final test phase was the operation of pilot-scale treatment facilities on the premises of the Fraunhofer Institute for Environmental, Safety, and Energy Technology (UMSICHT) in Oberhausen – with the wastewater from one of the institute's buildings and the nearby "CentrO" shopping and leisure complex. The systems for sanitation and

Representation of the potential uses of the KOMPLETT research project results, factoring in the remote diagnostics and special ceramics that have been developed.

treatment technology were coupled with those for recycling and visualisation, while the blackwater cycle was fully closed (treated water used to flush toilets and urinals) and the greywater cycle was largely closed (treated greywater used for showers and washing machines). This made it possible to inspect the accumulation of non-degraded substances in both water cycles. The project partners investigated acceptance of the sanitation products and water recycling in order to assess the recycling potential. The concluding tasks were a cost analysis of the Komplett system and a comparison with the costs of conventional technology for water supply and disposal. The results showed that the system can be used economically in areas lacking the infrastructure for supply and disposal and with a high use density, e.g. in hotel complexes. The aims of the project were therefore achieved.

Flushing with just 3.5 litres

The flush-optimised toilets and urinals with photo-catalytic surfaces◄ were pilot tested in Oberhausen. A new, 20% lighter sanitary ceramic was developed during the project; this saves considerable resources during production and also provides an antibacterial surface. The new 3.5-litre WC can flush away faeces and paper without any problems using two litres less water. Compared with a 6-litre WC, it saves 17,000 litres of drinking water a year in a four-person household. However, there is a higher proportion of solids in the blackwater portion of the Komplett system; while this reduces the cost of blackwater treatment, it does require adapted pipes to be installed in the home.

Project website ► **www.komplett-projekt.de**

Villeroy & Boch AG
Environment/Safety/Research – Corporate Coordination
Danuta Krystkiewicz
Postfach 11 20
66688 Mettlach, Germany
Tel.: +49 (0)6 86/4 81 13 32
Fax: +49 (0)6 86/4 81 14 16
E-mail: krystkiewicz.danuta@villeroy-boch.com
Internet: www.villeroy-boch.com

EnviroChemie GmbH
Dr.-Ing. Markus Engelhart
In den Leppsteinswiesen 9
64380 Rossdorf, Germany
Tel.: +49 (0) 61 54/69 98 57
Fax: +49 (0) 61 54/69 98 11
E-mail: markus.engelhart@envirochemie.com
Internet: www.envirochemie.de
Funding reference: 02 WD 0685

Water recycling in hotels – business as usual during conversion work

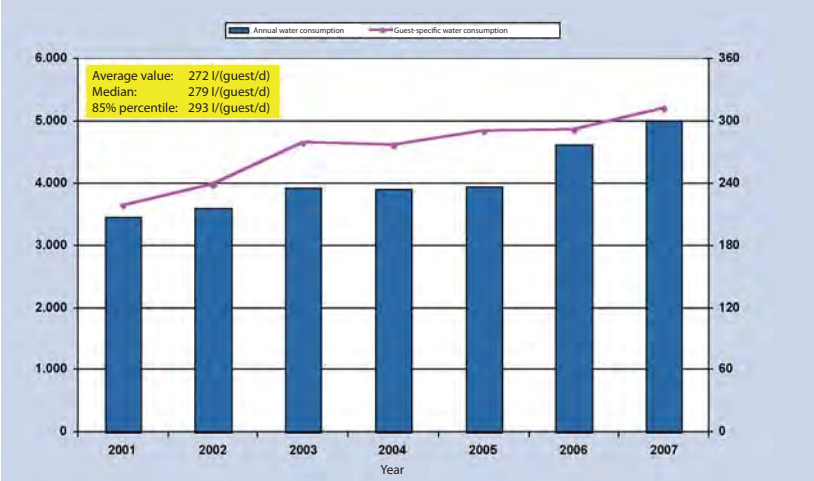
Water consumption per person is much higher in hotels and guest houses than it is in private households: a guest in a German hotel uses around 300 litres of water a day on average – more than twice the amount they would use at home. If the venues also have golf courses and swimming pools, consumption can be as much as 1,000 litres per overnight guest per day. The amount of fresh water used could be reduced significantly if the greywater produced on site were to be treated. One project shows that it is possible to make the necessary conversions without suspending business operations.

"Production integrated measures for environment protection in hotel and catering industry in special consideration of existing built volumes" was a research project run by the Institute for Environmental Engineering (ISA) at RWTH Aachen University from June 2006 to May 2009 that investigated how the concept described in its title could be implemented. The focus was on demonstrating that even standard systems for treating process water can considerably reduce the consumption of drinking water in hotels, and that the conversion work can take place with hotel business running as usual.

The ISA was able to secure the four-star "Hotel Am Kurpark" in Bad Windsheim (Middle Franconia) as a project partner. Founded in 1981, the hotel has 50 guest rooms with 90 beds, a restaurant seating around 100, plus conference rooms and a sauna. The bulk of the accommodation is located in the main building, with 20 guest rooms and the seminar rooms in a separate building (built 1992, extended 1998). The hotel's water consumption increased considerably between 2001 and 2007 (see diagram).

Greywater treatment system

The greywater◄ treatment system was installed by Hans Huber AG (Berching) in November 2008. The structure of the building made installation of the new water pipes unexpectedly difficult as they had to be integrated into the existing pipeline shafts. As hotel business was not to be interrupted, chasing and tiling was restricted to a bare minimum. While the seminar building was connected within the ten-day construction phase, work in the main building's cellar and the connecting shaft between the two buildings was conducted outside of this period. Overall, 460 metres of piping were laid for greywater and process water.



Progression of water consumption in the "Am Kurpark" hotel from 2001 to 2007

Other sources integrated

The low amount of greywater specifically from the guest rooms (shower, bath, hand basin) made it necessary to connect other sources of greywater to the treatment system in order to make it financially viable. The ISA therefore split operation of the system into three phases for evaluation purposes.

During the first phase of operation, a greywater yield of 35 to 130 litres per guest per day was recorded, with the average being 52 litres. When the washing machines were added as an extra source in the second phase, the average guest-specific greywater yield rose to 72 litres per guest per day. The bar and the glass/dishwashers were connected in the third phase of operation, bringing the specific yield to a final average of 82 litres. Including other sources

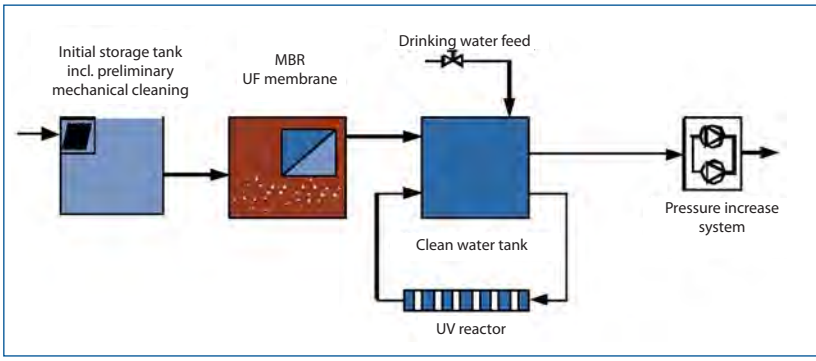


Diagram of the greywater treatment system at the "Am Kurpark" hotel

		Operating phase I Bath/shower, basin		Operating phase II Bath/shower, basin and washing machine		Operating phase III Bath/shower, basin, washing machine and bar	
		Input	Output	Input	Output	Input	Output
CSB	mg/l	98,5	10	133	19	474	11,5
BSB_5	mg/l	47	3	60	5,5	227,5	3
TOC	mg/l	30,7	2,2	42	6,75	98	4,75
NH_4-N	mg/l	3,4	0,1	5,2	0,3	1,4	0,1
N_{ges}	mg/l	3,6	6,24	5,35	3,8	1,2	1,63
PO_4-P	mg/l	0,22	1,3	0,3	0,37	7,5	4,35
P_{ges}	mg/l	0,5	1,4	1	0,63	11,8	8,25
AFS	mg/l	10		15		10	
pH	-	7,8	8,65	7,9	8,14	7,3	8
Colony count 20°C	n/ ml	270000	710[1] 290[2]	k.A.	k.A.	780000	230[1] 18[2]
Colony count 36°C	n/ml	$1,31 \cdot 10^6$	2100[1] 620[2]	k.A.	k.A.	3×10^6	730[1] 90[2]
Coliform germs	n/100 ml	88800	3[1] 0[2]	k.A.	k.A.	130000	165[1] 4,5[2]
E.coli	n/100 ml	1.000	0[1] 0[2]	k.A.	k.A.	1.600	1[1] 0[2]
Enterococci	KBE/100ml	1.220	0[1] 0[2]	k.A.	k.A.	1.410	0[1] 0[2]
GW produced	l/ (guest/d)	52 l/ (guest/d)		72l/ (guest/d)		82 l/ (guest/d)	

1) Permeate before UV disinfection
2) Permeate after UV disinfection

Comparison of the chemical-physical and microbiological properties of greywater and process water for the three phases of operation (averages)

of greywater in the treatment concept (connecting the bar and glass/dishwashers) meant that automated extraction of excess sludge was required.

Connecting extra greywater streams resulted in increased outflow concentrations: operating phase I recorded only three breaches of microbiological limits in the white water, but the microbiological quality of the white water deteriorated when other sources of greywater were connected. For some microbiological parameters, for which the ultrafiltration membrane (ultrafiltration◄) serves as a secure barrier (particularly for E. coli◄), the increased concentrations could only be traced back to recontamination effects within the permeate pipe. Adapting the recirculation rate enabled the required hygienic quality of the white water to be maintained even after tests in operating phase III (the diagram opposite provides a properties summary for the greywater and process water at all three phases).

Greywater becomes process water

The wastewater from the showers and baths is treated to turn it into high-quality process water, which is hygienically harmless and meets the requirements of the German Drinking Water Ordinance. This process water is used to flush toilets, in the prewash cycle of dishwashers and for irrigation and cleaning.

The project has demonstrated that concepts for water recycling can be implemented without affecting the running of the hotel. However, the extra construction effort involved may sometimes be considerable, thus increasing costs. Implementation is more economic in new builds or as part of general sanitation measures.

RWTH Aachen University
Institute for Environmental Engineering
Prof. Johannes Pinnekamp
Mies-van-der-Rohe Straße 1
52074 Aachen, Germany
Tel.: +49 (0)2 41/8 02 52 07
Fax: +49 (0)2 41/8 02 22 85
E-mail: sekretariat@isa.rwth-aachen.de
Internet: www.isa.rwth-aachen.de

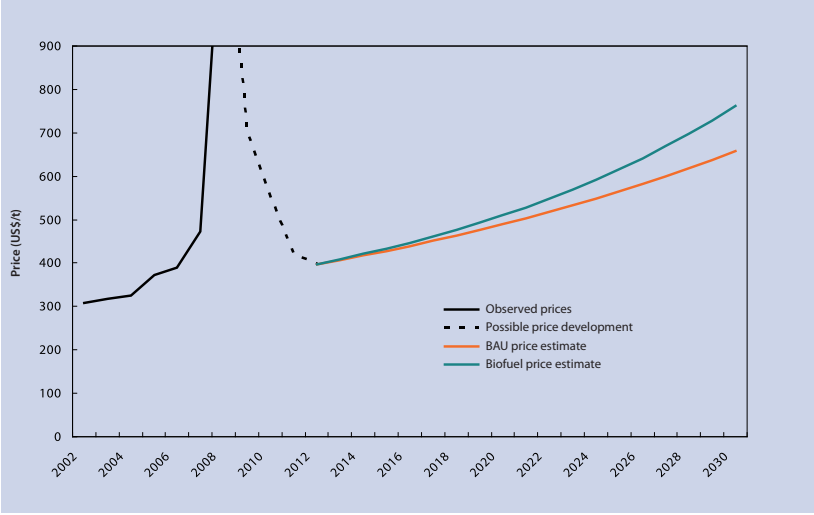
Phosphorous recycling – wastewater and sewage sludge sources of a valuable resource

Phosphorous is essential to all life. It requires a great deal of energy to take mined phosphate ore and produce mineral phosphorus fertiliser. What's more, these ores are finite: current knowledge indicates that the known reserves economically viable for mining will be exhausted in around 100 years. Scientists have therefore been working for some years now on procedures enabling the efficient recovery of phosphorus from wastewater and sewage sludge.

One of these research projects was funded by the Federal Ministry of Education and Research (BMBF). Entitled **"Recycling of Phosphorus – Ecological and Economic Evaluation of Different Processes and Development of a Strategical Recycling Concept for Germany" (PhoBe)**, it involved five institutes from various faculties and was led by the Institute for Environmental Engineering (ISA) at RWTH Aachen University. PhoBe (completion date: end of 2011) was an all-encompassing project summarising the results of the projects funded under the BMBF "Recycling management of plant nutrients, especially phosphorus" initiative and providing global analyses. This funding initiative was launched in 2004 in conjunction with the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

As the price of mineral raw phosphate is a deciding factor in evaluating the economic feasibility of recycling procedures, a medium to long-term assessment (2030) of the global price development was conducted within one of the eight work packages. The relevant phosphate-rich material flows in Germany were also identified and qualitatively measured. The phosphate products obtained from the recovery processes developed as part of the funding initiative were analysed for impurities and evaluated for their effectiveness as a fertiliser compared with conventional phosphate fertilisers (such as triple superphosphate).

In an additional step, the specific production costs of the developed processes were determined using a cost assessment and the processes were balanced in terms of ecological aspects. The step to follow this was to use the results gained to develop a recovery concept for Germany that demonstrates which material flow is appropriate for recycling. Another key focus was to look ahead from a technology perspective, by means of a survey of experts and the identification of future prospects for phosphorus recycling in Germany.



Price development of phosphoric acid

Forecast for price development

A methodical approach was used for the medium and long-term price development of phosphate, beginning by analysing the fundamental data separately – the development of supply and demand – and then merging them for a subsequent price development. Two scenarios were examined, assuming a rise in phosphate consumption (one or two percent a year). The slow increase mirrors the development of recent years (Business as Usual, BAU); the faster increase would be due to increasing cultivation of plants for biofuels.

As phosphoric acid is the base substance in producing phosphate-based fertiliser, the price development of both raw phosphate and phosphoric acid was assessed: the first scenario saw an increase in the price of phosphoric acid to USD 660 a tonne by the year 2030 and the second saw an increase to USD 760 (see graph on the price development of phosphoric acid).

The analysis of the secondary phosphate obtained in the funding initiative showed that all the magnesium ammonium phosphate (MAP) produced was beneath the limits (and almost all products beneath the level for labelling obligation) of the 2008 German Fertiliser Ordinance. The effectiveness of the fertiliser was tested on the first and second crop of maize planted in sandy and clay soil in comparison with triple superphosphate, raw phosphate and a zero control◄. Results so far indicate that the

Magnesium ammonium phosphate (MAP) and sewage sludge ash (small image)

recovered secondary phosphate is in no way significantly different from triple superphosphate and is therefore comparable with conventional fertilisers in this regard.

Secondary phosphate is not yet competitive

The cost assessment of the processes developed during the funding initiative showed that the specific production costs for a kilogram of secondary phosphate are – depending on the technical effort required and the recovery potential of the process – between EUR 2 and 13 per kilogram and are therefore not yet in a position to compete with conventional phosphate fertiliser (approx. EUR 1.50/kg). And yet phosphate recycling is worth it even today: in cases where there is an additional benefit – such as avoiding pipe blockages due to deposited MAP or improving the drainage of sewage sludge.

The material flow balance produced for Germany states that the amount of phosphorous in wastewater and sewage sludge theoretically available for phosphorous recycling is around 70,000 tonnes a year. The contribution from sewage sludge is particularly significant, around a quarter of which is currently disposed of in mono sewage sludge incinerators. The combustion process destroys most of the germs, odorous substances and organic matter, but the phosphorous content is still fully present as a residue in the ashes. Tests have shown that the proportion of phosphorous in sewage sludge ashes is around 6% and thus the highest concentration of phosphorus compared with other sources (sewage plant outflow, sludge liquor, sewage sludge).

Potential of up to 45,000 tonnes

The mono-incineration capacities in Germany are around 520,000 tonnes of sewage sludge a year, with current operation at more than 90%. If all sewage sludge ashes produced from mono incineration were fed into phosphorous recovery, around 13,000 tonnes of phosphorous could be recovered every year. If sewage sludge that does not undergo mono incineration or agricultural recycling were to be included, the major sewage plants (for >100,000 residents) could recover a further 5,000 tonnes. Assuming that agricultural recycling of sewage sludge will be further restricted in future and thus that heat recycling will increase, a scenario has been calculated in which all sewage sludge is burned in mono-incineration facilities and then used for recovery: this would recover around 45,000 tonnes of phosphorous a year, equating to around a 60% substitution of phosphorus fertiliser.

Experts believe that phosphate recycling could be implemented in industrial countries between now and 2030 and be economically viable – this is the result of a survey called “Dringlichkeit der Phosphorrückgewinnung, Erfolgspotenzial der Phosphorrückgewinnung aus Abwasserbehandlung und Klärschlamm, Potenziale der Rückgewinnung aus Klärschlammasche und Phosphatrückgewinnung im Kontext eines Systemwandels in der Wasser- und Abfallwirtschaft” (phosphate recovery as a priority, success potential of phosphorus recovery from wastewater treatment and sewage sludge, potential of recovery from sewage sludge ash and phosphate recovery within the context of change of system to a water and waste economy).

Project website ► **www.phosphorrecycling.eu**

RWTH Aachen University
Institute for Environmental Engineering (ISA)
Univ.-Prof. Dr.-Ing. Johannes Pinnekamp
Mies-van-der-Rohe Straße 1
52074 Aachen, Germany
Tel.: +49 (0)2 41/80-2 52 07
Fax: +49 (0)2 41/80-2 22 85
E-mail: isa@isa.rwth-aachen.de
Internet: www.isa.rwth-aachen.de
Funding reference: 02WA0805 – 02WA0808

Vietnam – clean water for the Mekong Delta

Although Vietnam gets plenty of rain, many regions lack both clean drinking water and water for farming. The Mekong Delta is one such region: a German-Vietnamese project is developing water supply and disposal solutions to suit the conditions found there. This not only involves securing drinking water for the population, but also recovering recyclable products from wastewater treatment for use in agriculture, e.g. compost and biogas.

The Mekong Delta in southern Vietnam is home to around 17 million people, about a fifth of the country's population. Most of them work in agriculture or fish farming. Around half those living in the cities have access to a regulated water supply and disposal facility, as opposed to just 10% in rural areas. As there are only a few sewage plants, most of the wastewater ends up getting into the rivers without being treated, and often fish ponds too in the rural regions.

Increasing water consumption in the Mekong Delta is causing the groundwater level to drop. Seawater is frequently getting into the groundwater in coastal areas, resulting in rising salt concentrations. Farming is the region's greatest consumer of water: farmers use around 90% of the water for growing rice because although the precipitation is plentiful, rice fields still need intensive irrigation.

Obtaining organic fertiliser from sewage water

Farmers use large amounts of expensive mineral fertiliser in order to increase the crops from their rice fields. But there could be cheaper and more environmentally friendly ways to add nutrients to the soil: human excrement, which currently contaminates the water. The German-Vietnamese SANSED project investigated how this could be achieved (full name **"Closing Nutrient Cycles in Decentralised Water Treatment Systems in the Mekong-Delta"**). The universities of Bonn and Bochum, Can Tho university in Vietnam and numerous German companies were involved in the project.

Decentralised systems aim to process drinking water as cost-effectively as possible while simultaneously treating wastewater so that local farmers can make use of the sludge and compost. In an ideal scenario, the 120,000 or so tonnes of nitrate and 19,000 tonnes of phosphorous produced in the Mekong Delta every year could be returned to the nutrient cycles through an environmentally friendly process.

Biogas plant used for agriculture

Seven aspects

Decentralised wastewater disposal and water supply systems that are adapted to local structures and also factor in the low income of the population are especially useful. The second phase set up demonstration systems and operated them together with Vietnamese partners: SANSED wants to demonstrate that the cost of constructing and operating the systems can be refunded through the sale of the products produced (biogas, fertiliser, compost). There were seven sub-projects within SANSED.

Biogas: The country's typical biogas plants, which use bacteria to break down waste, either do not produce enough gas or allow excess amounts to escape unused. The approach followed by SANSED uses fungi to break down degradation-resistant polymers in sugar; this triggers increased activity in the bacteria and thus increases the gas yield. Excess gas can be converted into power or stored in bottles.

Partial wastewater flow treatment: The project team installed toilets that separate the wastewater from the faeces in two university halls of residence to serve as models for wastewater cleaning. The urine and solids were used to obtain fertiliser for farming and biogas. Pathogens and organic contaminants from the urine water◄ were either removed or at least considerably reduced through sun-drying. The earthworms added to the solids converted the substrate into compost (cold rotting).

Drinking water supply system

Wastewater sieving/soil filtration: At one of the halls of residence, fine sieves filter out solids from the wastewater. The water is then cleaned further through soil filters, and the solids are composted.

Drinking water from surface water: One system treated surface water polluted with organic substances and micro-organisms – using slow sand filters and sunlight (UV disinfection) among other things – to supply water to one of the halls of residence.

Drinking water from groundwater: The scientists optimised the drinking water supply for around 100 households: quick sand filters treated the heavily ferrous groundwater.

Natural fertilisation used in farming

Further training: Many districts in Can Tho have a central supply of drinking water that could be described as process water at best. There is also a system that involves filling containers with drinking water. The project team devised a special information and training programme for the staff at the Can Tho Water Supply and Sewerage Company.

Handling recommendations: The team collaborated with the local supply company to create a sample feasibility study using a district of Can Tho that previously had no regulated water supply or disposal: the study shows where it would be useful to implement (de)centralised systems.

Verifying transferability

The SANSED project is to be used as a basis to verify whether decentralised wastewater treatment and water supply systems could be used in other regions with poor infrastructure.

The SANSED final report appeared in volume 31 of the "Bonner Agrikulturchemische Reihe" (Bonn agriculture-chemical series, ordered and purchased via www.ipe.uni-bonn.de/publikationen).

Further information can be found on the project website.
Project website ▶ **www.sansed.uni-bonn.de**

University of Bonn
INRES-Pflanzerernährung
Dr. Ute Arnold
Karlrobert Kreiten Straße 13
53115 Bonn, Germany
Tel +49 (0)2 28/73 36 39
Fax +49 (0)2 28/73 24 89
Internet: www.ipe.uni-bonn.de
Funding reference: 02WD0620

Clean and effective – decentralised disposal systems for hotel complexes

Many tourist resorts in southern countries do not have any environmentally friendly means of waste and wastewater disposal or energy supply. The MODULAARE research and demonstration project used a Turkish hotel complex to test a sustainable solution to these problems: the procedure developed combines the fermentation of organic waste with membrane technology for wastewater cleaning. The resulting products: process water, fertiliser and biogas.

Tourist resorts cannot enjoy stable economic development if their environment is not intact. Heavily visited regions, rapidly growing new resorts and ecologically sensitive areas in particular need to orient their tourism toward the guiding principle of sustainability – and ensure that their energy and water supplies and waste and wastewater disposal facilities are environmentally compatible.

Spot checks have determined a daily water consumption of up to 1,200 litres per guest in international holiday hotels (including apportioned consumption for green facilities and swimming pools). By way of comparison: households in Germany currently consume about a tenth of this, an average of 123 litres per resident per day. Wastewater often flows – poorly cleaned – into rivers or directly into the sea because sewage facilities in the hotel complexes are either poorly maintained or lacking altogether; it is often not possible to be connected to the central wastewater disposal system as tourism resorts are often outside built-up areas. Waste disposal causes just as many problems: large hotels produce up to 2.5 kilograms per guest every day, which is often disposed of at unauthorised dumps.

Integrated concept for tourism regions

One answer to these problems, particularly in ecologically sensitive regions, are **"Integrated modules for high-efficient wastewater treatment, solid waste disposal and regenerative energy production in touristic resorts" (MODULAARE).** This is the title of the project combining membrane technology◄ in wastewater treatment and anaerobic◄ fermentation in the treatment of bio-waste to enable targeted nutrient flow management for wastewater and organic waste. This results in a virtually closed nutrient cycle in an almost wastewater-free hotel – and also produces valuable by-products such as process water, fertiliser and energy.

The "Sarigerme Park" hotel complex in Turkey

To put this procedure to the test in a practical setting, the international project team set up a test facility at the "Hotel Sarigerme Park" on the Turkish Aegean coast in 2005. Concluded in 2008, the project was managed by the Verband zur Förderung angepasster, sozial- und umweltverträglicher Technologien e.V. (AT-Verband, association for the promotion of adapted, social and environmentally compatible technologies, Stuttgart); the Institute for Sanitary Engineering, Water Quality and Solid Waste Management at the University of Stuttgart was in charge of scientific management, MEMOS Membranes Modules Systems (Pfullingen) produced the membrane technology and Bio-System Selecta GmbH (Konstanz) produced the anaerobic system. The administrative authorities for the island of Mainau on Lake Constance supplied basic data and supported the project's public relations.

Membranes cleaning the wastewater

The procedure used recovers biomasses from the wastewater via membranes – not through final clarification◄ (sedimentation) as usual. Membranes not only remove all solids, but also large amounts of germs and viruses. The membrane bioreactor upstream is a mechanical cleaning process that removes the solids. The membrane filtration enables increased concentrations of biomasses (experts refer to a higher space-time yield): bio-membrane reactors◄ operate with biomass contents of 10 to 15 grams per litre. This value is about three times higher than conventional activated sludge reactors◄ (approx. 4 g/l) because the biomass concentration in the activation no longer depends on the sedimentation behaviour in the secondary settler. The MODULAARE process provides further treatment of excess sludge◄ together with kitchen and garden waste in the fermentation module.

A MODULAARE biogas module

MODULAARE membrane module

The membrane system offers a number of technical ways to eliminate nutrients. Carbon, nitrogen and/or phosphorus can also be reused to some extent – depending on the intended use of the cleaned wastewater. Phosphorus can be used within garden irrigation as a fertiliser; the process can also provide soil protection, especially in areas with a negative humus balance like the Mediterranean area. The modular nature of the system allows it to adapt to seasonal fluctuations in guest numbers, be it through a different solids content or activated/deactivated membrane modules.

Biogas covers energy requirements

Hotel waste can consist of more than 70% organic material. Due to the nature of the waste, only around a third of it can be treated aerobically◄ (compost) without major technical efforts. The high water content and the structure of the material means there can be sufficient anaerobic◄ areas to result in considerable odour; compost can also easily dry out in Mediterranean and arid zones due to the high air temperatures. Fermentation◄ on the other hand can treat up to 90% of the organic waste, and the fermentation residue can be used in agriculture.

The MODULAARE project has developed a practicable concept that permits optimum use of biogas: used either to provide heat or – converted into electricity – to cover the high amounts of energy required by the membrane bioreactor. Any wastewater (e.g. from drainage) is fed directly back into the membrane bioreactor.

Project website ► **www.modulaare.de**

Verband zur Förderung angepasster, sozial- und umweltverträglicher Technologien e.V. (AT-Verband)
Dr. Udo Theilen (Co-ordinator)
Dieter Steinbach, Andrea Schultheis (MODULAARE overall concept)
Waldburgstraße 96
70563 Stuttgart, Germany
Tel.: +49 (0)7 11/7 35 52 79
Fax: +49 (0)7 11/7 35 52 80
E-mail: atverband@aol.com
Internet: www.at-verband.de
Funding reference: 02WD0440

University of Stuttgart
Institute for Sanitary Engineering, Water Quality and Solid Waste Management
Departments of Wastewater Technology and Siedlungsabfall (municipal waste)
Prof. Dr.-Ing. Martin Kranert
(scientific management)
Bandtäle 2
70569 Stuttgart, Germany
Tel.: +49 (0)7 11/68 56 55 00
Fax: +49 (0)7 11/68 56 54 60
E-mail: martin.kranert@iswa.uni-stuttgart.de
Internet: www.iswa.uni-stuttgart.de
Funding reference: 02WD0441

Semi-decentralised concept for a new building development – the Knittlingen "water house"

When it comes to connecting new building developments to the water supply and disposal system, local authorities are faced with a choice: should the existing sewer system be expanded, or should a decentralised solution be implemented? The Fraunhofer Institute for Interfacial Engineering and Biotechnology used a model project in Knittlingen near Pforzheim to demonstrate the benefits of a semi-decentralised concept: as this method uses rainwater, it reduces the level of fresh water consumption. It also produces fertiliser for farmers and its operation is energy-neutral.

Industrial nations generally apply a combined-system principle to wastewater disposal: rainwater is used to dilute the wastewater before it enters the central sewage plant. This process is counter-productive as the sewage plant has the laborious task of extracting the contents from the water. A practical alternative from both an economic and ecological perspective could be to use cycle-oriented, semi-decentralised systems for water supply and wastewater disposal – in emerging and developing countries too.

The Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB) implemented such a concept as part of the **"DEcentralised Urban infrastructure System 21" (DEUS 21)** project in 2005, selecting a new business development with 100 buildings in Knittlingen near Pforzheim. The Fraunhofer Institute for Systems and Innovation Research (ISI) is working alongside the project to compare the ecological and economic aspects of the system with those of conventional processes.

Treated rainwater

At the heart of the system is the "water house", located at the edge of the DEUS 21 residential area. It serves as both the technical operations building and an information centre for residents and visitors. The rainwater flowing off the roofs and streets is stored in underground cisterns and treated in the water house. The aim is to treat the rainwater to render it potable and then use a separate network to channel it into homes so it can be used for flushing toilets, watering gardens, operating washing machines and dishwashers and also for washing and showering. The first step is to examine the treated rainwater over an extended period; the residents receive a second source of drinking water from the Knittlingen authorities during this test phase.

The water house in Knittlingen

A vacuum sewage system sucks the domestic wastewater from transfer chutes in front of the houses; it is then treated in the water house in an anaerobic◄ cleaning reactor with built-in membrane technology◄. The central vacuum station, commissioned in 2005, produces the vacuum required for this process. The builders can also lay a vacuum pipe in the home, enabling installation of a water-saving vacuum toilet and a shredder for kitchen waste.

Solids separated

Preliminary tests have shown that wastewater cleaning is more effective if the solids are separated beforehand. The output solids are therefore treated separately at 37°C using the high-load digestion◄ process developed by the Fraunhofer IGB with integrated microfiltration◄. Fermentation of the solids produces up to 5,000 litres of biogas every day. The hydraulic retention time in the reactor is approx. ten days; the solids retention time is freely adjustable to a certain extent but is considerably higher. An unheated, fully mixed bioreactor◄ with a volume of ten cubic metres is used to treat the overflow from the sedimentation tank (approx. 99% of the inflow); the outflow is handled by four parallel rotating disc filters (pore diameter of 0.2 µm).

The anaerobic sewage plant offers reliable functionality even at low temperatures: at reactor temperatures as low as 13°C the outflow values register less than 150 milligrams of the chemical oxygen demand (COD◄) per litre (limit value for sewage plants serving less than 1,000 residents). The inflow concentrations are between 400 and

A vacuum station (left) and bioreactors in the water house

1,100 milligrams COD per litre, with the average level of degradation at 85%. The maximum biogas production in the reactor for cleaning the primary treatment overflow is around 3,000 litres a day. The increase in biomass produces around 10% of the expected amount of excess sludge◄ from the activated sludge procedure◄. Since its commissioning in March 2009, the membrane filtration has been cleaned through automatic filtrate backwashing, with the first chemical clean taking place in April 2010.

Agricultural benefits

The water flowing out of the plant was suitable for irrigating and fertilising farmland. The bioreactor breaks down virtually no ammonium or phosphate, both of which occur in relatively high concentrations in the wastewater. The membrane filtration removes the bulk of germs from the water, so it is therefore safe to use as fertiliser. Spot checks in the outflow from the rotating disc filters used in the membrane filtration revealed no traces of Escherichia coli◄ bacteria, although it was present in the reactor sludge at a level of one million per millilitre.

If this cannot be used as fertiliser, one alternative is to recover the ammonium and phosphate: an electrochemical process precipitates the nutrients as struvite◄ (MAP, magnesium ammonium phosphate). Excess ammonium is bound to zeolite by means of an ion exchange process and recovered as ammonium sulphate through air stripping.

Energy-neutral operation

The fully anaerobic process technology is able to convert most of the organic materials from the wastewater into biogas: a daily yield of 40 to 60 litres per resident – as opposed to just 25 litres from conventional wastewater cleaning through sludge digestion. The energy in the biogas produced through anaerobic wastewater cleaning is over 100 kilowatt hours per resident each year. Large sewage plants consume around 30 kilowatt hours of electrical energy per resident per year (and around 30 kWh thermal energy): in comparison, anaerobic conditions enable energy-neutral wastewater cleaning at the very least.

Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB)
Prof. Dr. Walter Trösch
Dipl.-Ing. Marius Mohr
Nobelstraße 12
70569 Stuttgart, Germany
Tel.: +49 (0)7 11/9 70-42 20
Fax: +49 (0)7 11/9 70-42 00
E-mail: walter.troesch@igb.fraunhofer.de
marius.mohr@igb.fraunhofer.de
Internet: www.igb.fraunhofer.de
Funding reference: 02WD0457

Proven methods and high-tech analysis – management concepts to enhance health and hygiene

Around two million people worldwide die from a lack of drinking water or contaminated drinking water. Water, especially clean water, is a precious commodity – one that is however scarce in many regions of the world. There is an urgent need for new and efficient processes and management concepts to find ways to provide as many people as possible with a day-to-day supply of clean water. The aim is to achieve a high level of efficiency throughout the entire use cycle – from obtaining water through to cleaning wastewater.

The health of the global population is directly linked to the quality and quantity of fresh water available for use. According to data from the World Health Organization (WHO), the most important factor in world health is preventing the transferable pathogens (bacteria, viruses and parasites) present in contaminated drinking water. Unhygienic conditions, a lack of sanitation and poor-quality drinking water are the main reasons why a child under 5 dies every 3 seconds in developing and emerging countries.

In addition to mass contamination, the situation is also deteriorating in many developing countries due to a drastically worsening water shortage. Compared with developing and emerging countries, Germany and the other industrialised nations are mainly at risk through a multitude of new chemical substances and also pathogens that primarily spread via the waterways.

Germany's largest ultrafiltration facility

One of the world's largest ultrafiltration membrane facilities was commissioned in the Eifel region in 2005. Every hour, 7,000 cubic metres of water flow through the facility from the dam, and can then be used as drinking water. Dissolved substances, particles and micro-organisms are filtered out by the ultra-fine membrane pores within the facility. The BMBF funded extensive pilot tests as part of the research project on high-performance membrane technology before the facility was put into operation. The high-performance membranes tested in the Eifel regions met expectations in full: even when the water was extremely contaminated (e.g. after heavy rain), they eliminated almost 100% of the parasites and viruses present. The costs for materials and debt service including new buildings came to less than ten cents per cubic metre of drinking water (project 2.2.01).

AQUASens – a fast and mobile method for detecting water impurities

Even today, methods for detecting microbial contamination in water samples are incredibly laborious – and often take longer than a week. Within an interdisciplinary BMBF – research project involving scientific institutions and companies, a semi-automatic analysis device was developed that can detect both small molecules (such as hormones, antibiotics and pesticides) and much larger bacteria: by means of an immunological test that uses a tiny water sample and is complete within hours. This enables those responsible to obtain fast, reliable information on the degree of water contamination and the potential threats (project 2.2.02).

Pathogens in taps

Even top-quality drinking water can still be contaminated in the last few metres before it emerges from the tap: poor-quality seals and hoses are a bacterial paradise. Those working on the BMBF project researching biofilms in the home took 20,000 measurements over the course of four years to test the level of hygiene in hot water systems. The results showed that legionella was present in over 13% of these hot water systems (project 2.2.03).

Current aspects of swimming pool hygiene

When treating swimming pool water, chlorine must be used as a disinfectant (also see DIN 19643). However, the reactions of chlorine with substances that get into the pool either via the water or the pool users produce unwanted disinfection by-products. It is suspected that these by-products pose a risk to health. The aim of the project entitled "Gesundheitsbezogene Optimierung der Aufbereitung von Schwimm- und Badebeckenwasser" (optimizing the treatment of pool water with regard to health) is to investigate the effects of these by-products – particularly on those with respiratory or other chronic illnesses (project 2.2.04).

Dams as a source of drinking water – the benefits of the membrane procedure

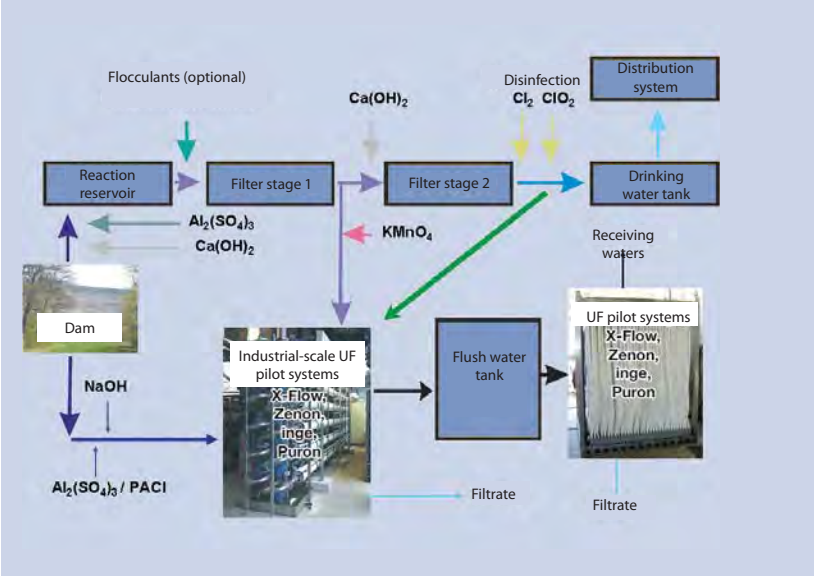
Pressure-driven membrane procedures◄ are gaining importance in the field of treating water. After several years of pilot testing, one of the world's largest ultrafiltration membrane facilities was commissioned in 2005 in the North Eifel region to turn the water from dams into drinking water. The expectations of this facility have been met in full. The preliminary tests were financed by the Federal Ministry of Education and Research.

The hygienic requirements of treating surface water for use as drinking water have increased considerably over the last few years. Membrane procedures are a solution with a great deal of development potential in order to meet these requirements: they can filter out dissolved substances and also serve as a barrier for particles and microorganisms. The universal application potential in removing salt from seawater, treating wastewater and producing process and drinking water provides the backing for the growth potential of pressure-driven micro◄, ultra◄ and nanofiltration◄ membrane procedures and also reverse osmosis◄.

The potential fields of application for the membrane filtration procedure depend on the impurities to be removed from the untreated water◄. Reverse osmosis for desalination has long been the technology of choice for treating brackish water and seawater for use as drinking water. The main methods used for processing untreated water inland are the ultra and microfiltration low-pressure membrane procedures◄ as well as nanofiltration. Wide-scale elimination of parasites and viruses has recently become a core interest. Both micro and ultrafiltration are used to remove most of these particles dissolved in the water (with microfiltration removing virtually all parasites, but ultrafiltration possibly not removing all the viruses). Processes using denser membranes are required to remove inorganic dissolved matter, e.g. nanofiltration or reverse osmosis.

Good combination potential

The success of the membrane procedure is in the way it can be combined with conventional water treatment procedures and techniques (e.g. flocculation◄). Other benefits are the greatly reduced price of membranes and the considerable reduction in energy requirements through low-pressure membranes and intelligent energy recovery.



Treatment schematic for the Roetgen water plant and integration of the pilot facilities

Wassergewinnungs- und -aufbereitungsgesellschaft Nordeifel (WAG) has been operating a membrane facility in Roetgen since the end of 2005, treating water obtained from dams for use as drinking water. The facility supplies around 500,000 people in the Aachen region with drinking water. With a capacity of up to 7,000 cubic metres an hour, the facility is one of the world's top-performing ultrafiltration membrane facilities producing drinking water from dam water. Even when the dam water is heavily contaminated (e.g. after heavy rain), it eliminates almost 100% of the parasites and viruses present.

Several years of preliminary testing

Before the facility was commissioned, WAG and the IWW Water Centre (Rheinisch-Westfälisches Institut für Wasserforschung) spent four years working together with the chair for water technology at the University of Duisburg-Essen carrying out tests: they used multiple test facilities with capacities of around ten cubic metres an hour and a pilot facility with a much higher treatment output (approx. 150 m^3/h). At the same time, pilot tests were performed using an immersed suction membrane to produce drinking water and to treat the flushing water for the membrane facility. The BMBF funded these tests as part of the research project entitled **"Hochleistungs-Membran-**

Ultrafiltration units for treating drinking water (stage 1)

Ultrafiltration unit for treating the flush water (stage 2)

technologie" (high-performance membrane technology). Wetzel + Partner Ingenieurgesellschaft mbH (Moers) was able to use the results of these tests to plan the industrial-scale facility in Roetgen, with scientific support from the IWW.

The facility in Roetgen combines flocculation and direct ultrafiltration. This reduces the amount of sedimentation on the filter membrane and thus the associated, irreversible drop in efficiency. The flakes collect on the surface of the membrane and stabilise filtration operation. Optimised membrane backwashing then enables the impurities to be removed from the surface of the membrane together with the flakes. Another feature of the facility is that the sludgy backwash from the membrane facility is treated during a second membrane stage. The resultant permeate – water cleaned through particulate filtration – is then mixed with the untreated water in the first stage. This increases the yield of the overall process to over 99%. The second stage has a treatment capacity of 630 cubic metres an hour, meaning it is also one of the world's largest facilities of its type.

Expectations met in full

The stable operation and outstanding quality of the water produced meet all expectations. The costs for material use and debt service (including the new buildings) amount to less than EUR 0.10 per cubic metre of drinking water.

IWW Rheinisch-Westfälisches Institut für Wasserforschung gGmbH
Prof. Dr.-Ing. Rolf Gimbel
Moritzstraße 26
45476 Mülheim an der Ruhr, Germany
Tel.: +49 (0)2 08/4 03 03-3 00
Fax: +49 (0)2 08/4 03 03-83
E-mail: r.gimbel@iww-online.de
Internet: www.iww-online.de
Funding reference: 02WT0658

WAG Wassergewinnungs- und -aufbereitungsgesellschaft Nordeifel mbH
Dipl.-Ing. W. Dautzenberg
Filterwerk
52159 Roetgen, Germany
Tel.: +49 (0) 24 71/1 30-0
Fax: +49 (0) 24 71/1 30-12 05
E-mail: walter.dautzenberg@enwor-vorort.de
Internet: www.enwor-vorort.de
Funding reference: 02WT0660

AQUASens analysis system – a fast and mobile method for detecting water impurities

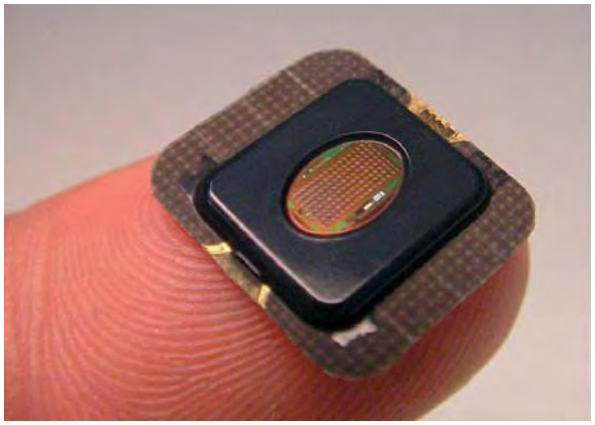
Microbiological tests of water samples have always taken a lot of time and effort. A new analysis system, the development of which was funded by the Federal Ministry of Education and Research, could provide a solution: it is fast, mobile and accurate – and good value to boot. There are many different ways this system could be used by industries and local authorities.

Before now, tracking water impurities through micro-organisms has required a specialised lab, where germs have had to be multiplied on a culture medium. While coliform (faecal) germs can be detected within a single day – as there are proven procedures in place – tests for most other bacteria still require a great deal more work and often take more than a week. However, if the water is potentially contaminated with microbes, those in charge need fast, reliable information on the degree of contamination and the potential threats.

Combined expertise

The Federal Ministry of Education and Research funded a project in order to provide a solution: "AquaSENS – Detection of micro-organisms in water with CMOS-based sensors". Companies and science institutes combined their expertise to develop a mobile analysis system that can quickly detect micro-organisms and germs in water – without the need for timely and costly cultivations in a lab. The parties involved in the project were Siemens AG, inge watertechnologies AG, Friz Biochem Gesellschaft für Bioanalytik mbH, the Institute of Hydrochemistry (IWC) at TU Munich, the IWW Water Centre (Rheinisch-Westfälisches Institut für Wasserforschung) and the Water Technology Centre Karlsruhe (TZW). Tasks within the project:

- Set up a compact, fully automated membrane filtration system for concentrating germs (from 10 litres of water into an eluate volume of 50 millilitres).
- Develop two sample preparation procedures on the basis of immunomagnetic separation and affinity chromatography for further concentration and transfer of germs in a 1 millilitre measurement buffer.
- Develop digital read-out biochips with built-in detection and analysis electronics.
- Develop and produce the compact and user-friendly read-out device for the biochips.



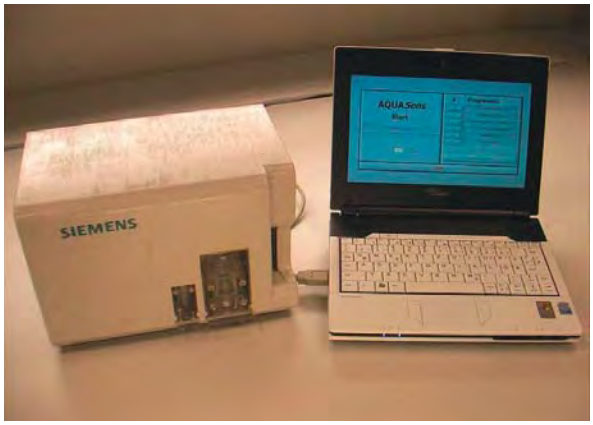
Small biochip, big performance: a sensor quickly detects micro-organisms in the drinking water.

- Identify biochemical detection molecules (antibodies) and DNA segments specific to the micro-organisms sought, and develop detection procedures (assays) for transfer to the biochips.

The AquaSENS project was able to complete all tasks set successfully: the semi-automatic device designed detected both small molecules (such as hormones, antibiotics and pesticides) and much larger bacteria: by means of an immunological test using a tiny water sample. This detection is based on the concept of the immune system: the ability of antibodies to identify foreign substances from characteristic constituents – antigens.

Biochips developed

This approach uses a biochip with a fully integrated CMOS (Complementary Metal Oxide Semiconductor). The small biochemical sensor and the associated read-out electronics are ideal for use in portable, compact and economical analysis systems. They are particularly advantageous for situations involving many different germs in a single measurement process alongside antibody-antigen interactions or the detection of specific DNA segments. The biochip and biochemical detection procedures have been developed for both of these principles.



The mobile reader provides a read-out for water impurity results

Because harmful germs such as legionella, salmonella and coli bacteria are usually only present in water in low concentrations and the biochips use just tiny samples of 100 microlitres, it is necessary to augment the germs being sought first. The project partners established the system required to do this by coupling a membrane filtration system with an "immunomagnetic separation column◄".

The result: coli bacteria could be detected within just 90 minutes. The biochip detection limit for E.coli bacteria was determined at 2,000 germs per millilitre of sample concentrate, with a measuring time of 30 minutes. The analysis system can therefore detect bacteria within two hours.

Multiple uses available

As well as being used for the quality assurance of drinking water supplies, the analysis system could also be extremely useful for samples of process water, ultra-pure water, groundwater and surface water; tests are still underway to determine whether and how this is possible.

AQUASens could be used in public buildings and hospitals to test the process water in the sewage system or to test for harmful substances in the hot water system. The new analysis system would also be useful in the food and pharmaceutical industries, which require ultra-pure water for production.

It may even be suitable for measuring sewage sludge or for process monitoring in biotechnological fermenters◄. First the relevant micro-organisms would be determined, then the corresponding assays developed. The crucial thing here is to identify and produce suitable antibodies first, as they are not currently available for all use cases.

Siemens AG
Corporate Technology
Dr. Daniel Sickert
Otto-Hahn-Ring 6
81739 Munich, Germany
Tel.: +49 (0) 89/63 64 50 89
Fax: +49 (0) 89/63 64 85 55
E-mail: daniel.sickert@siemens.com
Internet: www.siemens.com
Funding reference: 02WU0862 – 0867

Pathogens in taps – an underestimated problem

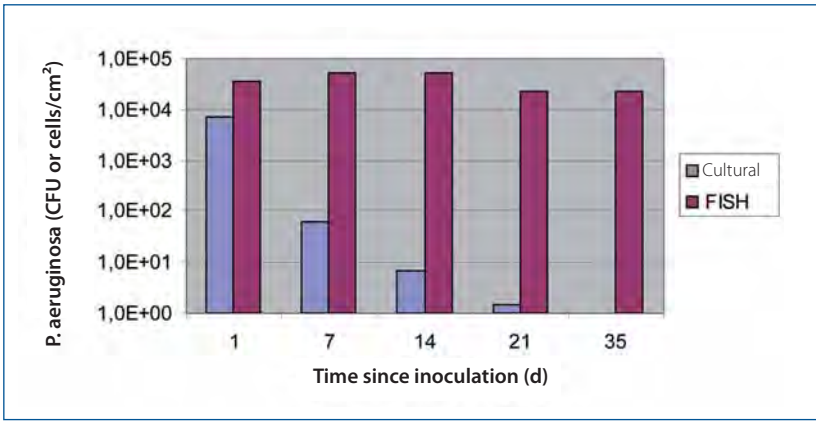
Even top-quality drinking water can still be contaminated in the last few metres before it emerges from the tap: poor-quality seals and hoses are a bacterial paradise – this can have serious consequences for people with a weakened immune system under certain circumstances. A new research project is currently investigating how to improve the hygienic safety of drinking water installations.

How does drinking water get to the consumer? It travels a long way to get there, from the waterworks through the pipelines and into the home, strictly monitored and kept at peak quality – until it reaches the water meter. "This is when it hits a grey area: the home installation. A highly visible variety of materials undergoing little control can be used here, some of which represent a paradise for micro-organisms", says Professor Hans-Curt Flemming of the University of Duisburg-Essen. Drinking water is not sterile and indeed should not be – it still contains bacteria that survive even with a lack of nutrients and are completely harmless. The key to success in waterworks is extracting the nutrient base for the bacteria. This produces "stable drinking water". "When these ravenous germs come across materials that provide them with food, then it's like paradise to them. They don't need much to thrive – small amounts of exuded softener, colouring, antioxidant and other products added to plastics are perfectly sufficient. They establish themselves there and form thick biofilms◄ in which pathogens can settle, grow, then be flushed out to contaminate the water", continues Flemming.

Then even the best water loses its level of quality, all in the last few metres on the way to the tap. What circumstances cause this? Are there any epidemics? What level of monitoring is there? Which materials are authorised? How can problems be avoided?

Hot water systems tested

These questions were the main focuses of the large-scale study funded by the BMBF called **"Biofilme in der Hausinstallation"** (biofilms in home installations), which ran from October 2006 to March 2010. Five research facilities and 17 industrial partners spent four years examining these questions under the co-ordination of Professor Hans-Curt Flemming (University of Duisburg-Essen and IWW Mülheim). The results were certainly worth attention: "The statistical analysis of more than 20,000 measurements taken by health authorities showed that

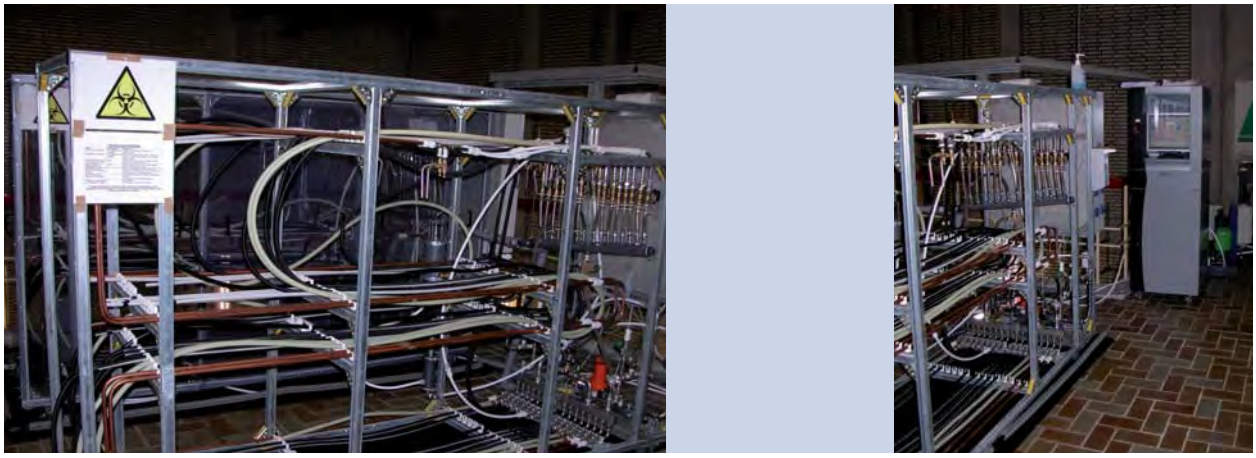


Evidence of Pseudomonas aeruginosa through cultivation (left column, blue) vs. fluorescence in-situ hybridisation (FISH) (right column, purple)

legionella was present in over 13% of the hot water systems tested", said Professor Thomas Kistemann from the Institute for Hygiene at the University of Bonn, one of the researchers involved. One particularly unpleasant pathogen is Pseudomonas aeruginosa, which causes inflammation of the lungs, urinary tract infections and also especially persistent infections of burns. This was found in 3% of the tests performed. Kistemann goes on: "Since monitoring was made mandatory four years ago, only half the public buildings and hotels affected have been tested. That is not to say that the authorities have not been active, simply that they are overwhelmed and understaffed. And who is responsible for water quality in multiple dwellings? Experience shows that anyone taking on this task quickly becomes unpopular."

Shower hoses – a bacterial paradise

The scientists were able to use true-to-life model systems to demonstrate that shower hoses and also relatively small seals become a paradise for bacteria when they contain materials that support germ growth. Biofilms could be spotted on some of them after one or two weeks – even with the naked eye. The usual suspects in such cases are plastics that no test has approved for use with drinking water. Low-cost taps often contain additives for biological use such as softener or remains of release agents, or become contaminated with substances during production and installation. An unfavourable combination of poor material quality (e.g. low-cost taps) and water quality encourages strong biofilm development – and thus provides a living environment for pathogens. "That does not necessarily mean that epidemics are going to break out,



Computer-controlled, semi-technical home installation for long-term testing with true-to-life consumption profiles

but illness could occur and lead to time off work and a temporary loss of quality of life", says Professor Kistemann. "When the immune system is weakened, e.g. after an operation, critical situations can arise", says Professor Martin Exner from the University of Bonn.

So what can be done? Firstly, it was demonstrated in the research project that the current monitoring methods need to be expanded on considerably in problem cases. It has been shown that the pathogens being sought can go into a sort of coma, which causes them to disappear from the radar of standard methods. However, they wake up as soon as their living conditions improve and can be just as infectious as they were before. Practical problem cases were able to demonstrate the benefits of new molecular biology methods for identifying the causes of persistent bacterial contaminations and eliminating them.

Greater attention towards home installations

One conclusion from this successful research project is to dedicate more attention to home installations, as this is where even the best water can lose its quality. "We have drawn up important notes on methods to prevent this", concludes Hans-Curt Flemming. However, it was clear that there is still a great need for research and regulation – not only for materials but also for the testing procedures. The last few metres before the tap are crucial, and yet amazingly underexposed.

As a result of the findings from this project, the consortium has drawn up a research proposal that addresses the problems in detail. It particularly focuses on the temporary disappearance of pathogenic germs from the monitoring radar and their sudden recurrence, the conditions under which this occurs and how the hygienic safety of drinking water installations can be ensured. The proposal was successful and will receive over EUR two million total funding from September 2010 to August 2013.

University of Duisburg-Essen
Essen Campus – Biofilm Centre
Prof. Dr. Hans-Curt Flemming
Universitätsstrasse 5
47141 Essen, Germany
Tel.: +49 (0)2 01/83-66 011
Fax: +49 (0)2 01/183-66 03
E-mail: hc.flemming@uni-due.de
Internet: www.uni-due.de/biofilm-centre/
Funding reference: 02WT1153-1157

Swimming pools – health risks posed by pool disinfection

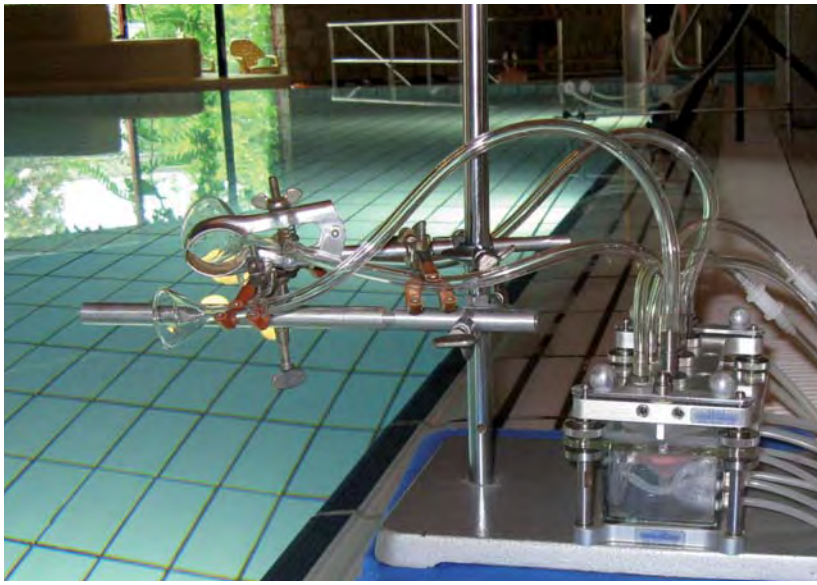
"Swimming is good for you": this is a commonly used phrase in health care. But does this also unequivocally apply to swimming in pools containing water disinfected with chlorine? Once water has been disinfected with chlorine, disinfection by-products can form – and these can pose a risk to human health. There are still many questions requiring greater scientific clarification regarding the risk posed to children and those suffering from chronic illnesses. A new research project is seeking answers to these questions.

When treating swimming pool water, chlorine must be used as a disinfectant (also see DIN 19643). However, the reactions of chlorine with substances that get into the pool either via the water or the pool users produce unwanted disinfection by-products. It is suspected that these by-products pose a risk to health. This is by no means a new problem, but the effects of pool water on hygiene have recently become the focus of scientific interest.

The results of studies conducted thus far connect respiratory and other chronic illnesses with swimming in chlorinated water. Particularly given the general acceptance of swimming from childhood ("swimming is good for you"), the issue is a hot topic for health policy. The public can often gain the impression that the risks of swimming in chlorinated water outweigh the health benefits. This is a task for health-related environmental research: it must provide reliable data that enables a scientific risk assessment in terms of prevention.

Instigating international momentum

Germany has a leading international role in pool water hygiene. The research work undertaken contributes towards sustainable health care and has an influence on international standards. Noteworthy projects are **"Swimming Pool Water Under Aspects of Health and Treatment Technology"** (funding reference: 02WT0004) and **"Integrated Risk Assessment for the new Generation of Disinfection By-products"** (funding reference: 02WU0649). The study involving top swimmers (project with funding reference 02WT0004) was the world's first population study that assessed the health risk of swimming in pools. It instigated international momentum to conduct similar studies.

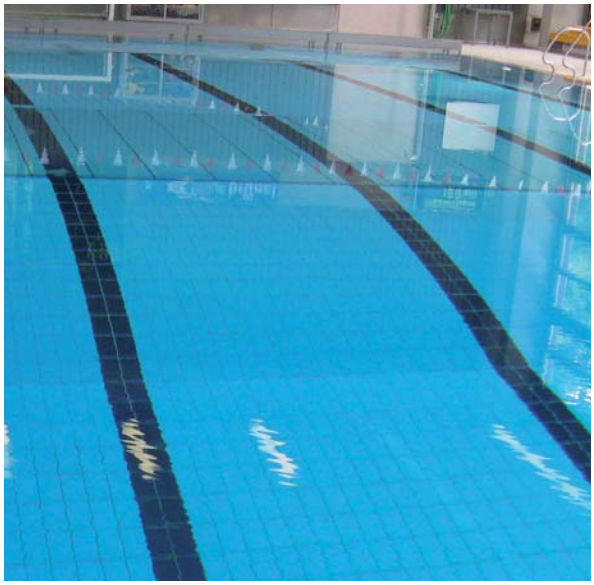


On-site measurement to determine the potential risk from disinfection by-products in the pool hall's air

Symposium held

A symposium called "Aktuelle Aspekte der Schwimmbeckenwasserhygiene – Pool Water Chemistry and Health" was held in Dessau in March 2009. The event brought leading scientists from around the world together; a survey was conducted and open issues identified. The scientists overwhelming agreed that German research has a clear edge in pool hygiene: all key aspects of risk management have already been examined in terms of their interactions – be it treatment of pool water or hazard assessment and risk evaluation of disinfection by-products.

The two research projects mentioned have shown that there are potential health risks associated with swimming in pools with chlorinated water. The aim of ongoing project **"Gesundheitsbezogene Optimierung der Aufbereitung von Schwimm- und Badebeckenwasser"** (optimizing the treatment of pool water with regard to health) is to work through pending issues that are extremely hot topics in health policy, especially regarding respiratory illnesses and with a particular focus on children. The overriding objective is to define parameters to rule out health risks across a broad consensus of science, authorities, politics, pool operators and the public.



Three questions are of particular interest to the project:

- Are the discussed exposure paths and associated chronic illnesses (inhalation/asthma, dermal/bladder cancer) relevant potential risks?
- If so, which exposure scenarios are responsible (chemical substances/treatment)?
- What options (treatment techniques/range of measures) are available to reduce or eliminate these potential risks?

The key element to the scientific work involved is the establishment of a pool model for conducting controlled tests. The various treatment options are accompanied by extensive chemical and toxicological analyses. The latest procedures were used to do this (e.g. exposure models for inhalation and dermal contaminants◄).

Bulletin published on baby swimming and disinfection by-products in swimming pools

A risk analysis of disinfection by-products as well as technical and legal measures based on the results is planned with the aim of reducing the build-up of these by-products. One key objective is to drive forward environmental research with regard to health. It is expected that research into pool hygiene will find its way into legal regulations. The first result is the publication of the bulletin entitled "Babyschwimmen und Desinfektionsnebenprodukte in Schwimmbädern" (baby swimming and disinfection by-products in swimming pools) by the Swimming Pool Water Commission (BWK) of the Federal Ministry of Health, which appeared in the Federal Health Gazette 2011 (54: 142–144). A potential risk was highlighted in terms of the care principle. Another aspect is the availability of equipment to minimise the concentration of TCA in the air of the pool hall through technical rules for treating pool water and for indoor pool ventilation. Current developments show that pool operators and visitors have become clearly conscious of a problem associating baby swimming and asthma as a result of the UBA's activities. Although the scientific evaluation of the toxicology data from the BWK and the Indoor Air Hygiene Commission's ad-hoc working group for indoor guidance values is as controversial as ever, the technically feasible guideline stipulated of 0.2 mg/m3 trichloramine within the pool hall's air means there is now a suitable monitoring parameter available in order to minimise the health risk.

Federal Environment Agency (UBA)
Bad Elster research centre
Dr. Tamara Grummt
Heinrich-Konen-Straße 12
08645 Bad Elster, Germany
Tel.: +49 (0)3 74 37/7 63 54
Fax: +49 (0)3 74 37/7 62 19
E-mail: tamara.grummt@uba.de
Internet: www.uba.de
Funding reference: 02WT1092

KMU-innovativ – giving the green light for top research by SMEs

It is often small and medium-sized enterprises (SMEs) that use and drive forward the most efficient technologies. They are therefore the pioneers of technological progress in many fields. Resource efficiency is improved through their own innovations or by catching onto highly innovative methods at an early stage. The BMBF "KMU-innovativ" funding initiative is supporting SMEs in the development of innovative technologies and services for improved resource and energy efficiency.

Efficient water treatment is a central funding area for KMU-innovativ

Innovations for resource and energy efficiency

KMU-innovativ is open to all topics within the field of resource and energy efficiency and is aimed at all innovative SMEs across all industries. The BMBF has been using "KMU-innovativ" to provide SMEs with new opportunities since 2007 by facilitating access to research funding in areas key to our future, as the risks associated with top research are often difficult to calculate. The BMBF has therefore improved consultancy services for SMEs and has simplified and accelerated the application and approval process.

Technology field: "sustainable water management"

One of the greatest challenges for the future is to ensure the supply of clean water to the global population. Population growth, water contamination and a growing water consumption per capita are all having a negative effect on water quality. Large-scale changes to climate and land usage are also affecting global and regional water cycles and are therefore calling the medium and long-term availability of water into question. The BMBF is supporting research and development projects in the following areas in order to develop solutions:
Innovative procedures for obtaining drinking water

- Strategies and technologies for saving water (including recycling technologies)
- Efficient irrigation technologies
- Energy-efficient wastewater treatment procedures and recovering energy from wastewater
- Innovative concepts and technologies for coupling material flows (e.g. water/energy/waste) and where applicable recovering materials/nutrients
- Resource-efficient and energy-efficient adaptation measures to increase export capability within the water sector

The following three projects are examples from this funding initiative.

1. Intelligent soil moisture sensor for efficient irrigation

Rising temperatures, dry summers and increasingly wet winters are causing the general availability of water to drop dramatically. The many places already experiencing a lack of water for irrigation are feeling this effect even more, and water as a resource is generally becoming a potential source of conflict.

The aim of the project therefore is to develop an intelligent soil moisture sensor to increase the efficiency of irrigation systems. The sensor is fitted with a microcontroller to enable autonomous detection of the soil's hydraulic properties (water tension curve), which enables it to determine exactly when to irrigate and how much water to use. Intelligent algorithms detect changes to the soil's hydraulic properties over time and adapt the irrigation logic accordingly. Contact partner: Parga Park- & Gartentechnik GmbH & Co. KG, Markus Blind, e-mail: blind@parga-online.de

2. Developing new solutions for water and energy-efficient irrigation technology

New solutions are being sought to improve irrigation efficiency within Egyptian farming in the Kalabsha region near the Aswan Dam, an undertaking by the Egyptian ministry for agriculture with substantial support from the World Food Programme (WFP). One problem along the Nile is that the growing population is increasing the amount of water used for farming. This results in environmental damage, e.g. through salinisation of irrigated farmland, and an increase in energy consumption for operating the pumps. The PREFARM project, a module intending to solve these irrigation efficiency problems, is being funded as part of the BMBF KMU-innovativ programme. drip irrigation products (dip GmbH), Alternativ Elektrobau Renger (AER) and Energiebau Solarstromsysteme GmbH are working together with the Institute for Technology and Resources Management in the Tropics and Subtropics (ITT) at the Cologne University of Applied Sciences to continue the successful co-operation between the ITT and Egypt on the Kalabsha project to introduce innovative drip irrigation systems.

The aims of the project are:

- Develop innovative drip irrigation systems (dip GmH drip irrigation products, Ellefeld)
- Innovative optical procedures for detecting water supply and bio-activity (AER Alternativ Elektrobau Renger Elektromeisterfachbetrieb, Ellefeld)
- Record measurement data for climate, water consumption and soil properties and ensure self-sufficient energy and water supplies through solar energy (Energiebau Solarstromsysteme GmbH, Cologne)
- Co-ordinate field work and the socio-economic analysis of innovative water and energy-efficient irrigation technologies across the overall project (Cologne University of Applied Sciences – Institute for Technology and Resources Management in the Tropics and Subtropics (ITT), Cologne; contact partner: Prof. Dr. Sabine Schlüter. Institute for Technology and Resources Management in the Tropics and Subtropics ITT, Cologne University of Applied Sciences)

3. Innovative sampling and measuring technology to protect groundwater resources

The resources of untreated water for the public water supply are increasingly representing an area of tension as a result of climate change. The national and international demand for water requires procedures for cost-effective planning, implementation and monitoring of how untreated water resources are used to obtain drinking water.

Climate-related changes to the supply of water are being examined as part of the BMBF research project entitled "Process-based Management Tool Water" by Trinkwasserversorgung Magdeburg GmbH (TWM) and the Grundwasserforschungsinstituts GmbH Dresden (GFI) using the Colbitz waterworks in Saxony-Anhalt as an example.

The Groundwater Center Dresden is developing innovative sampling and measuring technology to monitor groundwater – a resource worthy of protection. This involves:

- "Verfälschungsfreies Grundwasser-Probenahmesystem" (distortion-proof groundwater sampling system) – protecting the aquifer◄ upstream of the primarily chemically altered standing water and depth-oriented, isobaric sampling
- "Milieu-Fluid-Sampler" – pressure-maintaining deep water sampling down to 500 m and geophysical multi-parameter probe

Contact partner:
GFI Grundwasserforschungsinstitut GmbH,
Dr. Susann Berthold, e-mail: sberthold@gfi-dresden.de

Project co-ordinator: Karlsruhe
Karlsruhe Institute of Technology (KIT)
Water Technology and Waste Management
Division (PTKA-WTE)
Dr. Verena Höckele
Postfach 36 40
76021 Karlsruhe, Germany
Tel.: +49 (0)7 21/60 82 49 32
E-mail: verena.hoeckele@kit.edu
Internet: www.kmu-innovativ.de
www.ptka.kit.edu

Proven technologies in use abroad – progress through a global transfer of knowledge

The implementation of environmentally-conscious, high-tech and hygienic requirements for treating drinking water and cleaning wastewater comes with additional challenges in developing and emerging countries in particular. They begin with the question as to which procedures and technologies are suitable for the varying conditions and extend to reliable operation and maintaining facilities.

One of the government's key concerns is to build up specialist knowledge in developing and emerging countries. This means taking procedures established in Germany for treating water and cleaning wastewater and adapting them to the respective local conditions. The Federal Ministry of Education and Research (BMBF) has funded several projects in recent years that have shown how procedures and technologies that have proven themselves in Germany can be developed further and adapted to local conditions.

Example: drinking water supply

A joint research project funded by the BMBF has documented results of German water research and developed them to suit other conditions. For this purpose, reference values were determined for the size and operation of water treatment and distribution plants while taking extreme untreated water properties as well as deviating climatic and social conditions into account. Treatment methods tried and tested in Germany are assessed as to their applicability under amended conditions or when improved performance is to be expected (project 2.4.03). The project looking into long-term water resource management in connection with this is called "Abwasserbehandlung bei der Papierherstellung mit Stroh als Rohstoff zur Zellstoffherstellung am Beispiel der Shandong Provinz (Volksrepublik China)" (wastewater treatment for paper manufacturing using straw as a raw material for pulp production using the Shandong Province (PRC) as an example). One objective of the research project is to feed treated wastewater back into paper production as process water in order to reduce water consumption (project 2.4.06).

Example: bank filtration

Bank filtration is a well-established drinking water treatment procedure in Germany: waterworks use the natural cleaning power of the soil to improve the quality of the untreated water without the use of any energy or chemicals. Scientists examined the prerequisites for this in a project called "Determination of the potential purification performance of bank filtration/underground passage with regard to the elimination of organic contaminants under site-specific boundary conditions" (project 2.4.01).

Example: slow filtration

Slow filtration has become a well-established procedure for biological drinking water purification. The systems usually consist of an infiltration pond filled with different filter and support layers. However, uniform and well cleaned filter sand is not widely available. Several institutes have been investigating how the procedure can be adapted to local conditions as part of the slow sand filtration project. The cleaning performance of recycled glass granulate and coconut fibres among other things was analysed to serve as an example (project 2.4.02).

Example: wastewater technologies

Germany is a world leader in the field of water technology. However, some knowledge gaps still exist – the objective of the joint venture "Export-oriented research and development in the field of water supply and wastewater treatment part II: Wastewater technologies in other countries" was therefore to adapt technologies for communal wastewater treatment tried and tested in Germany to different climate zones. The project included investigations into the state of communal wastewater treatment in twelve nations (project 2.4.04).

Example: database for water management systems

Reliable information is essential for successful water management. The water authority of the megalopolis Beijing needs to be able to monitor the supply and consumption of water accurately due – among other things – to the region's climate causing significant fluctuations in available water levels. A computer program addressing this need has now been developed as part of a Sino-German joint venture – in the face of highly challenging conditions. The results of the project are also important to other megacities in Asia, where application is also possible (project 2.4.05).

A natural water filter – bank filtration

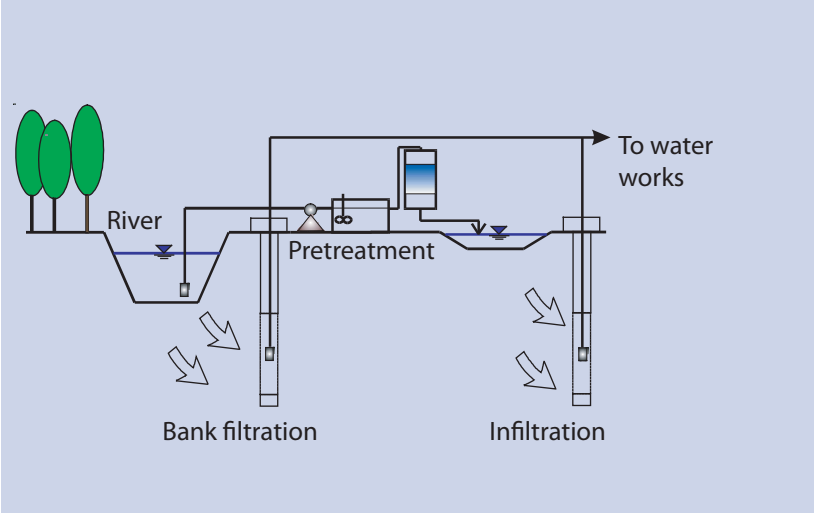
Bank filtration is a well-established and cost-effective drinking water treatment procedure in Germany: waterworks use the natural cleaning power of the soil to improve the quality of the untreated water without the use of any energy or chemicals. A research project was set up to investigate the ability of bank filtration to remove or at the very least reduce organic contamination under fluctuating conditions, the ultimate objective being to create planning and operating guides to enable this procedure to be used worldwide.

Depending on the wastewater discharge from industry, households and farming, surface water in industrialised and urban areas often contains many organic trace elements◄ or substances produced from their degradation: pesticides, mineral oils and chemicals with hormonal effects or active pharmaceutical agents can be detected in the water. These substances must be effectively removed if the surface water is a source of drinking water.

Bank filtration involves wells being established directly by the river used to supply drinking water, which artificially lowers the groundwater level. The result is a hydraulic slope between the riverbed and wells, and the surface water trickles over the bed or the bank to get underground: dirt and contaminants are filtered out and degraded by means of natural physical, chemical and biological processes. Depending on the geological conditions, the distance between the wells and the bank and the level of the river, this can take just a few days or as much as six months.

Fluctuating conditions on site

So to what extent is bank filtration suitable for removing organic compounds when these compounds have a whole host of different chemical-physical properties? Scientists examined this question in a project called **"Determination of the potential purification performance of bank filtration/underground passage with regard to the elimination of organic contaminants under site-specific boundary conditions"**, which ran from 2001 to 2005. They also wanted to discover the prerequisites a site must meet for bank filtration to be a success. This is because, alongside the range of contamination and the respective concentrations in the water, hydrogeological conditions also have a major role to play – especially the composition, permeability and sorption capability◄ of the soil, as well as climate factors such as water temperature.



How bank filtration works

Other aspects of bank filtration were examined by the Institute for Water Research, Dortmund (overall co-ordination of the "bank filtration" project), the Karlsruhe Research Centre and TU Berlin, TU Dresden and TU Hamburg-Harburg (guidelines: Kühn, W.; Müller, U. (editor) (2006): Export-oriented R&D in the field of water supply and wastewater treatment – part I: Drinking water. Volume 2. Guidelines. Water Technology Centre, Karlsruhe, ISBN 3-00-015478-7).

With the aim of creating planning and operating guides for using bank filtration in other climate zones, the project partners collated existing research results and experience gained in Germany and other countries and conducted an analysis. They filled any gaps in information – e.g. in relation to more extreme climatic conditions – with the results of true-to-life field and lab tests.

Clear improvement in water quality

The tests performed during the project showed that bank filtration can remove most (around 80%) of the organic trace elements found in the surface water, with a reduction in concentration observed at the very least in the remaining substances. Nevertheless, the behaviour of innovative substances is not 100% predictable in bank filtration as chemically similar substances occasionally react in very different ways. The project confirmed that the removal of organic compounds is attributed to sorption processes and biological and chemical degradation processes underground. This means the bulk of the

reduction in contamination takes place in the "infiltration zone", directly after the water gets into the soil. The conclusion from this is that removing the wells (20 to 400 metres) does not have a major impact on cleaning performance. Even so, the increased flow course/water retention time underground is significant as it ensures optimum effect. The project team therefore observed that many substances were eliminated to a much higher degree when the water spent longer underground.

Oxygen supply is crucial

The trace elements that are degraded and the extent to which this occurs depend heavily on the oxygen-reduction environment◄ in the soil, or in other words, the micro-organism oxygen supply. For example, some trace elements are removed more effectively in an aerobic◄ environment, and others in an anaerobic◄ one. This means that locations suitable for bank filtration are those where the water can spend a while in both aerobic and anaerobic areas of soil.

Regardless of the oxygen-reduction conditions, bank filtration is suitable for removing organic trace elements such as polycyclic aromatic hydrocarbons, polychlorinated biphenyls◄ (PCB) and many insecticides. Odours, tastes and substances affecting hormones are also degraded to a great extent. One key consideration for bank filtration in warmer climates: rising temperatures lead to increased metabolism and thus a higher conversion rate in most cases.

A well of the vertical well gallery in Düsseldorf

DVGW – Water Technology Center Karlsruhe (TZW)
Dr. Frank Thomas Lange
Karlsruher Straße 84
76139 Karlsruhe, Germany
Tel.: +49 (0)7 21/96 78 15 7
Fax: +49 (0)7 21/96 78 10 4
E-mail: lange@tzw.de
Internet: www.tzw.de
Funding reference: 02WT0279

Adapted slow filtration – versatile and cost-effective

Slow filtration is a near-natural, simple and cost-effective means of water treatment; in Germany, it is usually combined with other processes. It can also be performed using alternative, locally available filter materials. A number of research projects have looked at ways in which slow filtration could be technically improved and adapted to the specific conditions at locations outside Central Europe.

Slow filtration has become a well-established procedure for biological drinking water purification. The systems usually consist of an infiltration pond◄ filled with different filter and support layers. A drainage and support layer comprising stones, gravel and coarse sand is followed by an (approx.) one metre high filter layer. The primary filter material employed in Central Europe is sand (slow sand filtration); generally speaking, the longer the water remains in the sand filter, the greater the level of purification.

However, uniform and well cleaned filter sand is not widely available. Attempts to proliferate this procedure (particularly in developing and emerging countries) requires adaptation to local circumstances – for example, the use of locally available and cost-effective filter materials. This matter has been closely examined by the IWW Water Centre (Rheinisch-Westfälisches Institut für Wasserforschung) in Mülheim an der Ruhr (overall co-ordination of "slow sand filtration" projects) and the Institute for Water Research (IfW – Institut für Wasserforschung) in Schwerte (period of study: 2002 to 2005).

Sand alternatives examined

The scientists compared the cleaning performance of sand to that of recycled glass granulate and coconut fibres – employing a range of methods at varying temperatures and filter speeds. Another sub-project addressed the question of whether the effectiveness of slow filtration is improved by adding gravel, pumice or coconut fibres to the sand filter layer.

Extreme pollutant concentrations simulated

The research was performed in laboratories and semi-industrial test facilities. To establish the procedure's effectiveness in the face of extreme pollutant concentrations in the unprocessed water, tests were partially conducted using contaminated surface water with raised DOC and ammonium content◄. The researchers also employed the outflow of a sewage plant as untreated water◄ in the test

Column experiment system in a climatic chamber

Recycled glass granulate

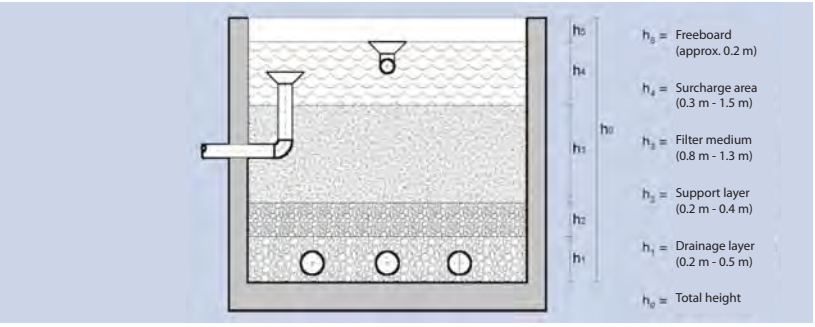
facilities; this was done to determine whether slow filtration is also suitable for the treatment of water in rivers that are greatly affected by wastewater discharge but still possess some assimilative capacity.

Another area of research was the nature of microbial colonisation in slow sand filters. To optimise system performance, the Water Technology Centre (TZW) of the Deutsche Vereinigung des Gas- und Wasserfachs (DVGW – German Technical and Scientific Association for Gas and Water) developed a module for the practical mathematical simulation of slow sand filtration under different environmental conditions.

Finally, the objective of the projects **"Boundary conditions for slow sand filtration, suggestions for technical modification and adaptation to regional conditions"** and **"Optimisation of slow sand filters by means of special protection layers and operating methods"** was to combine existing slow filtration data with current results in order to create guidelines for the planning and operation of slow filtration systems (Kühn, W.; Müller, U. (eds.): Export-oriented R&D in the field of water supply and wastewater treatment – part I: Drinking water. volume 2; Karlsruhe; at www.tzw.de).

Recycled glass granulate and coconut fibres as alternatives

The research showed that both recycled glass granulate and coconut fibres represent viable alternatives to sand as slow filtration materials. Under test conditions, however, the cleaning performance of these substances was not of a sufficient level to produce drinking water in all circumstances. The experiments highlighted specific strengths and weakness of the different filter materials, which are to be taken into account in practice and potentially



Schematic representation of slow sand filtration (section) according to DIN 19605, from DVGW work sheet W213-4

compensated by means of technical modifications (e.g. pre-separation or aeration).

The purification performance of slow filtration greatly depends on the temperature: the biodegradation processes become significantly slower at temperatures below 10°C, in some cases even coming to a complete standstill. At high temperatures and with a high concentration of biodegradable substances, the degradation processes result in significant oxygen consumption. Column experiments in an air-conditioned room showed that, in the selected operating conditions (filter layer thickness, operating method, filter speed etc.) and at 5 to 10°C, none of the filter materials was able to process the untreated water (high DOC and ammonium content) such that it met the drinking water regulations of the World Health Organisation (WHO) in terms of the examined chemical parameters. At 20°C, only the filtrate treated with recycled glass granulate exceeded the thresholds, while all filtrates met the WHO limits at 30°C. In these experiments, the sand-filtered water actually complied with the values stipulated by the even stricter German Drinking Water Ordinance.

Protective layer

The experiments showed that a 20 cm protective layer consisting of gravel, pumice or coconut fibres greatly increases the filtering time. Furthermore, a large portion of the particles contained in the water was retained in this layer, thus protecting the sand filter layer below and minimising agglutination. If the filtered particles are organic rather than mineral substances, they are already biodegraded in the protective layer. The disadvantage of this is the lack of oxygen further down, which – without additional aeration – has a negative impact on subsequent aerobic biodegradation processes◄, e.g. ammonium oxidation.

The scientists assessed the ability of slow sand filters to retain degradation-resistant trace elements◄ in a separate test system featuring an activated carbon layer below the sand layer. The result: layers of sorptive materials such as activated carbon◄ are highly effective in retaining organic trace elements from pesticides and pharmaceuticals. As this "sandwich" method entails high construction and maintenance costs, large-scale application is not currently a realistic option. Therefore, if slow filtration alone does not provide the desired water quality, a better option would be to integrate the procedure in a system of suitable pre- and post-treatment techniques adapted to the relevant location.

IWW Rheinisch-Westfälisches Institut für Wasserforschung gGmbH
Dr.-Ing. Hans-Joachim Mälzer
Moritzstraße 26
45476 Mülheim an der Ruhr, Germany
Tel.: +49 (0) 2 08/4 03 03-3 20
Fax: +49 (0) 2 08/4 03 03-80
E-mail: a.maelzer@iww-online.de
Internet: www.iww-online.de
Funding reference: 02WT0282

Institut für Wasserforschung GmbH Dortmund (IfW)
Frank Remmler
Zum Kellerbach 46
58239 Schwerte, Germany
Tel.: +49 (0) 23 04/95 75-3 53
Fax: +49 (0) 23 04/95 75-2 20
E-mail: remmler@ifw-dortmund.de
Internet: www.ifw-dortmund.de
Funding reference: 02WT0279

Export-oriented research & development – transfer to other countries

A joint research project funded by the Federal Ministry of Education and Research (BMBF) has documented results of German water research and developed them to suit other conditions. For this purpose, reference values were determined for the size and operation of water treatment and distribution plants while taking extreme untreated water properties as well as other climatic and social conditions into account. Ten institutes and universities participated in the project.

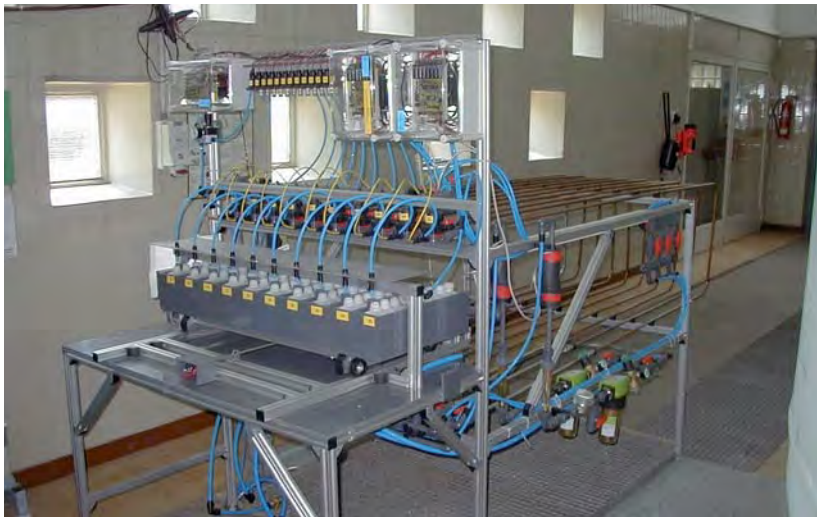
In the following, treatment methods tried and tested in Germany are assessed as to their applicability under special boundary conditions or when improved performance is to be expected.

Slow filters◄ with closed bottoms and infiltration ponds◄ with subsequent groundwater recharge represent possible alternatives for small systems in rural areas and cities of developing and emerging countries. It should be noted that slow filtration without pre-treatment should only be used to process low-turbidity◄ water with minimal microbiological contamination.

Wealth of experience in bank filtration

Since bank filtration has been used in Germany for over 100 years, the country has a wealth of experience in this area. This knowledge can be employed for targeted application in other nations – despite the existence of different climatic and hydrogeological conditions. To support this transfer of knowledge, the project participants developed a range of engineering aids and provided detailed descriptions in the form of user guidelines (see references at end of article).

A combination of flocculation◄, sedimentation and filtration is the standard procedure employed by many countries for the treatment of surface water. Important considerations during project planning are optimum hydraulic and technical conception with regard to the addition of processing agents for flocculation, the minimisation of flushing water requirements, optimised sludge water discharge as well as the use of measurement and control technology adapted to local standards.



Transportable test rig for assessing the influence of water quality on corrosion on site

Micro- and ultra-filtration – an alternative to conventional water treatment

In addition to conventional water treatment by means of flocculation and filtration, micro-◄ or ultra-filtration◄ represents a possible alternative for turbidity removal purposes. These processes can be used to purify either low-turbidity untreated water without pre-processing or high-turbidity untreated water following conventional pre-processing. Micro- and ultra-filtration is also a suitable means of processing eutrophic water◄. Sustainable use of these techniques requires an appropriate infrastructure for maintenance and operation.

The removal of heavy metals using ion exchangers◄ is particularly suitable for low-turbidity water; the capacity of the ion exchangers is barely reduced. In the case of water containing heavy metals, ion exchange can be an alternative to treatment via flocculation, for example.

Particularly when used with waters containing unknown compositions of water-based substances, the by-product generation connected with oxidation processes and removal of residual content must be taken into account. The combination of hydrogen peroxide and UV radiation has proven to be a very energy-intensive process; pre-oxidation with potassium permanganate◄ is not an effective means of enhancing the turbidity removal capacity of flocculation. Important planning criteria are the

Procedure	Sub-procedure	IC	EC	DC
Bank filtration		++	++	+++
Slow filtration	Slow filter infiltration	+	++	+++
Flocculation, sedimentation		+++	+++	+++
Filtration	Rapid filtration	+++	+++	+++
	Biofiltration	++	++	+++
	Micro-/ultra-filtration	+++	++	+
Ion exchange		+++	+	+
Oxidation	Atmospheric oxygen	+++	+++	+++
	Ozone	+++	+	+
	H_2O_2/Fe	+	+	+
Adsorption	Granular activated carbon	+++	++	+
	Powdered activated carbon	++	++	+++
Disinfection	With residual concentration	+	+++	+++
	Without residual concentration	++	Generally not used	

Suitability of treatment processes in industrialised (IC), emerging (EC) and developing countries (DC)
+++ Minimal expenditure or state of the art
++ Moderate expenditure or not yet widely used
+ Higher expenditure or availability only in specific cases

operational reliability of the process and the necessary qualification of the relevant personnel. The deficiencies of biological ammonium oxidation in cold water can be countered by a number of means. However, at water temperatures under 5°C, extremely long treatment periods (weeks to months) are required to eliminate high ammonium loads, which could effectively outweigh the benefits offered by the procedure.

Activated carbon◄ should, in principle, only be loaded with low-turbidity water (e.g. < 0.2 NTU, Nephelometric Turbidity Units). The effect of the water temperature on the adsorption◄ of natural, organic substances in water is relatively minor. High DOC concentrations◄ in untreated water can limit the activated carbon's adsorption capacity for trace elements◄, which should therefore be minimised as much as possible by other means prior to the adsorption. Although granulated iron hydroxide is very effective in the removal of arsenic, its ability to eliminate dissolved organic substances is quite limited.

Drinking water disinfection is the most important and frequently employed treatment process throughout the world. As a rule, drinking water purification outside Germany stipulates the disinfection of the water and its subsequent introduction to the distribution network with free disinfectant; this is often a necessity given the fact that conditions in the distribution network are frequently less than ideal. Since a residual chlorine level is desired at the water tap, appropriate disinfectants with a lasting depot effect are still required as a final safety step following the optimisation of the water treatment process. However, care must be taken to avoid overdosage due to the potential for disinfectant by-product formation and negative reactions on the part of consumers.

Component	Cost type	Factor for development standard IC	EC	DC
Structures	Frequently constructed by regional companies	1,0	0.6	0.4
Mechanical engineering equipment, Electrotechnology/measurement and control technology	Local/regional production	1,0	0.8	0.6
	Imported equipment		1.5-1.7	1.5-1.7

Cost factors in industrialised, emerging and developing countries (Gieb, 2005)

Water quality and corrosion in pipe networks

Outside Germany, the impact of water quality on pipe corrosion cannot be adequately assessed by the common-practice method of establishing the corrosion probability on the basis of ion ratios. More concrete information can be gained by conducting additional experiments with a special test rig (see photo) under the applicable specific conditions.

When assessing the basic applicability of the various procedures from a technical perspective, the country-specific conditions regarding infrastructure, availability etc. must be taken into account (see table). Provided that any climatic differences are taken into account, transferring these procedures to other industrialised countries does not represent a problem, since a virtually identical technological standard can be assumed. However, this does not apply to developing and emerging countries (or only to a limited extent).

The results of the joint project have been published in the form of guidelines, while an accompanying CD documents the final reports of the sub-projects: "Export-oriented R&D in the field of water supply and wastewater treatment.
Part I: Drinking water, volume 2: Guidelines, in-house publication of DVGW Water Technology Centre Karlsruhe (2006),
ISBN: 3-00-015478-7" (out of print)

DVGW Water Technology Centre (TZW)
Dr. Uwe Müller
Karlsruher Straße 84
D-76139 Karlsruhe, Germany
Tel.: +49 (0) 7 21/96 78-2 57
Fax: +49 (0) 7 21/96 78-1 09
E-mail: uwe.mueller@tzw.de
Internet: www.tzw.de
Funding reference: 02WT0273 – 0282, 02WT0323

Adapted wastewater technologies – knowledge gaps filled

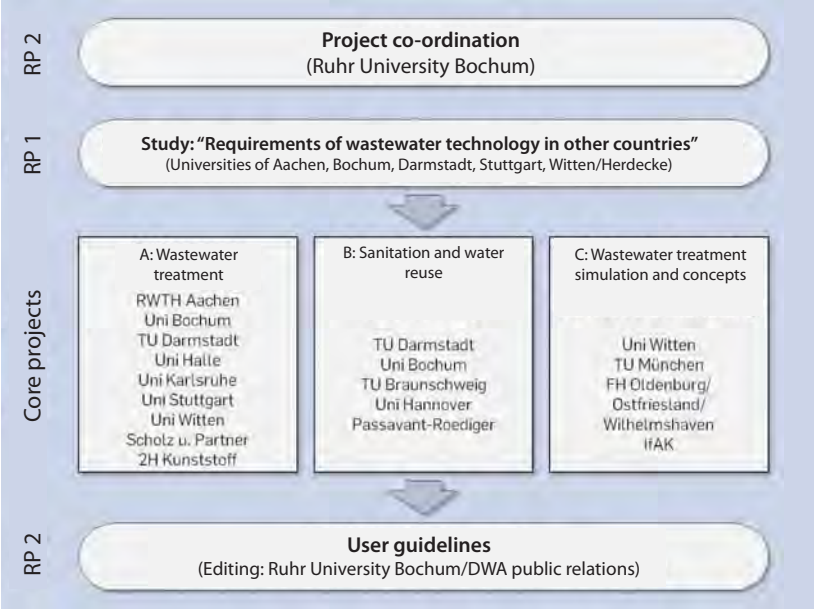
Germany is a world leader in the field of water technology. However, some knowledge gaps still exist – one example being the adaptation of wastewater technologies to altered conditions, such as the climate in different countries. These gaps have been successfully closed by a joint research project.

These altered conditions include extreme wastewater temperatures, low concentrations of easily degradable compounds, raised salt content or intensive algae growth in sewage ponds◄ due to high insolation levels. The objective of the joint venture **"Export-oriented research and development in the field of water supply and wastewater treatment – part II: Wastewater technologies outside Germany"** was to adapt technologies for communal wastewater treatment tried and tested in Germany to different climate zones and boundary conditions. A further objective was to place greater emphasis on the subjects of recycling and planning methods. The research project thus helped to raise the quality and efficiency of wastewater treatment while ensuring improved and more sustainable use of the resource water.

During the first project phase, investigations were performed of the special conditions of communal wastewater treatment in the following twelve nations, which were selected as being representative of different world regions and development levels: Egypt, Brazil, China, Indonesia, Iran, Jordan, Morocco, Russia, South Africa, Thailand, USA and Vietnam. This general survey was accompanied by 24 individual research and development projects, which were conducted by 11 different universities as well as numerous companies and focussed on three core areas.

Core area A: wastewater treatment

Core area A looked mainly at procedures that are standard in Germany and throughout the world: activated sludge processes◄, trickling filters◄, rotating biological contactors◄, submerged fixed beds◄ and sewage ponds. German water technology can provide a wealth of experience in this area, which must be adapted to the relevant conditions. The focus is on the composition of the waste water, the temperature of the waste water and ambient air as well as the specific requirements for the purification plant process or treatment stages (mechanical, biological, nutrient elimination).



Project structure

Core area B: disinfection and water reuse

The sub-projects of the second core area focussed on water recycling possibilities as well as the analysis, demonstration and enhancement of selected wastewater treatment procedures. One particular area of research was the different requirements of wastewater treatment plants – varying by time of year (summer, winter) or users – for the generation of irrigation water. In addition, the scientists examined the use of anaerobic processes for the treatment of wastewater. Examinations of sewage sludge treatment and utilisation were also part of the project.

Core area C: wastewater treatment simulation and concepts

Core area C comprised the projects in which locally adapted aids were devised for the planning of wastewater treatment plants outside Germany. These aids include adapted economic methods for variant evaluation, models for purification plant simulations, stepwise expansion concepts for adaptation to growing treatment requirements or rising pollution as well as working aids ("ExpoTool", available from ifak e.V., Magdeburg) for project assessment, which provide quantitative evaluations and visual

Demonstration system at the Yamuna Vihar treatment plant in New Delhi, India

representations of the various treatment plant alternatives. With these aids, available alternatives can be described and presented – e.g. to ordering or contracting bodies – in a clear and meaningful manner.

Extensive documentation

The project documentation produced by the research initiative provides a wide range of tools and information to support the adaptation of treatment plant technologies to the specific conditions in different countries. For the first time, quantitative recommendations can be made for a range of known qualitative phenomena. In this context, the impact of the water temperature is of primary importance: in all projects involving measurement and assessment, the water temperature is the most important parameter in terms of the adaptation of wastewater purification and sewage sludge treatment processes to different climatic conditions. One of the most significant observations in this regard is that higher wastewater temperatures may greatly increase performance, but can also result in operational problems (e.g. siltation, insufficient oxygen supply) without the implementation of suitable countermeasures.

As well as being the subject of scientific publications and presentations, the results of the research project are summarised in the three reports “Requirements of wastewater technology outside Germany”, “Cross-project closing report” and “Guidelines for wastewater technology outside Germany”. The reports are available from the Ruhr University Bochum via the address specified below.

Final clarification and digester of the Fujairah treatment plant, United Arab Emirates (provided by Passavant-Roediger GmbH)

Ruhr University Bochum
Institute of Urban Water Management and Environmental Engineering
Prof. Dr.-Ing. Hermann Orth
Building IA 01/147
Universitätsstraße 150
44801 Bochum, Germany
Tel.: +49 (0) 2 34/32-2 30 49
Fax: +49 (0) 2 34/32-1 45 03
E-mail: siwawi@ruhr-uni-bochum.de
Internet: www.ruhr-uni-bochum.de/siwawi/
Funding reference: 02WA0539

Water management in megacities – the role of the database

The water authority of the megalopolis Beijing knows all too well that correct decisions cannot be made without reliable information: since the region's climate causes significant fluctuations in available water levels, accurate data is required to control and monitor the supply and consumption of water. A computer program addressing this need has now been developed as part of a Sino-German joint venture – in the face of highly challenging conditions. The results of the project may also prove extremely useful to other megacities in Asia.

The sustainable management of water resources in semi-arid areas is an extremely complex task. As of a specific size (supply area, population) optimum management of multiple resources is required – both from a temporal and geographical perspective – whereby wastewater is also considered a resource in semi-arid areas. For megacities such as Beijing, with its 16 to 17 million inhabitants, this is a particularly challenging task.

Extreme situations

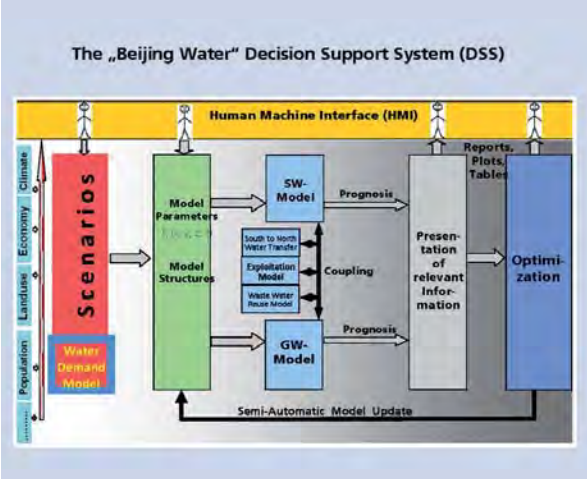
Due to its geographical situation at the northern edge of the North China Plain, Beijing has a semi-arid and intermittent semi-humid climate. Virtually the entire annual rainfall occurs over just two months (including flood events), while the area remains mostly dry for ten months of the year. The city's water authority is therefore required to manage two very different, yet equally extreme situations.

The most water is required for agricultural purposes in the areas surrounding the metropolis, whereby demand is largely covered by the 40,000 to 50,000 local groundwater wells. Drinking water is currently obtained from surface water (predominantly water reservoirs) as well as from groundwater – both sources are overused. The water carried by the two major rivers in the region (Yongding and Chaobai) has been seasonally or geographically restricted for years. In addition, groundwater levels are dropping by one to metres every year.

To ensure continued water supply in the face of ever growing consumption, plans were made in 2007 to channel water into the Beijing region from the South-North water transfer. The link-up has been delayed, however, and is currently scheduled for 2012/2013. The transfer is to convey an annual water volume of 1.4 billion cubic metres into the metropolis, but suitable reservoirs to store the water are still required.

Example of a dry river bed in the area under examination

These multifaceted tasks can only be addressed with the aid of a computer program tailored to these specific requirements. The creation of such an information system for the Beijing area was the remit of a Sino-German venture, which reached its conclusion in November 2009 with the delivery of the software system to the Beijing Water Authority (BWA). The project, which was supported by the Federal Ministry of Education and Research (BMBF), was overseen by the Fraunhofer Institute for Optronics, System Technology and Image Exploitation (IOSB).



Structure and functions of the information system developed for Beijing

Dried out littoral zone of Kunming Lake at the Summer Palace in Beijing

Multilayered program

The resulting "Beijing Water Decision Support System" (DSS◄) collates data and information of varying quality, quantity and controllability (see figure). The information ranges from easily measurable data (e.g. water abstraction from a specific source) to uncertain estimates (e.g. consumer behaviour, groundwater recharge rate). The system maps all resources onto mathematical models on the basis of balance equations: this allows the BWA to simulate various scenarios to support its decision-making.

As was to be expected, significant problems were encountered with the creation of a comprehensive information base as well as with the derivation of representative model structures with spatial and temporal parameters. Data is generally held by different institutions and authorities, and is therefore fragmented, inaccurate, inconsistent and occasionally even contradictory – something which greatly hinders efforts to implement the required modelling detail. Another exacerbating factor was that many model parameters (or model input quantities) were to be determined as functions of location and time – i.e. in the form of charts – but the available measurement data was severely lacking.

Creation of water balance system

The project partners tackled this problem by creating a coherent, multilayered system for water balances: it can be used, for example, to balance the water levels of different sources, groundwater recharge and untreated water abstraction, water consumption as well as the treatment and disposal of wastewater. The results can be used to identify and correct implausible data and close any gaps. The system also enables automated multi-criteria optimisation, in which simulations of pre-defined parameter variations are used to identify the specific scenario representing the best possible water supply solution under given conditions. Due to the high complexity of this process, the system always checks the consistency, plausibility and completeness of user entries.

The work performed on the Beijing Water Decision Support System gave rise to new methodical approaches for high-resolution modelling of water resources with meso-level analysis areas of over a thousand square kilometres (and larger), as well as for the determination of parameters on the basis of incomplete, inconsistent or contradictory raw data (as is usually the case with the water supplies of Asian or South American megacities). The success of these approaches was underlined by the high level of concordance between calculated and measured results as part of the verification of data from the period between 1995 and 2000.

Fraunhofer Institute for Optronics, System Technology and Image Exploitation (IOSB)
Prof. Dr. Michael Birkle
Fraunhoferstraße 1
76131 Karlsruhe, Germany
Tel.: +49 (0) 7 21/60 91-3 80
Fax: +49 (0) 7 21/60 91-5 56
E-mail: mb@iosb.fraunhofer.de
Internet: www.iosb.fraunhofer.de
Funding reference: 02WA0565, 02WA0849, 02WA1035

Transferable solutions for special wastewater problems – paper manufacture at the Yellow River

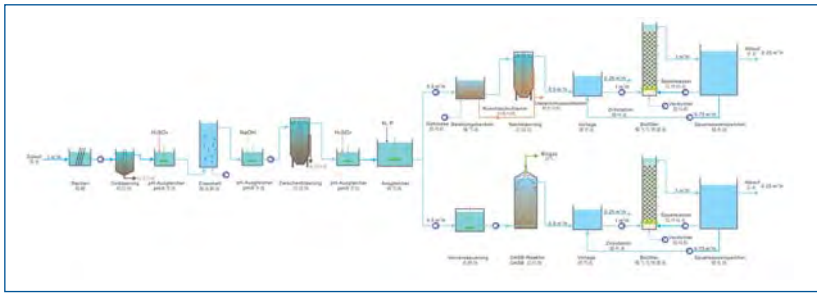
Paper factories are of great economic importance to the Chinese province of Shandong. However, the wastewater production of these factories is extremely high. A new research project supported by the BMBF has examined ways of making China's paper production more environmentally sustainable.

The Shandong province in the east of the People's Republic of China accounts for the second highest GDP of all Chinese provinces – and most of this can be attributed to the industrial operations based in the region. These primarily include paper manufacture, distilleries, dye industry and monosodium glutamate production.
The Shandong province has long suffered problems with its drinking water supply. In 2003, more than two million people did not have an adequate supply of drinking water. According to the annual report of the Shandong Ministry of Water Resources, more than six million people were without a short-term supply of drinking water, despite the relatively high level of precipitation experienced in 2003. As a result, the problems with the province's drinking water supply are likely to increase in the coming years.

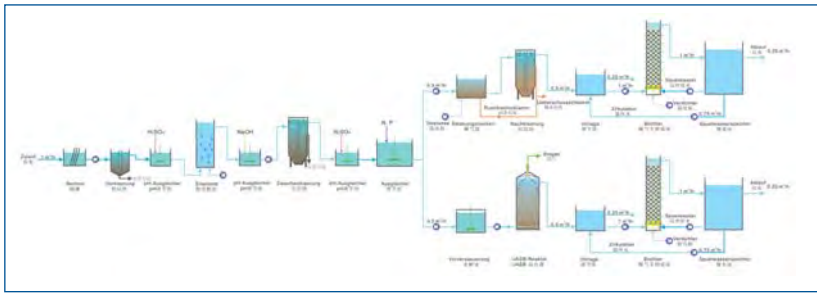
China's second largest river – the Yellow River – flows through the Shandong province. Water is channelled from the Yellow River into the "south-north transfer", particularly to supply the Beijing region with untreated water◄ for drinking water production. In this context, the establishment of sustainable water resource management in the basin◄ of the Yellow River and the transfer is a very important topic. Consequently, a large number of projects have been initiated to tackle this matter. The focus of these initiatives is on the cleaning of industrial wastewater from, for example, distilleries, textile dye works and paper factories in particular.

In 2005, 38 paper factories in Shandong were using straw as a raw material. The wastewater produced by these factories – 416 million cubic metres in 2000 alone – is extremely damaging to the province's waterways. A production output of some three million tons of paper in 2000 equates to 138 litres of wastewater per single kilogram of paper – by way of comparison, German paper factories produced a mere tenth of this.

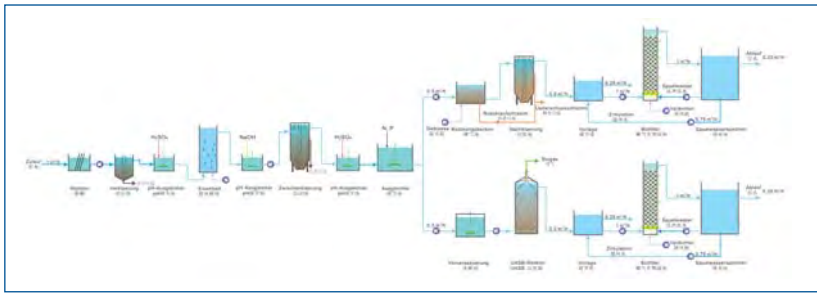
To ease the conflict between economic growth and environmental protection and gradually achieve all environmental goals, both the central government in Beijing and local government of the Shandong province issued stricter regulations concerning industrial wastewater disposal. As of 1 January 2011, wastewater fed directly into the receiving waters must not exceed a concentration of 100 mg COD◄/l ("Integrated Wastewater Discharge Standard in Shandong Peninsula Basin"). This discharge limit is lower than its European counterparts. This made it all the more impossible for the wastewater treatment plants in the Shandong paper factories to meet these requirements, both with regard to the polluting load and the pollutant concentration. It was therefore necessary to develop processes that would allow the factories to comply with the stipulated discharge loads and concentrations in a reliable and cost-effective manner.



Pre-treatment stage – micro-electrolysis procedure



Aerobic–aerobic treatment stage



Anaerobic–aerobic biological treatment stage

Iron bed (foreground), intermediate treatment and final clarification (background)

The overall aim of the commissioned research project was to identify purification solutions for the special paper wastewater of the Shandong province and to make initial improvements to general wastewater treatment. Another long-term goal was to optimise process water recirculation to reduce the overall water consumption in Shandong's factories. The project was also to assess the transferability of the examined procedures to other paper factories in the Shandong province and throughout China.

The initiative can be split into two main steps: in the first part of the project (project phase A), the micro-electrolysis procedure was examined on a laboratory scale at the Technische Universität Darmstadt (Darmstadt Technical University) in order to optimise the biodegradability of wastewater from paper production. The aim was to achieve significant BOD_5 ◄ and COD reduction and improve biodegradability in subsequent stages. This step supported the later research in the semi-industrial test facility (project phase B), which had been constructed in Shandong's Qufu factory as part of the Sino-German joint venture.

In the semi-industrial test facility, the paper wastewater was processed in a pre-treatment stage based on the micro-electrolysis procedure and a two-stage biological cleaning process (anaerobic ◄/ aerobic ◄ or aerobic/aerobic). The micro-electrolysis was used to pre-treat the wastewater, particularly to eliminate lignin compounds, degradation of which is very difficult. In a first basin, the wastewater was then processed in a highly concentrated activated sludge procedure ◄ and a subsequent biofilter stage. In the second basin, the wastewater was subjected to anaerobic pre-treatment with a UASB reactor ◄ and subsequent aerobic post-treatment using a biofilter. In addition to the semi-industrial test facility, project phase B also involved additional laboratory experiments with a modified treatment stage, in which the various treatment steps were processed in the following sequence: micro-electrolysis, UASB, activated sludge basin and biofilter.

In their tests with the semi-industrial facility, researchers were able to meet the 120 mg COD/l threshold applicable from 1 January 2010, but not the more stringent emission standards that would take effect in 2011. However, the additional laboratory experiments succeeded in reaching these future requirements (less than 100 mg COD/l).

The conducted research showed that it was possible to optimise the wastewater treatment in China's paper factories by affordable means; however, meeting the required pollutant limits would require the adaptation of procedures to the special wastewater streams and polluting loads. With regard to the transfer of results to other factories, researchers are currently still working on a water balance for the paper factory specified above However, the general assumption is that the employed procedures will be suitable for factories using straw as a raw material. In order to assess suitability for the paper wastewater treatment of factories using other raw materials, consideration and possible further examination of the specific conditions and wastewater composition is required.

Technische Universität Darmstadt
IWAR Institute
Department of Wastewater Technology
Prof. Dr.-Ing. Peter Cornel
Petersenstraße 13
64287 Darmstadt, Germany
Tel.: +49 (0) 61 51/16-21 48
Fax: +49 (0) 61 51/16-37 58
E-mail: p.cornel@iwar.tu-darmstadt.de
Internet: www.iwar.bauing.tu-darmstadt.de
Funding reference: 02WA0953

United for clean water resources – international co-operation

In its efforts to improve water supplies across the globe, the Federal Ministry of Education and Research (BMBF) supports a variety of research and development projects to devise technologies and concepts for the sustainable management of water resources. In the last funding period, these efforts focused primarily on Asia, the Middle East, Eastern Europe and Africa.

Technologies and procedures tried and tested in Germany generally require adaptation to regional, economic and social conditions. Another important factor is the training of local specialists. One of the main aims of the international water research projects is the transfer of knowledge to the relevant persons on site, thus enabling them to implement and pursue their own projects. German companies are contributing valuable expertise to these research and development initiatives. The BMBF-funded projects are thus also helping to establish new export markets for the German water industry – in areas that are likely to experience considerable growth over the coming decades.

Example of Indonesia. The southern coast of the island of Java is one of the poorest regions in Indonesia. The inhabitants suffer a severe lack of water, despite the relative abundance of this valuable resource underground. Previously, the water flowed straight into the sea via a complex underground water system comprising more than 1000 caves. As part of the project "Accessing and managing underground karst waters in Central Java, Indonesia", German and Indonesian scientists constructed a small underground hydroelectric power plant with which water can be transported to the surface to supply some 80,000 people (project 2.5.01).

Example of China. In the build-up to the Beijing 2008 Olympic Games, a water concept was devised for the 550 hectare Olympic Park with the Sino-German research project "Development of a sustainable water concept for the Olympic Park in Beijing, 2008". Research is also to be carried out to assess the transferability of the results to other regions of China as well as other states (project 2.5.02). The many hygienically relevant micro-organisms (viruses, bacteria, protozoa, worm eggs) present in the wastewater – even after biological cleaning – mean that adequate purification of the water is required before it can be reused. However, chlorination is generally accompanied by the formation of unwanted disinfection by-products. A comparison of various procedures has shown that alternatives exist to conventional wastewater treatment. The IWAR institute of the Technische Universität Darmstadt has tested four of these alternative procedures in China (project 2.5.08).

Example of Iran. Mashhad is the second largest city in Iran and is situated in an arid zone. To supply the population with low-nitrate drinking water, the BMBF worked with the Iranian Ministry of Energy on the project "Demonstration of different high-performance procedures developed in Germany for the removal of nitrate from drinking water and their adaptation to the treatment of groundwater with high concentrations of sodium nitrate and other salts using the example of drinking water purification in Mashhad, Iran" (project 2.5.03).

Example of Russia. At 3500 kilometres, the Volga is Europe's longest river. Massive intervention has altered the waterway on an almost unprecedented scale – with complex consequences for people and the environment. As part of a German-Russian project, sustainable solutions were developed for the economic and ecological management of the Volga and its feeder streams (project 2.5.04).

Example of Vietnam. Black coal is an important energy source in Vietnam, but mining efforts cause significant damage to the environment. The aim of the German-Vietnamese project "RAME (Research Association Mining and Environment)" in the Quang Ningh province is to transfer remediation technologies from the German coal mining industry to its Vietnamese counterpart (project 2.5.05).

Example of Israel. Scientists from Germany and Israel have worked together to develop new measuring procedures to serve as the basis for continuous monitoring of the pollutant content of drinking water sources in Israel (project 2.5.06). In another project detailed in this brochure, German and Israeli scientists are using cloud seeding in an attempt to counter desiccation of the land (project 2.5.07).

Adapted technology – an underground hydro-power plant on Java

The southern coast of the island of Java is one of the poorest regions in Indonesia. Water is in short supply, despite the relative abundance of this valuable resource beneath the ground; however, the water flows directly into the sea via a complex underground water system comprising well over 1000 caves. Scientists in Germany and Indonesia have found a simple solution for one region on Java: a small underground power plant that transports enough water to the surface to supply some 80,000 people.

The approx. 1400 square metre karst landscape◄ in Java's Gunung Sewu region is littered with hundreds of interconnected caves and underground streams. Although there is plenty of water beneath the earth, the region's inhabitants suffer extreme water shortages during the dry seasons due to an absence of appropriate storage facilities – the limited rainfall simply seeps into the karstic ground. Previously, diesel-powered pumps were used to transport the water from the caves up to the surface. Not only does this system use a great deal of energy and carry significant operating and maintenance costs, but the water volume conveyed is not enough to cover the water requirements of private households, local industry and the region's agriculture.

Cave water

A feasibility study commissioned by the BMBF concluded that it would be technically possible to transport the cave water using hydraulic energy. On this basis, the German-Indonesian pilot project **"Accessing and managing underground karst waters in Central Java, Indonesia"** was launched in 2002, with the aim of constructing a demonstration hydro-power plant in Gunung Sewu. The project was overseen by the Institute for Water and River Basin Management (IWG) of the Karlsruhe Institute of Technology (KIT) and involved seven institutes from different specialist disciplines as well as industrial partners from the fields of tunnelling, pump and control technology.

Following intensive on-site research, the specialists decided on the (Gua) Bribin cave. It has a capacity of some 300,000 cubic metres and a water flow rate of over 1000 litres per second, even in dry seasons. The project participants decided to construct a barrage in the cave to dam the continuous flow of water, a part of which was to be transported along a 100 metre riser pipe by means of a small hydro-power plant; this would then supply some 80,000 people in the surrounding shanty towns with

Drill site in the karst area

water. During research and development, a conscious effort was made to employ easily manageable techniques adapted to the needs of the local people and the environment.

To determine the potential water levels and storage volumes, large portions of the cave were measured using state-of-the-art laser technology and the resulting data compiled to form a high-resolution, three-dimensional model. The rock porosity and mineralogical composition was determined through macroscopic and microscopic analyses of samples. This provided the scientists with the means to predict potential water losses and signs of corrosion, thus allowing them to assess the long-term stability of the system. A monitoring network was then installed to enable continuous recording of the water quality as well as hydrological, hydraulic and hydrogeological conditions.

Upon completion of necessary preparations at the project site, the Department of Public Works, Yogyakarta, drilled a first sounding hole (103 m) on the basis of the measurements obtained by the IWG. Following an additional drilling and detailed analysis of the drill samples, work on the access shaft began in 2004; for this purpose, Herrenknecht AG developed a vertical tunnelling machine tailored to local conditions and excavated a shaft around 100 metres deep with a diameter of 2.5 metres. The tunnelling from the surface through to the cave was completed in December 2004.

Exploration of the cave system

Construction work in the cave

Pumps instead of turbines

For the construction of the dam with its integrated hydropower plant, a number of different building, material and design variations were examined. As well as focussing on functionality, safety and availability, the project participants were conscious of the fact that the technology employed for the small power plant would have to be adapted to the abilities and expertise of local technical personnel, specifically with regard to control, repairs and maintenance. For this reason, inversely operated pumps developed jointly by the IWG and KSB AG were used instead of turbines. These pumps are affordable, highly robust and easy to maintain.

Work interrupted by earthquake

Upon completion of the planning work, construction of the underground barrage began in April 2005. At the end of 2005, work ceased due to the early onset of the rainy season; shortly after construction resumed in May 2006, the region was struck by a severe earthquake measuring 6.3 on the Richter scale, the epicentre of which was just 30 kilometres from the project site. The site itself escaped relatively unscathed, but the water level rose by approx. two metres following the quake, thus rendering any further work impossible. Professional divers from Germany discovered that the increased water level was caused by fallen rubble after the downstream siphon: over 1000 cubic metres were blocking the flow cross-section at this virtually inaccessible location. At the end of 2006, German and Indonesian specialists blasted a path through the rubble – work then resumed in June 2007.

Following successful completion of the dam and installation of the first pump module, the first test of the system was performed in August 2008 amid great public interest. Based on saturation processes in the surrounding mountains, it was estimated that it would take one to two weeks to fill the man-made reservoir – in actual fact, the targeted water level of 16 metres was reached after just two days. The first filling of the reservoir was also accompanied by a test of the first pump module, during which the scientists measures a delivery rate of 20 litres per second at the end of the 100 metre vertical pipe – the results were thus in line with expectations. A further four pump modules were then installed, along with an electric system to control the plant.

In March 2010, the project partners were able to hand over the finished system to the responsible Indonesian authority, the employees of which had already received the necessary training to operate the plant. To assess the behaviour of the system in continuous operation and assist with any problems that may occur, the KIT continues to offer its support as part of the follow-up project "Integrated water resource management (IWRM) in Gunung Kidul, Java, Indonesia" (see project 1.3.05).

Project website ▶ **www.iwrm-indonesien.de**

Karlsruhe Institute of Technology (KIT)
Institute for Water and River Basin Management (IWG)
Prof. Dr.-Ing. Dr. h. c. mult. Franz Nestmann
Dr.-Ing. Peter Oberle
Dr.-Ing. Muhammad Ikhwan
Kaiserstraße 12
76131 Karlsruhe, Germany
Tel.: +49 (0) 7 21/6 08 63 88
Fax: +49 (0) 7 21/60 60 46
E-mail: peter.oberle@kit.edu
Funding reference: 02WT0424

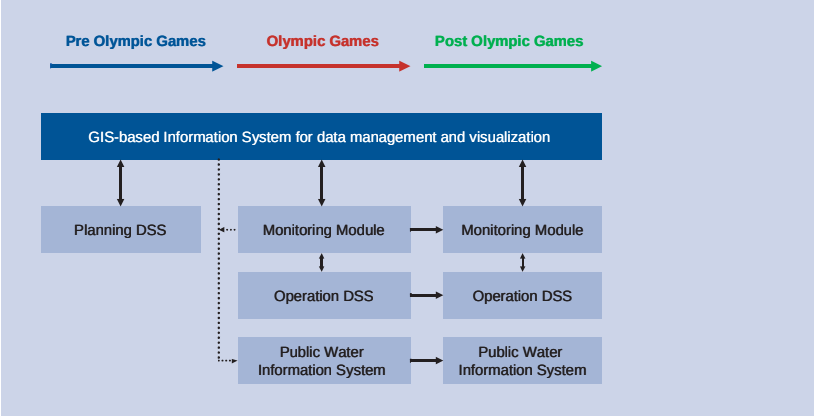
2008 Olympics in Beijing – a water use concept

Having won the honour of hosting the 2008 Olympic Summer Games, the Chinese government was anxious to improve the environmental situation in the region around the capital and host city, Beijing. A Sino-German research project was therefore tasked with devising an exemplary water concept for the 550 hectare Olympic Park constructed in the north of the metropolis. The concept was built around a large artificial lake as well as an artificial river within the park.

The environmental situation in the Beijing megalopolis is extremely challenging. In addition to air pollution, the city is also encountering problems with its water supply: water requirements are rising constantly while groundwater levels are falling by one to two metres per year and water quality is also declining. For the 2008 Olympic Games – dubbed the "Green Olympics" by the organisers – a functional and reliable water management system was required for the Olympic Park, which was home to some 18,000 athletes and officials. After the Games, the park became a green recreation area between the city and its surroundings. In addition to extensive forestation measures, an approx. 60 hectare lake was created in the north of the park. A small river was also formed in the central area of the Olympic Park. The latter was filled with water of the highest quality (reverse osmosis◄) and the lake to the north with municipal wastewater treated with microfiltration◄.

Public and private partners

The bilateral joint venture **"Development of a sustainable water concept for the Olympic Park in Beijing, 2008"** was to contribute to the sustainable management of the limited water resource for 2008 and beyond – with the additional aim of transferring findings and experiences to other regions of the country as well as different states. Funded by the Ministry of Science and Technology (MOST) of the People's Republic of China as well as the BMBF, the project involved both the University of Duisburg-Essen and the Technische Universität Berlin (TUB – Berlin Technical University) as well as a number of mid-sized companies: WASY Gesellschaft für wasserwirtschaftliche Planung und Systemforschung mbH from Berlin (now known as DHI-Wasy GmbH), Institut für angewandte Gewässerökologie GmbH, GeoTerra GmbH and the consulting firm Obermeyer from Munich. The Chinese project participants were the Tsinghua University of Beijing and the Beijing Water Authority. As well as performing a detailed appraisal of the planning basis, the project examined the use of domestic water-saving technology in the Olympic Village, modern techniques for wastewater and stormwater treatment as well as the waterway construction in the Olympic Park. One of the outcomes of the project was the creation of a decision maker's handbook for sustainable water management in cities.



OWIS – Olympic Water Information System

Among other things, the research project focussed on the selection of suitable technologies for the treatment and reuse of wastewater in the Olympic Park, particularly for the water bodies. The recycling concept involved the management of hygiene, algae and odour problems through regulated nutrient concentrations. Hygiene was ensured by means of a multi-barrier system (dual low-pressure membrane procedure◄, soil filtration), which allowed the treated water to be used as process water for toilet flushing, fountains and street cleaning.

Combined process technology

On the grounds of the Beixiaohe purification plant in the north of Beijing, water specialists from the Technische Universität Berlin worked with representatives of Tsinghua University and the Beijing Drainage Group (BDG) to construct a pilot system for all planned water recycling procedures. Combined, modern process technologies were used: membrane bioreactors (MBR), fixed beds, phosphate adsorption materials and ultrafiltration◄ with near-natural treatment processes such as artificial bank filtration. The MBRs separated the biomass and germs, thus ensuring particle-free water flow. Since orthophosphate serves as a fertiliser for algae and plants in the lake, thus potentially upsetting the ecological bal-

Part of the pilot system at the BeiXiaoHe purification plant

ance of the water, the orthophosphate was removed in an adsorptive stage. The suitability of the systems with regard to the required water quality was successfully verified during prior testing (2005). In the test lake of the purification plant, mesotrophic◄ conditions were maintained throughout, while excellent process water quality was achieved following artificial bank filtration in the test lake and subsequent processing with ultra-filtration membranes. The results from the pilot system and test lake were established during the first phase of the project (2004 – 2008). However, the recommendations of the project partners BDG and TUB were only partially implemented in the Olympic Park as the authorities only wanted to use reverse osmosis water in the central area. Here the partners had recommended a combination of bio- and ultra-filtration.

Electronic information and monitoring system

In conjunction with Tsinghua University, employees of WASY GmbH developed the "Olympic Water Information System" (OWIS) for the planners, organisers and operators of the Olympic Park. This database included new information and research results established over the course of the project as well as existing data provided by the Chinese project partners. OWIS enables continuous monitoring of the water system in the Olympic Park and features an integrated alarm module. OWIS can also be used to assess the consequences of potential decisions or events for the water system and compare different courses of action – for example, which measures would need to be taken in the case of a sudden dramatic worsening of the water quality in the Olympic lake.

Map of the Olympic Park
(source: www.strategy4.china.com)

DHI-WASY GmbH
Prof. Dr. Stefan Kaden (Managing Director)
Waltersdorfer Straße 105
12526 Berlin, Germany
Tel.: +49 (0) 30/67 99 98-0
Fax: +49 (0) 30/67 99 98-99
E-mail: s.kaden@dhi-wasy.de
Internet: www.dhi-wasy.de
Funding reference: 02WA0526

Nitrate reduction in Iran – knowledge export improves drinking water quality

Across the globe, agricultural deposition and untreated household wastewater are causing high nitrate concentrations in the groundwater. Without appropriate treatment, the resulting drinking water can be harmful to health. To reduce this risk for the inhabitants of the Iranian city Mashhad, a German-Iranian project has tested four different methods for removing nitrate from groundwater. The results will help to decide whether and with which technology drinking water treatment plants will be built in Iran in the future.

Nitrate is a nitrogen compound, low concentrations of which are naturally contained in most water sources. However, for many years now nitrate concentrations have been on the rise in numerous regions across the globe – a fact that is frequently attributed to nitrogen depositions from the agricultural sector. Groundwater is also affected by untreated household wastewater seeping into the ground. When drinking water is sourced from nitrate-containing groundwater – without sufficient treatment – the nitrate content remains in the end product. Excessive nitrate concentrations are damaging to health.

Significantly raised nitrate levels

With a population of over two million, Mashhad is Iran's second largest city and is located in an arid zone in the north-east of the country. Untreated groundwater accounts for around 85% of the city's water supply. The summer months in particular are characterised by severe water shortages. Over the past few years, the nitrate concentration in many of Mashhad's wells has risen significantly – up to values of 150 mg/l (in some cases even exceeding 250 mg/l). By way of comparison: the guide value stipulated by the World Health Organisation (WHO) is 50 milligrams of nitrate per litre of drinking water. These high values are likely to be caused by untreated domestic wastewater seeping into the ground, thus causing high nitrogen deposition in the aquifer◄. Although the wastewater situation in Mashhad has greatly improved in recent years, the nitrate concentrations in the water resources are unlikely to diminish in the short or medium term.

To supply the population with low-nitrate drinking water in the future, the Iranian Ministry of Energy and the BMBF had agreed a joint venture in 2002; the project was entitled **"Demonstration of different high-performance procedures developed in Germany for the removal of nitrate from drinking water and their adaptation to the treatment of groundwater with high concentrations of sodium nitrate and other salts using the example of drinking water purification in Mashhad, Iran"**. The parties involved in the project were the IWW Water Centre (Rheinisch-Westfälisches Institut für Wasserforschung), VA TECH Wabag Deutschland GmbH, Forschungszentrum Karlsruhe (Karlsruhe Research Centre, now part of the Karlsruhe Institute of Technology (KIT)), the WETECH – Institute for Water and Environmental Protection Technology as well as the local water supplier Mashhad Water & Wastewater.

Erection of test systems on the grounds of the well pump station in Mashhad

Combined processes

The aim of the project was the first ever parallel application of four different methods for removing nitrate from drinking water; the processes employed were ion exchange◄, reverse osmosis◄, electrodialysis◄ and biological denitrification◄. As these procedures were developed in Germany and had never been used with such heavily polluted groundwater, they needed to be adapted to the specific conditions in Iran – not least to ensure reliable nitrate removal in the face of similarly high sulphate concentrations. The test systems with throughputs of around three cubic metres per hour were constructed in Germany in modular format and installed in Mashhad in October 2004. A German-Iranian team (IWW, Mashhad

Water & Wastewater Co.) was responsible for the operation and optimisation of the systems and performed extensive scientific research between 2004 and 2007.

Upon completion of the project at the end of May 2008, it had been established that the four procedures could be successfully applied to the situation in Mashhad. All test systems worked reliably and reduced the nitrate concentrations in drinking water to levels below the WHO guidelines. However, the project partners identified significant differences between the individual procedures – e.g. with regard to the specific wastewater volume and required resources (energy, chemicals, personnel) as well as the ecological and economic consequences. These aspects were recorded for all four processes and assessed in the form of a cost/benefit analysis. Taking the situation in Iran into account (e.g. the extremely low energy prices), biological denitrification and reverse osmosis were identified as the most suitable means of achieving the targeted water quality in Mashhad. However, these findings may be different if the boundary conditions were to change (e.g. due to increased energy prices).

Transferable results

The experiences gained over the course of this project are also relevant for new water works in Mashhad and other cities in the region, since they provide an ideal basis for Iranian experts to decide whether and with which procedures future nitrate removal plants are to be built Another important outcome of this research initiative is the new contact established between German and Iranian water experts.

The project partners have already presented their findings at numerous international conferences and trade fairs as well as in international publications. The final report entitled "Demonstration of high-performance procedures developed in Germany for the removal of nitrate from drinking water in Iran" is available online via the German National Library of Science and Technology (TIB) Hanover (http://edok01.tib.uni-hannover.de/edoks/e01fb09/590090909.pdf; 7.4 MB).

Reactor for biological nitrate removal (denitrification)

IWW Water Centre (Rheinisch-Westfälisches Institut für Wasserforschung)
Water Technology division
Dr.-Ing. Stefan Panglisch
Dipl.-Ing. Oliver Dördelmann
Moritzstraße 26
45476 Mülheim an der Ruhr, Germany
Tel.: +49 (0) 2 08/4 03 03-243, -321
Fax: +49 (0) 2 08/4 03 03-82
E-mail: s.panglisch@iww-online.de
o.doerdelmann@iww-online.de
Internet: www.iww-online.de
Funding reference: 02WT0393

Sustainable water management on the Volga – safeguarding the future of Europe's longest river

At 3,500 kilometres, the Volga is Europe's longest river. Massive intervention has altered the waterway on an almost unprecedented scale – with complex consequences for man and nature in the river basin. As part of a German-Russian project, sustainable solutions were developed for the economic and ecological management of the Volga and its feeder streams. The initiative focussed on water quality, water management and the safety of hydraulic structures.

Nizhegorodskaya hydroelectric power station near Nizhny Novgorod (source: RusHydro)

The basin◄ of the Volga with its approx. 200 feeder streams is the economic and cultural centre of the Russian federation and is home to around 40% of the population. Thanks to its water and resulting energy resources, the river offers enormous economic potential, which Russia has been exploiting for decades: as early as the mid 1930s, eleven large dams were constructed on the Volga and its largest tributary stream, the Kama. These structures (collectively known as the "Volga-Kama Cascade") now generate a total output of 11 gigawatts. However, these massive interventions in the region's ecosystem have resulted in far-reaching risks and conflicts.

The minimisation of these risks was the objective of the **"Volga-Rhine project: a German-Russian joint venture for water quality and resource management on the Volga and Rhine"** (period of study: 2004 to 2006). Funded by the BMBF and the Russian Research Ministry, the project involved a number of different parties: the Institute for Water and River Basin Management (IWG), the Engler-Bunte Institute (EBI), department of Water Chemistry, and the Institute of Concrete Structures and Building Materials (IfMB) of the Karlsruhe Institute of Technology (KIT), the Institute for Environmental Geochemistry of Heidelberg University and the Soil Physics department of the Helmholtz Centre for Environmental Research (UFZ) as well as the companies Voith Siemens Hydro (Heidenheim), MC-Bauchemie (Bottrop) and RusHydro (formerly RAO EES), Russia's largest energy supplier. The project was co-ordinated by the IWG and EBI institutes of the KIT.

Precipitation and outflows analysed

Of particular significance are the statistical analyses and simulations of the precipitation/outflow behaviour in the Volga basin: how often and intensively does it rain? How does rainfall affect the natural outflow of the Volga? The relationship between precipitation and outflow is of central significance to the entire river system: only when modelled on the basis of precise data, can accurate statements be made regarding the solute transport and high-water levels of the river.

To be able to analyse the flood zones, water depths and outflow during flooding, the scientists developed digital terrain models of five important barrages on the Volga. While the Russian contributors recorded and processed the available data, their German partners simulated the hydraulic conditions of the Volga using hydrodynamic numerical models. They also developed the program "Volga decision support system" to analyse different outflow scenarios. This program enables computer-based simulation of the entire Volga system and reservoirs, thus allowing the scientists to identify the most energy-efficient and ecologically sound management strategy for each barrage. To satisfy the various usage requirements for reservoir management, fundamental principles were devised for the simulation of barrage chains including automation functions for improved management.

Structures and water quality assessed

One of the main prerequisites for economical and environmentally friendly management of the Volga is the functionality and operational safety of the existing hydraulic structures. At the Volgograd hydroelectric station, scientists and engineers examined the condition of the structure and its individual components (weir overflows and pillars, concrete walls). The results of these on-site inspections and laboratory analyses then formed the basis for a restoration concept, the implementation of which was supported by the project partners with their combined technical expertise.
Although the former Soviet Union initiated extensive efforts to control its water quality in the mid 1940s, the results have never been published. Following the dissolution of the Soviet Union, these initiatives ground to a halt

Extraction and analysis of samples in the research area

due to lacking materials and personnel. As a result, little is known about the current condition of the Russian waterways – despite the role of the Volga and other rivers as important sources of drinking water. The project thus also involved analyses of the pollutant content of Volga water and sediments. In the examined area of Nizhny Novgorod, the water quality was surprisingly good; introduced pollutants are greatly diluted by the massive water volumes transported by the river and contaminant levels reduced by self-cleaning processes.

Eutrophic reservoirs and their consequences

However, the nutrients in the water are leading to critical levels of eutrophication◄, particularly in reservoirs; this is caused by the introduction of phosphorous compounds from household wastewater (e.g. detergents) and nutrient inputs from the agricultural industry. In the summer months, this eutrophication is causing massive algae growth in reservoirs in particular; this in turn results in a reduced oxygen content of the water and the release of toxins. These effects are exacerbated by the relatively high concentrations of natural organic substances. The consequence: anaerobic◄ zones are appearing at many locations, which in turn leads to decomposition processes. Therefore, one of the main aims of the research project was to put the results to use, as a means of improving preventative measures and removing sources of pollution – for example, by practising ecological agriculture in the river basin.

Longitudinal section of the Volga and Kama barrage chain

Area 1: water resource management
Karlsruhe Institute of Technology (KIT)
Institute for Water and River Basin Management
Prof. Dr. Dr. h.c. mult. Franz Nestmann
Prof. Dr. Rolf Krohmer
Kaiserstraße 12
76128 Karlsruhe, Germany
Tel.: +49 (0) 7 21/6 08 21 94
Fax: +49 (0) 7 21/60 60 46
E-mail: iwg@iwg.uka.de
rolf.krohmer@kit.edu
Internet: www.iwg.uni-karlsruhe.de
Funding reference: 02WT0484

Area 2: water quality
Karlsruhe Institute of Technology (KIT)
Engler-Bunte Institute and DVGW Research Centre – Department of Water Chemistry
Prof. Dr. Fritz H. Frimmel
Dr. Gudrun Abbt-Braun
Engler-Bunte-Ring 1
76128 Karlsruhe, Germany
Tel.: +49 (0) 7 21/6 08 25 80
Fax: +49 (0) 7 21/69 91 54
E-mail: fritz.frimmel@kit.edu
Internet: www.wasserchemie.uni-karlsruhe.de
Funding reference: 02WT0480

Protecting the world heritage site Ha Long Bay – German expertise supports mine rehabilitation

Black coal is an important energy source in Vietnam, but mining efforts are causing significant damage to the environment. In a joint venture, technologies and experiences from the German coal mining industry are being employed to make Vietnamese mining more environmentally compatible. Scientists and engineers from both countries are working on site to determine which techniques and procedures can be adapted to local requirements.

Some 95% (45 million t/a) of Vietnam's coal extraction occurs in the Quang Ninh province in the north-east of the country. Yet the province is not only home to Vietnam's most important coal field, but also to the unique natural landscape that is the Ha Long Bay. The Bay, with its countless limestone karsts and small islands, became a UNESCO World Heritage Site in 1994 and is a very popular tourist destination. The Vietnamese government wishes to develop the tourist appeal of Ha Long and further increase the number of visitors. But the country has also massively increased its mining efforts in recent times – and thus also the level of environmental damage to the area. The lack of vegetation on spoil tips and abandoned mining areas, combined with the transport of coal to harbours and power stations in open-bed trucks, have caused a high level of dust pollution – many villages and entire stretches of land are covered in grey dust.

Mine and seepage water entering the Bay

The mine and seepage water from the spoil tips is contaminating the streams and rivers in the mining areas; it flows into the Ha Long Bay, where it endangers or damages the unique and highly sensitive coastal and marine fauna and flora. Large-scale erosion of the unvegetated mining areas exacerbates the situation by transporting carbonaceous fines into the Bay. Another problem is the lacking space for spoil tips: to save space, the tips are usually built up very steeply and in direct proximity of nearby villages; this can lead to landslides posing a significant risk to the residents.

To eliminate or at least reduce the negative consequences and risks of Vietnam's coal mining to man and nature, rehabilitation measures are urgently required. But how can German expertise in mine rehabilitation be adapted to specific Vietnamese requirements? This question is being addressed by the BMBF-funded, German-Vietnamese research programme "RAME (Research Association Mining and Environment) in Vietnam, Quang Ninh province". The project is being overseen by the Chair of Environmental Engineering and Ecology of the Ruhr University Bochum (Prof. Dr. Harro Stolpe), with a study period of 2007 to 2012. The project participants are RWTH Aachen University (Chair of Mining Engineering I), the Helmholtz Centre for Environmental Research (UFZ), CBM GmbH – Gesellschaft für Consulting, Business und Management mbH (Aachen), Brenk Systemplanung GmbH (Aachen), LMBV International GmbH, eta AG engineering (Cottbus), GFI Grundwasserforschungsinstitut GmbH (Dresden), BioPlanta GmbH (Leipzig) and DHI-WASI GmbH (Berlin). Work is being performed in close co-operation with the Vietnam National Coal-Mineral Industries Holding Cooperation Limited (VINACOMIN), which has provided the research team with an office at its Hanoi headquarters. The German partners are developing the technical concepts to be implemented by VINACOMIN at the example locations in the form of pilot projects.

Ha Long Bay is a recognised world heritage site

During the first project phase (2005 to 2007), the aim was to identify, isolate and describe the specific problems as well as to find suitable example locations to perform analyses for the adaptation of German technologies (topic: mining and the environment in Vietnam, problem analysis and solution strategies). Since 2007, the project partners have been developing concepts for selected locations: the Chinh Bac Nui Beo spoil pit (stabilisation and recultivation), the mining location Vang Danh (wastewater treatment) as well as the mining areas Dong Trieu (treatment of mining-impacted water in a passive water purification system) and Hon Gai (environmental management).

Pilot system and experiments

After establishing the ecological consequences of mining during the first phase, the project team – in collaboration with VINACOMIN – designed an adapted mine water purification system that would remove both the fine carbon particles as well as the high iron and manganese content. Extensive field experiments were conducted on the selected spoil tip, e.g. relating to the pouring technology After selection of suitable local species, plant experiments for the recultivation efforts were also introduced on this tip and are currently examined on a regular basis. Based on the data recorded for Hon Gai, an environmental information system is being implemented that will facilitate the environmental management and reporting of VINACOMIN. Furthermore, a handbook for Vietnamese environmental engineers is to be created by the end of the project on the basis of knowledge acquired from the pilot systems and various experiments.

Vietnamese experts trained

An important aspect if the project is the cultivation of contact with Vietnamese research institutes, ministries, authorities and companies. In this regard, an excellent working relationship has already been established with scientists of the Vietnam Academy of Science and Technology (VAST) and the Hanoi University of Mining and Geology (HUMG). This scientific collaboration is also paving the way for later economic co-operation between German and Vietnamese companies.
The capacity building◄ measures of the joint venture are another important aspect of the technology transfer conducted in this project. A number of one to three-week courses were held for VINACOMIN employees in Vietnam; these were taught by German mining experts and covered topics such as dust, spoil tip design and mine water. In addition, technical excursions to Germany were organised to show the decision-makers of VINACOMIN examples of mining locations with effective rehabilitation◄ and recultivation measures.

A village in front of a spoil tip in Quang Ninh

Acacia seedlings planted by VINACOMIN

Project website ► **www.vinacomin.vn**

Ruhr University Bochum
Environmental Engineering and Ecology
Prof. Dr. Harro Stolpe
Universitätsstraße 150
44780 Bochum, Germany
Tel.: +49 (0) 2 34/32-2 79 95
Fax: +49 (0) 2 34/32-1 47 01
E-mail: harro.stolpe@ruhr-uni-bochum.de
Internet: www.ruhr-uni-bochum.de/siwawi/

Research Association Mining and Environment in Vietnam (RAME)
Vietnam National Coal & Mineral Industries Group (VINACOMIN)
Dr.-Ing. Katrin Brömme (CEO)
226 Le Duan
Ha Noi, Viet Nam
Tel.: 00 84/4 35 18 83 07
Fax: 00 84/4 35 18 83 41
E-mail: katrin.broemme@rub.de
Internet: www.rame.vn

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Water quality monitoring – new measuring procedures developed

Drinking water sources require continuous monitoring of their contaminant content – a time-consuming and expensive process. Yet monitoring is particularly important in crisis regions, where there is a risk of terrorist attacks – for example, poisoning of drinking water sources. Scientists from Germany and Israel have worked together to develop new measuring procedures, which can serve as the basis for early warning systems. These processes are based on the infrared absorption spectrum◄ of substances.

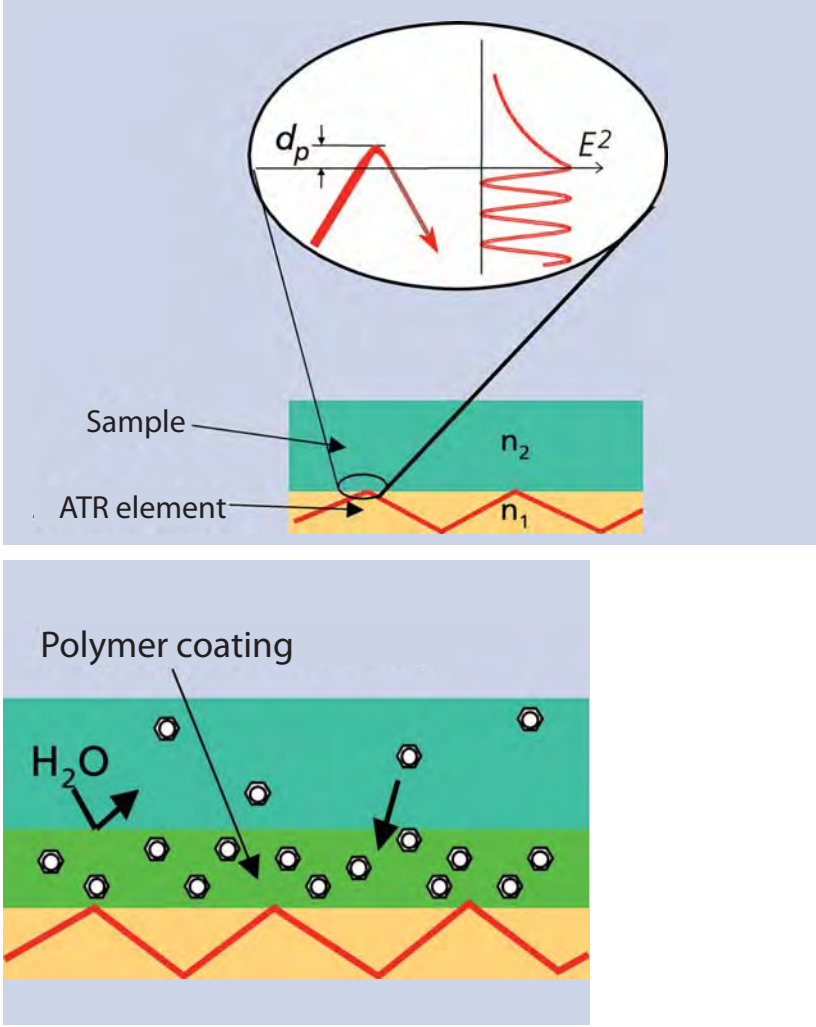
Continuous monitoring is essential to the reliable and timely detection of pollutants and contaminants in drinking water sources. In politically sensitive regions such as Israel, there is also a risk of targeted poisoning of water sources (chemo-terrorism). As a result, there is great demand for measuring procedures that can provide continuously reliable information on water quality.

German-Israeli co-operation

Previously, groundwater testing in Israel primarily took the form of laboratory analyses. The samples had to be taken from the measurement locations before being transported to the lab for processing – a time-consuming, expensive and error-prone process. Funded by the BMBF as part of the German-Israeli scientific co-operation, the project **"Compact fibre-optic infrared system for online monitoring of pesticides and other pollutants in water"** was set up to develop a measurement system that would enable continuous, reliable monitoring of the water quality in real-time and across great distances. The research was conducted by the School of Physics and Astronomy of Tel Aviv University and the Fraunhofer Institute for Physical Measurement Techniques (IPM).

Analysis of radiation spectrum

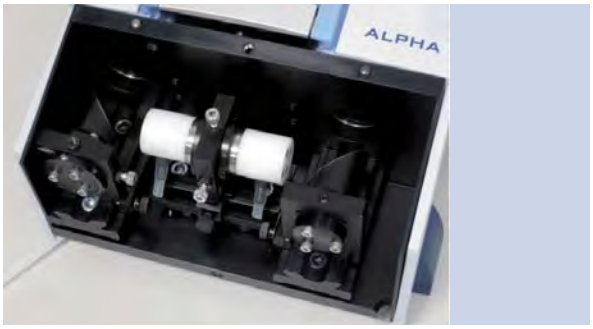
The IPM had already laid the technical foundation in the form of a wide-band spectrometer, which was originally developed to monitor landfill and seepage water online as well as to control industrial processes. The analytical device is programmed to detect different organic molecules (e.g. pesticides). The measuring process is based on the property of all substances to absorb infrared radiation in a specific spectrum. Infrared spectroscopy◄, a technical analysis method, can be used to identify substances via their infrared absorption spectrum. The researchers employed the technique of attenuated total reflectance



Schematic representation of ATR technology

(ATR) spectroscopy◄, which is based on an optical system. The analytical radiation spectrum provides information on the presence and concentration of contaminants. This enables identification of water contamination by most harmful chemicals and immediate radio transmission of the data to a central monitoring station.

The measurement system of the wide-band spectrometer consists of three modules: a light source, a sensor element and an infrared spectrometer. The radiated light of a miniaturised emitter is directed into the ATR sensor element where it passes through the measuring path and is recorded by the spectrometer. The individual substances in the water, and their concentrations, are then determined in the subsequent spectrum analysis.



An ATR measurement module for recording infrared absorption spectra (the sensor fibre is located on the cylindrical measuring cell, through which the water sample flows via the two water connections.)

Detection of minimal contaminant concentrations

ATR technology is based on the fact that the field of a light wave passing through a transparent medium partially extends into the surrounding medium. This so-called evanescent field is ideal for performing absorption measurements. A sensitive fibre serves as the sensor: when it is coated with a suitable polymer, the targeted molecule is enriched, thus amplifying the measured signal up to a thousandfold. The water-resistant polymer also offers protection against water, which would otherwise greatly interfere with the measurement. A movable grid allows the spectrometer to measure wavelengths between 8 and 12.5 micrometres. Other wavelength bands can be analysed by replacing the grid. Absorption measurements in the mid-infrared range enable detection of organic molecules with concentrations of less than 1 ppm◄.

Two measurement systems developed

Over the course of the project, which started in 2003 and was concluded in June 2006, the German-Israeli team developed two different measurement systems based on ATR technology: a large device with higher sensitivity – but which was also more expensive and not suitable for field use – as well as a handy and more cost-effective model with lower detection sensitivity. In a follow-up project, advances in the miniaturisation of commercial Fourier transform infrared (FTIR) spectrometers was utilised to create a measurement system offering virtually the same detection sensitivity as the expensive counterpart (see photo). These projects have formed the basis for the development of compact, reliable and user-friendly measurement systems. The devices have been subjected to initial field tests and are at a high stage of development. Additional field use in Germany and Israel is planned.

Fraunhofer Institute for Physical Measurement Techniques (IPM)
Dr. Werner Konz
Heidenhofstraße 8
79110 Freiburg, Germany
Tel.: +49 (0) 7 61/88 57-2 89
Fax: +49 (0) 7 61/88 57-2 24
E-mail: werner.konz@ipm.fraunhofer.de
Internet: www.ipm.fraunhofer.de
Funding reference: 02WU0268

Tel Aviv University
School of Physics and Astronomy
Prof. Abraham Katzir
Ramat Aviv
PO Box 39040
69978 Tel Aviv, Israel
Tel.: 00 97 23/6 40 83 01
Fax: 00 97 23/6 41 58 50
E-mail: katzir@post.tau.ac.il
Internet: www.tau.ac.il
Funding reference: FZK0201

The rainmakers of Israel – cloud seeding increases rainfall

Despite many years of research across the globe, attempts to increase rainfall in arid regions through human intervention have enjoyed little success. However, significant progress has now been made in a joint research venture between German and Israeli scientists: their simulations show that precipitation increases when clouds are seeded with suitable minute particles.

Israel is one of the world's driest countries, yet water is a key economic factor for the state: Israel has a highly productive agricultural industry and exports both fruit and vegetables. Around 70% of the fresh water consumed by the country is used for agricultural irrigation, but high water requirements have caused a continuing decline of groundwater levels. The river Jordan is gradually being reduced to a trickle since 85% of its water is used to supply the population and agricultural areas. This in turn has had a direct impact on the water level of the Dead Sea (into which the Jordan empties), which has fallen by more than 20 metres over the last 70 years – a trend that is showing no sign of abating.

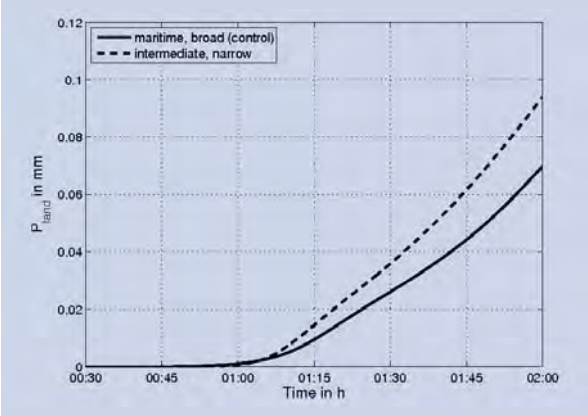
German-Israeli water technology co-operation

Israel – and the rest of the Eastern Mediterranean – would benefit greatly from increased rainfall, and this is exactly what scientists are working on. Supported by the BMBF, the Institute of Earth Sciences of the Hebrew University in Jerusalem and the Institute of Meteorology and Climate Research (IMK) of the Karlsruhe Institute of Technology (KIT) have given the "rainmakers" a significant boost in the form of their joint research project entitled **"Numerical investigations on the effect of aerosol particles on the precipitation dynamics of clouds in the Israeli coastal region"** (period of study: 2004 to 2008), which was conducted as part of the German-Israeli water technology co-operation. Computer-simulated calculations have shown that artificial "cloud seeding" off the Israeli coast delays rainfall such that inland precipitation is increased in the event of a westerly wind. Optimum results are achieved when (sea/table) salt particles of a specific size are dispersed into the clouds.

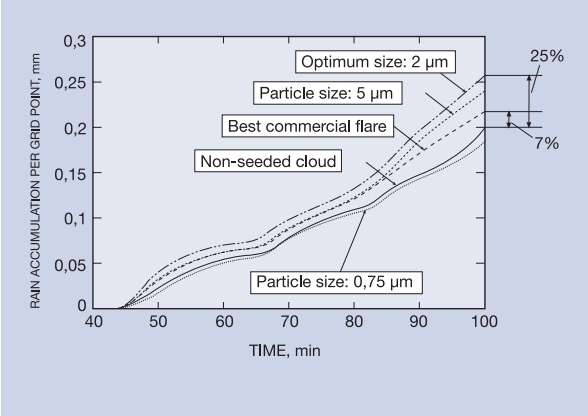
The focus of the project was on aerosol particles◄. These tiny suspended particles are everywhere in the air and are required for the formation of cloud droplets and the production of rain: when air is oversaturated with water vapour, the aerosol particles act as condensation nuclei to which the water vapour attaches, thus creating drops. The number and size of the drops depends on the composition of the condensation nuclei. For example, the air in coastal areas contains few but very large salt particles – large drops thus form in the clouds in small numbers. The air over the mainland, on the other hand, contains many aerosol particles and the cloud droplets are relatively small.

Satellite image of the region (source: visibleearth.nasa.gov)

The project team discovered that manually released aerosols also have a significant influence on the temporal development, spatial distribution and volume of the resulting precipitation. For may years, researchers have been observing a decline in the rainfall over the Judean Highlands. Their calculations suggest that this development can be attributed to an increase in man-made suspended particles (e.g. soot, dust).



Calculated temporal development of total inland rainfall after seeding with hygroscopic particles. Solid line: control calculation without seeding; dashed line: simulation with seeding using medium-sized particles



Calculated temporal development of total rainfall with seeding of deep convective clouds using hygroscopic particles of optimum size

Simulation models employed

To determine the impact of the aerosol effect on precipitation formation, the scientists utilised two different numerical simulation models: the complex computer model "Spectral Bin Cloud Microphysical Module" (SBM) of the Hebrew University and the enhanced program "Two-Moment Parameterization" (TMP) of the Karlsruhe IMK. The latter represents a rough (yet still sufficiently accurate) means of reducing the overall computing time. The German-Israeli team started by testing the ability of the two models to predict natural weather processes – both functioned very well and provided similar results. They then calculated means of actively influencing rainfall. The results showed that artificial seeding of the clouds forming off the coast successfully delays the formation of precipitation. The rate of rain development is slowed and the clouds blown east by the westerly wind then rain over the mainland, generally near the coast (though sometimes up to 50 km inland).

Particle size decisive

The size of the particles is of central importance to the precipitation development. Large hygroscopic particles◄ accelerate the formation of rain, while smaller particles slow the development and often reduce the volume. The scientists used computer simulations to establish the particle size that would most effectively raise the level of rainfall achieved with cloud seeding: the optimum size – depending on cloud height and other meteorological parameters – is between 1.8 and 2.5 micrometres. Using hygroscopic particles of this size, the inland precipitation volume can be increased by 20 to 25%, while overall rainfall is marginally reduced.

To compare the model calculations with the actual natural effects of cloud seeding, a number of practical tests were performed in Israel, whereby aircraft were used to disperse salt particles of the calculated optimum size into the clouds; the observed results largely matched the theoretical calculations.

Karlsruhe Institute of Technology (KIT)
Institute of Meteorology and Climate Research (IMK)
Prof. Dr. Klaus Dieter Beheng
Kaiserstraße 12
76128 Karlsruhe, Germany
Tel.: +49 (0) 7 21/6 08-4 35 95
Fax: +49 (0) 7 21/6 08-4 61 02
E-mail: klaus.beheng@kit.edu
Internet: www.imk-tro.kit.edu
Funding reference: 02WT0536

Four methods, one goal – wastewater disinfection in China

A comparison of disinfection procedures in the effluent discharge of Chinese wastewater treatment plants has highlighted the existence of alternatives to conventional chlorination. As part of a joint research project funded by the BMBF, the IWAR institute of the Technische Universität Darmstadt (Darmstadt Technical University) tested four different procedures in conjunction with the Tongji University in Shanghai (period of study: August 2006 – March 2011).

The many hygienically relevant micro-organisms (viruses, bacteria, protozoa, worm eggs) present in the wastewater – even after biological cleaning – necessitate adequate purification of the water before it can be introduced to sensitive surface waters (especially prior to reuse). While wastewater disinfection is a legal requirement in the People's Republic of China, this process is frequently omitted for cost and operating safety reasons (Xin, 2004).

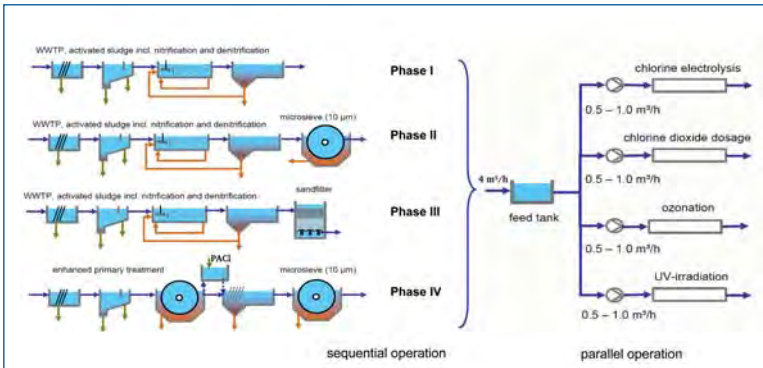
An alternative to conventional disinfection methods is required for a number of reasons. The most common procedure, chlorination, is generally accompanied by the formation of unwanted disinfection by-products. Other disadvantages of chlorine and its compounds are the ever-present concerns regarding operating safety and the limited effectiveness against chlorine-resistant organisms. Therefore, the aims of the joint research project are to:

- Improve the hygienic water quality in the effluent of municipal treatment plants to protect against waterborne diseases
- Provide a scientifically verified contribution to the issue of cost-effective application of effective, innovative wastewater disinfection processes
- Avoid new risks by minimising the formation of disinfection by-products

Employed methods

Relevant factors influencing the choice of disinfection method include effectiveness, operational safety, investment and operating costs, practicality (transport, storage, production etc.) and the creation of unwanted by-products. Having been selected during a pre-project literature study, the processes tested over the course of the project were as follows:

UV radiation: UV rays with a wavelength of 245 – 265 nanometres alter the nucleic acid in the cell nucleus, thus resulting in the irreversible loss of the cell's multiplication



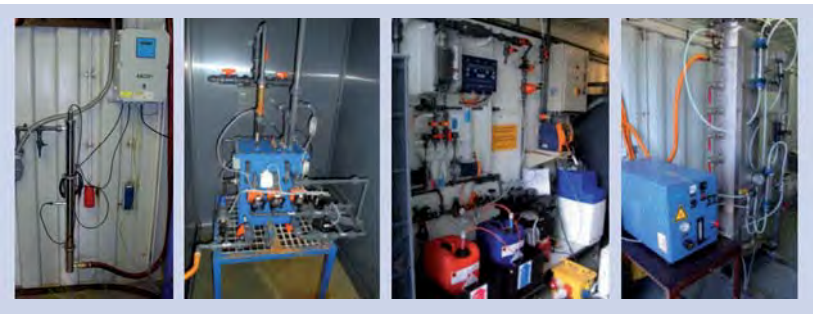
Pilot disinfection systems (right) with various wastewater treatment stages (left); intake = untreated communal wastewater

capacity and subsequent inactivation of the cell when its regenerative ability is exceeded. No addition of disinfectants remaining in the water occurs with this disinfection method. As a result, negative environmental and health impacts can be largely eliminated, though a potential depot effect in the discharge water is also excluded. The UV system features two replaceable UV lamps with outputs of 80 and 120 watt. The desired radiation dose can be set via a control unit (from 80 – 800 J/m).

Electrochlorination: The electrochlorination system produces gaseous chlorine (Cl) and other electrochemical oxidants from table salt, water and electric current on site, thus eliminating the transport and storage of chlorine (gas). Chlorine causes the oxidative destruction of the cell wall of micro-organisms. The maximum dosage is 20 mg Cl_2/l.

Chlorine dioxide: The disinfectant properties of chlorine dioxide can be mainly attributed to its high oxidation potential (approx. 2.5 times higher than that of chlorine gas). When wastewater is disinfected with chlorine dioxide rather than chlorine (gas), the potential for formation of ecologically damaging compounds is lower, since no trihalomethanes (THM), chlorophenols or reaction products with ammonium and amino compounds are produced. The dosage of chlorine dioxide is between 1 and 20 mg ClO_2/l. Chlorine dioxide (ClO_2) is created on site from hydrochloric acid and sodium chlorite by means of the chlorite/acid process.

Ozone: Ozone (O_3) is one of the most effective disinfectants. Ozone attacks the cell membrane directly or permeates the wall to enter the cell interior, where it attacks the DNA, RNA or other cell components, this inactivating the



Pilot system for wastewater disinfection (from left): UV radiation, electrochlorination, chlorine dioxide, ozone

cell. Wastewater ozonation can also be used to remove pharmaceutical residues, endocrine disruptors as well as odourants and colourants (Schuhmacher, 2006). Ozone generators are used to create ozone on site by means of electrical discharges from industrially produced oxygen. Ozone dosage varies between 2 and 20 mg O_3/l.

All of the above procedures (with the exception of ozonation, which was only tested in Germany) were operated and examined over the course of the project using identical semi-industrial test systems at a communal treatment plant in Darmstadt-Eberstadt and in Shanghai.

In addition to the choice of disinfection process, the manner in which the water is pre-treated is also of decisive importance – both with regard to the success of disinfection and the potential for by-product formation. In many cases, the overall performance of a disinfection system and the potential health risks are greatly determined by the shadowing and inclusion of micro-organisms in wastewater particles. In this project, disinfection capacity was assessed by using standard methods for microbiological cultivation to quantify the indicator organisms E. coli, total coliforms, enterococci and somatic coliphages.

Achieved results

Both micro-screening and sand filtration can reduce COD concentrations◄ by around 30%, UV absorption (at 254 nm) by approx. 10% and turbidity by some 80%. During test phases I to III (see figure), all four disinfection processes were able to reduce the level of indicator organisms below the detection threshold or by up to four orders of magnitude (Bischoff, 2009). An increased toxicity◄ of the wastewater, measured as the effect on the luminescence of Vibrio fischeri organisms, was not significant in this case (order of toxicity rise: Cl_2>O_3>ClO_2; UV radiation: no increase).

In addition to the disinfectant dosage and the organic substances contained in the wastewater, the water temperature was also found to have a significant impact on the success of the disinfection process. Phase IV was terminated after four weeks, as stable operation of the disinfection system was rendered impossible after two weeks by the increasing biofilm growth◄. As a result, a critical assessment was made of wastewater disinfection procedures in which no biological treatment methods are employed. Depending on the employed dosage, the examined disinfection methods with prior biological wastewater treatment◄ produced environmentally sound water that could be introduced even to sensitive surface waters and is perfectly suitable for a range of reuse scenarios. A more detailed assessment of the test results can be found in the final project report.

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Technische Universität Darmstadt
IWAR Institute
Department of Wastewater Technology
Prof. Prof. Martin Wagner
M.Sc. Astrid Bischoff
Petersenstraße 13
64287 Darmstadt, Germany
Tel.: +49 (0) 61 51/16-37 59
Fax: +49 (0) 61 51/16–37 58
E-mail: m.wagner@iwar.tu-darmstadt.de
a.bischoff@iwar.tu-darmstadt.de
Internet: www.iwar.bauing.tu-darmstadt.de
Funding reference: 02WA0764

An accessible version of the article is available at
http://waterresources.fona.de/reports/bmbf/annual/2010/nb/English/50/3_-economy-and-education.html

Economy and education

In this country, clean drinking water and functioning wastewater disposal are a matter of course. Thanks to tailored and professional management, costs can be regulated effectively and reduced if necessary. As well as contributing to the optimisation of domestic concepts, the BMBF intensively supports the transfer of knowledge and expertise in emerging and developing countries across the globe; the aim is to train skilled personnel and educate them in the environmentally sustainable handling of the resource water.

Communal water and waste management – escaping the cost trap with sustainable concepts

Nowadays, costs for drinking water, wastewater disposal and refuse collection account for the majority of our ancillary living costs. Responsible utility companies are already looking for ways to minimise customer expenses and raise the efficiency of their own operations while maintaining highest quality levels. Supported by the Federal Ministry of Education and Research (BMBF), a number of pilot projects have shown that adaptive management and optimised instruments, such as performance indicators and benchmarking, enable the implementation of efficient and sustainable supply and disposal processes. In this context, even the smallest of measures can have a big impact.

In Germany, clean drinking water and a functioning wastewater and waste disposal system are a matter of course. Yet in the face of high investments in system maintenance and expansion, many communities and their public or private utility companies are under great economic pressure. As a result, cost-effective management is becoming ever more important.

Cost and fee debate intensifying

To provide consumers with safe and reliable supply and disposal services, the German water and waste industry has spent the last decades investing heavily into the expansion and modernisation of plants, sewers and water supply networks. This expenditure must pay off in the long term, yet the sector is constantly called upon to tackle new requirements: the cost and fee debate is intensifying, while demographic and structural changes are necessitating expensive alterations of the supply and disposal system in some regions. All the while, consumers are demanding affordable costs and fees – without suffering a drop in quality levels.

Practicable instruments

In order to meet these requirements, sustainable planning and actions are required on the part of the waste and water sector; it is essential that optimised solutions are found on the basis of social, ecological and economic aspects. To develop practicable concepts, the various research disciplines must work closely together and seek the input of other experts. Transdisciplinary work is very much the name of the game.

The dialogue between representatives from the worlds of politics, economy, society and research must be intensified in an effort to co-create suitable instruments for practical application. These should allow the utility companies to better assess the consequences of their actions in the context of sustainability and develop appropriate strategies on this basis. Tried and tested measures from other sectors must be adapted such that they can be applied to water and waste management (projects 3.1.01 and 3.1.02).

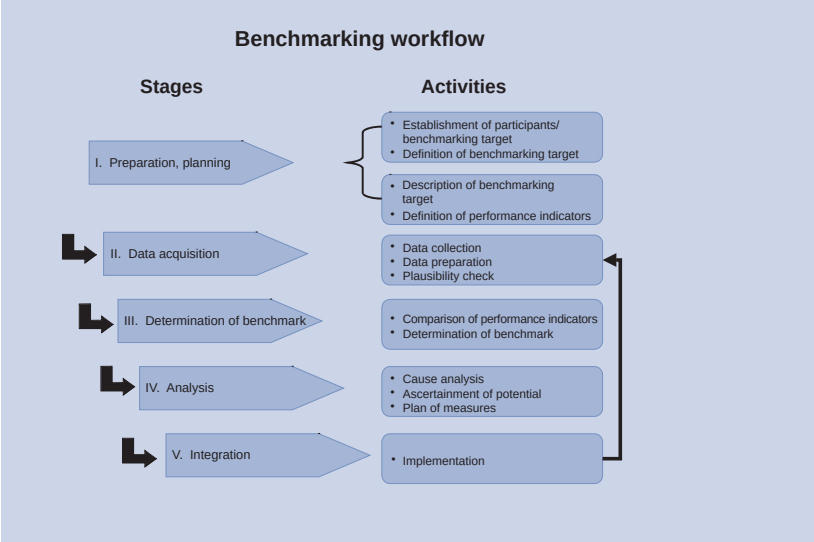
Professional management delivers cost benefits

The transdisciplinary projects funded by the BMBF have shown that professional management raises the efficiency of operations and thus also reduces the financial impact on consumers. A range of measures are available to utility companies in this regard: business tools such as integrated management systems (IMS), effective control of processes via performance indicators, systematic, cross-company comparison of processes in the form of benchmarking and application of resource-friendly technologies and procedures.

In many cases, even small changes, such as more flexible working time models, can lead to significant savings – and not just in the field of water management: instruments such as benchmarking or effective controlling also allow waste disposal companies to improve their performance (project 3.1.03).

Learning from the best – benchmarking in the field of wastewater disposal

In 2002, the German Bundestag initiated a modernisation strategy for the German water industry in the form of its resolution "Sustainable water management in Germany". This also includes the development of modern procedures for comparing the performance of different operations (benchmarking). In its corresponding project, the water board Emschergenossenschaft/Lippeverband (EG/LV) – in conjunction with its partners Aggerverband, RINKE Unternehmensberatung and the Universität der Bundeswehr München (Bundeswehr University Munich) – adapted this method to the field of wastewater treatment and devised strategies for its application in other areas of the water industry. The project thus became a building block of the modernisation strategy and set the tone for the successful development of the benchmarking instrument.



Benchmarking workflow

The boundary conditions for the water economy have changed significantly: demands for efficiency have risen and fees are now only accepted if the underlying costs are sufficiently transparent. To be able to perform their duties in a reliable and economical manner, companies must devise methods for efficient wastewater disposal without losing sight of other important requirements. Launched by EG/LV in 1999, the aim of the project "**Benchmarking in wastewater disposal on the basis of techno-economic indicator systems**" was to improve the operational processes in sewage plants. Since benchmarking was an entirely new concept in the water industry at the time, its implementation required a significant amount of development work. One particular challenge facing the project partners was to ensure the comparability of the various technical solutions and their costs despite the differing boundary conditions. This required the development of standardised assessment criteria. The partners compared over 100 sewage plants with population equivalents (PE)◄ of 420 to 2,400,000. The project consisted of four parts:

1. Application of the methodology to all plants

The results of a precursor project concerning the benchmarking of sewage plants with a PE of 10,000 to 100,000 were applied to all EG/LV and Aggerverband plants. The experts defined the technical and economic parameters to be determined, collected the data, calculated the performance indicators, analysed the reasons for deviations from the optimum values and identified improvement measures. To compare the "wastewater treatment" process across multiple plants, six sub-processes were examined: mechanical, biological and advanced purification, sludge stabilisation, sludge recycling and disposal as well as miscellaneous facilities (e.g. external plants, labs and workshops).

2. Creation of strategies for the inclusion of other operators

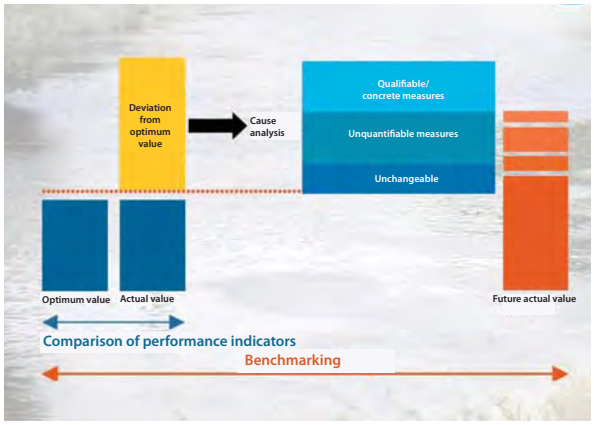
The experts also succeeded in including other operators of treatment plants with different databases in the benchmarking process. The parameters were adjusted according to the requirements of small and medium-sized enterprises.

3. Generation of techno-economic assessment criteria for planning

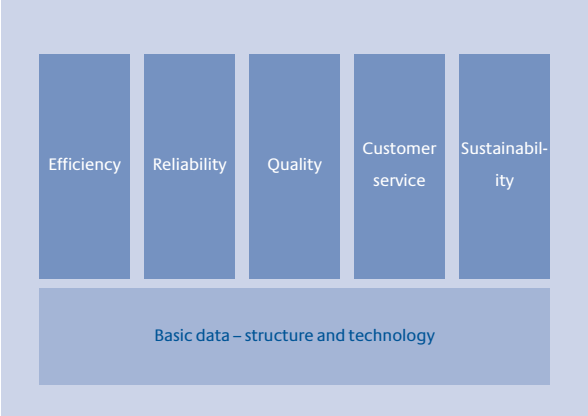
The benchmarking not only relates to plant operation but also to planning. EG/LV has documented the investment costs for all its plants, sub-divided into the cost types structural engineering and mechanical/electrical engineering. Based on the established data, the experts are able to assess the economic efficiency of structural solutions and process combinations in terms of investment costs and operational expenditure.

4. Development of the methodology for other areas of wastewater disposal

The project partners also applied the benchmarking process to other areas, such as wastewater discharge. For this purpose, they created survey forms, which were tested



Benchmarking methods and core elements



Criteria for assessing the performance of a water management company

with other local authorities along with the system itself. The benchmarking of rain overflow basins and pump stations of the sewage network was also examined.

Practical benefits

The venture succeeded in establishing a solid foundation for benchmarking in the water industry. The method is now used throughout the world and is helping to reduce annual operating costs by 3 to 12%. Furthermore, sewage plants of all sizes can be compared using a techno-economic indicator grid. Since the performance indicator system presents all wastewater disposal sub-processes in a uniform manner, comparisons of individual process steps are also possible. Targeted improvements can thus be made on a structural and selective basis.

The experts enhanced the system to be able to implement the requirements of the EU Water Framework Directive◄. The results of the project served as the basis for the benchmarking organisation aquabench GmbH, which is made up of Emscher Wassertechnik GmbH and Aggerwasser GmbH, the cities of Hamburg, Bremen, Dresden, Zurich, Cologne, Düsseldorf, Munich and Berlin – or their corresponding water companies – as well as the consulting firm on.valco. aquabench provides online access to a wide range of benchmarking products, which relate to different processes and enable comparisons at company level.

The experts continuously presented the results of their research project and experiences gained from follow-up projects to the relevant trade associations. A uniform, quality-assured process is supported by a leaflet and guidelines published by the German Association for Water, Wastewater and Waste (DWA) and the German Technical and Scientific Association for Gas and Water (DVGW) as well as an example indicator system of the DWA. Since 2005, the associations have also been informing politicians, the public and companies about the industry's performance via their "Profile of the German water sector". Benchmarking projects are now conducted and corresponding reports published in virtually all German states (e.g. www.abwasserbenchmarking-nrw.de).

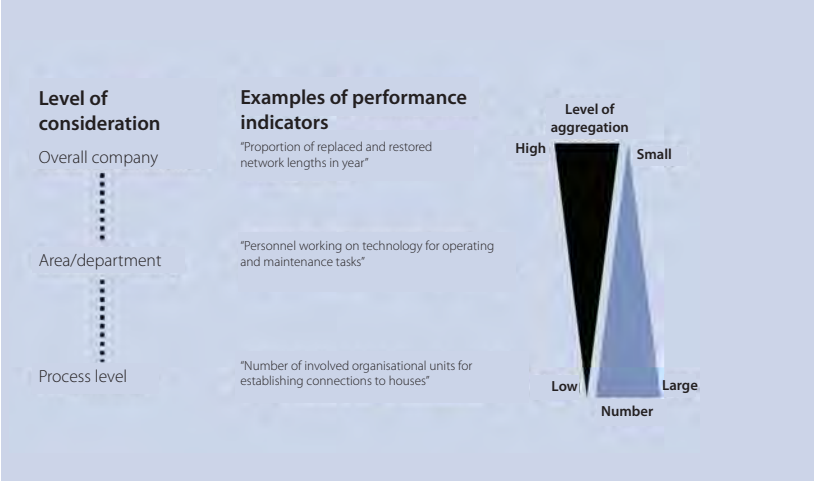
The aim is to continue the proliferation of benchmarking and to establish an international performance indicator basis to enable comparisons between different projects. In accordance with the Water Framework Directive, means of extending the observation period beyond company boundaries must also be examined. An initial investigation of this subject was performed by EG/LV, aquabench, the Universität der Bundeswehr München (Bundeswehr University Munich) and the University of Duisburg-Essen in their pilot project "Benchmarking the management of river basins◄".

Project website ► **www.aquabench.de**

Emschergenossenschaft and Lippeverband
Prof. Dr.-Ing. Andreas Schulz
Kronprinzenstraße 24
45128 Essen, Germany
Tel.: +49 (0) 2 01/10 4-27 23
Fax: +49 (0) 2 01/10 4-27 86
E-mail: schulz.andreas@eglv.de
Internet: www.emschergenossenschaft.de
Funding reference: 02WI9913/9

Peak performance indicators – professional management in the water industry

Quality, supply reliability, customer service, sustainability and efficiency are important target variables in the water supply sector. To raise its effectiveness in these key areas, the water industry is increasingly relying on performance indicators – a business tool that is already used successfully in industrial applications. The IWW Water Centre (Rheinisch-Westfälisches Institut für Wasserforschung) has developed a performance indicator system that has now become the industry standard. It is based on a model of the International Water Association (IWA) and supports the process analysis of water production and examination of sustainability aspects of the water supply.



From highly aggregated performance indicators for assessing the overall company to detailed process indicators

To exploit all means of cost reduction and identify any optimisation potential, the companies of the water industry require a suitable database. More and more of these operations are therefore employing indicator systems, since they supply reliable information to act as a basis for business decisions but can also be used for benchmarking purposes – i.e. comparisons with other companies in the sector. Company management can thus monitor the development of their operation, establish in what areas it performs better than the competition and identify where a need for improvement exists.

The aim of the project **"Performance indicators for water supply services: Field test of the IWA performance indicator system"**, which was conducted by the IWW and funded by the BMBF, was to create and test an indicator system for the German water industry on the basis of international standards. 14 operations joined the project group and agreed to test and develop the system over the course of three survey periods.

Performance indicator system of the IWA

The IWA indicator system has eight key characteristics:

- The system contains all tasks of a water supplier, organised into the areas of technology and administration.
- The hierarchical structure of the system enables interlinking of all performance indicators – from main tasks, subtasks and individual tasks to specific processes, with an increasing level of detail.
- All terms, derivations and data structures (e.g. financial structure) are uniquely defined.
- In the data model, all entered information is evaluated as to its reliability and accuracy.
- Depending on the user group (e.g. companies, authorities, trade associations, banks) the performance indicator system and the weighting of the indicators can be flexibly adapted to different requirements.
- The system is designed for electronic data processing – a mandatory requirement for the continuous use of performance indicators as a management tool. Companies will find the process much easier if they collect data variables before calculating and evaluating the performance indicator results.
- To support the persons responsible for the operations in interpreting the indicator results, the German IWA manual provides context information relating to corporate structures (e.g. size, legal form, management systems), supply systems (e.g. protected areas, wells, water works, pipeline data) and supply areas (e.g. topography◄, soil condition).
- A total of 55 performance indicators and 19 context information items are assigned to the five main features of the drinking water supply – reliability, quality and sustainability of the supply, customer service and efficiency.

Multiple benefits

Continuous indicator analyses and comparisons are not only an excellent means of identifying and eliminating weaknesses in a company. Based on the experiences of the operations involved in the project, the system also offers a range of additional benefits:

- The system necessitates the creation and maintenance of a structured data model that reflects the conditions within the company.
- The tasks, workflows and results for all performance features become more transparent.
- The system enables the conclusion of target-oriented agreements with the responsible company divisions, which promotes cost awareness and efficiency in the maintenance of quality and reliability.
- The decision-makers are better able to assess where co-operation with external partners (e.g. utility companies, service providers) would be beneficial, since they may be able to deliver a specific service in a more efficient manner.
- Delivered services and rectified deficiencies can be made transparent to the public.

Practical and successful

The practical and internationally compatible IWW performance indicator system, with its specific enhancements, has since been widely accepted in practice and has become the industry standard for German water supply services. More than 500 water supply companies throughout the German-speaking region have used the system in numerous benchmarking projects.
Based on this wide-spread application, the IWA system

Pipes and fittings in a water works (filter outlet and flush water distribution)

Well chamber and turbine in a water works

became the focus of a joint follow-up project entitled "Sustainability of water services" conducted by the IWW, the Institute for Social-Ecological Research (ISOE) and the Regional Planning and Environmental Research Group (ARSU). In the context of a detailed efficiency and performance analysis of the operational processes employed in water production, the project also served as the starting point for a joint research venture between the IWW and the Technische Universität Hamburg-Harburg (Hamburg University of Technology) entitled "Development and practical test of process indicators for the management, supply and treatment of water".

The project gave rise to the following publication, among others: "Kennzahlen für Benchmarking in der Wasserversorgung. Handbuch zur erweiterten deutschen Fassung des IWA-Kennzahlensystems mit Definitionen, Erklärungsfaktoren und Interpretationshilfen" [Performance indicators for benchmarking water supply services. Handbook for the extended German version of the IWA performance indicator system with definitions, explanatory factors and interpretation aids] (wvgw Wirtschafts- und Verlagsgesellschaft Gas und Wasser mbH, Bonn 2005 – ISBN 3-89554-152-4)

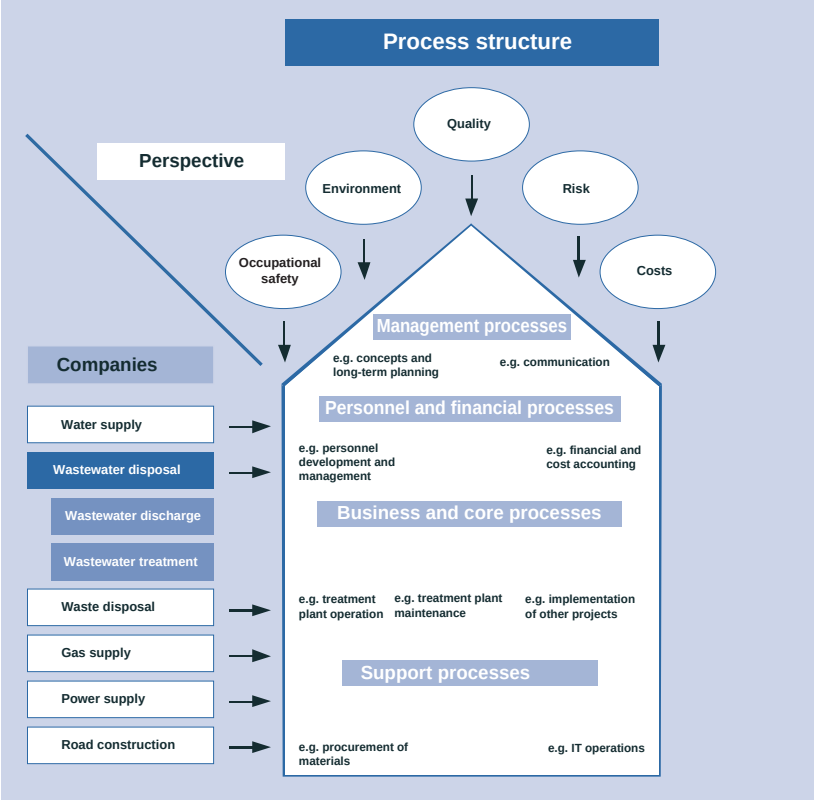
IWW Rheinisch-Westfälisches Institut für Wasserforschung gGmbH
Dr.-Ing. Wolf Merkel
Chief Technical Officer
Moritzstr. 26
45476 Mülheim an der Ruhr, Germany
Tel.: +49 (0) 2 08/4 03 03-0
Fax: +49 (0) 2 08/4 03 03-80
E-mail: info@iww-online.de
Internet: www.iww-online.de
Funding reference: 02WT0224

Waste disposal and city cleaning – continuous optimisation of public utility companies

As well as extremely high requirements, municipal waste management companies now face constantly changing legal provisions and regulations. In addition to the ever-present economic demands, the companies have found themselves under increasing environmental pressure in recent years. They must comply with strict environmental regulations and ensure separate collection, recycling and disposal of all waste. The responsible managers are now being called upon to increase both the productiveness and cost-effectiveness of their operations while continuing to tackle these sometimes very complex tasks. In a joint research project, representatives from 19 such companies have worked with experts to analyse possible means of implementing more efficient waste management and city cleaning, assess the feasibility of these approaches and devise corresponding recommendations.

The project was started in 1999 as a result of an ideas competition held by the BMBF to reduce costs in public waste disposal. The aim of the venture **"Cost reduction in public waste disposal and city cleaning"** was to establish some basic recommendations. The project participants included representatives from waste management companies located in German cities and communities of varying sizes. These organisations embodied a number of different business types – ranging from government- and owner-operated companies to mixed enterprises and public limited liability companies. The project was co-ordinated by INFA GmbH (Ahlen), with technical support provided by the Institut für Umweltökonomie (IfU, Mainz), uve GmbH (Berlin) and intecus GmbH (Dresden). Five working groups were set up and each tasked with identifying cost reduction potential in one of the following areas: waste logistics, street cleaning, depots and workshops, cost accounting and efficiency management as well as organisation and administration.

The first step was to perform a survey of selected operations, during which the experts recorded important performance data. They worked with the companies to examine new organisational forms, methods and techniques with the potential to raise operating efficiency. Based on experiences gained during this process, the project team devised a target concept, performed target/actual comparisons and determined performance indicators. The five working groups identified savings potential in all five areas, which in some cases was quite considerable. They also found that these savings could be successfully applied to other operations in the sector.



Corporate process structures (from: DWA-M 801, "Integrated quality and environmental management system for operators of wastewater facilities", April 2005)

Waste logistics

In the area of waste logistics, a range of possibilities were examined with regard to their potential cost savings and practicability. These included the collection and vehicle systems, collection intervals, type and scope of separate collections, the route planning and software used for this purpose, personnel and vehicle deployment planning, internal procedures, business information systems and new working time models. The project team identified significant savings potential. Depending on local circumstances, examples included intelligently controlled vehicle and personnel deployment using route planning software, adapted collection intervals, the separation of waste collection and transport using swap bodies, more flexible working time models, the use of an improved documentation and management information system as an effective controlling instrument and more intensive personnel training. In the area of waste logistics, many companies had already achieved a high level of efficiency before the project was launched, but were still able to reduce costs by 5 to 20% as a result of the joint venture.

Street cleaning

Significant savings potential – of 5 to 15% – also exists in the area of street cleaning. The corresponding measures are frequently employed to raise the quality of street cleaning, since the image of a clean city has become increasingly important in recent times. Examples of these measures are an improved and requirement-based deployment of vehicles, longer and more effective cleaning times as well as close co-operation of manual and mechanical cleaning systems. The introduction of group systems, optimised route planning and the supportive use of small sweepers can also help to reduce costs.

Depots and workshops

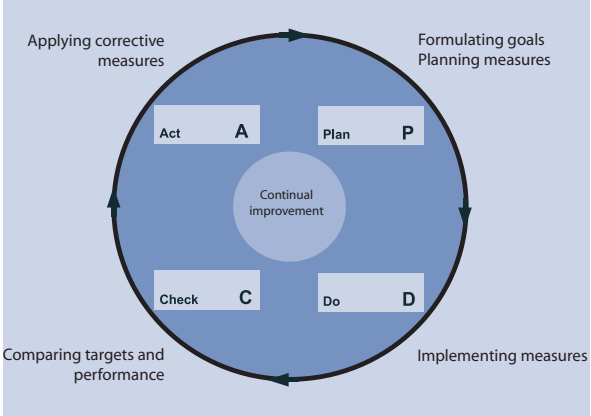
The members of this working group investigated six workshops dealing with refuse and street cleaning vehicles to assess their workshop configuration, order acceptance process, operational workflows, working hours and co-operation as well as the areas of planning, software and controlling. Among other things, they found that fewer interfaces between the computer programs for time recording, workshop order management, invoicing and payroll accounting would enable significant time and cost savings. A functioning controlling system proved to be particularly significant with regard to business decision-making.

Cost accounting and efficiency

To allow operations to work more efficiently, this working group developed a controlling system with integrated reporting. It allows employees to gather, prepare and present information in a manner that facilitates management decisions. For this purpose, the company must know, record and systemise its various services. The project participants therefore created service catalogues for their individual operations. These can be combined with the basic cost accounting and reporting pyramid to form an integrated management system.

Organisation and administration

Administrative employees should be able to focus on their core activities. Therefore, the experts of the working group for "organisation and administration" recommend that a service centre and administrative office be set up, individual service areas reorganised and procurement centralised; this should be done in line with the size of the operation and on the basis of local conditions. One public waste disposal company was given advice and how to improve its call centre, while the working group supported another operation with the implementation of suitable fleet and workshop management software. Notes on more efficient waste management can be found in DStGB document no. 58 "Handlungsempfehlung zur Kostensenkung in der kommunalen Abfallentsorgung" [Recommendations for reducing costs in municipal waste disposal] (published in 2006), while the efficiency of street cleaning is addressed in DStGB document no. 67 "Handlungsempfehlung zur Optimierung der kommunalen Straßenreinigung" [Recommendations for optimising municipal street cleaning] (published in 2007). DStGB document no. 58 appeared in the supplement of the German Association of Towns and Municipalities (DStGB) "Stadt und Gemeinde INTERAKTIV", issue 4/2006 (http://www.dstgb.de/dstgb/DStGB-Dokumentationen/).



PDCA cycle (from: DWA-M 801, April 2005)

INFA – Institut für Abfall, Abwasser und Infrastruktur-Management GmbH
Prof. Dr.-Ing. Klaus Gellenbeck
Dr.-Ing. H.-J. Dornbusch
Beckumer Straße 36
59229 Ahlen/Westfalen, Germany
Tel.: +49 (0) 23 82/9 64-5 00
Fax: +49 (0) 23 82/9 64-6 00
E-mail: info@infa.de
Internet: www.infa.de
Funding reference: 02WA0728

International environmental education – safeguarding our future through knowledge and co-operation

Education is an important aspect of many of the water management projects supported by the Federal Ministry of Education and Research (BMBF). The aim is to inform different target groups about new or established processes and technologies as well as important aspects of water management, thus raising awareness of the importance of our sustainable and environmentally sound use of the resource water. Another important aspect is the training and education of local project partners: if initiatives in countries outside Germany are to be successful in the long term, they must be continued independently upon project completion.

To simply regard international environmental education as an instrument of acute environmental protection would be short-sighted: it also represents an essential tool in the fight against poverty in developing and emerging countries. The programmes funded by the BMBF are thus in tune with the United Nations Decade of "Education for Sustainable Development" (2005 to 2014).

Projects with strong educational value also create a sustainable basis for international co-operation in regions with scarce water resources and help to strengthen the position of the German water industry by opening up new markets. Last but not least, such initiatives also build the international reputation of Germany as a centre of science and technology.

Programmes for global knowledge exchange

The disciplines of environmental protection and sustainable development are highly reliant on the continuous advancement of theoretical and practical knowledge. Germany can look back on many years of environmental and sustainability research and thus has both an opportunity and a duty to share its extensive technological and planning expertise with the rest of the world. Just one example of this is the project "Introduction of a German post-graduate course for environmental sciences in China", which was successfully completed in 2008. In 1999, the long-standing water technology co-operation between the BMBF and the Israeli Ministry of Science and Technology (MOST) also saw the creation of the "Young Scientists Exchange Program" (YSEP) with the aim of motivating young scientists to participate in this international co-operation. The YSEP is primarily geared towards graduates, PhD students and post-docs and offers research stays of up to six months at partner institutions in Germany or Israel. As part of the German-Israeli co-operation, over 100 research projects have been completed over the last few years. Developed in conjunction with numerous European universities, the study module "Integrated Flood Risk Management" (FLOODmaster) and its e-learning component are also suitable for specialists who wish to expand their knowledge in this area (project 3.2.01).

Knowledge transfer in Uzbekistan

The transfer of knowledge also plays a central role in a BMBF-funded project in the Central Asian republic of Uzbekistan entitled "Economic and ecological restructuring of land and water use in the Khorezm region". Khorezm is situated on the Aral Sea, which has all but disappeared over the last few decades as a result of the massive irrigation required for the region's intensive cotton production. Working with their Uzbek partners and local farmers, the project participants are promoting environmentally sustainable agriculture in the region and supporting the inhabitants of Khorezm with the independent implementation of necessary measures. This is done by providing regular training to farmers and water technicians and by developing appropriate organisational and communication tools. The initiative also supports the education of Uzbek students (project 3.2.02).

International scholarship programme

In 2001, the BMBF launched a scholarship programme under the title of "International Postgraduate Studies in Water Technologies" (IPSWaT). The programme offers scholarships for Masters degrees (M.Sc.) and doctorates (Ph.D) as a means of supporting young, highly qualified scientists from home and abroad with their research into integrated, sustainable water management. By awarding these scholarships, the BMBF hopes to improve the international transfer of knowledge and technology in the field of water management and support future decision-makers in developing and emerging countries. The programme is also laying the foundation for future scientific and economic co-operation (project 3.2.03).

Learning from the experience of others – progress through global knowledge transfer

The disciplines of environmental protection and sustainable development are highly reliant on the continuous advancement of theoretical and practical knowledge. Germany can look back on many years of environmental and sustainability research and thus has both an opportunity and a duty to share its extensive technological and planning expertise with the rest of the world. After all, conserving the foundations of life and protecting people from natural hazards are not just domestic concerns. Three examples from the field of water management highlight the many means of imparting knowledge to young scientists across the globe.

German environmental experts teaching in China

Co-operation between China and Germany in the fields of education and research has greatly increased in recent years China has thus become an important partner to the Federal Republic – both with regard to the number of projects and the funding volume. Two main goals are being pursued: firstly, the expertise of German specialists is being used to promote environmental protection efforts in China. Secondly, the transfer of environmental knowledge is to familiarise the Chinese people with German standards, environmental technologies and expertise, while also paving the way for the entry of German companies into the Chinese market.

As an important aspect of this knowledge transfer, the project **"Introduction of a German post-graduate course for environmental sciences in China"** was launched in January 2003. This study programme is open to decision-makers and specialists from the fields of economics, industry and administration, who hold a Bachelor's degree or are current Masters students, and provides them with an in-depth insight into German technologies and standards. Elements of the Environmental Sciences postgraduate course offered by the Institute of Environmental Engineering (ISA) of the technical university RWTH Aachen have been integrated in the Masters degree courses of two Chinese universities. German tutors are delivering series of lectures on the subjects of water management and waste disposal to students at these institutions. At the end of the lecture programme, the top 15 students of each class are invited to Germany to experience our water technologies and water management structures first-hand.

ISA employees teaching at the Tsinghua University of Beijing

Exchange programme for young German and Israeli scientists

Since its initiation in 1974, the water technology co-operation between the BMBF and the Israeli Ministry of Science and Technology (MOST) has given rise to over 125 research projects. In 1999, the co-operation was further enhanced by the addition of the "Young Scientists Exchange Program" (YSEP). The aim of this initiative is to motivate young scientists to participate in the German-Israeli co-operation in the field of water technology.

The YSEP programme his since become one of the most important aspects of the joint efforts between these two countries. It is geared primarily towards graduates, PhD students and post-docs and offers research stays of up to six months at partner institutions in Germany or Israel. Up to the end of 2011, a total of 70 budding scientists (35 Israeli, 35 German) participated in the programme – one particularly positive aspect being that female students have accounted for half of this number.

Test drilling for a well in the Judean desert near the Dead Sea as part of a research project

International study module on flood management

Extreme flood events continue to underline the importance of comprehensive risk management – both in Germany and abroad. Transdisciplinary analyses of complex flood risks and assessments of management options are proving particularly challenging both from a research and practical perspective. By providing an appropriate range of courses, university education can instil young scientists and experts with a better understanding of the issue as a whole. This includes both the connections between the hydro-meteorological causes of floods and social, economic and ecological vulnerability◄ as well as the effectiveness of preventative measures and disaster management.

This is the aim pursued by the international study module "Integrated Flood Risk Management" (FLOODmaster), which is taught at the Technical University of Dresden as part of the Masters degree course in Hydro Science and Engineering. The international, English-language study programme effectively combines basics of natural sciences and engineering with economic, social and planning expertise. The course is aimed at Masters candidates, students in higher semesters and graduates. The special e-learning component of the programme is ideal for experts who wish to expand their knowledge in this field. The teaching materials are made available on the Internet both for full-time students and distance learning purposes.

The study concept comprises the following components:

- Two series of lectures on the subjects "processes of extreme flood risks" and "integrated flood risk management".
- Three focus workshops dealing with the most important flood types; conflicts in the development of management strategies are addressed in an actor's workshop involving specialists and professional experts.
- Transnational issues are covered in the form of a multi-day excursion to a European flood risk area.
- The theoretical and methodical basics from the individual components are combined in a seminar paper on a specific subject.

The module was developed in close co-operation with multiple European universities and scientists from national and international research initiatives and is supported by a scientific advisory board. The programme arose from the BMBF initiative RIMAX (Risk Management of Extreme Flood Events) in co-operation with the European research project FLOODsite (Integrated Flood Risk Analysis and Management Methodologies). Today, this university course is taught as a dual module in Flood Risk Management as part of the international Masters course in Hydro Science and Engineering at the TU Dresden and represents a perfect example of the successful practical application of a BMBF-funded initiative.

Students assessing the flood risk along the Elbe river as part of the River Flood Workshop in Dresden

China
Technical University RWTH Aachen
Prof. Dr. Max Dohmann
Templergraben 55
52056 Aachen, Germany
Tel.: +49 (0) 2 41/80-2 66 24 (secretary's office)
Fax: +49 (0) 2 41/87 09 24
E-mail: kueppers@fiw.rwth-aachen.de
Internet: www.fiw.rwth-aachen.de
Funding reference: 02WA0418

Israel
PTKA-WTE Research Centre Karlsruhe
Dr. Hans Joachim Metzger
P.O. Box 3640
76021 Karlsruhe, Germany
Tel.: +49 (0) 721/60 82 23 55
Fax: +49 (0) 721/60 89 22 35 5
E-mail: hans-joachim.metzger@kit.de
Internet: www.ptka.kit.edu/wte
Funding reference: KII1101-YSEP

International
TU Dresden
Institute of Hydrology and Meteorology
Prof. Dr. Christian Bernhofer
01062 Dresden, Germany
Tel.: +49 (0) 3 51/4 63-3 13 40
Fax: +49 (0) 3 51/4 63-3 13 02
E-mail: christian.bernhofer@tu-dresden.de
Internet: www.floodmaster.de
Funding reference: 0330680

Opening up new perspectives – sustainability in Uzbekistan

Stopping the inefficient and ecologically damaging use of the soil and waters while alleviating poverty among the people: these are the objectives of a German-Uzbek project at the Aral Sea. There is an urgent need for action in this area as decades of intensive agriculture (cotton production) have resulted in the gradual disappearance of the Aral Sea. At the same time, the initiative hopes to provide local farmers with the necessary knowledge to improve their income using ecologically sustainable farming methods.

The irrigation agriculture practised in Central Asia reduces the productivity of soil and water resources, while poverty continues to rise – issues that can be attributed to the inefficient and unsustainable use of available resources. This applies particularly to the irrigated lowlands of the Aral Sea basin in Uzbekistan, an area that is home to some 27 million inhabitants: intensive cotton production has had a serious environmental impact on the region's soil and waters.

To halt this downward spiral, the Uzbek population should be able to work in a more market-oriented manner. After all, farmers account for over 70% of the population, and they are most likely to protect their resources if this will help them to raise their income. However, they have insufficient experience of private agriculture, having only recently become independent operators. In addition, their economic freedom is still quite limited: the farmers are still under the strict control of the central government and are bound by its plans. Merely demonstrating to these people how sustainable agriculture works would therefore be wholly inadequate. It is equally essential that they understand the local decision-making structures and consider the interests of the different policy-makers.

Concepts for irrigation agriculture

To make sustainable improvements to the utilisation of resources at the Aral Sea, the Centre for Development Research (ZEF), an interdisciplinary research institute at the University of Bonn, joined forces with UNESCO and the Uzbek government to launch the research project **"Economic and ecological restructuring of land and water use in the Khorezm region"** (period of study: 2002 to 2012). Institutes from Germany, Uzbekistan and other countries are also involved in the project.

A ship graveyard on the dried up ground of the Aral Sea

Experts from a range of disciplines (land use, agricultural sciences, water management, economics and social sciences) are developing concepts for the ecologically sustainable and economically efficient use of resources in the Aral Sea basin. The model region of the BMBF-funded project is the Uzbek province of Khorezm, situated south of the Aral Sea along the lower Amu Darya. The most important local partner is the Urgench State University, where a modern laboratory building was constructed and equipped for the project.

One of the fundamental objectives of the initiative is to support the persons responsible in the region in their independent implementation of the necessary measures. The scientists are therefore looking closely at local decision-making structures in order to make recommendations for improving the organisation of land cultivation and water management – in conjunction with the local decision-makers. Studies relating to agricultural business and macroeconomics and covering the entire product chain are to uncover potential for a more efficient management of resources and improved value creation. New land use technologies are also being tested. The project also supports the academic training of Uzbek students: many are given the opportunity to attend a Masters degree course in Tashkent, while 22 postgraduate students have gained their doctorate at the ZEF in Bonn (many of whom have found positions in Central Asia or are now supporting the transfer of knowledge as post-doctoral fellows in this initiative).

Forestation of a degraded area

An irrigation channel with distribution structure

Participatory approach

The success of technological innovations is also greatly dictated by the level of participation: the needs and expectations of the partners must be addressed, while technical and institutional changes must be adapted to local circumstances. Close co-operation with the Uzbek partners has a significant impact on local acceptance. Regular training of farmers and water technicians is equally essential, as is the development of appropriate organisation and communication tools. With regard to technical co-operation, the project team is working closely with German, Uzbek and international organisations.

Part of the initiative included the creation of interdisciplinary models for water and land use, which incorporate ecological, social and economic aspects. These have proved particularly helpful in examining the interplay between the various factors and participants, thus allowing the team to predict the long-term effect of specific measures. At the same time, cost/benefit calculations are employed to highlight the financial benefits if individual technologies, thus enabling the local decision-makers to implement suitable measures.

Four project phases

The ten-year project has been broken down into four phases. The first phase involved the creation of the local infrastructure and required database (e.g. digital maps), both from existing materials and the team's own research.

Based on intensive field studies and model developments, the second phase saw the generation of options for the future management of resources. These included new, soil-friendly cultivation methods, optimised irrigation strategies and technologies as well as the introduction of alternative crops and tree species, which not only offer environmental benefits but also increase the earnings of local farmers.

These concepts were then tested by the project participants during the third phase, in close co-operation with farmers, representatives from the water authorities and the partner institutions in the Khorezm region. Phase 4 (2012) is the implementation stage, in which the scientists and their Uzbek partners intend to spread their restructuring concept across the province. The ultimate aim is to implement a long-term solution that will allow the region to enjoy an ecologically, economically and socially sustainable future.

University of Bonn
Centre for Development Research (ZEF)
Prof. Dr. Paul L. G. Vlek
Dr. John P. A. Lamers
Walter-Flex-Straße 3
53113 Bonn, Germany
Tel.: +49 (0) 2 28/73-18 38
Fax: +49 (0) 2 28/73-18 89
E-mail: JLamers@uni-bonn.de
Internet: www.zef.de/khorezm.O.html
Funding reference: 0339970A, 0339970C

International scholarship programme – imparting knowledge and cultivating contacts

The BMBF scholarship programme "International Postgraduate Studies in Water Technologies" (IPSWaT) represents the direct implementation of a recommendation made in the "Action Concept: Sustainable and Competitive German Water Industry" from 2000. The aim of the programme is to support highly qualified young scientists, promote the international transfer of knowledge and cultivate long-term contacts in the fields of science, water management and development co-operation.

The Federal Ministry of Education and Research (BMBF) launched the IPSWaT programme in 2001 as a means of providing highly qualified students and budding scientists from Germany and abroad with scholarships for international, English-language Masters courses and Ph.D degrees at German universities. In the context of capacity building◄, the granting of these scholarships is to promote the international transfer of knowledge and technology in the field of water management and support future decision-makers in developing and emerging countries in particular. The programme is also to lay the foundations for future co-operation.

Scholarships are available for Masters courses (M.Sc.) and Ph.D degrees. Around 35 M.Sc. and Ph.D. scholarships are awarded in two annual selection rounds. Candidate applications should ideally refer to a specific problem in their home country or region and include a methodical solution approach. The relevant issue should be studied in the context of a bi- or multi-lateral research project. The selection panel is particularly interested in applicants intending to research areas of integrated, sustainable water management including aspects of economic value creation. Depending on the desired scholarship, applicants must have acquired a Bachelors or Masters degree. The scholarship will allow Masters students to participate in one of 20 accredited German degree programmes for a period of two years. Ph.D degrees are funded for a period of three years and can be completed at any German university.

Numerous universities and technical colleges have been accredited for the IPSWaT programme (source: IPSWaT brochure)

Applications assessed by experts

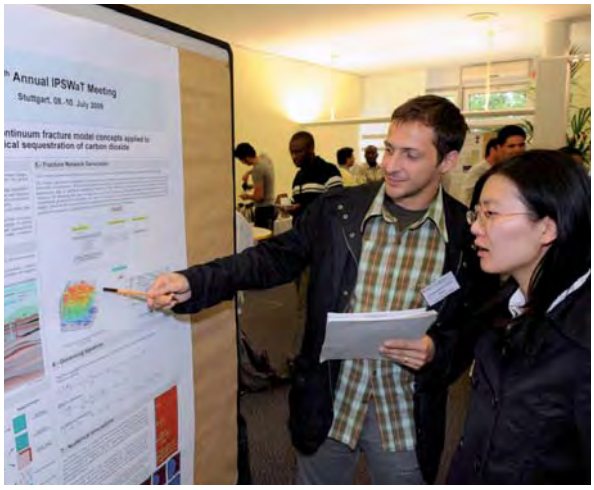
An expert panel meets twice a year (April and November) to assess received applications. Once the successful applicants have been selected by this external, independent committee, the relevant universities are notified of the results by the International Bureau of the BMBF. Candidates are selected first and foremost on the basis of their outstanding academic qualification. Other selection criteria include:

- Potential to be included in bilateral or multilateral co-operation in science, industry or development policy
- Practical relevance and transferability of the planned research work
- Institutional links to countries of origin and/or partner countries
- Relevance of the research project to integrated water resource management

Scope of scholarship

In addition to the monthly stipend (and family allowance, where applicable), the following will be paid to IPSWaT scholarship holders: travel allowance for one return journey to the place of study, a German language course at the start of the scholarship, health, accident and liability insurance for the duration of study, tuition fees for the first semester, maintenance grants for research visits abroad, a one-off start-up payment and a monthly bonus in the form of a research grant. During the study pro-

A group of students at the IPSWaT scholarship meeting in Leipzig, July 2010



A poster session at the IPSWaT scholarship meeting in Stuttgart, July 2009

gramme, the scholarship will also cover attendance of any relevant international conferences, training courses and trade fairs, field studies abroad as well as placements of up to three months at a German water technology company or water supplier. The following are not covered: Insurance and travel costs for family members as well as multiple journeys to and from the place of study.

Creation of networks

Since the programme was launched, the BMBF has funded over 350 students from 60 different countries. A central aspect of the IPSWaT is the creation of networks both among current and former students as well as with German partner organisations from the fields of water management, research and development co-operation (e.g. with the BMBF programmes IWRM and IWAS or the institutions DAAD, DED, GIZ, InWEnt, KfW). The annual scholarship meetings have proved to be a successful platform for internal and external networking. At these events, students can discuss their research work with one another and also have the opportunity to meet relevant stakeholders from German water institutions representing the worlds of business, science and development co-operation.

The programme is currently scheduled to run until the end of 2014.

Project website ▶ **www.ipswat.de**

International Bureau of the BMBF
German Aerospace Centre (DLR)
International Postgraduate Studies in Water Technologies (IPSWaT)
Cornelia Parisius
Heinrich-Konen-Straße 1
53227 Bonn, Germany
Tel.: +49 (0) 2 28/38 21-4 22
Fax: +49 (0) 2 28/38 21-4 44
E-mail: cornelia.parisius@dlr.de

Glossary

Acidification: Entry of acid into water bodies and soil. This can be the result of "acid rain", for example, or degradation products of the pyrite on coal spoil tips.

Activated carbon: Collective name for a group of artificially produced, highly porous carbons with a sponge-like structure. This pure material is characterised by its large specific surface area (up to 300 m^2/g). Activated carbon is manufactured from peat, wood, lignite, black coal or nutshells. The materials are first carbonised, during which tiny pores are created. Activated carbon adsorbs organic substances from water and the air and is thus able to clean contaminated water or polluted air.

Activated sludge: The biomass formed in an activated sludge basin during ► aerobic biological wastewater treatment as a result of the degradation of substances in wastewater. Microscopic examinations have verified that activated sludge flocs consist of bacteria and protozoa.

Activated sludge procedure (also referred to as Activated sludge process): With this procedure, the wastewater is biologically cleaned using ► activated sludge (also known as bulking sludge). The micro-organisms in the sludge (bacteria, fungi) break down the organic substances: the oxygen required by the micro-organisms is added in the activated sludge basin. Once the wastewater has been cleaned, the activated sludge is separated from the wastewater in the secondary sedimentation tank and returned to the activated sludge basin (or disposed of as waste sludge).

Activated sludge process: See ► Activated sludge procedure.

Activated sludge reactor: see ► Activated sludge procedure

Adsorption: The accumulation of gaseous or liquid substances on the surface of a solid.

Aerobic: State involving the presence of oxygen (O_2). Also used in the context of organisms that require oxygen to live, or to describe chemical reactions that require the presence of oxygen.

Aerobic and anaerobic wastewater treatment: See ► Biological wastewater treatment.

Aerobic biodegradation processes: Degradation of micro-organisms with the aid of oxygen.

Aerosol: Mixture of a gaseous substance and liquid or solid, finely distributed elements referred to as "suspended particles". These particles are everywhere in the air and are so small that, individually, they cannot be seen with the naked eye. Examples are salt crystals, sand grains, pollen and soot as well as other particles in industrial fumes. Aerosol particles accumulate air humidity and thus act as cloud condensation nuclei.

Ag ions: Ag (Argentum) is the chemical symbol for silver. Silver is an ancient antiseptic: its use as a preventative medicine and for treating infections can be traced back to approx. 1000 BC. Nowadays, silver is used in drinking water disinfection, among other things.

Anaerobic: Absence of oxygen (O_2). Also used in the context of organisms that do not require oxygen to live, or to describe chemical reactions that occur in the absence of oxygen.

Aquifer: In the field of hydrogeology, an aquifer (from the Latin words aqua = water, and ferre = to bear or carry) is an underground layer carrying groundwater. Aquifers are also referred to as water-bearing strata. Different types of aquifer are distinguished depending on the individual rock type (and thus the rock's porosity).

Arid regions: Regions with a dry climate.

Aromatic hydrocarbons: The aromatic hydrocarbons benzene, toluene, ethyl benzene, xylene (► BTEX aromatics) are contained in coal tar but usually obtained from crude oil. They increase the octane number of petrol and are also used as solvents and degreasing agents or as raw materials in the chemical industry. Aromatic hydrocarbons are generally highly toxic and – at least in the case of benzene – carcinogenic.

ATR spectroscopy: "ATR" stands for attenuated total reflection – an analytical procedure for measuring thin surface layers. The reciprocal action of an infrared beam on the interfacial surface of a permeable material and the surface of the material to be examined results in the absorption of a characteristic part of the beam (see ► Infrared spectroscopy).

Basin: Part of the earth's surface that is drained by a river and its tributaries. We distinguish between above-ground and underground basins. The drainage divide marks the boundaries of the basin.

Batch test: A test set-up used to examine the speed or time at/over which a substrate (in this case, the substances in wastewater) is broken down by means of biological processes under specific conditions.

Biocide: Agents (chemicals and micro-organisms) used for pest control in the non-agricultural sector. Examples are disinfectants, rat poison, wood preservatives etc. See also: ► Microbicide

Biocoenotic: The term biocoenosis is used to describe a community of plants, animals, fungi and micro-organisms in a separate habitat (biotope).

Biofilm: Layer of living and dead micro-organisms. Biofilms are formed when micro-organisms (e.g. bacteria, algae, protozoa) accumulate on interfacial surfaces between gaseous and liquid phases (e.g. at free water level), liquid and solid phases (e.g. gravel on river beds) or liquid/liquid phases (e.g. oil droplets in the water). A thin, usually closed slime layer (film) embedding the micro-organisms forms on the interfacial surface.

Biogas reactor: System that creates biogas from a biomass. Methane accounts for 50 – 70 of biogas, which can be used as an energy source. Artificial biogas production occurs in multiple stages in a heated reactor at an average temperature of 30 – 35°C and in the absence of oxygen (► Anaerobic).

Bioindication: Determination of natural or human environmental influences by means of suitable organisms (bioindicators).

Biological denitrification: Procedure employing the natural ability of micro-organisms (bacteria) to convert nitrate (NO_3) into elementary, gaseous nitrogen (N_2). The process occurs under anoxic conditions, i.e. in the absence of oxygen, and requires a substrate (e.g. acetic acid) to enable the bacteria's denitrification. In drinking water purification, the ► denitrification stage must generally be followed by comprehensive post-treatment (gas exchange, filtration, disinfection).

Biological wastewater treatment: With biological wastewater treatment, the organic compounds contained in wastewater are subjected to a biodegradation process. Degradation is performed mainly by micro-organisms in conjunction with dissolved oxygen in the case of ► aerobic processes or in the absence of oxygen in the case of ► anaerobic processes. Inorganic compounds and biomass are created through conversion processes. The most frequently used method of biological wastewater treatments is the ► activated sludge procedure.

Bioreactor: A bioreactor is a vessel in which micro-organisms, cells or small plants can be cultivated or fermented under optimum conditions. The breakdown of chemical compounds using bacteria can also be performed in bioreactors. In this context, they play in important part in the biological cleaning of wastewater, for example.

Black water: Collective term for all sanitary wastewater from toilets and urinals.

BOD_5 (biochemical oxygen demand): This value indicates the amount of oxygen in mg/l consumed by bacteria and all other water-based micro-organisms over a period of five days at a temperature of 20°C, and thus serves as the basis for establishing the volume of biodegraded organic substances.

Boreal coniferous forests: The earth's most northerly forests, which stretch across Northern Eurasia and North America in a wide belt.

Brillouin frequency range analysis: Measurement systems using the method of Brillouin frequency range analysis are based on the non-linear optical effect of stimulated Brillouin scattering (SBS), which transfers the extension of an optical glass fibre to a measurable frequency shift in the backscattered light of an optical signal.

Brown water: Sanitary wastewater without urine (see ► Urine water).

BTEX: ► Aromatic hydrocarbons (benzene, toluene, ethyl benzene, xylene)

Capacity building/development: In the context of international co-operation for human resource and organisational development, the aim of capacity development is provide technical support and advice to people in developing countries. This involves strengthening local competence in a sustainable manner and raising the capacities of the country such that effective solutions can be found to social, political and economic problems.

Capillary networks: Networks of tiny vessels and ramifications (capillaries).

Capillary pressure: This is the force that causes liquids to rise up when in contact with narrow tubes, gaps or hollow spaces. This effect is caused by the surface tension of liquids and the interfacial tension between liquids and the solid surface.

Catalysis: Chemical reaction in which a suitable substance is employed as a catalyst (accelerator), usually with the aim if increasing the reaction speed.

cDCE degradation product: The formula stands for cis-1,2-dichloro-ethene. It is created by the degradation of ► tetrachloroethylene (PCE) and ► trichloroethylene (TCE). Both substances are examples of volatile chlorinated hydrocarbons (► VCHC).

CFU: Colony-forming unit

CHC (chlorinated hydrocarbons): Collective name for organic compounds containing at least one chlorine atom bound directly to a carbon atom. CHCs are contained in many products and are used as base materials in the chemical industry, as solvents and as pesticides. As a result of their wide-spread use and high stability, CHCs are now ubiquitous in the environment.

Chlorobenzene: Aromatic organic compound used, among other things, as a thinner in the paint industry, a degreasing agent in the textile and metal industry and as an extracting agent.

COD: The chemical oxygen demand (COD) is a measure of the amount of water-based substances that can be oxidised under specific conditions. It indicates the volume of oxygen (in mg/l) required for the oxidation of these substances.

Co-fermentation: Addition of ► anaerobically degradable substances in a ► digester or biogas plant.

Combined heat and power (CHP) plant: System for the combined generation of power and heat based on the principle of cogeneration. In a CHP plant, the heat lost as waste heat in conventional power generation is converted to steam, which can then be used for heating purposes (district heating).

Contaminant plume: The spread of dissolved contaminants in the ► aquifer.

DDT (dichlorodiphenyltrichloroethane): Insecticide that works as a contact and stomach poison and has been used since the early 1940s. DDT is an example of a persistent chlorinated hydrocarbon. Its use has been prohibited in most industrialised countries since the 1970s. In 2004, its international use was restricted to the sole purpose of combating malaria vectors. The substance is highly stable and is broken down very slowly in the environment. As a result, it has become ubiquitous in the environment and is even contained in breast milk. DDT is mutagenic and suspected of being carcinogenic.

Decision support system: ► DSS.

Dehalogenated: Dehalogenation is the removal of halogens (especially chlorine) from organic compounds. In a narrower sense, the term refers to the removal of halogens from ► volatile halogenated hydrocarbons (VHHC). Volatile halogenated hydrocarbons (VHHC) with up to three chlorine atoms can be dehalogenated through microbial activity.

Denitrification: Process in which bacteria break down nitrate and release nitrogen (N_2) as it occurs in the air. By-products of denitrification are nitrous oxide (N_2O) and nitrogen oxide (NO_x).

Desertification: Process of gradual desert formation in arid areas.

Digester: A tower-like vessel constructed from concrete, prestressed concrete or steel and used in wastewater treatment for the controlled and regulated execution of ► anaerobic degradation processes. Just like other digestion tanks, digesters are usually found in sewage plants. The digested sludge is used to break down fermentation gases such as methane (CH_4), which must be captured or combusted due its high global warming potential. The captured gas can be converted into energy, particularly for the generation of power in a combined heat and power plant.

Direct-push procedure: Procedure used for depth-oriented groundwater sampling. A special filter probe is advanced directly into the aquifer at the required depth, thus enabling groundwater sampling from pre-defined depth ranges.

DNAPL: The term dense non-aqueous phase liquids (DNAPL) is used to describe organic liquids that are insoluble in water an have density greater than 1 g/cm^3 (i.e. heavier than water). The group of ► volatile halogenated hydrocarbons (VHHC) is of particular importance in this regard. DNAPLs frequently occur as groundwater contaminants.

DOC content: DOC stands for dissolved organic carbon. It combines with the particulate organic carbon (POC) and the volatile organic carbon (VOC) to form the total organic carbon (TOC). This organic sum parameter indicates the organic substance dissolved in water.

Drainage elements: These serve as a substitute for natural, water-permeable drainage layers consisting of, for example, expanded clay, lava, gravel or expanded shale. Drainage elements are used for the mechanical stabilisation of the substrate and to prevent water retention and are therefore often employed in dyke construction, among other things.

DSS (decision support system): Computer-based tool that assists decision-makers in evaluating information and assessing the impact of different courses of action.

Dynamic drilling: Dynamic drilling is a simple means of analysing the soil structure and extracting samples using a hollow steel probe that is driven into the ground.

Ecomorphology: Structural configuration of a water body, including littoral zones (see also ► Morphological).

Elbe DSS: A decision support system for river basin management. It provides a basic structure for the specialist knowledge, computer models and data relating to the Elbe basin.

Electrodialysis (ED): Membrane process in which the ions contained in water are passed through a membrane by applying an electric voltage. Using an alternating configuration of cation- and anion-selective membranes, the majority of the ions can be removed from the water. After passing through the membranes, the cations and anions are gathered in a concentrate stream, which is then discharged. In contrast to reverse osmosis, the untreated water does not pass through the membranes, thus making electrodialysis a relatively stable process.

Energy recovery: Use of waste as a substitute fuel in cement works, coal-fired power stations and refuse incineration plants.

Environmental federalism: Allocation of (decision-making) powers and responsibilities to different parties in the environmental field.

Escherichia coli (E. coli): Bacteria found in the gut flora of humans and animals; named after its discoverer, the doctor Theodor Escherich (1857-1911). The presence of E. coli in drinking water is an indicator of faecal contamination.

EU Water Framework Directive: Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy – more commonly known as the Water Framework Directive (► WFD) – represents the regulatory framework for the protection of all water bodies. The primary aim of the directive is to achieve a "good status" of water bodies. The WFD follows a comprehensive, basin-wide approach in which all significant pollution in ►basin areas is recorded and its effect on the relevant water bodies assessed.

Eutrophic: Rich in nutrients (see also: ► Mesotrophic and ► Oligotrophic).

Eutrophication: Excessive input of nutrients, particularly phosphorus and nitrogen compounds, into standing or slow flowing water, thus resulting in the mass formation of algae and aquatic plants. The decomposition of dead plants and algae leads to oxygen depletion in the water and decay accompanied by the formation of hydrogen sulphide and other harmful substances (ecosystem collapse, fish kills, odours).

Fermentation: Breakdown of biogenic material through micro-organisms in the absence of oxygen (anaerobic conditions). In the case of close co-operation between multiple groups of bacteria, biomass is transformed into biogas.

Fermenter: ► Bioreactor

Final clarification: Sub-process of biological wastewater treatment in which the purified wastewater is separated from the sewage sludge involved in the cleaning process. Final clarification generally occurs in the secondary sedimentation tank. This part of a wastewater treatment plant is usually preceded by a biological stage (e.g. activated sludge basin), in which the flow velocity is reduced to bring about sedimentation of the degradable substances. Membrane procedures can also be used for final clarification under specific circumstances.

Flocculation: A procedure used in drinking water purification to reduce existing turbidity; insoluble substances are removed from the water in the form of large particles (flocs) through the addition of flocculants such as aluminium and iron salts in the form of chlorides and sulphates. The flocs are then separated by sedimentation, for example.

Flotation sludge: Large volumes of fat are produced during the slaughtering process, and this fat is separated from its carrier substance (water) in flotation plants. Flotation sludge is a mixture of fat, blood and water as well as other contaminants from the slaughtering process, such as feathers.

Fluvial: Something which is created (eroded), transported, deposited (sedimentation) or enriched (soaps) through the movement of water (river/stream). Taken from the Latin word fluvius = river. Fluvial sediments are usually well rounded and can comprise virtually all rocks found in the basin of the relevant river or stream.

Free phase: The individual parts in a mixture of different substances (e.g. a liquid with a solid) are known as ► phases. The "free phase" is the part of a liquid (or gas: liquid or gaseous phase) that is not bound (sorbed) to the solid parts of the mixture (solid phase) via bonding forces.

Funnel-and-gate systems: Funnel-and-gate systems consist of underground walls arranged to form a funnel, which channels the stream of contaminated groundwater into an underground gate, at the end of which the groundwater flow can continue as before. The water is cleaned as it passes through the system. If correctly configured, the procedure requires no pumps or additional power.

Geo-electric profile recording: In geo-electric profile recordings, the structure and properties of a substrate are determined by means of an applied current.

Geogenic background contamination: Natural pollution of the ground, water or air resulting from chemical compounds in the rocks of the earth's crust.

GIS-based: Mapping, measurement or determination based on geo-information systems.

Grey water: Domestic wastewater from the kitchen, bath, shower, washing machine etc. (no faecal matter or urine) (see also ► Brown and ► Urine water).

Groundwater aquifer: See ► Aquifer

Habitat: Living environment for organisms or space inhabited by a species.

Heterocylics: Organic compounds with a ring-shaped structure in which one or more carbon atoms are substituted with a heteroatom (e.g. nitrogen, oxygen).

High-rate digestion: This procedure was developed by the Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB). The procedure is characterised by its enhanced efficiency through the use of a smaller ► digester, shorter retention times of the sewage sludge in the digester and a higher biogas yield. With high-rate digestion, the amount of residual sludge requiring disposal is also reduced.

Hydraulic effect: Effect of a specific measure on the properties of a river, e.g. on outflow distribution, flow speed or water levels.

Hydraulic resistance: Resistance offered by a medium against the free flow of water. This property depends on the thickness and hydraulic conductivity of a material or ground layer.

Hydraulic soil and groundwater remediation: Remediation process based on the mechanical properties of fluids.

Hydraulics: Study of the mechanics of fluids.

Hydrodynamics: A branch of fluid mechanics dealing with the dynamic, storage and transport processes in hydraulic systems.

Hydrology: The scientific study of water, its spatial and temporal distribution and the associated biological, chemical and physical properties.

Hygroscopic particles: Substances that bind moisture from the atmosphere.

Immunomagnetic separation column: Immunomagnetic separation columns are used to retain micro-organisms previously bound to magnetic particles. As the liquid flows through the magnetised column, the magnetically activated micro-organisms adhere to its walls. The magnet is then removed and the column rinsed with a measurement buffer via which the micro-organisms leave the column.

Infiltration pond: Reservoir for surface water which is introduced to the groundwater after being filtered through gravel and sand.

Infrared spectroscopy: Physical analysis procedure based on the properties of infrared light. It is used for the quantitative and structural determination of substances.

Inhalation and dermal contaminants: Contaminants that are either inhaled via the respiratory tract or absorbed through dermal contact.

Injection logs: Measurement system for establishing the hydraulic permeability of soil.

In-situ chemical oxidation (ISCO): Remediation procedure whereby chemical oxidising agents (e.g. potassium permanganate) are injected into the aquifer to remove contaminants.

In-situ chemical reduction (ISCR): With this process, reducing chemicals (e.g. molasses) are injected into the subsoil where they react with contaminants which are then chemically destroyed.

In-situ measurement networks: In-situ measurements are performed on site, i.e. under natural conditions. Measurement networks comprise multiple measurement stations, which are often distributed across large areas.

Ion exchangers: Natural or artificial materials which replace ions (charged particles) dissolved in water with other ions. The ions to be replaced are bound to the ion exchanger material, which itself releases ions into the solution.

Karst/karst landscape: Type of landscape where soluble bedrock (limestone, gypsum and salt rock) has been destroyed (eroded) by water. Typical features are jagged rocks, sink holes and caves.

Lamella separator: In lamella separators or clarifiers, particles are separated from contaminated water using lamellar honeycomb structures.

Life-cycle costing: This calculation method indicates which costs occur at which points in a life-cycle, e.g. of a product.

Life-cycle assessment: A life-cycle assessment provides a comprehensive analysis of the entire product life-cycle and the associated ecological impact. The turnover of materials and energy during the life-cycle is also assessed, as are the resulting environmental consequences.

LNAPL: Most hydrocarbons (i.e. non-chlorinated compounds, see ► DNAPL) are lighter than water and form phases that float on its surface (e.g. on groundwater). Organic liquids with densities less than 1 g/cm³ are known as light non-aqueous phase liquids (LNAPL). The most important LNAPL compounds are fuels (gasoline, kerosene, diesel), with heating oil EL being another example. The ► BTEX compounds are of particular relevance in this regard.

Low-pressure membrane procedure: See ► Membrane procedure.

Low-turbidity: Water turbidity is caused by organic and inorganic suspended matter as well as by living organic substances that are hard to remove through filtration. Low-turbidity water has a greater level of clarity and can be cleaned by means of slow filtration.

Material recycling: Recovery of raw materials from waste, their re-introduction into the economic cycle and use in the creation of new products.

Mechanical-biological waste treatment: Procedure whereby waste is broken down mechanically before being biologically decomposed (e.g. through composting).

Membrane bioreactor: Combination of ► activated sludge procedure and membrane filtration. The aim of this process is the extensive cleaning of biologically contaminated wastewater such that it can be used as service or process water.

Membrane process/technique: Use of a filter applied to a supporting layer for removing anything from tiniest particles to dissolved substances from wastewater. Depending on the individual application, the filter material can be made of stainless steel, plastic or textile fabric.

Membrane-supported Pd catalysts: Pd is the chemical symbol for palladium, a white transition metal that belongs to the platinum group of metals and is thus also a precious metal. Palladium is an excellent catalyst for the acceleration of chemical reactions. Its uses include dechlorination in water treatment, for which it is finely distributed across membranes.

Mesotrophic: Possessing a balanced, moderate nutrient level. Condition of water bodies between nutrient-rich (► Eutrophic) and nutrient-poor (► Oligotrophic).

Methyl tert-butyl ether (MTBE): Colourless, volatile organic compound. MTBE/vapour/air mixtures are highly flammable and explosive. Primarily used as an antiknock agent in gasoline.

Microbicide: Chemical substances used to kill microbes (virucides for viruses, bactericides for bacteria, fungicides for fungi etc.). They belong to the group of (see also ►) biocides and are contained in many paints, cleaning agents and cosmetics, primarily to ensure long shelf lives.

Micro-biocoenosis: Community of micro-organisms.

Micro-filtration: Physical (mechanical) ► membrane (separation) procedure (filtration method). All substances within a liquid that are larger than the membrane pores are retained by the membrane. Filtration using membranes with a pore size > 0.1 µm is known as "micro-filtration", while pore sizes < 0.1 µm are used in "ultra-filtration".

Millennium Goals: Eight development objectives agreed by the heads of state and government of 189 countries in the Millennium Declaration of 2000. The goals, which originate from four spheres of action (1. Peace, security and disarmament, 2. Development and eradication of poverty, 3. Protection of our shared environment, 4. Human rights, democracy and good governance) and have a primary aim of securing a sustainable future, are to be implemented by 2015.

Mineralisation: Conversion to inorganic substances.

Mixed-in-place procedure (MIP): The mixed-in-place procedure (MIP) is used to create vertical concrete walls in the soil. The ground is mixed with a cement suspension thus forming a concrete-soil structure. The main advantage of this process is that no other materials are required. The procedure is used to seal off landfills and contaminated sites.

Morphodynamics: Dynamic formation of landforms through erosion and sedimentation, e.g. due to weather effects or hydrological processes.

Morphological: Relating to the external form.

Nano-filtration: Pressure-driven membrane process in which nanometric particles are retained.

Nitrification: Bacterial degradation (oxidation) of ammonium compounds into nitrate (NO_3).

NSO-HET: Heterocyclic hydrocarbons (see ► Heterocylics).

Oligodynamic effect: Damaging effect of metal cations (positively charged metal ions) on living cells.

Oligotrophic: Low in nutrients (see also ► Eutrophic and ► Mesotrophic). (► Eutrophication).

O-phosphate: Oxygen-phosphate bond (O is the symbol for the chemical element oxygen).

Oxidation all-metal catalysts: Catalysts (reaction accelerators) that clean water using oxygen.

Oxygen-reducing combination reactors: Contaminated groundwater does not usually contain any dissolved oxygen since it has been used up (as in the case of combustion) for the oxidation of carbon – i.e. the contaminant compounds. Combination reactors are used in the successive treatment of pollutant mixtures: for the complete degradation of all contaminants, oxygen is first added to the water to bring about positive redox conditions. Thereafter, the groundwater returns to a negative redox condition, i.e. absence of oxygen. Some additional pollutants can then be destroyed in these reduced conditions.

Oxygen-reduction environment: A redox reaction (or more precisely: reduction oxidation reaction) is a chemical reaction in which electrons are transferred from one reactant to another. Such electron transfer reactions therefore involve the loss of electrons (oxidation, as in the case of combustion) by one substance and the gain of electrons (reduction) by another. In this context, the oxygen-reduction environment describes the chemical state of the surrounding medium.

Perchloroethylene (PCE): See ► Tetrachloroethylene.

Permeability: Measure of the ability of a porous material, such as rock or soil, to allow gases or fluids to pass through it.

Phase: A phase is a spatial area in which the physical parameters and chemical composition of the relevant matter are homogeneous.

Photo-catalytic surfaces: Surfaces on which (sun)light breaks down organic materials.

pH value: Measure of the H+ ion concentration, i.e. of acidity (pH < 7) or basicity (pH > 7). A pH value of 7 is neutral.

Population equivalent (PE): Measure of the level of contamination of commercial/industrial wastewater, specified as the number of persons producing a corresponding pollution load.

Polychlorinated biphenyls (PCB): Group of toxic substances used up to the 1980s, primarily in transformers, capacitors and hydraulic systems; PCBs were also used as softening agent in paints, sealing compounds and plastics. The substances have since been included in the "dirty dozen" group of known organic toxins, which were banned throughout the world in 2001. In addition to their chronic toxic effect (chloracne, hair loss and hyperpigmentation), PCBs are also suspected of being carcinogenic and hormonally active.

Polycyclic aromatic hydrocarbons (PAH): Group of organic compounds. PAHs are natural components of coal and crude oil that are created during the pyrolysis (incomplete combustion) of organic material (e.g. coal, heating oil, fuel, wood, tobacco) and are thus ubiquitous in the environment. Due to their degradation resistance, toxicity and prevalence in the environment, PAHs are considered highly potent pollutants.

ppm: Parts per million. Measure indicating the proportion of one substance to another.

Precipitate: Substance that separates from a solution and settles (precipitation).

Precipitation: In this process, chemical reactions cause the transformation of dissolved substances into insoluble substances, which then settle at the bottom of a vessel or water body – e.g. in the form of flocs – where they can be more easily removed from the water.

Pre-oxidation with potassium permanganate: Potassium permanganate ($KMnO_4$) is a powerful oxidising agent (see also: ► ISCO), which can be used in drinking water purification (e.g. to remove iron) and to oxidise sulphite into sulphate.

Pressure-driven membrane process: Membranes are fine filters that allow liquids to pass through but retain the contained substances. In a pressure-driven membrane process, the liquid is pressurised when transported through the membrane. Depending on the cut-off or pore size of the membrane, the processes micro-, ultra- and nano-filtration as well as reverse osmosis are distinguished.

Pump-and-tracer procedure: With this procedure, the water is artificially "marked" (e.g. with a colourant) in order to monitor its flow behaviour (e.g. flow velocity).

Pump-and-treat procedure: Remediation procedure in which the contaminated groundwater is extracted via wells or drainage systems before being cleaned.

Quaternary aquifer: Quaternary ► aquifers were formed during the most recent period in the earth's history, the Quaternary, which started 2.6 million years ago and continues to this day.

Receiving waters: This term is used in the field of hydrology to describe the channels, such as watercourses and soil drainage, via which water can flow into a water body in the form of wastewater, rainwater or drainage water. Examples of natural receiving waters are open streams that take in and discharge water from other watercourses, groundwater bodies and discharge systems.

Reduction dechlorination: Procedure in which chlorine is removed from chemicals in the absence of oxygen. This process is important for the remediation of groundwater contamination, for example.

Rehabilitation: Removal of river straightening measures and river bed linings with the aim of restoring natural flow conditions.

Remote technology: Remote system monitoring.

Retardation: This term is taken from the Latin word "retardare" (= delay) and is used in the context of material transport. It describes the deceleration of a substance relative to the moving medium in which it is transported.

Retention: In the field of water management, this term refers to the balancing effect of reservoirs on the outflow of flowing waters; see also ► Retention basins.

Retention basins: In the case of flooding, part of the water is stored in reservoirs at the sides of the river and on the flood plains. As a result, the water downstream rises at a slower rate. This in turn delays the flood wave and makes it flatter. The lower the gradient, the higher the level of ► retention. The areas contributing to the retention are known as retention areas.

Reverse osmosis: The process of osmosis involves the diffusion (movement) of a solvent (e.g. water) through a semi-permeable membrane (i.e. permeable only to the solvent). The solvent moves from the area with the lower concentration of the dissolved substance to that with the higher concentration. In the case of reverse osmosis, the natural osmosis process is reversed through the application of pressure. The salts are retained by the membrane and discharged in the form of concentrate.

River basin management: Collective term for the measures employed to manage bodies of water such that they serve the common good. The aim is to prevent avoidable impairments of their ecological function. In addition, the water balance of terrestrial ecosystems and wetlands directly dependent on these water bodies must be protected, such that sustainable development is ensured. In this context, planning areas are river basin districts, which include the ► basins themselves as well as the groundwater and coastal waters.

Rotating biological contactor: Mechanical unit featuring discs mounted on a horizontal axis positioned just above water level; the rotating discs are submerged approximately halfway into the wastewater container. The rotation of the discs supplies the biofilm on the surface of the water with substrate and oxygen.

Salination: Process whereby the salt load of a water body is increased, e.g. by salts not removable during wastewater purification or through the introduction or recirculation of salts from a seawater desalination system into a body of water.

Salt (water) intrusion: Entry of salt or brackish water into the groundwater through the movement of fresh/salt water boundaries.

Sediment: Deposits in water bodies created through settling (sedimentation) of mineral and/or organic solids. We distinguish between clastic (suspended matter, sand, rock), chemical (substances separated from aqeuous solutions, e.g. carbonate) and biogenic sediments (deposited organisms or their remains, e.g. coquina).

Seismology: Study of the earth's crust through the use of artificially generated seismic waves.

Semi-industrial scale: Test or pilot systems are usually assessed on a smaller semi-industrial scale – i.e. with practical relevance – before a full-size system is built.

Sewage ponds: Small ponds in which wastewater is cleaned biologically by means of plants.

Sewage sludge: In sewage plants, water flows into the primary sedimentation tank via the sand and grease trap. In this first treatment chamber, undissolved substances are deposited in the form of sewage sludge (mechanic purification).

Sewage Sludge Ordinance (AbfKlärV): Regulates the application of sewage sludge from wastewater treatment plants to agricultural, forested or horticultural land.

Slow filter: Slow filters are based on the principles of natural soil filtration and are characterised by their low flow velocity. The high surface area requirements are a disadvantage of this method. However, slow filters are beneficial wherever surface water is to be used.

Sorption: Process whereby a solid or liquid substance takes up or holds another gaseous or dissolved substance. The term sorption refers to processes resulting in the enrichment of a substance within a phase (absorption) or on an interfacial surface between two phases (adsorption). The term is used when absorption and adsorption cannot be clearly distinguished. The sorbing substance is also referred to as the sorbent (or sorbent material).

Spectroscopy: The measurement of a spectrum from a radiation source.

Spin-off company: When part of a company or institution is set up as a separate business, this is described as a spin-off.

Stratigraphy: Geoscience discipline involving the study and dating of rock strata.

Stripping: Removal of water-based substances through the injection of air/gas. The dissolved substances are transferred to the gaseous phase and consequently removed from the water.

Struvite (also known as: magnesium ammonium phosphate): A sparingly soluble compound of ammonium and magnesium named after the scientist Heinrich Christoph Gottfried von Struve (1772–1851).

Submerged fixed beds: In fixed bed reactors, which are frequently used in biotechnology, the elements responsible for the substance conversion (micro-organisms, enzymes) are bound to fixed carrier materials (fixed bed). A liquid stream directs the other components involved in the process (e.g. substrates, gases) past the fixed bed, which can be made of ceramic, glass, plastic or natural material. In the case of a submerged fixed bed, the carrier material of the fixed bed is fully immersed in the untreated wastewater. Oxygen is supplied by means of pressure aeration (which is also used for flushing purposes).

Surface tension: An interfacial surface is the contact zone between two phases, e.g. between water and air or between oil and water. Surface tension causes the surface of a liquid to behave like an elastic film.

Suspension: The term suspension is used to describe a liquid containing finely distributed solid particles which are held in a suspended state – e.g. through agitation or stirring.

Technogenous region: Underground water supply and disposal networks (sewage systems) are also described as technogenous regions.

Tectonics: Study of the structure or composition of the earth's crust.

Tertiary: The Tertiary is the geological period of the Cenozonic era, i.e. from the start of the Cretaceous period (65 million years ago) to the start of the Quaternary (approx. 2.6 million years ago).

Tetrachloroethylene: Colourless, volatile liquid; also referred to as perchloroethylene (PCE). Tetrachloroethylene is a highly toxic chlorinated hydrocarbon (► CHC) and is classified as a category 3 carcinogen.

Thermal waste treatment: Incineration of waste.

Topography: Scientific discipline involving the surveying, portrayal and description of terrain, locations and landscapes.

Toxicity: Degree to which a substance can damage a living or non-living organism.

Toxicity parameters: Characteristic properties relating to the toxicity of a substance.

Trace elements: Trace elements are substances with a concentration in water of less than 100 micrograms per litre. These can be inorganic or organic trace elements that effect the quality of water.

Trichloroethylene (TCE): Aliphatic, chlorinated organic compound. One of the most commonly used cleaning and degreasing agents. It also serves as an extracting agent for natural fat, resin, oil and wax. The substance belongs to the group of volatile chlorinated hydrocarbons (► VCHC) and is classified as a category 1 carcinogen and germ cell mutagen.

Trickling filters (also known as trickle-bed or trickle-flow reactors): Wastewater treatment system in which the water is cleaned by being trickled over a porous fixed bed (e.g. volcanic slag). The organic materials separated from the water are biodegraded by micro-organisms on the fixed bed (the "microbial film").

UASB – upflow anaerobic sludge blanket: UASB is a continuous process involving the constant flow of wastewater and sludge through the reactor. The system employs a counterflow configuration with the wastewater supplied at the bottom of the reactor. The special structure of the reactor well comprises a sludge bed (anaerobic reaction zone), gas/solid separator and sedimentation chamber.

Ultra-filtration: See ► Micro-filtration.

Untreated water: Water before it has been purified or cleaned, e.g. to produce drinking water.

Urine water: Urine from separation toilets and urinals, with or without flush water.

Vermicomposting: ► Aerobic composting process performed by micro-organisms and worms. The advantages of this method over conventional composting are a higher process speed, increased mineralisation rate of contained nutrients and ability to process relatively small volumes.

Viscosity: Viscosity is the resistance of a liquid to flow. It is defined by the frictional resistance offered by a liquid against deformation.

Volatile chlorinated hydrocarbons (VCHC): Organic compounds in which up to four hydrogen atoms are replaced with chlorine atoms. VCHCs were commonly used as solvents and cleaning agents well into the 1980s and primarily evaporated into the atmosphere. Due to their longevity, VCHCs are still ubiquitous in the atmosphere today. In the past, large volumes of these substances found their way into the subsoil due to carelessness, improper handling, sedimentation or accidents.

Volatile halogenated hydrocarbons (VHHC): Organic compounds containing both carbon and hydrogen as well as halogen atoms (fluorine, chlorine, bromine, iodine). VHHCs were (and sometimes still are) used as cleaning and extracting agents, solvents, refrigerants, greenhouse gases (CFCs, freons) or as fire-extinguishing agents (halons). Similarly to the three ► BTEX aromatics, they accumulate in the soil gas but, unlike the former, can penetrate down to the confining bed. Some VHHCs are not only toxic but also damaging to the ozone layer (CFCs, halons) or carcinogenic.

Vulnerability: In the field of ecology, this terms refers to a particularly high sensitivity to environmental conditions and outside interference.

Waste sludge: The excess biomass produced during biological wastewater treatment (► activated sludge). It is extracted from the activated sludge basin and dehydrated to form "sewage sludge".

Water Framework Directive (WFD): See ► EU Water Framework Directive.

Water governance: Term for a holistic water management process comprising ecological, economic and social aspects as well as regulatory and non-regulatory measures. The comprehensive and early involvement of the public in decision making-processes (e.g. poor persons who have little or no access to drinking water) is of central importance to the "water governance" approach, as is the participation of groups with different interests. In this context, water governance also represents a means of conflict prevention or resolution (particularly in areas where water is scarce).

WFD: Water Framework Directive of the European Community; see ▶ EU Water Framework Directive.

Zeolite-supported Pd catalysts: The active substances of a catalyst are often precious metals of the platinum group, in this case palladium (Pd). In a conventional vehicle catalytic converter, these fine precious metal particles are applied to porous ceramic surfaces to maximise contact with the medium to be cleaned. In this case, the same function is performed by zeolites, both in their naturally occurring form and as industrially manufactured minerals with a large surface area (porosity). They are also referred to as "molecular sieves". The tiny palladium particles in the pores of the zeolites break down the small contaminant molecules, while the large sulphurous molecules, which also occur in groundwater, remain outside.

Zero control: Untreated control serving as the standard in experiments against which the other, treated samples are measured.

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